



# How small and medium-sized enterprises in developing countries can protect the ozone layer



United Nations Environment Programme  
Division of Technology, Industry and Economics  
OzonAction Programme



Multilateral Fund for the Implementation  
of the Montreal Protocol

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## Foreword



*Dr Klaus Töpfer*  
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It has been more than ten years since a global community who agreed to protect the ozone layer signed the Montreal Protocol to phase out ozone depleting substances. During this time, a number of cases illustrating the success of this unique international agreement have been circulated, often giving rise to the notion that the ozone problem is now solved.

As a large number of countries are receiving assistance from the Multilateral Fund of the Montreal Protocol, more projects to phase out the use of ODS are getting completed. However, this is not the reason for complacency. Although many large

enterprises in developed and developing countries are now using ODS-free alternatives, there is still a sector remains a challenge to the Protocol implementation: small and medium sized enterprises (SMEs).

Large numbers of SMEs are found in many of the rapidly growing ODS consuming countries. Because of their size, and the nature of their enterprise, they are not very easy to reach, and are often difficult to locate. In many cases, they also have limited or specialized technical capabilities. It is however recognized that they are an important part of the efforts to phase out ODS, and contribute a substantial share of the ODS consumption of many countries.

UNEP, in its role as information clearinghouse under the Montreal Protocol is committed to providing assistance and knowledge to SMEs to help them with their phase out efforts. Through this handbook designed specifically for SMEs, it is hoped that these enterprises will assess their present operations and find out options available for them to phase out ODS in their specific sector. The handbook is also expected to provide ways to eliminate or at least substantially reduce ODS use through illustration of case studies of specific SMEs who have succeeded using alternatives. It presents both technical and policy options that an SME can consider and eventually adopt for the long term, including resources and contacts that they can easily get in touch with if more detailed information is necessary.

It is hoped that this document, along with UNEP's other existing information materials, will contribute greatly to facing one of the remaining challenges under the Montreal Protocol, and that its use will facilitate the phase out of ODS in SMEs.

## Is this handbook for you?

**If your enterprise is involved in one of the following businesses, this handbook is for you:**

### Refrigeration and air conditioning

- refrigeration service companies which service and repair existing, installed industrial, commercial, domestic and mobile refrigeration and air-conditioning equipment;
- manufacturers or installers of new refrigeration or air-conditioning equipment;
- manufacturers of compressors, condensers, evaporators and other refrigeration components.

### Foams

*Manufacturers of:*

- flexible polyurethane foams for comfort, automotive and packaging applications;
- rigid polyurethane foams for appliances, building, transportation and thermoware applications;
- integral skin or microcellular polyurethane foams for furniture, automotive and shoe sole applications;
- extruded polystyrene foam sheet for food packaging;
- extruded PE foams for general packaging and pipe insulation in building applications.

### Aerosols

*Fillers of aerosol cans for:*

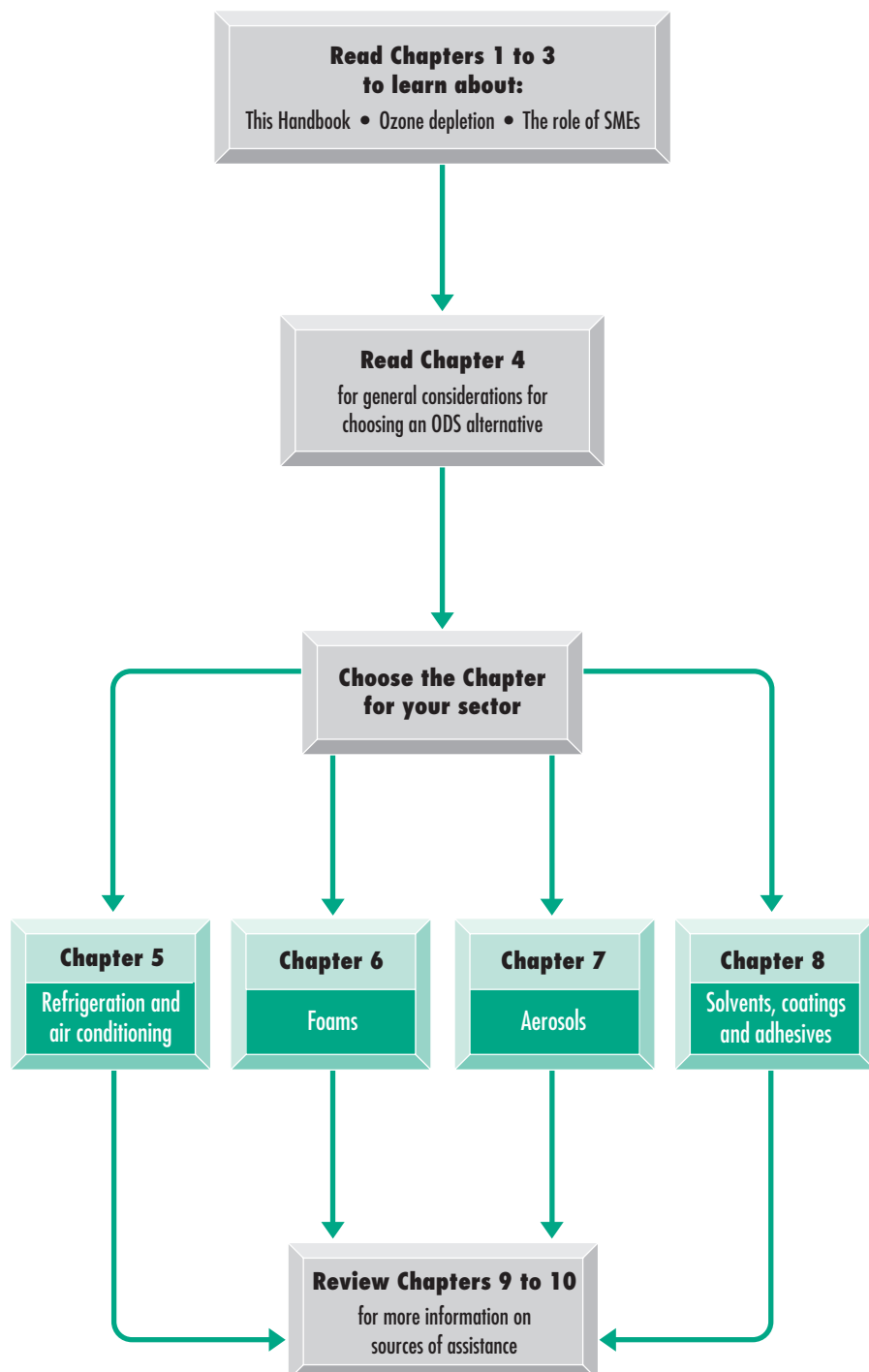
- personal household products such as colognes and perfumes, hair sprays, pet sprays, glass cleaners;
- household cleaning products such as furniture polishes, fabric sizers, carpet and upholstery cleaners;
- pesticides;
- solvents;
- medical products.

### Solvents

*Preparation or users of solvents for:*

- cleaning during manufacture of jewellery, belt buckles, printed circuit boards;
- general metal cleaning during manufacture or maintenance of equipment;
- precision cleaning of medical equipment, aircraft controls, auto-rivetting;
- dry cleaning of fabrics and clothing;
- for adhesives in foam, particle board and plywood;
- manufacturers of cleaning equipment;
- blenders of custom solvents.

## How to use the handbook



## Contents

<b>Part I: Introduction</b>	<b>1</b>
① About this handbook	2
② Depletion of the ozone layer: a global problem with local solutions	5
③ How SMEs in developing countries can protect the ozone layer	9
<b>Part II: Alternative technologies in ODS-using sectors</b>	<b>15</b>
④ Options for change in major ODS-using sectors	16
⑤ Refrigeration and air conditioning	20
⑥ Foams	33
⑦ Aerosols	41
⑧ Solvents, coatings and adhesives	47
<b>Part III: Sources of assistance</b>	<b>59</b>
⑨ The Multilateral Fund for the implementation of the Montreal Protocol	60
⑩ Further information sources	62



# PART I

# **INTRODUCTION**

## 1

**About this handbook****SMEs and the depletion of the ozone layer**

This handbook is a tool to be used by you, the owners, operators or employees of small and medium-sized enterprises (SMEs) in developing countries. It was written to assist you in looking at your present operations to see if they include the use of chemicals that are damaging the ozone layer. If you find that you are using these chemicals, this handbook will help you find ways to substantially reduce and eventually eliminate, their use.

**What is an SME?**

The definition of small and medium enterprises (SMEs) varies from country to country. SMEs generally have a small number of employees (from 1 to 150), small production capacity, and limited financial resources. In many countries they dominate the economy, accounting for up to 80 percent of economic activity.

Businesses which use ozone depleting chemicals are classified in four sectors:

- Refrigeration and Air Conditioning
- Foams
- Aerosols
- Solvents, Coatings and Adhesives

If your enterprise is in one of these sectors, this Handbook is for you.

It may surprise you to discover that your relatively small business could have an impact on something as distant and vast as the ozone layer far above the earth. But because there are so many SMEs in

most countries—they can account for up to 80 percent of the economy in some countries—their activities taken as a whole significantly increase the amount of damaging chemicals being released into the atmosphere. Ozone damaging chemicals are called ozone depleting substances or simply ODS; which is the term we will use in this handbook.

World action to save the ozone layer focused first on the large companies in developed countries, particularly the multinationals. Their activities were so extensive that it was important for them to lead the way in converting to non-ozone depleting substances. To a large extent, they have been very successful in rising to this challenge. Now it is the turn of small business people, like you, to do their part to protect the ozone layer.

As the largest users of ODS, developed countries agreed to start reducing their use of ODS first. You should be aware that the first freeze on the consumption of commonly used ODS in developing

**The 1999 Freeze**

The first control measure for developing countries commenced in 1999. Starting from July 1999, the consumption of the following chemicals are frozen at 1995–1997 levels and will be gradually eliminated by 2010.

- CFC-11
- CFC-12
- CFC-113
- CFC-114
- CFC-115

countries, particularly CFCs, has come into effect in 1999. In following years, these chemicals will be phased out entirely. This marks the second stage of a phase-out strategy which will eventually result in the elimination of almost all ODS production and consumption in both developed and developing countries.

### There are good reasons to change

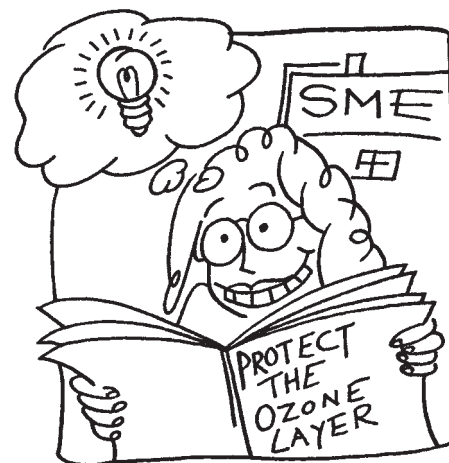
This means that there are some good reasons for you to start now to plan for a change in products or production methods used in your business:

- If a substance you now use is being phased out globally, you will soon find that it will no longer be available or may only be available at significantly higher cost.
  - It is also likely that your government, as signatory to the Montreal Protocol, which contains measures to eliminate the use of ODS, has introduced or is in the process of introducing its own measures to end or discourage the use and/or production of ODS.
  - If you start phasing out now, you may find you are eligible for technical or financial assistance which will not be available to those who wait until the end.
  - If you are an exporter you may well find that in your export market, products containing or processed with ODS may no longer be legally imported.
  - You will be protecting your environment by helping to reduce the destruction of the ozone layer.
- In many instances, the private sector has been highly successful in finding new processes or substances to replace the use of ODS. Research and experimentation has already produced several alternatives which work as well or better than the old ones and ...
  - Some alternatives even cost less as well.

### How to use this handbook

This handbook will help you get started on the process of eliminating ODS use in your operations. Each Part is designed to address an aspect of your needs as you begin your plans.

- Read **Part 1** (Chapters 1–3) to find the background information you require to understand the global process which is driving the need for you to make changes in your operations. It will answer many of the questions you have about the impact of change on your business.
- Read **Part 2** (Chapters 4–8) to find out about the alternatives which you will want to consider as you undertake the conversion to non-ozone depleting practices. Read Chapter four first for a general discussion of ODS alternatives and the issues you will have to consider in making a change and then turn to the sector chapter that applies to your business.
- Use **Part 3** (Chapters 9–10) to help you find sources of information, technology and financial assistance.



### Why change?

- ODS will be phased out globally
- alternatives are available and some cost less as well
- technical and financial assistance is available from the Multilateral Fund of the Montreal Protocol

## What you will find in this handbook

### Part 1

We begin, in Chapter 2, with some basic information on the ozone layer, what it does and why its preservation is crucial to life the earth. We also introduce you to the chemical processes which are responsible for ozone depletion and list the substances which trigger these processes. Here you will find references to the chemicals you are currently using in your business that will eventually have to be eliminated. We introduce you to the Montreal Protocol, providing you with its key provisions and its timetable for the phase-out of ODS in participating countries.

One of the most important sources of assistance for developing countries is the Multilateral Fund for the Implementation of the Montreal Protocol which was established specifically to assist developing countries in meeting the requirements of the Protocol. The mandate, structure and activities of the Fund are described here. You may find that the support you need will be provided through the activities sponsored by the Fund.

In Chapter 3, we look at SMEs to help you identify how you fit into the picture. We take a general look at SMEs and their importance to their national economies. We look at the key concerns of SMEs and indicate how the strategies adopted by various national and international organizations are helping to meet these concerns.

### Part 2

This Part provides a discussion of the most viable ODS alternatives in four

sectors: refrigeration and air conditioning, foamed plastics, aerosols and solvents.

In Chapter 4 we introduce the main ODS alternatives and discuss the criteria that should be considered in selecting the right option for you.

The chapters devoted to individual sectors (Chapters 5–8) include a discussion of the sector, current practices which involve the use of ODS, and a description of viable alternative processes and substances. The discussion of each substance will provide you with both the benefits and problems related to its use. In many cases, a switch to a new substance will require different or additional equipment, staff training and/or the adoption of an entirely new process. Of critical importance to you as you consider various options is the listing of additional sources of information, assistance, technology and suppliers which is provided at the end of each chapter.

### Part 3

In Chapter 9 you will find some guidelines to assess your eligibility for assistance from the Multilateral Fund.

Chapter 10 provides general information sources as well as listing of agencies which have programs to assist SME conversion.

# 2

## Depletion of the ozone layer: a global problem with local solutions

### What is happening to the ozone layer?

Ozone is a naturally occurring gas which is created by high energy radiation from the Sun. The radiation breaks down oxygen molecules, releasing free atoms which bond with other oxygen molecules to form ozone. The greatest concentration of ozone, known as the ozone layer, occurs at 20–25 kilometres above the Earth in the stratosphere. Its critical role for humans, animals and plants is the absorption of the certain ultraviolet rays of the sun (UV-B) which are harmful to almost all forms of life on Earth. UV-B radiation is known to cause human skin cancer, eye damage and cataracts; and to increase susceptibility to infectious diseases such as malaria.

In 1985 a ‘hole’ was discovered in the ozone layer over the Antarctic, associated with increased levels of chlorine in the stratosphere. This confirmed growing scientific evidence that the ozone layer was being depleted by the expanding use of certain man-made chemicals, commonly known as CFCs. When released to the air, chemicals containing chlorine and bromine gradually infiltrate all parts of the atmosphere. Once in the stratosphere they are broken down by the high levels of solar UV radiation, freeing extremely reactive chlorine and bromine atoms which, through a complex series of reactions, destroy thousands of ozone molecules.

It is now known that even very small concentrations of chlorine or bromine can break down sufficient ozone to seriously deplete the ozone layer. For example there are large scale losses to the ozone layer over the Antarctic every spring and

similar, though weaker, losses over the Arctic. There is also evidence that ozone levels decrease in the spring and summer in both hemispheres and also during the winter in the southern hemisphere.

### What attacks the ozone layer?

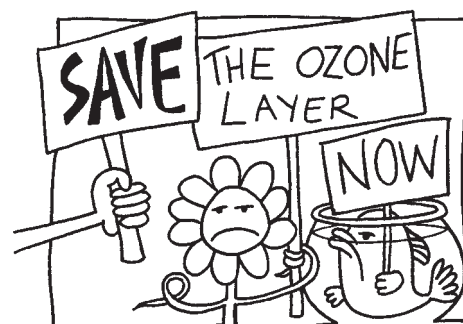
A number of man-made chemicals are capable of destroying stratospheric ozone. They all have two features in common:

- in the lower atmosphere they are remarkably stable, being largely insoluble in water and resistant to physical and biological breakdown;
- they contain chlorine and bromine.

