MONTREAL PROTOCOL
ON SUBSTANCES THAT DEPLETE
THE OZONE LAYER

UNEP

2002 REPORT OF THE
TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

(PURSUANT TO ARTICLE 6 OF THE MONTREAL PROTOCOL)

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Technology and Economic Assessment Panel

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1 Executive Summary

1.1 Introduction

Since the 1998 Assessment of the Technology and Economic Assessment Panel (TEAP), a large number of technical developments have taken place. The direction many of these developments have taken could not have been predicted in 1998. Hydrocarbon refrigerants are capturing greater market share and CO_2 is commercialised in some refrigeration sub-sectors, including heat pump water heaters, and proposed in vehicle air conditioning. Newly available HFCs are currently being introduced into some foam sectors, but price and responsible use criteria are limiting the uptake to specific applications where they are needed. Large quantities of ODSs are potentially available for destruction with significant efforts underway in Australia, Canada, Europe, and Japan.

The Panel's Technical Options Committees, on aerosols, MDIs, miscellaneous uses and CTC (ATOC), on foams (FTOC), on halons (HTOC), on methyl bromide (MBTOC), on refrigeration and AC (RTOC), and on solvents (STOC) have each issued a 2002 Assessment Report. The Executive Summaries of these reports form the body of the 2002 TEAP Assessment Report and their Abstract Executive Summaries form the Executive Summary of the 2002 TEAP Assessment Report.

During the year 2002, separate Task Forces under the TEAP have reported their findings, which are part of the TEAP Progress Report, published April 2002. In particular the findings of the Task Force on Collection, Recovery and Storage (TFCRS) are interlinked with the results reported by the different TOCs in their 2002 Assessment Reports. The summary of these findings was thought to be so important that it should again be part of the TEAP 2002 Assessment Report.

The following structure has been adopted in each section:
- Current status; what has been achieved
- What is left to be achieved
- The way forward.

This structure does not apply to the Executive Summary of the TFCRS Report.

1.2 Aerosols, Sterilants, Miscellaneous Uses and CTC TOC

(a) MDIs for Asthma and COPD

Current status

Asthma and COPD have remained common and their prevalence is increasing world-wide. Technical barriers for CFC-free MDIs are currently being overcome. A range of alternatives, including CFC-free MDIs and DPIs, are now available increasingly around the world. In 2001, each of the three inhaler types, i.e., (1) the CFC-containing MDI inhalers, (2) the CFC-free MDI inhalers and (3) the DPI inhalers had one third of the market in the European Union.

What is left to be achieved

The remaining 7,000 ODP tonnes of CFCs used annually in MDIs for asthma/COPD can be phased out. The timing is difficult to predict, but it depends on:

- the availability of affordable alternatives
- the adoption and effectiveness of transition strategies by Parties.

The way forward

Parties could aid their transition by collecting data on the local availability of alternatives. However, the availability of alternatives alone does not drive transition to completion, and effective transition strategies are needed. Some non-Article 5(1) Parties have developed transition strategies for the phase-out of the production of CFC containing MDIs. As of November 2002, ten Parties (out of 43 non-Article 5(1) Parties) had submitted transition strategies to the Ozone Secretariat.

(b) Aerosols, Sterilants and Miscellaneous Uses

Current status

In the last four years there has been a substantial phase-out of CFCs in non-MDI aerosols. Between 1997 (14,700 ODP tonnes) and 2001 (4,300 ODP tonnes) there was a 71% reduction in the CFC consumption that remained in Article 5(1) Parties and CEIT.

The use of CFCs for sterilisation has been phased out in most non-Article 5(1) Parties. Many alternatives have been developed.

Most miscellaneous uses have been phased out, whilst some laboratory uses still remain under a global exemption. However three uses (the testing of oil, grease and total petroleum hydrocarbons in water; testing of tar in road-paving materials; and forensic fingerprinting) were eliminated from the exemption.

What is left to be achieved

A complete phase-out for non-MDI aerosols is achievable. There are difficulties including the availability of hydrocarbon aerosol propellants, the conversion of small CFC users, and also the conversion of non-MDI pharmaceutical aerosols.

There remain about 500 ODP tonnes of CFCs used annually in sterilants in some Article 5(1) and CEIT Parties.

Regarding miscellaneous uses, about 1,000 ODP tonnes of CFCs are used for tobacco expansion in China and 1,500 ODP tonnes of CFCs and CTC world-wide for laboratory and other miscellaneous uses.

The way forward

A complete phase-out of the remaining CFCs for the use in non-MDI aerosols requires specific actions from Government/Ozone officers and may need technical and financial assistance.

Sterilisers are expensive equipment, which are needed to provide good quality health care. Drop-in substitutes are available at a higher cost, reason for which financial assistance may be needed in Article 5(1) countries.

Use of CFCs for tobacco expansion in China is scheduled for phase-out by 2007. Continued use for laboratory and analytical applications under the global exemption requires that all Parties adopt packaging and reporting systems as specified in the exemption. Licensing systems will be needed in order to manage supplies of ODS into the laboratory and analytical sector.

(c) Carbon Tetrachloride

Current status

The primary source of atmospheric emissions of CTC is from manufacturing facilities that use it as a feedstock to produce CFCs. Through closures of facilities substantial reductions have been achieved recently and more are expected in the future.

What is left to be achieved

CTC emissions from process agent use in non-Article 5(1) Parties are estimated at 220 ODP tonnes annually, but emissions are very difficult to estimate in Article 5 (1) Parties. A number of applications for CTC exist in Article 5(1) Parties, although it is not clear which exact amount can be attributed to CFC production, feedstock, process agent, and other applications such as solvents; further data on consumption and emissions are required. The extent of inadvertent production of CTC in other chemical production processes in both Article 5(1) and non-Article 5(1) countries is currently unknown