The stability and safety of these chemicals, primarily CFCs, led to their increasing use by industry in a wide variety of areas. They include the following, all of which are to be phased out under the measures established by the Montreal Protocol:

*Chlorofluorocarbons (CFCs)* which are used as a refrigerant in refrigerators and air conditioners; as a propellant in aerosol spray cans; as a blowing agent in the manufacture of foams and as a cleaning agent for printed circuit boards and other equipment.

*Hydrochlorofluorocarbons (HCFCs)* are related to CFCs and were largely developed as substitutes for CFCs, especially as refrigerants and blowing agents. HCFCs are less destructive than CFCs because their extra hydrogen atom makes them more likely to break down in the lower atmosphere, preventing much of their chlorine from reaching the



### The price of ozone depletion

#### For humans

*Increases in:*

- skin cancer
- snow blindness
- cataracts

*Less immunity to:*

- infectious diseases
- malaria
- herpes

#### For plants

- smaller size
- lower yields
- increased toxicity
- altered form

#### For marine life

*Reduced:*

- plankton
- juvenile fish
- larval crabs and shrimps

### Decreasing ozone levels

When	Where
Every spring	Antarctica Arctic
Every summer	Southern and Northern Hemispheres
Every winter	Southern Hemisphere

stratosphere. However HCFCs still have an ozone depleting potential (ODP) which means they are unsuitable for long term use.

*Carbon tetrachloride and methyl chloroform* are chlorine-containing chemicals that have been widely used as solvents, mainly for cleaning metals during engineering and manufacturing operations.

*Bromofluorocarbons (BFCs)* are bromine-containing chemicals called Halons that have been used primarily to extinguish fires. Some of these are among the most potent ozone destroyers—up to ten times more powerful than the most destructive CFCs.

*Methyl bromide* is mainly used as an agricultural fumigant used mainly in soil application.

### **The Montreal Protocol**

Concerted global action to halt ozone destruction began in 1985 with the signing of the Vienna Convention for the Protection of the Ozone Layer. Through the Convention, member countries agreed to take ‘*appropriate measures*’ to reduce ODS consumption. These measures were transformed to legal commitments in 1987 with the adoption of the Montreal Protocol on Substances that Deplete the Ozone Layer. With evidence mounting that the ozone levels were in serious danger, a worldwide effort began to safeguard the ozone layer. And for the first time, controls on the production, consumption and use of ODS were globally agreed.

The original Montreal Protocol called for the limitation of the production and consumption of eight ‘*controlled substances*’. At subsequent meetings of the Parties to the Protocol held in London, Copenhagen, Vienna, Montreal and Beijing requirements for action have moved from reduction in production and consumption of 5 CFCs and 3 halons, to the phase-out of 15 CFCs, 3 halons, 34 HBFCs, carbon tetrachloride, and methyl chloroform. A longer-term reduction schedule has been agreed to for 40 HCFCs and the list of controlled substances has now been extended to include methyl bromide.

By March 2000, more than 160 countries had ratified the Protocol and were legally bound by its requirements. About one-third of the ratifying countries are developed and two-thirds are developing countries. Parties to the Protocol are listed in Appendix 1.

Recognizing the need of developing countries for economic development and, until recently, their modest use of CFCs, the Parties to the Protocol agreed to provide them with a ‘*grace period*’ of ten years more than developed countries to implement the phase-out measures of the Protocol. The schedule for phaseout by developing countries is provided on page 14.

The Parties also agreed that developed countries would provide technical and financial assistance to developing countries through a financial mechanism, the Multilateral Fund for the Implementation of the Montreal Protocol.

## Results of international action

Parties to the Protocol agreed to reduce and then eliminate the use of ODS before substitutes and alternative technologies were fully available. This has proved to be a successful strategy. ODS replacement has been more rapid, less expensive, and more innovative than was anticipated. Industry has led the way in developing alternative substances and processes for almost every use of ODS. And in many cases, the alternative technologies adopted have been effective and inexpensive enough that consumers have not yet felt any noticeable impact. Today many countries are well on their way to a complete phase-out of ODS.

The need for alternatives initiated the use of several new substances and processes. It not only promoted technical creativity, it contributed to the creation of new information networks and new cooperative ventures. It now provides considerable experience in carrying out conversions and a sense of shared challenges and commitments as those in the global ozone network (including industry, scientists, governments and non-governmental organizations) work together to come up with practical solutions to this urgent problem.

As you read through the sections on your sector you will see that you are not alone in finding a solution for your operations. Considerable work has already been done to find a viable alternative for the ODS you are using. Several organizations—international, non-governmental, industry, governmental—are there and ready to provide information, technical support and, in some cases, financial assistance to you.

## The Multilateral Fund for the Implementation of the Montreal Protocol

In 1990 the Parties to the Montreal Protocol decided to establish the Multilateral Fund to provide financial and technical cooperation, including technology transfer, to developing countries to help them comply with the controls established by the Protocol. Since these countries operate under Article 5 of the Montreal Protocol, they are often referred to as Article 5 countries. There are now some 120 Article 5 countries.

The Fund provides a range of assistance including:

- technical expertise
- information on new technologies
- training workshops and seminars
- demonstration programs
- funding to develop and implement investment projects and programmes to phase out ODS


Through these activities the Multilateral Fund has been an important vehicle for transferring environmentally sound and proven technologies to developing countries.

The work of the Fund is carried out by four implementing agencies:

**The United Nations Development Programme (UNDP)** assists in preparing national—or country—programmes, investment project planning and preparation, training and demonstration projects.

## Some definitions

- ODS** Ozone-depleting substances which include CFCs, HCFCs, HBFCs, halons, methyl chloroform (TCA), carbon tetrachloride and methyl bromide.
- ODP** Ozone-depleting potential: a measure of the amount of stratospheric ozone that can be destroyed by a substance compared to CFC-11, which is rated as having an ODP of 1.0.
- GWP** Global warming potential: a measure of the effect a substance can have on warming the Earth's atmosphere leading to climate change.
- VOC** Volatile organic compound: will evaporate during use and contribute to ground level air pollution (smog).
- HFCs** Hydrofluorocarbons: a family of chemicals related to CFCs but which contain neither chlorine nor bromine so they do not deplete the ozone layer.



**The United Nations Environment Programme (UNEP)** Through the UNEP DTIE OzonAction Programme, UNEP collects data, provides an information clearinghouse and offers training and networking assistance.

**The United Nations Industrial Development Organization (UNIDO)** runs small-to medium scale investment projects and offers technical assistance and training for individual enterprises.

**The World Bank** cooperates and assists in administering and managing a programme to finance the costs of phase-out activities.

In addition to financial contributions to the Fund, many developed countries carry out bilateral cooperation projects with developing countries. While carried

out within the provisions of the Protocol, these bilateral projects provide an opportunity for donors to work directly with recipient countries and to demonstrate some of their leading technological and training capabilities.

Requests for Multilateral Fund assistance must be submitted by a national government and require approval by the Executive Committee of the Fund. Interested SMEs should request their governments to submit their requests to the Fund Secretariat, to an implementing agency or to an agency providing bilateral assistance. In all cases it is essential that you have the support of your national ozone unit or environment department in developing plans for your project. For more information on the Multilateral Fund, see Chapter 9.



# 3 How SMEs in developing countries can protect the ozone layer

## What is an SME?

SMEs are often called the backbone of the economy. This is not surprising. In many countries they account for the largest share of economic activity and an even larger share of employment. This is particularly true of developing countries where SMEs can account for up to 80 percent of economic activity. In addition, many SMEs are family-owned and operated businesses, providing employment and income within their local communities. There is no doubt that SMEs are vital to the economic and social structures of their countries.

The definition of SMEs varies from country to country. It can be based on the number of employees, annual sales, total enterprise assets or a combination of these factors. In practice there is enormous variability in the size of SME enterprises; ranging from larger, more established ones functioning within the formal economy (e.g. established as a legal entity, belonging to an industry association) to small one-person operations with no legal status. An SME may be a 5 person aerosol filling operation, a 120 person custom blender of solvents, a two unit spray foam insulation contractor, or a one-man refrigerator repair service.

Most SMEs are small, having fewer than 50 employees. In some cases facilities can be quite basic, with hand-operated systems and few safety measures. SMEs are geographically scattered. Some are concentrated in urban centres while others are distributed throughout the countryside. Many small SMEs operate in the informal sector without legal status or the assistance of industry associations or government.

## Why are SMEs important to ODS phase out?

As developing countries grow and industrialize, consumer demand also increases. Much of this growth in demand is for goods and services that use ODS in their production. The result is increasing ODS consumption.

Large numbers of SMEs are found in many of the rapidly growing ODS consuming industries. For example, items such as refrigerators, air conditioners, specialized cleaning solvents, aerosol dispensers and foam packaging are increasingly in demand. The SMEs that make or service these and other products are significant consumers of ODS. With the coming reduction on the consumption of several CFCs used in these products, early plans for a reduction and eventual phase out of their use is essential.

Industry, governments and international agencies recognize that SMEs are an important part of the effort to phase out ODS. They have therefore developed a number of programs to assist SMEs in meeting the phase-out schedules adopted as part of each government's country programme for ODS elimination. These schedules are often supported by laws which will restrict or ban the use, manufacture or importation of ODS over the next few years.

## What are your concerns?

As an SME owner or employee, you will be familiar with many of the characteristics associated with SMEs listed above. If financial and technical resources are not readily available for



### General characteristics of SMEs

- small production capacity
- limited financial and human resources
- limited or specialized technical capabilities
- dependent on outside sources for raw materials and technology
- flexible and adaptable
- responsive to customer needs
- operate in competitive markets

### SME phase-out concerns

- Cost increases
- Product quality and effectiveness
- Maintenance of competitive position
- Technical complications
- Worker safety
- Access to funding
- Access to new technology, substances and equipment

## Incentives for change: an example from the Philippines

In an effort to eliminate an important source of ODS consumption in the Philippines, a project was completed that assisted 20 SMEs that are custom formulators of solvents to eliminate the use of CFC-113, TCA, CFC-11 and CFC-12 in their operations. There is a concern that ODS use in this sector is increasing rapidly. This is primarily due to the expansion of the electronics and metal cleaning industries.

A number of incentives have thus been put in place to bring this change about:

### Regulatory restrictions

The Philippine Government restricts imports of ODS to 1991–92 levels and has also announced a ban on imports of TCA and carbon tetrachloride at the end of 1997, both of which are 100 percent imported. In addition at the end of 1998, the import of CFC-113 will be banned and CFC-11 and 12 will be restricted to maintaining existing equipment.

### Customer demand

Large corporations and multinationals are informing their suppliers, including custom blenders, that they wish to see ODS removed from any product they purchase.

### Public recognition

A publicity programme will give public recognition to the first six companies to be converted. This is expected to give them greater credibility in the marketplace.

### Financial and technical assistance

The remaining 14 companies will be encouraged to step forward to obtain similar benefits of acknowledgement and technology transfer. After the second wave of conversion, no further funding will be made available.

Source: UNDP Project: Elimination of the Use of CFC-113, TCA, CFC-11 and CFC-12 at Multiple Corporations that Manufacture Special Formulations for Various Industrial Markets

conversion to a non-ODS alternative, it may be difficult for you to change your mode of operation. In addition, you may not be familiar with the new technologies proposed for your industry and you may be unaware of some of the environmental, health and safety issues associated with the chemicals you will need to use for conversion. The ozone

community (comprised of Montreal Protocol organizations, national ozone units and ozone specialists around the world) recognizes that SME owners and operators have major concerns about conversion to non-ozone depleting practices and substances and is working to address them.

## Addressing your concerns: questions and answers

### Cost increases

**SME:** *Conversion to new technologies or substances implies changes for me and my customers. I operate in a highly competitive market; if my customers are dissatisfied I may lose my share of the market. If new substances are more expensive or a large capital investment in new equipment is required, my costs will be higher.*

As the phase-out of ODS is adopted on a global basis the supplies of banned substances will be limited, increasing their costs considerably. Many CFCs are already more expensive. This means that conversion to alternatives will be less expensive in the long run. In addition, as research and experimentation continues, several of the alternatives are no more costly than current practices.

### Product quality and effectiveness

**SME:** *My customers and I want to be assured that the new product will be as good as or better than the old one. Will I lose my customers if they have to change their operations or purchase additional equipment to achieve the desired results?*

In most cases quality alternatives have been developed. In some instances, it may not yet be possible to convert to alternatives because a suitable one has not yet been developed. With improved access to new technologies through industry associations, the private sector, national ozone units and international agencies, SMEs are being provided with alternatives which will ensure quality. In instances where you or your customers have to make equipment changes to

manufacture or use your new products, financial assistance may be available.

### Maintenance of competitive position

**SME:** *What will the impact on our business be if we convert to new processes or substances and our competitors do not? If we are 'ahead of the pack', will we enjoy a competitive advantage? Or will we lose customers if our prices are higher or our product requires customer adjustments not imposed by our competitors?*

If your country has imposed restrictions or bans on the use of ODS, it is likely that you and your competitors will have to convert at about the same time, so that you should be able to maintain your competitive position. In many countries efforts are being made to work with SMEs on a sector, sub-sector or industry-wide basis. Industry associations and government organizations frequently offer training programs to assist with conversion.

### Technical complications

**SME:** *It may be difficult for some of our staff to understand the requirements of new substances and technologies. Also I believe that we lack the expertise required to assess the various options for conversion. We may have to rely on suppliers or local dealers or importers for information on new products, and I am not sure that they have the necessary information or time to pass it on to us.*

A wide array of technical assistance programs are available to SMEs. Workshops and specialty programmes are offered by industry groups, international agencies, local NGOs and national governments. In addition,

several international business organizations offer their assistance in developing countries. The OzonAction Programme has a broad information mandate and provides detailed technical information to National Ozone Units (NOU) and through publications. You will find references to several useful information sources in the sector chapters which follow.

#### **Worker safety**

**SME:** *Many of the alternative substances are flammable or toxic. My first choice would be the safest alternative, but what do I do if I have to choose a more dangerous substance? Facilities at my plant are not equipped to meet new safety requirements and I am concerned about the safety of the workers and about the costs of renovating the premises and installing adequate safety equipment. Employees will also need to be trained to work in these new conditions.*

If you have to choose a substance that is flammable or toxic, training programmes are provided for you and your workers through national and international groups. You can find out about these programmes from your NOU. For conversions that require safety renovations or equipment, funds for incremental costs are available through projects approved by the Multilateral Fund. In some instances, centralized facilities are being established to ensure that SMEs have access to safe modern equipment.

#### **Access to funding**

**SME:** *Where will I get financing to pay for the required changes? In my community local financial institutions may*

*be unwilling to lend the money required for conversion.*

For eligible projects, financial assistance for conversion is available through the Multilateral Fund. The steps required to apply for funding are listed in Chapter 10. Information on available financial assistance is supplied by your NOU.

#### **Access to new technology, substances and equipment**

**SME:** *As I convert to non-ODS operations, I want to be assured that I have access to the most appropriate technology, substances and equipment. I want to know how to contact the suppliers who can best meet my needs.*

The Technical Options Committees (TOC) established by the Montreal Protocol include many of the world's leading experts on ODS replacements. Their advice is supplied through TOC Reports or Source Books which provide the detailed technical information you need to choose the most appropriate option for you. These Source Books also supply the names of the major suppliers of the substances or technologies required. Workshops on technology conversion are available to SMEs.

#### **Developing a strategy to reduce ODS consumption**

The Ozone Community has developed a wide variety of strategies to make you aware of ozone depletion and to help you find a suitable alternative to the ODS you are now using. These strategies include the preparation of information material through books and pamphlets, workshops, training courses,

### SME action checklist

- ✓ Make sure you have all the information you need. Contact your local industry or business association, national ozone unit, responsible government department, and your buyers or suppliers and ask for information and up-coming activities that are relevant to your sector and references guiding you to more detailed information.
- ✓ Learn all you can about alternative technologies and substances. After you finish this chapter, turn to Part 2 where you will find an introductory discussion of the alternatives recommended for your sector.
- ✓ Ask your suppliers to provide you with information on new substances or processes.
- ✓ If your present suppliers can't provide the substances or information you need, find out about other sources.
- ✓ Attend information sessions, training courses, technology cooperation workshops.
- ✓ Learn about your national phase-out strategy through your national ozone unit.
- ✓ Discuss the availability of technical and financial assistance with your national ozone unit

and industry and business organizations. They have also used the experience of early phase-out in developed and some developing countries to help them determine the best options for you. Many of these options are being introduced in projects that assist conversion of a large number of SMEs within a single project.

For your part, there are also actions which you can take to ensure that you make the choices that are right for you and your business. The technological options available to you are discussed in Part 2. In addition to reviewing these options, you may want to follow up on one or more of the following suggestions as part of your own strategic approach to ODS phase out.

### Latest phase-out schedule for countries operating under Article 5 as agreed by the Parties to the Montreal Protocol at their 11th Meeting (Beijing 29 November–3 December 1999)

Year beginning and thereafter	Control measures
1 July 1999	Freeze of Annex A CFCs <sup>1</sup> at 1995–1997 average levels <sup>5</sup>
1 January 2002	Freeze of halons at 1995–1997 average levels <sup>5</sup> Freeze of methyl bromide at 1995–1998 average levels Phase out of bromochloromethane
1 January 2003	Annex B CFCs <sup>2</sup> reduced by 20% from 1998–2000 average consumption <sup>6</sup> Freeze in methyl chloroform at 1998–2000 average levels
1 January 2005	Annex A CFCs reduced by 50% from 1995–1997 average levels <sup>5</sup> Halons <sup>3</sup> reduced by 50% from 1995–1997 average levels <sup>5</sup> Carbon tetrachloride reduced by 85% from 1998–2000 average levels Methyl chloroform reduced by 30% from 1998–2000 average levels Methyl bromide reduced by 20% from 1995–1998 average levels
1 January 2007	Annex A CFCs reduced by 85% from 1995–1997 average levels <sup>5</sup> Annex B CFCs reduced by 85% from 1998–2000 average levels <sup>6</sup>
1 January 2010	CFCs, halons and carbon tetrachloride phased out per the London Amendment Methyl chloroform reduced by 70% from 1998–2000 average levels
1 January 2015	Methyl chloroform and methyl bromide phased out
1 January 2016	Freeze of HCFCs <sup>4</sup> at base line figure of year 2015 average levels
1 January 2040	HCFCs phased out

<sup>1</sup>Annex A: CFCs 11, 12, 113, 114, 115

<sup>2</sup>Annex B: CFCs 13, 111, 112, 211, 212, 213, 214, 215, 216, 217.

<sup>3</sup>Halons 1211, 1301, 2402

<sup>4</sup>34 hydrochlorofluorocarbons

<sup>5</sup>calculated level of production of 0.3 kg/capita can also be used for calculation, if lower

<sup>6</sup>calculated level of production of 0.2 kg/capita can also be used for calculation, if lower

PART II

**ALTERNATIVE  
TECHNOLOGIES IN  
ODS-USING  
SECTORS**

## 4

## Option for change in major ODS-using sectors

### The major ODS sectors

In chapters 5 to 8, you will find a discussion of alternative substances and technologies for each of the major ODS-consuming sectors:

- the manufacture, maintenance and repair of refrigeration and air conditioning equipment;
- the production of foamed plastics;
- the production of aerosol products; and
- the manufacture, blending or use of solvents.

Each chapter contains a brief description of the sector and its sub-sectors, a review current CFC use and a discussion of the non-ODS alternatives available to you. The properties of alternatives are provided, together with an examination of the advantages and disadvantages of each alternative. On their own, these chapters will not provide you all the detail you need to make a decision. What they are designed to do is provide you with an introduction to the options available and to guide you to the sources of more detailed information and assistance.

### Considerations in choosing a non-ODS alternative

#### Ways of reducing or eliminating ODS

There are four general methods of making a change:

- *Conservation of ODS*—where there is reduction of CFC losses by capture, recovery, recycling and/or reuse. This is important in the refrigeration and solvent sectors where losses are relatively high.
- *Process changes and technological alternatives*—where conditions are

changed or equipment is adapted so that the ODS is no longer required.

- *Product substitution or not-in-kind*—where the product is replaced by something completely different, for example, rigid foam insulation is replaced by a vacuum chamber.
- *Alternative substances*—where the ODS is replaced with an alternative substance.

### Factors to consider when choosing an ODS alternative

The selection of an ODS alternative requires consideration of a number of issues. As you review your sector you will find that several considerations must be carefully examined and compared. A major consideration will be cost. For example, the best alternative for the environment may also be the most expensive one. In such a case, you will have to measure the trade-offs of a cost reduction against the impact on the environment in order to choose the best alternative for you.

The factors to be considered in making a decision are listed below with samples of the questions you will want answered as you evaluate the impact of various options on your operations.

#### 1. Economic considerations

- What is the least expensive alternative that meets my needs?
- Can my company obtain the capital to pay for equipment changes that may be required?

#### 2. Technical considerations

- Will the alternative do the job properly so that product quality or reliability is maintained?



- Will I have to retrofit or replace equipment in order to introduce the new process or substance?
- Will the new process require new or upgraded technical skills?
- Is financial assistance available to cover the incremental cost of training or new equipment?

### 3. Health and safety considerations

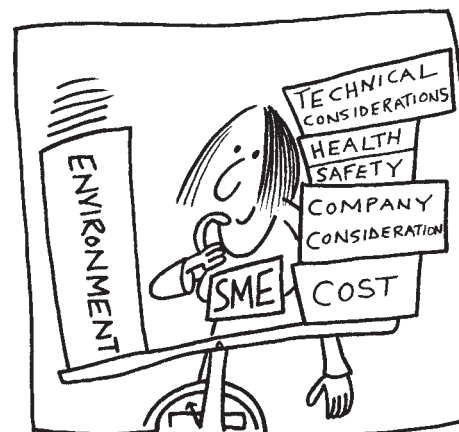
- Is the alternative safe or will it require worker protection?
- Does the alternative require

protective equipment ?

- Is it flammable, requiring special procedures, equipment and/or insurance?

### 4. Company considerations

- Is the alternative compatible with company objectives such as quality and performance?
- What impact will it have on production?
- If it requires a temporary shut-down, how will I look after my customers?



## Chemical, common and trade names for ozone-depleting chemicals

Ozone-depleting chemicals	Chemical names, common names, trade names
Chlorofluorocarbons (CFCs)	<p><i>Chemical Names:</i> 1,1,2,2-tetrachlorodifluoroethane; 1,1,2-trichloro-1,2,2-trifluoroethane; 1,2-dichlorotetrafluoroethane; chlorofluorocarbons; chloropentafluoroethane; chlorotrifluoromethane; dichlorodifluoromethane; pentachlorofluoroethane; trichlorofluoromethane</p> <p><i>Common Names:</i> CFCs; CFC-11; CFC-12; CFC-13; CFC-111; CFC-112; CFC-113; CFC-114; CFC-115; CFC-500; CFC-501; CFC-502; CFC-503; CFC-504</p> <p><i>Trade Names:</i> Algofrene; Arcton; Arklone; Asahifron; CG Triflon; Daiflon; Flon Showa; Floron; Forane; Freon; Friogas; Fronsolve; Genetron; Isceon; Korfron; Mafron; Magicdry; Taisoton</p>
Hydrochlorofluorocarbons (HCFCs)	<p><i>Common Names:</i> HCFC-21; HCFC-22; HCFC-31; HCFC-121; HCFC-122; HCFC-123; HCFC-124; HCFC-131; HCFC-132b; HCFC-133a; HCFC-141b; HCFC-142b; HCFC-151; HCFC-225ca; HCFC-225cb.</p> <p><i>Trade Names:</i> Algofrene; Arcton; Dymel; Floron; Flugene 22; Forane; Formacel; Frigen; Genosolve; GHG-12; Halotron; Isceon; McCool; Solkane; Suva; Taisoton; Vertrel</p>
1,1,1-trichloroethane	<p><i>Chemical Names:</i> 1,1,1-trichloroethane; methyl chloroform; CH<sub>3</sub>CCl<sub>3</sub></p> <p><i>Common Names:</i> 1,1,1-Tri; TCA.</p> <p><i>Trade Names:</i> AC Delco Fabric; Aerolex; Aerothene; Aquadry; Ardrox; Asahitriethane; Baltane; CG Triethane; Chemlok; Chlorothene; CRC; Dowclene; Electosolve; Eithana; Genklene; JS-536B; Kanden Triethane; Krylon; Molybkombin; New Dine T; Norchem; Prelete; Proact; Propaklone; Shine Pearl; Solvathane; Sunlovely; Swish; Tafclen; Three Bond; Three One; Toyoclean.</p>
Carbon tetrachloride	<p><i>Chemical Names:</i> CCl<sub>4</sub>; carbon tetrachloride</p>

This information was obtained from the UNEP DTIE OzonAction Programme's Information Paper on Trade Names of Chemical Products Containing Substances Controlled Under the Montreal Protocol. March 1996



### 5. Environmental considerations

- Does the alternative cause ozone depletion?
- Does the alternative cause global warming?
- Is the alternative classed as a volatile organic compound which could cause smog formation?
- Does the new process use water which would then be contaminated and could pollute local bodies of water unless treated?
- Does the new process involve chemicals which could pollute the ground water if there was a spill?

### 6. Regulatory considerations

- Does the alternative meet local and national government regulations covering things like air and water quality?
- Is this a transitional substance which will have to be phased out in the future?
- What are the regulations regarding this substance in my export markets?

### Alternative substances— some general issues

Many of the alternative substances discussed in the sector chapters have applications across several sectors. A general discussion of the advantages and disadvantages of these substances is therefore included here.

#### Will you choose a current or 'transitional' alternative?

**Current options:** In many instances there will be an existing alternative which is currently commercially available, works satisfactorily and presents no serious health, safety or environmental problems which cannot

be effectively controlled. You will want to consider these options carefully.

**Transitional options:** In some cases, current alternatives may have an undesirable health, safety or environmental characteristic. Replacing CFCs with HCFCs may provide some businesses with an important transitional period, while manufacturers, raw material suppliers, governments and other researchers work towards developing long-term replacements.

**Long-term options:** These are alternatives which have no ODP and insignificant other unwanted side effects.

#### Characteristics of leading ODS alternatives

When you examine alternative substances you will note that there are few that can fully replace all the positive qualities of CFCs. You will thus have to consider whether the problems presented by the alternatives are manageable in your current situation.

It will be relatively easy to evaluate the technical considerations by matching the physical and chemical properties of each alternative to the requirements of each application to determine the best substance to do the job. But the equipment and safety issues will be more complicated.

The leading alternatives have at least one serious disadvantage that must be considered, such as:

- ammonia is toxic and flammable;
- hydrocarbons are highly flammable and are VOCs;
- HCFCs are ODS;

- HFCs are expensive, may not be readily available in many countries, and are greenhouse gases with long atmospheric lives; and
- methylene chloride is a VOC and toxic.

Your choice will depend on product application and availability, size and location of your enterprise and local regulations. Some of the alternatives which are hazardous in certain situations are being widely used by large corporations which have the experience, training, equipment and finances to deal with any difficulties. However, use of the same substances in small, basic operations in enterprises that may not have the proper equipment, experience, training or technical personnel to handle them could be very dangerous. Many developing country SMEs, for example, are located in congested urban areas where the risk of leaks, fires or explosions could have a serious impact on employees and the surrounding community.

### Hydrocarbons

Hydrocarbons have numerous advantages including their widespread availability, low cost, low toxicity, low GWP and zero ODP. However their high flammability is an important disadvantage. It requires safety precautions for all aspects of use including transportation, handling, and storage. Higher equipment costs could result from the need for explosion-proof equipment and better ventilation facilities. Employees will also require additional training to deal with the safety aspects. Hydrocarbons are also volatile organic compounds (VOCs), which means their use may be restricted or prohibited in some areas.

### HCFCs

Probably the most controversial alternatives are the HCFCs. Because they have ODPs (ranging from 0.055 to 0.11 ) they are classified as ODS and are scheduled to be phased out under the Montreal Protocol. For this reason they are considered to be ‘transitional’ alternatives rather than ‘long-term’ alternatives. Yet they are a very practical option for smaller enterprises in developing countries because they are readily available and do not have the flammability or toxicity disadvantages of some of the other alternatives.

HCFCs have many of the same properties that make CFCs so useful as solvents, refrigerants, aerosol propellants and blowing agents for foams. This means that in many applications they can be substituted as a ‘drop-in’ replacement without costly changes to equipment and extensive training. For all these reasons, HCFCs are sometimes a practical way of buying time while better ‘long-term’ alternatives are being developed and made available. And while they are ODS they will still reduce the ODP by about 90 percent (HCFC-22 has only 5 percent of the ODP of CFC-12).

However, there is a cost in using these transitional substances. Technical and financial assistance from the Multilateral Fund is available on a once-only basis. Thus you cannot get assistance for converting to an HCFC system and then further assistance for converting from a transitional solution to a final one. You will want to keep these issues in mind as you review the alternatives for ODS in your sector, which is included in one of the four following chapters.

# 5

## Refrigeration and air conditioning

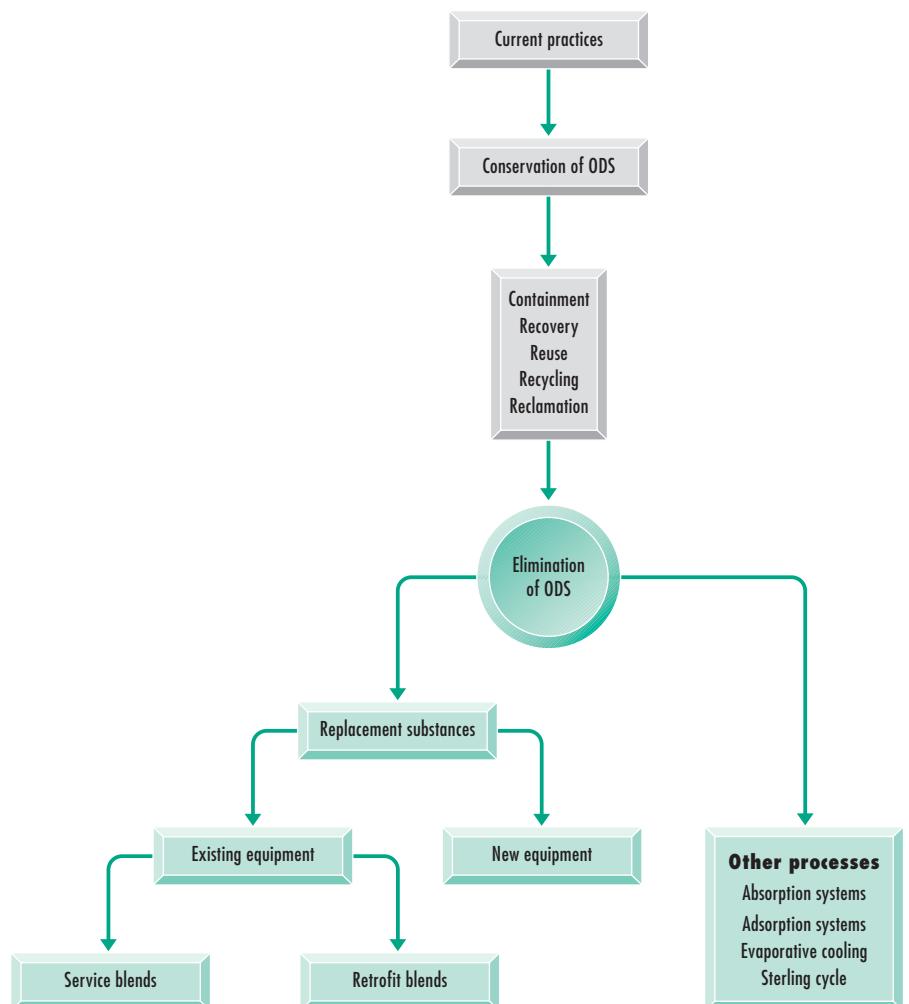
### Introduction

Refrigeration has become an important component of the domestic economies of many developing countries. As industrialization increases, the demand for domestic and commercial refrigeration grows with it. The need for sophisticated and mobile refrigeration equipment has also grown to facilitate the distribution of food on a national basis and to transport a variety of perishable products, such as food, flowers and plants to export markets.

The tourism industry has also increased refrigeration and air conditioning requirements for many countries.

The refrigeration and air conditioning sector accounts for the largest share of consumption of ODS in developing countries, ranging from 50 to 90 percent of national consumption. Depending on whether a country has manufacturing facilities or not, servicing and maintenance of refrigeration equipment could produce between 60 and 100

### Management and elimination of ozone-depleting refrigerants



percent of ODS consumption in the sector. Most service companies are SMEs, and most of these are small enterprises that consume less than 10 tonnes of ODS annually.

Conditions in the refrigerant sector make it important for SMEs to plan for current and future requirements. Most important to planning is the upcoming reductions on the consumption of CFCs, many of which are commonly used refrigerants. Combined with this is the current widespread use of refrigeration equipment using CFCs. Since it is unlikely that these units, particularly domestic, commercial and industrial refrigerators and air conditioners, will be replaced before they become obsolete, competent maintenance and repair service of equipment will be critical. Of equal importance to users will be the recapture and re-use of existing CFC refrigerants.

### **National Refrigerant Management Plans**

In low-volume consuming countries a Refrigerant Management Plan (RMP) has been adopted to provide a comprehensive approach to CFC phase-out at the national level. This national strategy is structured to:

- contain, recover and recycle refrigerants in order to provide the CFCs needed for CFC-using equipment that is not yet obsolete; and
- provide for retrofits and timely replacements of equipment to ensure a smooth transition to non-ODS equipment and operations.

If your country has an RMP it will be implementing programmes—including a recovery and recycling system and training—to meet these targets. Action will be encouraged through voluntary agreements, legislation, regulations and economic incentives.

You should contact your NOU so that you can participate in these activities.

Whether or not there is a national RMP in place, it will be important for you to undertake your own refrigerant management plan in order to ensure that you are prepared for future conditions. Training is an essential part of the RMP, as it is an almost inevitable counterpart to non-ODS conversion, it is important for countries to initiate the preparation of their own RMPs to ensure phase out in this sector.

### **Refrigeration sub-sectors**

The sector has been divided into the eight categories listed in the table on page 23. The table also indicates applications, currently used ODS and potential alternative substances for conversion. The sub-sectors accounting for the largest ODS use are mobile air conditioning, commercial refrigeration and cold storage and food processing.

### **Current practices**

The vast majority of present refrigeration and air conditioning equipment uses the vapour compression cycle because of its simplicity and good efficiency. This is unlikely to change with the introduction of new refrigerants. This cycle uses a fluid called a refrigerant and has four basic



components: evaporator, compressor, condenser and expansion device.

Because they have so many of the properties required in a refrigerant, CFCs have been used for many years as the refrigerant fluid in domestic and commercial refrigerators, for cold storage and food processing, in industrial and transport refrigeration equipment, and in stationary and mobile air conditioning units. The most common ODS refrigerant is CFC-12 (60 percent of total). Others include CFC-11, CFC-114, R-500 (CFC-12 and HFC-152a), R-502 (CFC-115 and HCFC-22) and HCFC-22.

### Conservation of CFCs

#### Why conservation is important

Refrigerant conservation serves two important purposes:

- it minimizes damage to the atmosphere by reducing refrigerant emissions; and
- it provides a supply of CFC refrigerants after CFC production stops by ensuring that refrigerants are reused.

Conservation of CFCs will ensure availability as supplies of new CFCs decline. Supplies of CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115 are now frozen at 1995-97 average levels and will be completely eliminated by 2010. If you are using any of these substances you will have to conserve your supply or change to a replacement.

Besides protecting the environment, conservation will also help you reduce breakdowns, lower your operating costs

and prolong equipment life. In addition, the reduction in CFC losses will greatly reduce your refrigerant costs especially as the price of CFCs increases.

#### Containment: the prevention and reduction of CFC losses

**Refrigerant losses** account for a large proportion of ODS consumption. For example, in industrial refrigeration, with equipment that has a life span of up to 30 years, about 60 percent of all CFCs required are used to replace losses through leakage and servicing. In commercial refrigeration world-wide average yearly leakage is estimated at 20-25 percent of the operating charge. In addition, disposal and servicing further add to the consumption of CFCs. On the other hand, the operation of domestic refrigerators involves relatively little leakage because the units are sealed and few need servicing. In this case problems arise during disposal.

While various refrigeration sub-sectors have different problems with refrigerant losses, there are three general sources of loss which affect them all in some way. These are:

- losses from leaks during operation
- venting and disposal during servicing
- disposal of obsolete equipment and refrigerant

To be effective, containment techniques must be applied to equipment design, operation, maintenance and servicing, and to refrigerant use, recovery, reuse, transport and storage.

## Alternatives to ozone-depleting substances: refrigeration and air-conditioning sector

Sub-sector	Application	Current ODS	Alternatives
<b>Domestic refrigeration</b>	Household refrigerators	CFC-12	HFC-134a and isobutane (new equipment); HFC/HCFC and propane/isobutane blends (existing equipment)
<b>Commercial refrigeration</b>	Medium and high Temperature	CFC-12, HCFC-22, R-502	HFC-134a, HFC blends (new and existing equipment)
	Low temperature		HCFC-22, HCFC blends (new and existing equipment)
<b>Cold storage and food processing</b>	Chilled and long term storage, dairy and soft drink industries.	CFC-12, R-502	HCFC-22, HCFC blends (new and existing equipment)
<b>Industrial refrigeration</b>	Chemical, pharmaceutical, petrochemical and metallurgical industries	CFC-12	HCFC-22, HCFC blends, Ammonia (new and existing equipment)
<b>Air-cooled air conditioning (heat pumps)</b>	Domestic and small commercial use	HCFC-22	HCFC blends (existing equipment), HFC-134a, HFC blends (new equipment)
<b>Air conditioning (chillers)</b>	Commercial building air conditioning systems	CFC-11, CFC-12	For CFC-11, HCFC-123 and HFCs; for CFC-12, HFC-134a, HCFC and HFC blends
<b>Transport refrigeration</b>	Truck, rail, ships	CFC-12	HCFC-22, HCFC blends, HFC-134a (new equipment)
<b>Automotive air conditioning</b>	Automobiles	CFC-12	HFC-134a (new vehicles), HCFC blends

## Elements of refrigerant conservation

<b>containment</b>	the prevention of refrigerant waste and leakage at all stages, from equipment design, through installation and servicing to disposal
<b>recovery</b>	removing refrigerant from a system in any condition and storing it in an external container
<b>reuse</b>	putting recovered refrigerant into a system without testing or cleaning it
<b>recycling</b>	cleaning refrigerant, usually on-site or at a local vehicle servicing centre, for reuse in the same type of equipment. This involves reducing contaminants by separating oil, removing non-condensibles, and using devices such as filter-driers to reduce moisture, acidity, and particulate matter
<b>reclamation</b>	reprocessing refrigerant, usually at a reprocessing facility, to new purity specifications

### *Design*

The first step in containing refrigerants is therefore the design of equipment to minimize losses during use. A good design will include:

- tight systems which will not leak during the normal life of the equipment
- leak tight valves that permit the removal of replaceable parts without loss of refrigerant
- hermetically sealed compressors
- valves located at low points for efficient liquid refrigerant recovery during servicing or disposal of equipment.

### *Installation*

Proper installation of refrigeration systems by well-trained people is important for efficient operation of the equipment during its useful life. Make sure that:

- joints are tight;
- proper piping materials are used;
- the size of the refrigerant charge is kept to a minimum;
- the system is tested for leaks and defects;
- the system is evacuated to remove air and non-condensibles.

### *Operation*

- improve maintenance of existing systems to detect and reduce leaks.

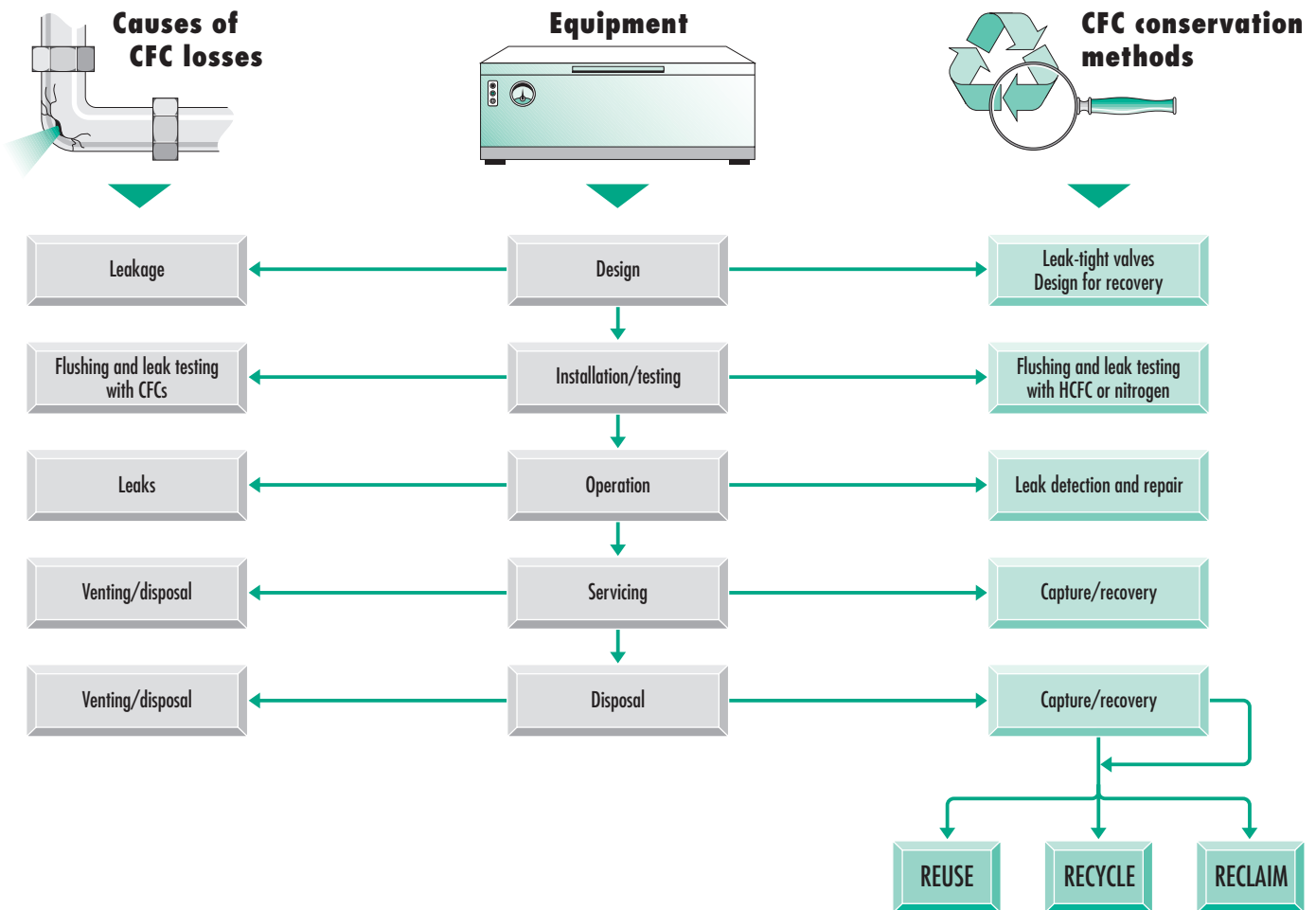
### *Servicing*

Servicing should be done on a regular basis by trained personnel. It should include:

- recovery of refrigerant into proper cylinders (cylinders certified for filling);
- minimization of refrigerant venting to the air;
- detection and repair of leaks and measurement of performance.



Conservation of CFC refrigerants



Disposal of equipment

One of the major sources of emissions is from the improper disposal of old equipment. Use proper recovery cylinders to capture refrigerant:

- liquid recovery is the quickest form;
- compressor technique is the usual method;
- vapour recovery is also done with a compressor.

Recovery

Cylinders used to recover CFCs should be clearly labelled and identified to

prevent mixing different refrigerants. Small diameter hoses and connections should be avoided because they can slow down recovery time greatly. **Liquid recovery** is the quickest and best method especially when recovering amounts over 50 kg. Several techniques are available for liquid recovery. The most developed is by compressor; others include using difference in static pressure, difference in temperature, centrifugal or pneumatic pump. **Vapour recovery** is necessary to get all of the refrigerant out of the system. The usual method is the compressor/evaporator method.

## Refrigeration management in Zimbabwe

In 1996 Zimbabwe established a National CFC Refrigerant Recovery and Reclaim Network to:

- (1) prevent the release of ODS—particularly CFC 12, CFC 22 and CFC 502—into the atmosphere during the service and disposal of refrigeration equipment;
- (2) reclaim a substantial part of these refrigerants;
- (3) educate the industry and the public on the dangers of emitting ODS

Services provided by the Network include:

- (1) improved maintenance procedures for cooling equipment
- (2) the introduction of up-to-date practices in CFC charging and handling
- (3) the distribution of modern recovery machines
- (4) establishment of a central reclamation unit in Harare to ensure reclaimed refrigerants are not contaminated
- (5) a training and awareness campaign with the refrigeration industry, stakeholders and the public
- (6) enactment of relevant legal and regulatory measures to make it mandatory to participate

SMEs in the refrigerant servicing sub-sector will have access to the most up-to-date recovery equipment free of charge including clean tested cylinders/tanks to recover used refrigerant, delivery and collector services, laboratory analysis of the refrigerant, and a training and up-dating program. In addition, reclaimed refrigerant will be available at a competitive price

Source: Zimbabwe Ozone Solutions, The National CFC Refrigerant Recovery and Reclaim Network and Zimbabwe Ministry of Environment and Tourism, Network Progress Report

### Reuse

Using recovered refrigerant without testing or cleaning it is most commonly done in the same equipment that the refrigerant was recovered from. It is a simple way of saving money if the refrigerant is not too highly contaminated with oils or other non-condensibles which would lower the efficiency of the system.

### Recycling

The high cost of CFC refrigerants

compared to the cost of a technician's time means that recycling is cost effective in developing countries. Unlike direct reuse, recycling equipment is designed to remove oil, acid, particulate, chloride, moisture and air from the used refrigerant. A variety of recycling equipment is available over a wide price range. Recycling is most common in the automobile air-conditioning industry at present. One problem, however, is that recycling equipment can neither detect nor separate mixed refrigerants.

**Reclamation**

Reclaimed refrigerant refers to refrigerant which has been cleaned and tested to new product specifications so it has the advantage that it can be used in any system without danger of damaging the equipment.

**Options for change****Equipment needs**

When you have to stop using ODS substances and turn to an alternative, there are two general options:

- Keep your existing equipment and adjust it to use an alternative substance. This can be either a minor change (retrofit) or a major one (re-engineering).
- Buy new equipment designed to use an alternative substance.

Retrofitting involves using a refrigerant in a system which was not designed for its use. In cases where you can use a 'service blend' which has very similar properties to the ODS refrigerant you can make small changes to your system. This is called using a 'drop-in' replacement—for example, HCFC-123 as the retrofit alternative to CFC-11 centrifugal chillers.

In cases where the chosen replacement refrigerant has very different characteristics from the old one, changes will have to be made to the system such as replacement of major components like the compressor, heat exchanger or pipework. This is more generally known as 're-engineering' and often involves the use of 'retrofit blends'—for example, R-410A as the alternative to HCFC-22.

If your equipment is old or in very poor condition it may be better to install new equipment designed to operate with a non-ODS refrigerant rather than make major repairs and changes to your existing equipment.

*General considerations when retrofitting*

- Make sure your equipment is in good condition.
- Do tests before retrofitting to determine your normal level of performance for comparison after the changes are made.
- Get information from suppliers about recommended changes to equipment and operating procedures needed for a successful retrofit.

*Planning for new equipment*

You will also want to plan for new refrigeration equipment which uses non-ODS refrigerants. For manufacturers, this may involve new equipment and training; for service companies, technicians will have to be trained in the use and management of new equipment and substances. In this rapidly changing area it will be important to ensure that you are supplied with up-to-date information on new substances and equipment.

**Alternative refrigerants**

The most important current alternatives to ODS are discussed below. The sub-sectors where they are suitable are shown in the table on page 23. Properties of these alternative refrigerants are shown in the table on page 29.

**HFC 134a**

There are a number of HFC compounds which are being used in 'retrofit blends'

as non-ODP alternatives but the most commonly used and most readily available is HFC-134a. This refrigerant is already used widely in new refrigeration equipment in developed countries. It is regarded as an important alternative in the phase out of CFC-12 and R-500 in medium- to high-temperature applications such as mobile air conditioning and refrigeration equipment, some stationary air-conditioning equipment (air- and water-cooled), and domestic refrigerators. It does not work well for low-temperature applications (freezing) with evaporating temperatures below  $-30^{\circ}\text{C}$ . Improvement in compressors and lubricants are among the continuing changes which are making this an acceptable alternative to CFC 12.

Retrofitting from CFC-12 to HFC-134a requires the following system modifications:

- change of mineral oil to polyol ester lubricant;
- adjustment or change of the expansion device;
- change of desiccant filter;
- if necessary, change compressor, or if open compressor is used, increase speed.

HFC 134a has a significant global warming potential (GWP), and HFC emissions are now regulated under the Kyoto Protocol. If HFCs are used, emissions must be reduced to a minimum.

#### **HCFC-22**

The most common replacement for new commercial and industrial

refrigeration is HCFC-22. A number of commercial blends based on HCFC 22 are being used. While these are considered as transitional substances because of their ODP, they will be important alternatives until suitable substitutes have been developed.

HCFC blends resemble existing refrigerants and can be used as drop-in replacements which require minimum changes to existing systems. Retrofitting from CFC-12 to HCFC-22 requires the following system modifications:

- change of compressor or reduction of compressor speed;
- change of expansion device;
- change of desiccant filter; and
- installation of an oil separator.

#### **HCFC-123**

This is the only currently available alternative to replace CFC-11 in existing centrifugal chillers. One problem with using it is its toxicity. Worker time-weighted exposure limit is 30 ppm which requires good ventilation systems and gas detectors to warn workers if there is a leak. It also requires replacing non-metallic seals and gaskets because it is a strong solvent. Typical modifications for retrofitting CFC-11 installations are:

- if a semi-hermetic compressor is used, switch to an open compressor;
- change O-rings to materials that will work with HCFC-123;
- adjust or change the expansion device;
- change desiccant filter.

#### **Custom blends**

The above substances can either be used alone or in custom blends with other

Properties of alternative refrigerants				
Property	HCFC-22	HFC-134a	Ammonia	Hydrocarbons
Cost (CFC-12 =1)	moderate (1.5)	most expensive (3 to 5)	cheapest (0.2)	low (0.4)
Flammability (LFL-%)	non-flammable (0)	non-flammable (0)	moderately high (15.0)	high (1.5 to 2.1)
Toxicity (TLV-ppm)	low (1000)	low (1000)	high (25)	low (800 to 1000)
Ozone-depleting Potential (ODP)	low (0.055)	none (0)	none (0)	none (0)
Global Warming Potential (GWP)	high (1600)	high (1200)	low (3)	low (1)
Volatile Organic Compound (VOC)	no	no	no	yes
Molar Mass (kg/kmol)	86.47	102.03	17.03	44.10 to 58.13
Normal Boiling Point (°C)	-40.8	-26.1	-33.3	-0.4 to -42.1
Critical Temperature (°C)	96.2	101.1	132.3	96.8 to 152.1
Critical Pressure (bar)	49.9	40.6	113.3	36.7 to 42.6

From *Refrigeration Source Book* (1994) p 3-25, p 3-27

materials that diminish or eliminate some of the problems associated with each substance.

#### 'Service blends'

'Service blends' are custom blends which copy existing ODS refrigerants very

closely so that they can be used as 'drop-in' replacements. There are a number of these commercially available refrigerant blends based on HCFCs (mainly HCFC-123 and HCFC-124). Some custom blends also contain HFCs. They have some ODP and some GWP.

Except for HCFC-123, they have low toxicity and they are non-flammable. The blends that have been designed to replace CFC-11, R-12 (R-500) and R-502 in existing equipment are listed in the box upper right.

#### ***'Retrofit blends'***

'Retrofit Blends' are a second type of custom blends. They are mainly HFCs and are not 'drop-in' replacements. Significant modifications have to be made to existing systems which can be time-consuming and costly. This major retrofitting can involve replacing major parts such as the compressor, heat exchangers or pipe work and is more generally called re-engineering. The change to HFC blends also requires an oil flushing procedure because these blends are not compatible with mineral oils currently used in most equipment.

Retrofit blends have zero ODP but a significant GWP. Like service blends they have health and safety advantages because they are non-flammable and have low toxicity. The refrigerants and blends that have been designed to replace ODS refrigerants after re-engineering are shown in the box lower right.

#### **Other alternative substances**

Anhydrous ammonia and hydrocarbons (isobutane, propane, LPG, HC blends) are used in some instances as CFC refrigerant alternatives. However, they have properties such as toxicity, flammability and high working pressures which require costly and sophisticated safety equipment. Their advantage is that they have zero ODP and GWP. Ammonia and hydrocarbons are not recommended for field charged units.

Propane (R-290), iso-butane (R-600a), butane and other hydrocarbons have excellent properties for refrigerants, however, because of their flammability they should only be used in smaller sealed units with low refrigerant charge, such as domestic and commercial refrigerators and freezers where health and safety hazards can be controlled.

Ammonia is an excellent alternative for replacing CFCs in new equipment. With zero ODP and GWP, it is a long term alternative and there is a great deal of experience with it because it has been used for many years. Because it is toxic and flammable, the use of ammonia has been limited to large industrial applications. It is available commercially as R-717.

#### **Other processes**

Experimentation and testing with old and new processes is producing new cooling systems which do not use ODS refrigerants. These are shown below. They may point in the direction of a whole new generation of refrigeration equipment.

- absorption systems for industrial refrigeration using ammonia or water as refrigerants.
- adsorption systems using zeolite/water as a refrigerant are being tested in Germany for use in mobile coolers, domestic refrigerators and automobile air conditioners. Not available in the short term.
- evaporative cooling is a very old technology which uses the cooling effect of evaporating water into air. This is a simple and economical system which works well in hot, dry climates.

- Stirling Refrigeration Cycle is a highly efficient, experimental system using helium gas which can be used over a wide temperature range. The limited supply of helium could limit its widespread use. Not available in the short term.

### Sources of technology, information and assistance

If you require additional information before taking action, there are a number of organizations that may be able to help you. These include the refrigeration industry association in your country, your National Ozone Unit, Ministry of the Environment or similar authority in your country. Lists of these are available from the UNEP DTIE OzonAction Programme by mail or on the internet at <http://www.unepie.org/ozonaction.html>

- *The Catalogue for Refrigeration, Air Conditioning, and Heat Pumps* (1997) contains alternative data sheets which include a description, use and availability, environmental, health and safety considerations, material and equipment changes required (if any), associated costs or savings. It gives case studies of alternative technologies which are being used in developed countries to eliminate the use of CFCs. There are also suppliers' lists for alternative and traditional refrigerants, lubricating oils, compressors, components and heat exchangers, and sources for more information.
- *UNEP 1998 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee 1998 Assessment*  
This report contains information on present practices and properties of existing refrigerants, possibilities for alternative refrigerants, new equipment and properties of alternatives, retrofitting, alternative technologies, refrigerant conservation methods, leak detection, containment and recovery, recycling and reclamation, service practices and training.
- *Recovery and Recycling*, UNEP IE, 1994
- *Training Manual on Good Practices in Refrigeration*, UNEP IE, 1994
- *Training Manual on Chillers and Refrigerant Management*, UNEP IE, 1994
- *Blends as Refrigerants to replace CFCs and HCFCs*, Information Papers, UNEP IE, 1995
- *Mobilizing Developing Country MAC Technicians to Reduce CFC Emissions*, Stratospheric Protection Division, US EPA, 1995
- *Refrigerant Recovery and Recycling, Case study*, UNEP IE 1995
- *Safety Aspects of Hydrocarbon Refrigerators*, UNEP IE
- *Phase Out Ozone-depleting Refrigerants in Developing countries: implementation and design of codes of good servicing practice in refrigeration*, UNEP IE, 1997
- *How the Hotel and Tourism Industries can Protect the Ozone Layer*, UNEP IE, 1998
- *Study on the Potential for Hydrocarbon Replacements in Existing Domestic and Small Commercial Refrigeration Appliances*, UNEP DTIE, 1999
- *Protecting the Ozone Layer, vol. 1: Refrigerants*, 2001 update, a technical brochure, UNEP DTIE, 40 pp.

*The World Bank, Ozone Operations  
Report Group Reports:*

- *Domestic Refrigeration Refrigerant Alternatives*
- *Chiller Refrigeration ODS Phaseout Alternatives*
- *Commercial Refrigeration and HCFCs in Developing Countries, Report Number 13, July 1995*
- *Mobile Air Conditioning (MACS) Conversion to Zero ODS Use*
- *Reducing ODS use by Developing Countries in Refrigeration*
- *Reducing ODS use in Developing Countries in Domestic Refrigeration/Freezer*

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# 6 Foams

## Introduction

SMEs are important producers of foam in both developed and developing countries. Growth in all sector segments is rapid in developing countries and without conversion to non-ODS substances damage to the ozone layer will be significant.

On a global basis reductions in the use of CFCs have been significant. In 1993 the foam industry used 133 000 tonnes of CFCs worldwide, an important reduction from the 267 000 tonnes consumed in 1986. This 50 percent reduction took place despite a 45 percent increase in the size of the foam market during that time. The use of CFCs in foam manufacture was completely phased out in developed countries in 1996. Phase-out has taken place through conservation, product reformulation and the use of alternative blowing agents and new manufacturing technologies. This means that several alternative technologies and substances are already proven and are available to you in the market place.

It is important to remember that the use of all the CFCs used in foams—CFC-11, 12, 113 and 114—are now frozen at 1995–97 levels and will be

reduced in stages until January 2010 when they will be phased out completely.

There are four main types of foams that have been made using CFCs. In 1990 their relative consumption of CFCs were as shown in the box above.

Building and appliance insulation accounts for close to 80 percent of the CFCs used in foams. The rest is used in cushioning, packaging, flotation and micro cellular foams.

The major applications by foam sector segment are included in the table on page 35.

## Current practices

Foams are produced by using gas or volatile liquid ‘blowing agents’ to create bubbles or ‘cells’ in the plastic structure. In some foams, the cells are closed, trapping the blowing agent inside, while in others, the cells are open and the blowing agent escapes. A number of materials have been used as blowing agents, including CFCs (mainly CFC-11, with some CFC-12, CFC-113 in phenolic foams and CFC-114), HCFCs, hydrocarbons and carbon

‘In India 80 percent of the foam sector is comprised of small enterprises and growth in the rigid polyurethane sub-sector now averages 30 percent a year.’  
(UNDP Project Report)



### CFC consumption by foam type (1999)

Sector segment	Share of CFC consumption
Polyurethane foams	84 percent
Extruded polystyrene	7 percent
Polyolefins	7 percent
Phenolic foams	2 percent

dioxide. To be considered a good blowing agent a material should have the following properties:

- non-reactive with the plastic;
- sufficiently soluble in liquid plastic, but insoluble in solid plastic;
- suitable boiling point and vapour pressure;
- preferably non-flammable.

Since CFCs met these requirements and until recently were relatively inexpensive, they have been commonly used as blowing agents for many years. CFCs are used as a blowing agent (non-insulating foams) or as a combined blowing/thermal insulation agent (insulating foams). Other functions include acting as a softener, as a heat sink and as a viscosity reducer. Due to these different functions a universal replacement is not possible.

### Options for change

There are three potential methods of reducing CFCs in the production of foam products. They are:

- changing the production process or using an alternative technology;
- replacing the CFCs with an alternative blowing agent; and
- replacing foam products with an alternative product

The recovery and recycling of CFCs from existing stocks of foam is impractical because of technical problems so the best option is incineration combined with energy recovery.

### Changing the production process/alternative technology

There are process changes and new methods which reduce CFC emissions. These are:

- Preventing the release of CFCs into the atmosphere during foam production. Using best management practices you can reduce CFC consumption by up to 10 percent. This can be done by using a closed loop CFC unloading system, using a closed CFC blending system or flushing without CFCs. One method for capturing CFCs and HCFCs is carbon adsorption. This works best with open-cell foams such as flexible polyurethane foams because of the large amounts of CFCs released during manufacturing.
- Reducing or eliminating the need for CFCs. Changes in polyols and other chemicals used in the foaming part of the production process can also reduce or, in favourable cases, eliminate the need for CFCs in both rigid and flexible foams. New equipment such as variable pressure foam equipment (which lowers the external pressure) allows lower density flexible polyurethane foams to be produced without an auxiliary blowing agent. You can also modify the production process for polyurethane foams by the use of increased levels of water in the chemical reaction so that CFC use can be reduced.

### Replacing CFCs with alternative blowing agents

#### *Evaluation of CFC alternatives*

In addition to the general considerations involved in choosing an alternative to an

### Alternatives to ozone-depleting substances: foams sector

Sub-sector	Application	Current ODS	Alternatives
Flexible chloride, polyurethane	Slabstock—bedding, cushions, carpet lining	CFC-11	Methylene  water blown, Liquid CO <sub>2</sub>
Flexible polyurethane	Moulded foam—seating, sound barriers	CFC-11	Water blown
Flexible polyurethane	Integral skin—steering wheels, automobile bumpers, shoe soles	CFC-11	Water blown, HCFC-141b, pentane
Rigid polyurethane	Appliance foams—Refrigerators, freezers, air conditioning units, water heaters	CFC-11	Cyclopentane, HCFC-141b
Rigid polyurethane	Construction foams—Lining and roof boards, pipe sections, cold store panels, doors, spray systems	CFC-11, CFC-12	HCFC-141b, n- and iso-pentane
Rigid polyurethane	Transportation foams—Sandwich panels for , trucks reefer boxes, flotation	CFC-11, CFC-12	HCFC-141b
Phenolic Foams	Building and pipe insulation	CFC-114	HCFC-141b, pentane, methylene chloride
Extruded polystyrene foams	Sheet—food packaging, art boards	CFC-12	Pentane, butane, HCFC-22
Extruded polystyrene foams	Board—roof, floor and wall insulation, sandwich panels	CFC-12	HCFC-142b/ HCFC-22

ODS which were discussed in Chapter 4, there are technical properties which specifically apply to the choice of a foam blowing agent. These are:

- **Insulation capability:** a good blowing agent should produce a low relative heat transfer through the foam so that it is a good insulator.
- **Cell control and size:** cell size affects a number of foam visual and mechanical properties. Smaller foam cells will reduce heat transfer by radiation across the cells and improve the insulating capability of the foam.
- **Solubility/viscosity:** a good blowing agent lowers the viscosity of the foam mix at the beginning and it rapidly becomes less soluble as the foaming reaction continues. This gives a good cell structure combined with good thermal performance.
- **Diffusion rate:** all blowing agents will diffuse out of the foam eventually but the time can vary from days ( $\text{CO}_2$ ) to hundreds of years (HCFCs, HFCs, HCs). High diffusion rates as with  $\text{CO}_2$  can cause the foam to shrink and will lower its insulating properties.
- **Exotherm control/antioxidants:** water blowing of polyurethane foams generates heat which can cause discolouration by scorching or damage to the foam structure. CFCs and HCFCs remove heat by endothermic evaporation which controls the overheating.
- **Blowing efficiency:** the molecular weight/boiling point relationship of the blowing agents is important to the blowing efficiency. Blowing efficiency is the amount of agent needed to produce a certain foam

density. This will affect the cost and the environmental impact.

#### **Alternative substances**

Many materials have been tested as possible blowing agents and the alternative substances currently available to replace CFCs for each of the foam sectors are listed in the table on page 35. A comparison of the properties of these substances is provided in the table opposite. Each of these options has certain advantages and disadvantages which you must consider. The choice will depend on the type of foam required and will vary from country to country because of availability, climate, environmental regulations, product specifications and energy efficiency requirements. Important issues not included in the table opposite are discussed below.

#### **HCFCs**

These compounds are considered transitional rather than permanent alternatives to replace CFCs because they do have a measurable ozone-depleting potential, although it is much lower than the CFCs. Several countries regulate their use because of this. The three most suitable materials for blowing agents are HCFC-141b, HCFC-142b and HCFC-22. They are widely used and are a proven technology. Some manufacturers are using them to 'bridge the gap' to liquid HFCs to avoid the major expense of converting to hydrocarbons before returning to non-flammable materials.

HCFC-141b is commonly used for polyurethane and phenolic insulation applications because it provides the best combination of product characteristics available.

## Properties of alternative blowing agents

Property	HCFC-141b	CO <sub>2</sub> (water blown)	Hydrocarbons	Methylene chloride	HCFC-22
Flammability (flammable limits in air)	moderate (as a gas) (7.3–16.0)	non-flammable (none)	high (1.5–2.1)	non-flammable (none)	non-flammable (none)
Toxicity (TLV-ppm)	low (500)	non-toxic	low (800–1000)	high (25–50)	low (1000)
Ozone-depleting Potential (ODP)	low (0.11)	none (0)	none (0)	none (0)	low (0.055)
Global Warming Potential (GWP)	moderate (630)	very low (1)	low (11)	no	high (1600)
Volatile Organic Compound (VOC)	yes	no	yes	yes	no
Boiling point (°C)	32	-139	-0.4–49	40	-40.8
Gas conductivity (mW/mK at 10°C)	8.8	14.5	11.0–14.0	n/a	9.9

From *Foam Source Book* (1996) p XXI

### **Hydrocarbons**

Hydrocarbons used in foam blowing include butane, isobutane, normal pentane, isopentane and cyclopentane, and mixtures of these compounds. Because of their high flammability they require great care during processing, and formulations require increased fire retardant levels to control flammability of the final product.

### **Methylene chloride**

A widely-used option for flexible polyurethane slabstock which is technically and commercially available today. Its use requires caution because of its toxicity and volatility. It may also be carcinogenic but this is unproven.

### **CO<sub>2</sub> (water blown)**

This is a good option from a health, safety and environmental view. There are some quality issues with the foam including a higher thermal conductivity and lower production rate. The increase in foam density (about 15 percent) makes this option unsuitable where insulation efficiency is important. This is a good option for moulded polyurethane flexible foams and many integral skin applications.

### **Long-term non-ODS blowing agents**

Other materials are being evaluated in developed countries and will be available in the longer term. Among these are a

### Liquid carbon dioxide technology for foam blowing

Technologies using carbon dioxide (CO<sub>2</sub>) have gained wide attention. The application in slabstock requires liquified CO<sub>2</sub>—an application called LCD technology. The basic principle is the blending of CO<sub>2</sub> with other foam components prior to the initiation of the chemical reaction. This blend is then released and, triggered by the decompression, will release the CO<sub>2</sub>, resulting in a froth. This froth will further expand due to the CO<sub>2</sub> released from the water/isocyanate reaction. While the wet end of the process requires considerable modifications to allow the storage and processing of liquified CO<sub>2</sub>, the dry end remains essentially unchanged.

There are no known toxicity or flammability issues connected to the use of CO<sub>2</sub>. The substance is also photochemically inactive, has no ODP and provides no net contribution to global warming. Three proprietary technologies are offered by four manufacturers. LCD technology has proven commercially viable for a variety of foam grades in the 15–35 kg/m<sup>3</sup> density range and it is claimed it can be used for densities as low as 10 kg/m<sup>3</sup>.

The use of LCD offers large potential savings because of its lower cost price and higher blowing power. These advantages are somewhat offset by the higher cost of other chemicals, energy and maintenance as well as licence fees. In addition, a significant learning curve can be expected when introducing this technology.

The application of LCD in flexible moulded foams has not been as rapid as in slabstock. This may be because the current major CFC replacement technology—the use of water-based formulations—does not currently face regulatory restrictions and requires significantly lower investment. In addition, the largest use of moulded foams is in automotive seats, an application that requires intensive product scrutiny before product changes are allowed.

Some 20–30 plants are currently using LCD in moulding operations.

*From 1998 Report of the Flexible and Rigid Foams Technical Options Committee (UNEP)*

number of liquid HFCs. They have the advantages of low toxicity and zero ODP, but will not be readily available until the year 2000. However, they are expensive and may be restricted because of their global warming potential.

#### Alternative products

The third way of eliminating ODS is to replace foam with a completely

different product. This has not been a major factor to date because few of the substitutes work as well as the foam they try to replace. Some examples of these are:

- vacuum panels partially replacing rigid polyurethane insulation in refrigerators
- expandable polystyrene bead board, cellular glass board, and fibreboard

## Conversion to water blown systems in the manufacture of rigid polyurethane foam in India

### Umbrella Project for SMEs

The Indian Ministry of Environment and Forests and the UNDP have developed a project which will eliminate the use of CFCs by 80 SMEs in the Rigid Foam sub-sector. The SMEs will convert to the CFC-free system in cooperation with a locally owned system supplier who will customize and validate the required formulations. In addition a low cost, locally developed foam dispenser will be evaluated and introduced for implementing the new technology. This project will cover all identified SMEs in the sub-sector and the choice of technology will be common to all participating SMEs.

### Introduction of indigenous CFC-Free Technology

The technology to be used is a fully water-blown system selected as a permanent technology. The use of a combination water and HCFC-141b based system may be needed in the interim period required to achieve acceptable product standards. The water based system will result in changed mixing ratios, leading to increased viscosities of the chemical mixture. Many of the enterprises have low pressure fixed ratio dispensers, manually operated stirrer-cum-dispensers or are engaged in hand mixing. These methods will need to be replaced with variable ratio, high pressure foam dispensers which are expected to result in more efficient handling of chemicals.

Source: UNDP and Indian Ministry of Environment and Forests Project, *Elimination of CFCs in the Manufacture of Rigid Polyurethane Foam in SMEs*.

- replacing extruded polystyrene board
- polyester fibre, steel springs and latex foam replacing flexible polyurethane foam for furniture and bedding products

### Sources of technology, information and assistance

If you require additional information before taking action there are a number of organizations that may be able to help you. These include the foam industry association in your country, your National Ozone Unit, ministry or department of the environment or similar authority in your country. Lists of these are available from the UNEP IE OzonAction Programme by mail or on

the internet at <http://www.unepie.org/ozonaction.html>

*Sourcebook of Technologies for Protecting the Ozone Layer: Flexible and Rigid Foams, September 1996 Update* is an important source of technical information as it includes the following items for each foam sector:

- description of sector showing applications;
- technical options overview—lists available alternatives;
- case studies which describe successful conversions noting:
  - new technology used
  - end product quality

- operational implications
- safety and environmental issues
- implementation, operational and maintenance costs;
- data sheets which cover the same items as above plus:
  - scale of operation
  - technical constraints
  - stage of technology
  - level of commercialization
  - investment costs.

*UNEP 1998 Report of the Flexible and Rigid Foams Technical Options Committee: 1998 Assessment, Ozone Secretariat. To order, contact:*  
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Summaries of CFC-free technologies are also available through the Implementing Agencies of the Multilateral Fund or direct from Bert Veenendaal at Rappa Inc.:

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These cover:

- foamed plastics
- non-insulation foams;
- flexible polyurethane foams;
- rigid polyurethane foams;
- extruded thermoplastic foams;
- shoe soles; and
- properties of methylene chloride.



# 7

## Aerosols

### Introduction

In 1976, aerosol products used 432 000 metric tonnes of CFCs which accounted for about 60 percent of the world's consumption. Since then, the reduction of CFC consumption in the aerosol sector has been very substantial in developed countries and some developing countries. World-wide use has declined from 180 000 tonnes in 1989 to an estimated 15 000 tonnes in 1995. The low costs of conversion for medium-sized and large companies and the existence of readily available substitutes has spurred the fast pace of phase out. While costs are generally higher for SMEs, the experience gained and expertise developed by larger firms provides a good

basis for developing appropriate and cost-effective conversion plans.

SMEs in this sector include both users and manufacturers of aerosol products. In most countries they include a large numbers of small-scale operations that function both in the formal and informal economies. They frequently serve as an important source of employment. Production facilities range from modern plants to small, simple filling facilities filling fewer than one million cans a year. At this level of activity, the amount of CFCs used per year is less than 100 tonnes.



### Alternatives to ozone-depleting substances: aerosols sector

Sector	Application	Current ODS	Alternatives
Aerosols	Personal household products	Propellants: CFC-12, CFC-114. Solvents: CFC-11, TCA	Finger pump sprayer
Aerosols	Household cleaning products	Propellants: CFC-12, CFC-114. Solvents: CFC-11, TCA	Trigger pump sprayer
Aerosols	Most applications, except where flammability is a problem.	Propellants: CFC-12, CFC-114. Solvents: CFC-11, CFC-113, TCA	Hydrocarbons (HC) such as propane and butane
Aerosols	Water-based paints, hairs sprays, aerosol deodorants, colognes, perfumes	Propellants: CFC-12, CFC-114. Solvents: CFC-11, CFC-113	Dimethyl ether (DME)
Aerosols	Non-flammable applications- solvent cleaning sprays, some lubricants, mould release agents, pesticides, medical products.	Propellants: CFC-12, CFC-114 Solvents: CFC-11, CFC-113, TCA	HCFC-22, HFC-134a, HFC-227ea, perfluoroethers

### Properties of aerosol propellant alternatives

Property	Hydrocarbons (HC)	Dimethylether (DME)	HCFC-22
Vapour pressure 3.0–6.5 bar	2.2–8.5	5.4	9.5
Internal pressure	Good	Good	Good
Spray particle size 30–50 micron	Good—in solvent	Good— in solvent and water	?
Solubility	Low	Strong	Moderate
Flammability	High	High	Non-flammable
Ozone depleting potential	Zero	Zero	Low
Volatile organic compound	Yes	Yes	No
Global warming potential	Very low	Very low	Very high
Toxicity	Low	Low	Low
Cost	Low	Medium	High

### Current practices

#### Why we used CFCs for aerosols

CFCs have been used in aerosol products since 1942 in the United States and since 1951 in Europe. They are primarily used in aerosols as propellants (CFC-12 and CFC-114) and solvents (CFC-11 and CFC-113) all of which are subject to the 1999 freeze. CFCs were used so extensively because they offered the following advantages:

- they are non-flammable and evaporate quickly;
- they give an even pressure from start to finish;
- they can produce a large range of spray particle sizes;
- they are good solvents;
- they are not harmful to worker health and safety when used correctly.

Currently no single alternative has all these advantages. Because there is no perfect non-ozone-depleting replacement you will have to examine the options discussed below to see which is the best for your end use.

## Options for change

### Conservation

If you cannot convert right away or if there is not yet a suitable alternative for your operations, you can at least take steps to reduce ODS emissions as much as possible. Make sure that your equipment is in good order, eliminate leaks and wasteful processes and attempt to recover and recycle ODS whenever possible, for example by using a compressor/condensor unit to recover vapours from propellant cylinders.

### Alternatives

The most practical replacement substance for your operations will be either hydrocarbons (HC), dimethyl ether (DME) and HCFC-22 or HFC-134a for non-flammable applications. These all have suitable properties for aerosol applications and are generally available. While each has different properties that you must consider, these can be judged according to your needs for particular effectiveness in areas such as vapour pressure, solubility and safety. The table opposite lists the properties of alternatives in several important performance areas. Equally important considerations for you will be the cost and availability of alternatives.

### *Hydrocarbon aerosol propellants (HAPs)*

Hydrocarbons are the most common substitute for CFCs in aerosol

propellants. They account for 96 percent of worldwide conversions from CFCs. The most frequently used hydrocarbons are propane, n-butane, and isobutane. Hydrocarbons are derived from liquefied petroleum gases (LPGs) which contain varying levels of unsaturated hydrocarbons, sulphur compounds, water and other impurities. This is purified by removal of these contaminants to various grades including aerosol grade. Although hydrocarbons are widely sold as liquefied petroleum gas for use as a fuel, many developing countries do not have butane or propane of suitable quality to be used as feedstock for purification to aerosol propellant grade.

The advantages of hydrocarbons include:

- their widespread availability;
- low cost;
- low toxicity;
- good dispersion characteristics.

They also have some important disadvantages.

- High flammability is a problem which requires safety precautions for all aspects of use including transportation, handling, storage and filling. Safe facilities must be explosion and fire proof and have adequate ventilation. Employees will also require additional training in handling a flammable substance.
- There may be difficulty of obtaining low-odour blends of the desired pressure.
- Safety considerations may restrict or prohibit their use in some areas.

HAPs are used in most aerosol applications where flammability is not a concern or where the risk of flammability can be controlled. There are benefits in applications where the product itself is flammable as in engine starters, carburettor cleaners and charcoal starters. Their low toxicity makes them suitable for use in a variety of personal care and household products.

Hydrocarbons are the least costly aerosol propellants currently available and the propellant filling equipment is basically the same as that used for CFCs. However, higher equipment costs could result from the need for explosion-proof filling equipment and better ventilation facilities. In warm climates, open air filling using natural ventilation may be an inexpensive option.

#### *Dimethyl ether (DME)*

DME is important in certain uses such as water-based paints, hair sprays and perfumes, because of its high solvency and easy reformulation to water-based products. However its strong solvency means that filling equipment, container material and gaskets must be resistant to dissolution or deterioration. Like HCs, DME is flammable and requires the same precautions for handling, storage, transportation and filling. It is more expensive than HCs.

#### *HCFC-22 and HFC-134a*

These are available non-flammable liquid propellants which can be used in products such as solvent cleaning sprays, lubricants, medical products and pesticides, that require non-flammability. Because of its high pressure relative to CFCs, HCFC-22

may be blended with a pressure-depressing solvent or low-pressure propellant or may require the modification of filling equipment. HCFCs should be used only for applications where there are no other alternatives since they are scheduled for eventual phase out under the Montreal Protocol. HCFCs are no longer permitted in aerosols in Europe and the United States. HFC-134a is used as a freeze spray. It is in plentiful supply and the cost is about the same as for CFCs. Worker health is not a problem because it is neither flammable nor toxic. No equipment changes are required by the user. HFC-134a is a greenhouse gas that should be used only where no other alternatives are suitable; its pressure is similar to that of CFC-12 but it is a very poor solvent.

#### **Special considerations for SMEs**

Production facilities in developing countries are often very basic with manual filling machines and propellant feeding pumps driven by non-explosion proof motors. In addition they may be located in congested areas. In such circumstances, conversion to flammable propellants would be very dangerous. Relocation may thus be essential. For small producers the solution may be to join forces, creating a shared facility which meets all the necessary safety requirements. Such a common approach would also reduce the cost of employee training. Consultation with your national ozone office or local business association may help you in finding suitable partners for such a project. Whether working alone or with others these organizations can assist you in

## Establishment of an aerosol filling centre for SMEs in Indonesia

In Indonesia the production of aerosol products is about equally split between self-fillers and contract fillers. Currently, CFC use in the country is largely limited to room deodorants, personal care products, industrial, automotive and medical aerosols. Many of the small fillers—typically in small shops in urban areas—use CFC propellants because the costs of switching to a safe hydrocarbon operation are too high.

Because it is not economically feasible to convert all the SMEs, a larger company—PT Candi—is receiving funds to provide a filling service centre that can be used by smaller SMEs. In this way SMEs will not have to face the expense of the new installations needed to handle flammable and explosive hydrocarbons.

This cash and carry 'rent a filling line' system is preferable to contract filling because it eliminates the need for complicated paperwork. In addition costs can be kept low and the confidentiality of formulations can be maintained. This project will assist SMEs to comply with the Government of Indonesia's ban on CFC use for all aerosols by December 1997.

Source: World Bank Project, *PT Candi Conversion and Aerosol Filling Center*

finding technical assistance and in determining if financial assistance is available to you.

If you can't make any of these changes, the best choice may be to convert to the use of HCFC-22, HCFC blends or HFC-134a.

### Not-in-kind alternatives

If your business is in an area such as personal and household cleaning products or pesticides, you may be able to convert to a non-propellant process which uses mechanical devices such as finger-pumps, trigger-pumps or roll-on and stick deodorant dispensers. Pump sprayers are the largest alternative to aerosol propellants for product dispensing devices. Finger and trigger-pump sprayer valves are generally

available from the same firms that produce aerosol valves. Both kinds of pump sprayers require only single stage filling operations. These are generally used for water-based, water-alcohol or alcohol based blends because the pump valve can be affected by stronger solvents.

- Trigger-pump sprayers are more costly than finger-pump sprayers and are usually larger in size (up to 5 litres). They are used for household products such as spot cleaners, carpet cleaners, laundry and dishwasher detergents. They usually deliver 2 to 4 ml per shot but can do up to 30 ml.
- Finger pump sprayers are smaller and are used for personal products such as colognes and perfumes, hair sprays, bug and weed killers. They can deliver from 0.050 to 0.200 ml per

shot. Spray particles are coarse and wet so they are best for surface application.

### Sources of technology, information and assistance

Before making any final decisions you should get the newest information available because technology, regulations, costs and availability of replacement substances are changing often and information on them is always being updated.

Specialized information on aerosol alternatives is available in the following documents:

*Protecting the Ozone Layer, Volume 5, Aerosols, sterilants, carbon tetrachloride and miscellaneous uses*, 2001 update, UNEP DTIE.

This booklet summarizes the current use of ODS in the sector, the availability of CFC substitutes and the technological and economic implications of conversion. It is less technical and detailed than the catalogue listed above and the information is older.

*Report of the Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee*, 1998 UNEP

*Sourcebook of Technologies for Protecting the Ozone Layer, Aerosols, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride*, September 1996 Update, UNEP IE. It contains a 'Guidance for Selecting non-ODS Alternatives' which discusses organizational, regulatory, economic, environment, health and safety, and technical considerations concerning replacement substances. It also includes data sheets which provide a detailed description of the uses and availability, environmental, health and safety considerations, material and equipment changes required (if any), associated costs or savings likely resulting from the phase out of ODP substances. Finally it contains a list of suppliers of alternative materials and/or equipment and sources of more information.

*Safe Sprays (video)*, 1999. This 15-minute video gives an overview on the safety considerations needed to be taken in using hydrocarbon as propellants. Available in English, French and Spanish.

## 8

## Solvents, coatings and adhesives

### Introduction

The solvents sector accounts for about 15 percent of the chemicals covered by the Montreal Protocol, and most of these are used for industrial cleaning. However, their contribution to ozone depletion is proportionally higher because of the largely emissive nature of their use. They are mainly used for cleaning printed circuit board assemblies, for precision cleaning and for metal degreasing. Smaller amounts are used in the dry cleaning industry and in the manufacture of coatings, inks and adhesives. The solvents sector includes users involved in the manufacture of jewellery, cardiac pacemakers, aerospace components, belt buckles, printed circuit boards, surgical implants and materials, and artificial limbs.

SMEs consume a significant proportion of ozone-depleting (OD) solvents in some developing countries. It is estimated that fully two-thirds of solvent consumption is by enterprises with an annual consumption of less than 2.5 tonnes of CFC-113 or 10 tonnes of 1,1,1-trichloroethane (TCA or methyl chloroform). In China, 63 percent of users are considered small and the estimate for India is about 70 percent. In India and some other developing nations, a large quantity of carbon tetrachloride is used by very small enterprises for metal degreasing and dry cleaning, often under uncontrolled conditions.

The supply of quality grades of CFC-113 has become uncertain because of its phase out in developed countries in 1996 and the freeze on its use at 1995–97 levels in 1999 in developing countries. Use of 1,1,1-trichloroethane will be frozen in

January 2003 at 1998–2000 levels and phased out by the year 2015. Carbon tetrachloride will be reduced by 85 percent from 1998–2000 average levels by 1 January 2005 and phased out totally by 2010, along with CFC-113. It is therefore prudent for enterprises in developing countries to move quickly to reduce or eliminate dependence on these substances where cost-effective alternatives are readily available. There is no single alternative to replace these solvents but there are usually several alternatives for each solvent application.

### Current practices

The main OD solvents are carbon tetrachloride, CFC-113 and 1,1,1-trichloroethane. Carbon tetrachloride has a very high ODP (greater than unity) and is much used because of its low cost and excellent degreasing properties. However, it is very toxic and will cause cancer with repeated exposure: for this reason, it has been banned in most developed countries for nearly 40 years. CFC-113 has a relatively high ODP and has been used because of its non-corrosive properties, chemical inertness, non-flammability, low viscosity and low surface tension. 1,1,1-trichloroethane has a lower ODP but is widely used because of its low cost and easy availability.

Solvent applications, current OD solvent use and their alternatives are indicated in the table on page 49.

### Options for change

#### Conservation

Much solvent use in SMEs is in cold cleaning. This consists of dipping the



parts to be cleaned into one or more successive baths of the solvent at ambient temperature, possibly with agitation or brushing. The containers are often shallow trays or even ordinary buckets. Because the losses by evaporation are high with this method, it is usually restricted for use with low-cost solvents, such as carbon tetrachloride or, possibly, 1,1,1-trichloroethane. However, CFC-113 is also occasionally used in this manner for defluxing, particularly for field repairs, and for precision cleaning, in glass beakers. This method is inevitably emissive. The only possible conservation measures are to keep the solvent as cold as possible, make sure it is used where there are no draughts, in containers that are deep enough to be usable when less than one-third full and to keep the containers closed with tight-fitting lids when parts are not actually being cleaned. A change to non-OD solvents as rapidly as possible is the ideal method for this category of use. However, this also presents some problems for some very small users (see below).

Because some of the main sources of emissions in the slightly larger user-industries are losses of solvent vapour from equipment and leaks from equipment and piping, conservation is an important method of reducing the emissions of OD solvents. This is particularly true of older equipment that is generally less efficient and likely to have higher losses. As CFCs become more expensive and less easily available, large cost savings can result from careful handling of solvents. The savings will continue after change to non-OD solvents, some of which are expensive and/or toxic. Good conservation

practices will also lower the exposure of employees to these substances.

Conservation and recovery are especially important in the electronics, general metal cleaning, precision cleaning and dry cleaning sub-sectors. In the electronics sub-sector, solvent losses can account for 90 percent of total consumption.

In many operations, the following five steps can be taken to reduce consumption:

- eliminate unnecessary cleaning;
- isolate open sources of vapour loss (this can save 50 to 80 percent);
- fit open-top vapour degreasers with sliding covers;
- turn off vents; and
- automate vapour degreasing and other processes.

Drag-out losses can be as high as 40 percent of the total but can be reduced by better basket and rack design and, above all, by adequate dwell periods in the vapour phase (so that the parts reach the full vapour temperature throughout their mass) and then in the refrigerated freeboard zone for the vapours to fall out of any crevices back into the machine. Solvent recycling can be useful in the dry cleaning industry where most existing machines have built-in recovery equipment which, when combined with careful operation, can reduce solvent emissions by up to 25 percent. It is important never to allow a dry cleaning machine to be opened until all the solvent has been dried out of the clothes.

Details on solvent conservation and recovery are given in Appendix C of the



## Alternatives to ozone-depleting solvents

Sub-sector	Application	Current ODS	Alternatives
Electronics industry	Dry film development	TCA	Aqueous development
Electronics industry	Defluxing PCB assemblies processes	CFC-113, TCA	No-clean, water soluble
Precision cleaning	Aerospace, automotive, medical, fine mechanics, navigational instruments	CFC-113, TCA	Conservation/recovery, aqueous cleaning, semi-aqueous cleaning, non-chlorinated solvents, halogenated solvents, HFCs, HFES
Metal cleaning	Primary production, maintenance, repair, service	TCA, CTC, CFC-113	Conservation/recovery, aqueous cleaning, non-chlorinated solvents, halogenated solvents, no-clean, delayed cleaning
Dry cleaning	Cleaning fabrics, clothing and leather goods	TCA, CTC CFC-113	Conservation/recovery, HCFC blends, non-chlorinated solvents
Adhesives	Foams, particle board, plywood, melamine lamination, furniture making	TCA	Water-based adhesives, high solids adhesives
Coatings	Paint, inks, conformal coatings, resists varnishes, building protection, correction fluids	TCA, CTC	Water-based coatings reactive resins, high-solids coatings, non-chlorinated solvents
Aerosols	Automotive, agricultural, horticultural, industrial and household products, contact cleaners, pesticides	TCA, CFC-113, (CTC), CFC-11	Water-based or soluble products, non-chlorinated solvents, HCFC blends, HFCs, perfluoroethers
Special solvents	Mould release agents, archive and antiquities conservation, forensic applications, special hi-tech applications	CFC-113, CFC-11, CFC-12, TCA	Water-based mould releases, film mould releases, non-chlorinated solvents, HFCs, HFES, PFCs

*1998 Report of the Technical Options Committee* listed at the end of this chapter. Depending on what steps have already been taken, application of the guidelines described can reduce total emissions considerably.

The guidelines are concerned with the best available technology for:

- cold cleaning;
- vapour-phase cleaning (including equipment with spray/ultrasound); and
- continuous 'in-line' cleaning.

### Alternative substances

A number of alternative substances are currently in use or under development

to help phase out carbon tetrachloride, CFC-113 and 1,1,1-trichloroethane. The most viable alternatives for developing countries are:

- aqueous cleaning;
- semi-aqueous or hydrocarbon/surfactant cleaning;
- non-chlorinated organic solvent cleaning
- non-ozone depleting halogenated solvents

#### *Aqueous cleaning*

From a global environmental aspect, aqueous and semi-aqueous cleaning are good alternatives. Aqueous cleaning technologies, with proper controls and monitoring, are generally considered to have low environmental impact due to the low toxicity of the constituents. Hydrocarbon/surfactant or semi-aqueous cleaning is more likely to create wastewater treatment problems. However, poor housekeeping practices such as unnecessary dumping of the cleaning tanks, can cause problems, especially if the

effluent is untreated. In an area with water management or water supply problems, aqueous cleaners may be a poor choice unless efficient water recycling is possible. Aqueous additives and semi-aqueous formulations should be carefully screened to avoid components that are harmful to human health or the environment.

In aqueous cleaning, water is the main solvent. Surfactants, synthetic detergents, soaps and other additives such as water softeners and corrosion inhibitors improve the cleaning process.

Advantages:

- safety;
- effectiveness;
- low costs; and
- containment of pollution.

Disadvantages:

- difficulties in rinsing and drying;
- need for clean water supply;
- possibly high energy consumption; and
- wastewater disposal, in some cases.

### **Solution for a widely-dispersed and growing solvents sector in China**

The solvents sector in China is growing by an estimated 14 percent a year. With as many as 3200 widely dispersed SMEs using cleaning processes based on ODS, the Government of China faces a major challenge in reducing OD solvent consumption in this sector.

The strategy adopted in China's Country Programme is to study the needs of various cleaning processes, develop alternatives, and then develop and deploy the appropriate redesigned equipment and know-how in demonstration projects throughout the country.

Once a new equipment manufacturing line is established, SMEs will receive new high quality, low cost, OD-solvent-free cleaning equipment, as well as training in its start-up and operation.

Source: UNDP Project, ODS-Free Cleaning Equipment Manufacturing Center for Phasing out ODS Consuming Solvents Across China

## Properties of alternative solvents

Property	OD solvents (reference)			Substitute solvents and processes			
	CTC	CFC-113	1,1,1-TCA	Aqueous cleaning	HCS/semi-aqueous cleaning	Non-halogenated organic	Non-ODS halogenated
Ozone depletion potential	very high	high	medium high	none	none	none	none
Global warming potential	?	very high	low	none	none	none	none
Volatile organic compound	yes	yes	yes	no	yes	yes	yes
Solvency effectiveness	high	medium	high	high (with additives)	high	high	high
Toxicity	very high (carcinogenic)	medium low	medium high	very low	medium	medium	high to very high
Flammability	none	none	almost none	none	medium	medium to very high	none
Possibility of explosion	none	none	very slight	none	high	very high	usually none
Viscosity	low	low	low	low to medium	low to medium	low	low
Surface tension	very low	very low	very low	low to medium	low to medium	low to medium	low
Compatibility with metals	good	excellent	good	poor to excellent	poor to excellent	good to excellent	usually good
Compatibility with plastics	poor	medium	poor	excellent	medium	medium to poor	usually poor
Recycling	possible	easy	easy	possible (large plants)	possible (large plants)	difficult	easy
Operating cost	low to medium	high	medium	medium	high	medium to high	medium
Capital cost medium	low	low	low	medium	high	high	low to
Air pollution risk	very high	very high	very high	very low	medium	medium to high	high
Water pollution risk	low	low	low	high	high	low	low
Soil pollution risk (accident)	high	medium	high	low	medium	medium	high

***Semi-aqueous cleaning***

This option involves using hydrocarbon solvents and surfactants which are either emulsified with the water or, more commonly, are used by themselves and followed by water cleaning.

Advantages:

- effective;
- may lower solvent costs; and
- compatible with most metals and some plastics.

Disadvantages:

- can increase process costs because of wastewater disposal;
- recycling of the solvent and water may be costly;
- capital equipment usually more costly;
- may introduce flammability and odour concerns; and
- the solvents are volatile organic compounds.

***Non-chlorinated organic solvents***

This group includes solvents which are often less toxic than non-OD halogenated solvents such as alcohols, ketones, aliphatic hydrocarbons and alkanes. Although toxicity is a concern with some substances, the main risk is from the high flammability of the more volatile compounds. Such solvents are not recommended unless precautions are taken such as installing explosion-proof electrical equipment and using proper ventilation and worker protective equipment. The danger from fire should be considered even more seriously in densely populated regions, particularly if other flammable or combustible materials are likely to be present in the neighbourhood or in places with a high seismic activity. The possibility of soil or

groundwater contamination could also be a problem if proper material handling practices are not followed.

***Non-OD halogenated solvents***

This group includes trichloroethylene, perchloroethylene and methylene chloride. These non-flammable solvents are toxic and require special measures to protect workers from exposure. Perchloroethylene and methylene chloride are particularly toxic and, in high doses, have been known to cause cancer in rodents. Low emission cleaning equipment minimizes worker exposure levels and emissions to the environment and, along with good management practices, makes these solvents a practicable alternative. When used with this technology they give equivalent or better cleaning than OD solvents using older equipment. The compatibility of these substances with plastics and elastomers should be tested. The possibility of soil or groundwater contamination could also be a problem if proper material handling practices are not followed.

***Other alternative substances***

There are other alternatives such as the more toxic organic solvents, HCFCs, perfluorocarbons, and a growing number of non-solvent cleaning processes which will not be discussed in more detail because of their environmental effects, high cost, hazards, lack of availability or other difficulties.

**Current and alternative processes for solvent sub-sectors****Electronics**

The electronics industry is the largest user of CFC-113, consuming about 45

percent of the total world usage. It is used mostly to remove flux residues from electronics assemblies. The industry is successfully converting to a number of non-OD solvent processes. 'No-clean' technologies are the best alternative and have been used in more and more electronics manufacturing applications in recent years. 'No-clean' processes, using low solids content fluxes, can lower costs and, if the process is operated under a controlled atmosphere, reduce solder dross. It is the preferred choice for consumer and some other electronic products. In more sophisticated products, especially where enhanced reliability is important, cleanliness standards may require that some form of cleaning take place. To change to 'no-clean', you will have to work with manufacturers and suppliers of flux to choose the formulation that meets your process and quality specifications. To ensure success, however, 'no-clean' processes require skilled operators, increased quality control of incoming components, including printed circuit boards, and, in some cases, superior machinery.

#### 'No-Clean' processes

- low-solids 'No-Clean' processes;
- high-solids 'No-Clean' processes;
- controlled atmosphere soldering.

The use of water-soluble fluxes and pastes is the most economical method of soldering and cleaning and has been in use since the 1960s. Used correctly, water-soluble fluxes can produce superlative soldering and cleaning qualities. However, this can be achieved only if a rigorous process control system is set up. As a general rule, new cleaning

machinery will be required and some of the available equipment scaled for SMEs may have relatively high energy demands. For smaller companies, water recycling is not practical and an adequate supply of drinking-quality water becomes a must. The need for wastewater treatment can be avoided, in many cases. For medium enterprises, especially where adequate water is expensive, partial water recycling can be considered to avoid excessive costs. If situated near the coast, low-cost seawater purification units may be an option, especially multiple-stage solar flash stills in countries with much sun.

#### Water soluble defluxing processes

- traditional water-soluble process;
- 'glycol-free' water-soluble process.

Another important application in the electronics industry is the development of dry film photoresists and solder resists during PCB manufacturing. This uses a special grade of stabilized 1,1,1-trichloroethane, followed by a water rinse. Aqueous-developed substitutes have been available for more than 20 years and, whereas early types were not always suitable for some applications, today's products are considerably better. Notwithstanding, wet photo-imaging processes, either with curtain or silk-screened coating, offer another possibility, particularly for high density interconnect structures.

#### Precision cleaning

Precision cleaning is the second largest application of CFC-113 and 1,1,1-trichloroethane solvents. CFC-113 is used in the electronics and other industries to clean delicate instruments and surfaces, which may be made of

## Brominated solvents

A number of OD solvent blends containing bromine have recently appeared on the market. These look tempting as they are not too expensive and the makers claim they are 'drop-in' substitutes for other OD solvents. Currently being studied under the Montreal Protocol, they are often based on chlorobromomethane or n-propyl bromide (which have synonyms) and are marketed under trade names

The Solvents, Coatings and Adhesives Technical Options Committee does not recommend their use because of their ODP, which is within the same range as that of regulated HCFC solvents. These solvents may become scheduled for rapid phase out because they have no outstanding characteristics which cannot be found in other, more benign solvents. Any investment in these solvents would therefore be wasted. It is not likely that aid from the Multilateral Fund would be made available for them.

The position of these solvents with regard to Health and Safety is equivocal. It is known that n-propyl bromide has a very low flash point (lower than 0°C). Both of the types mentioned are believed to be quite toxic, although long-term testing has not been done. Concern has been expressed about mutagenicity, neural toxicity and reduced sperm counts.

metal, plastic, or glass and optical components. Precision cleaning is also needed in some specialized forms of manufacture, maintenance, testing and assembly. 1,1,1-trichloroethane has been used in cleaning some types of medical equipment and was appropriate for precision cleaning of heavy grease.

Much solvent loss can be avoided by reducing the number of cleaning operations. For example, all the components of a precision device may not need to be cleaned individually if, after assembly, the device must be cleaned again, anyway.

Available options to replace OD solvents include aqueous cleaning, semi-aqueous cleaning, non-chlorinated solvents and halogenated solvents.

#### *Aqueous cleaning*

There are three common types of process equipment:

- immersion with ultrasonic agitation (best cleaning in parts with minute interstices, most expensive);
- immersion with mechanical agitation (simple to operate, harder to automate);
- spray washer (least expensive, may be less effective in cleaning some types of complex parts).

The water must be thoroughly degassed, filtered and temperature-controlled if ultrasonic agitation is to be used, otherwise cavitation will not occur close to the parts being cleaned. This involves complex pre-treatment facilities. Some materials may be totally or partially incompatible with pure water.

#### *Hydrocarbon/surfactant (semi-aqueous) cleaning*

Semi-aqueous cleaning process steps and equipment are similar to aqueous cleaning, with an additional stage for the organic solvent. The five major steps in the cleaning process are solvent-cleaning (with a hydrocarbon/surfactant), gross water-cleaning, water-rinsing, drying and wastewater disposal. Both the solvent and water may be partially recycled in large installations but this requires very careful process control where it is possible. Combustibility of the organic solvent dictates that it must never be sprayed through air.

#### *Non-chlorinated solvents (alcohols and ketones)*

Isopropanol (IPA, isopropyl alcohol) has been successfully used in a number of applications as it is compatible with most metallic and non-metallic materials. However, precautions must be taken because of its flammability and low flash point. Aliphatic hydrocarbons such as mineral spirits or naphtha are used extensively in maintenance cleaning as they are compatible with most materials, have good cleaning properties and, like isopropanol, can be recycled. They are also highly flammable.

#### *Non-OD halogenated solvents*

Halogenated solvents are effective cleaners but must be used carefully because of their health risks. If modern, low-emission, vapour-phase equipment was used for OD solvents, it may usually be easily modified for non-OD solvents, at little cost. These solvents are not necessarily compatible with all non-metallic parts and careful testing is advised.

**General metal cleaning**

Metal cleaning applications include all those in which metal parts are cleaned during manufacturing or maintenance except for those metal parts that are included in precision cleaning. 1,1,1-trichloroethane and CFC-113 are used extensively in general metal part cleaning in a wide range of manufacturing and maintenance processes in industry. Processes involve dipping parts manually or hydraulically into a solvent solution. Soaking, mechanical agitation, ultrasonic cleaning and vapour degreasing are used, and there is often high solvent consumption because much equipment currently contains no vapour level controls or containment facilities and up to 80 percent of purchased solvent can be lost.

It has been estimated that aqueous cleaning could replace at least 60 percent of the OD solvents used in degreasing metals. The main stages in aqueous cleaning are washing, rinsing and drying. Aqueous cleaning processes include immersion cleaning, ultrasonic cleaning and spray cleaning.

There are specific metal-cleaning operations in which halogenated solvents such as methylene chloride are considered to be the only alternative to CFC-113 and 1,1,1-trichloroethane. Great care must be taken to avoid operators being exposed to the vapours from these solvents, in view of their toxicity.

**Dry cleaning**

The fabric and clothing dry cleaning industry is a relatively minor user of carbon tetrachloride, 1,1,1-trichloroethane and CFC-113, consuming less than 5 percent of all

CFC-113. Organic solvents are ideal for dry cleaning because, unlike water, they do not distort fabrics.

Conservation is important because solvent losses from dry cleaning machines result from poor recovery (drying), leakage, distillation losses and incorrect handling during refilling and servicing. Efficient operation of the refrigeration unit can reduce solvent losses by up to 25 percent.

A number of HCFCs and HCFC blends are commercially available as dry cleaning solvents and may be used in modern machines designed for CFC-113 with little modification. They should not be used in machines designed for chlorinated solvents. They are stable, non-flammable and have excellent solvency. It should be noted that they are transitional alternatives subject to phase out under the Montreal Protocol by the year 2030.

Before carbon tetrachloride was introduced for dry cleaning, an aliphatic hydrocarbon solvent (Stoddart's solvent) was used extensively. Some new solvents of this type, with special characteristics to suit many different applications, including suede and leather cleaning, have been introduced in recent years. However, these are flammable or, at least, combustible and their use requires special new machinery which has also become readily available. This technique may lower overall costs compared to CFC-113 cleaning and can be used for most garments bearing an 'F' label.

**Adhesives, coatings and aerosols**

The quantities of carbon tetrachloride, CFC-113 and 1,1,1-trichloroethane employed for these miscellaneous uses

are less than 5 percent of the total. 1,1,1- trichloroethane is used to improve adhesive performance, to dissolve the main binding substance in coatings and inks, and as a spray-coating thinner.

#### *Adhesives applications*

Water-based adhesives come in three forms; solution, latex or emulsion, and they can replace OD solvent-based adhesives in many applications. In general, water-based adhesives show good durability, water resistance and adhesion to a wide variety of materials. Another alternative is high solids adhesives where the amount of solvent used is reduced by replacing it with a higher amount of solids. High-solids adhesives have good performance and can mostly be used on existing equipment at normal line speeds with minor modifications. Reactive adhesives contain no solvents.

Instantaneous contact adhesives are also available with toluene or xylene solvent systems. These have the disadvantage of high flammability but are excellent in performance.

#### *Coating applications*

The drying time, durability, stability, adhesion and ease of application properties of water-based inks, paints and coatings have been improved recently allowing them to replace solvent-based products in many printing and coating applications. Even tough applications, such as on road vehicles, are successfully using water-based paints. Much conformal coating in the electronics industry uses reactive products, containing no solvents, and reactive paints based on epoxy, polyester

and polyurethane resins are also available for some applications.

#### *Aerosol applications*

The simplest replacements for carbon tetrachloride, CFC-113 and 1,1,1-trichloroethane in aerosol applications as solvent sprays are HCFC blends. However, this is only a temporary solution because of their restrictions under the Montreal Protocol. (This applies only to the sprayed solvents and not to the propellants.)

#### **Specialized solvent uses**

There are a number of other applications such as mould release agents, film and skin cleaning and vapour-phase soldering and reflow where very small amounts of CFC-113 and 1,1,1- trichloroethane are used.

Water-based mould release agents are available worldwide and are being used in a variety of manufacturing operations, especially in rubber moulding applications. They are the safest option currently available from a worker viewpoint (non-toxic, non-flammable) and they have reduced VOC emissions compared to solvent-based processes. There is no water-treatment or disposal required and they are cheaper than the current CFC processes.

CFC-113 is used as a secondary blanket with some types of vapour-phase soldering and reflow equipment, to lower the cost of primary vapour losses. PFC drop-in substitutes have become available. They are not ODS but are more costly than CFC-113 and have extremely high Global Warming Potentials (several times that of CFC-113).



### The problems of very small enterprises

Very small enterprises are those with usually less than five employees and often only one, and an OD solvent consumption of less than 1 tonne per year. They present a particular problem that has yet to be resolved. Initially, as there are often many such enterprises in developing nations, many of them in low-tech sub-sectors, such as bicycle repair shops, it is almost impossible to identify them. They can therefore be approached only through their solvent suppliers, depending on the goodwill of the latter, which cannot always be guaranteed.

A second problem is the administrative cost of offering technical or financial aid to such enterprises, which may have almost no capital investment in cleaning equipment and may purchase solvents worth a few hundred dollars or less a year. None of the regular channels for funding from national or international sources would undertake the expense of developing projects to thousands of such enterprises, either individually or collectively, even though the aggregate evaporation from all such sources represents an important proportion of the solvents sector emissions.

One approach that has not yet been tried is to request the solvents manufacturers or importers to substitute, for example, trichloroethylene when a very small customer orders carbon tetrachloride for simple degreasing applications. The difference in price is not prohibitive, the two solvents have reasonably similar characteristics and the

trichloroethylene, while being quite toxic, is far less so than carbon tetrachloride, so that the changeover will pass almost unnoticed.

Trichloroethylene could also be supplied in place of 1,1,1-trichloroethane for metal-cleaning applications but, in this case, the higher toxicity could present a severe problem and warnings would be necessary. CFC-113 does not have such an almost-acceptable substitute within a reasonable price range.

The same applies to slightly larger enterprises which may be equipped with a small two-tank vapour degreaser, whose new value may be as low as a few thousand dollars. To replace this machine with the smallest aqueous machine and to supply the cleaning know-how may cost a total of only some US\$10 000. On top of that, as such a machine is, almost by definition, not very efficient when not used to full capacity, the running costs may rise from, say, US\$1000 to US\$2000 a year, assuming there is an adequate water supply available. The total aid package thus amounts to some US\$15 000. In this case, there may be a chance of financial and technical aid, but not as an individual project. The only hope would be to group, say geographically, all the companies requiring exactly this aid with the same problem, to be resolved in the same way. Under these conditions, an implementing agency could consider it worthwhile to propose an 'umbrella' project with a dozen or so such identical installations. This is not ideal, because each company loses its flexibility of choice and training would be centralized.

### Sources of technology, information and assistance

The *UNEP 1998 Report of the Solvents, Coatings and Adhesives Technical Options Committee 1998 Assessment*, provides detailed technical descriptions of the leading alternatives including the advantages and disadvantages of each. It also includes a discussion of cost of alternatives and environmental and energy considerations. A 1998 Report will soon be released. The text of the 1994 report can be downloaded from the Internet and it is planned that the 1998 report will also become available on-line at <http://www.protonique.com/unepstoc>.

The *STOC Ready Reference of OD Solvents* lists all trade names of commercial products known to contain OD solvents, as an aid to their identification. It may be downloaded from the Internet at <http://www.protonique.com/unepstoc>

*The Sourcebook for Specialized Solvent Uses* (UNIDO, September 1996 Update) has alternative data sheets which include a description, use and availability, environmental, health and safety considerations, material and equipment changes required (if any), associated costs or savings, and the suppliers of alternative materials and/or equipment in the special solvents sub-sector as well as sources of more information.

UNEP DTIE has also produced a guide for the hotel and tourism industry: *How the Hotel and tourism Industry can Protect the Ozone Layer* (UNEP IE, 1998).

*Solvents: Sector Specific Issues*, United Nations Industrial Development Organisation (UNIDO), Solvents Unit, June 1995

### ICOLP-US EPA publications

- *Alternatives for CFC-113 and Methyl Chloroform in Metal Cleaning*
- *Aqueous and Semi-Aqueous Alternatives for CFC-113 and Methyl Chloroform Cleaning of Printed Circuit Boards*
- *Eliminating CFC-113 and Methyl Chloroform in Precision Cleaning Operations*
- *No-Clean Soldering to Eliminate CFC-113 and Methyl Chloroform Cleaning of Printed Circuit Board Assemblies*
- *Conservation and Recycling Practices for CFC-113 and Methyl Chloroform*
- *Manual of Practices to Reduce and Eliminate CFC-113 Use in the Electronics Industry*

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# PART III

## **SOURCES OF ASSISTANCE**

## 9

## The Multilateral Fund for the implementation of the Montreal Protocol

### Introduction

The origin and purpose of the Multilateral Fund was discussed in Chapter 2. As an institution created to assist developing countries meet their commitment to phase-out the use of ODS or 'controlled substances', the Fund supports a variety of activities. These include projects to assist companies to phase-out ODS, to access new technologies and to receive training or attend demonstration workshops in their particular sectors.

In this chapter you will find some guidelines for accessing Fund support and a sampling of projects that assisted SMEs in each of the four sectors to convert to new technologies or substances or to adopt conservation techniques that considerably reduced the consumption of ODS.

### Guidelines for financing projects for SMEs

*To be eligible for assistance you must:*

- Operate your enterprise in an article 5 country. That is a developing country which has an ODS consumption rate of less than 0.3 kg per capita.
- Be a citizen of a country that has ratified the Montreal Protocol. See Appendix 1 for the list of developing countries that have ratified the Protocol.
- Have a project that has the approval of your government. Remember that applications for a project can only be submitted by national governments, national ozone units or the implementing agencies of the Fund.

Once submitted, they must also be approved by the Executive Committee of the Fund.

- Ensure that your project fits in with the industrial strategy and Country Programme of your government.
- Develop a project that is based on environmentally sound alternative technologies or substitutes to ODS.
- Propose the most cost-effective and efficient option, taking into account your national industrial strategy. Because umbrella or group projects are often the most cost-effective for SMEs, it is likely that most SME projects will include several enterprises.
- Understand that the Fund only provides financial assistance for the incremental costs of your project. That is, it will cover only the cost of conversion from ODS to non-ODS operations. If this change requires the purchase of safety equipment, it could also be considered as an incremental cost.

*How to proceed*

- Start with your industry association. It will frequently have programs to assist members to convert to non-ODS. In many instances, it will be faster and more effective to proceed to make the needed changes without financial assistance from the Fund.
- Use your national ozone office. This is where you will get the information and assistance you need. The ozone officer(s) will be able to direct you to appropriate sources, inform you of



training or information workshops, if they exist, and provide advice on the possibility of receiving assistance from the Fund.

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## 10

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UNEP

## About the UNEP DTIE OzonAction Programme

Nations around the world are taking concrete actions to reduce and eliminate production and consumption of CFCs, halons, carbon tetrachloride, methyl chloroform, methyl bromide and HCFCs. When released into the atmosphere these substances damage the stratospheric ozone layer—a shield that protects life on Earth from the dangerous effects of solar ultraviolet radiation. Nearly every country in the world—currently 172 countries—has committed itself under the Montreal Protocol to phase out the use and production of ODS. Recognizing that developing countries require special technical and financial assistance in order to meet their commitments under the Montreal Protocol, the Parties established the Multilateral Fund and requested UNEP, along with UNDP, UNIDO and the World Bank, to provide the necessary support. In addition, UNEP supports ozone protection activities in Countries with Economies in Transition (CEITs) as an implementing agency of the Global Environment Facility (GEF).

Since 1991, the UNEP DTIE OzonAction Programme has strengthened the capacity of governments (particularly National Ozone Units or ‘NOUs’) and industry in developing countries to make informed decisions about technology choices and to develop the policies required to implement the Montreal Protocol. By delivering the following services to developing countries, tailored to their individual needs, the OzonAction Programme has helped promote cost-effective phase-out activities at the national and regional levels:

### Information exchange

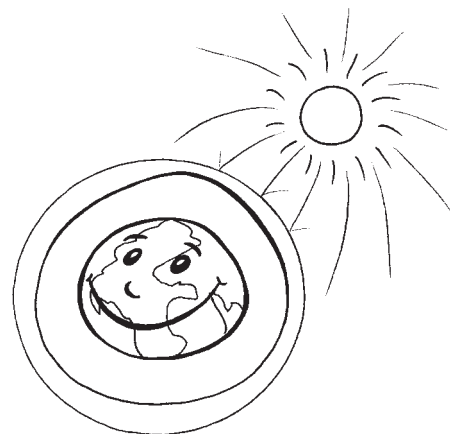
Provides information tools and services to encourage and enable decision makers to make informed decisions on policies and investments required to phase out ODS. Since 1991, the Programme has developed and disseminated to NOUs over 100 individual publications, videos, and databases that include public awareness materials, a quarterly newsletter, a web site, sector-specific technical publications for identifying and selecting alternative technologies and guidelines to help governments establish policies and regulations.

### Training

Builds the capacity of policy makers, customs officials and local industry to implement national ODS phase-out activities. The Programme promotes the involvement of local experts from industry and academia in training workshops and brings together local stakeholders with experts from the global ozone protection community. UNEP conducts training at the regional level and also supports national training activities (including providing training manuals and other materials).

### Networking

Provides a regular forum for officers in NOUs to meet to exchange experiences, develop skills, and share knowledge and ideas with counterparts from both developing and developed countries. Networking helps ensure that NOUs have the information, skills and contacts required for managing national ODS phase-out activities successfully. UNEP currently operates 8 regional/sub-regional Networks involving 109 developing and 8 developed countries,



which have resulted in member countries taking early steps to implement the Montreal Protocol.

### **Refrigerant Management Plans (RMPs)**

Provide countries with an integrated, cost-effective strategy for ODS phase-out in the refrigeration and air conditioning sectors. RMPs have to assist developing countries (especially those that consume low volumes of ODS) to overcome the numerous obstacles to phase out ODS in the critical refrigeration sector. UNEP DTIE is currently providing specific expertise, information and guidance to support the development of RMPs in 60 countries.

### **Country Programmes and Institutional Strengthening**

Support the development and implementation of national ODS phase-out strategies especially for low-volume ODS-consuming countries. The Programme is currently assisting 90 countries to develop their Country Programmes and 76 countries to implement their Institutional-Strengthening projects.

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## About the UNEP Division of Technology, Industry and Economics

The mission of the UNEP Division of Technology, Industry and Economics is to help decision-makers in government, local authorities, and industry develop and adopt policies and practices that:

- are cleaner and safer;
- make efficient use of natural resources;
- ensure adequate management of chemicals;
- incorporate environmental costs;
- reduce pollution and risks for humans and the environment.

The UNEP Division of Technology, Industry and Economics (UNEP DTIE), with its head office in Paris, **is composed of one centre and four units:**

- **The International Environmental Technology Centre (Osaka)**, which promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins, in developing countries and countries in transition.
- **Production and Consumption (Paris)**, which fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.
- **Chemicals (Geneva)**, which promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety world-wide, with a priority on Persistent Organic Pollutants (POPs)

and Prior Informed Consent (PIC, jointly with FAO)

- **Energy and OzonAction (Paris)**, which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The UNEP/RISØ Collaborating Centre on Energy and Environment supports the work of the Unit.
- **Economics and Trade (Geneva)**, which promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.

UNEP DTIE activities focus on raising awareness, improving the transfer of information, building capacity, fostering technology cooperation, partnerships and transfer, improving understanding of environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and catalysing global chemical safety.

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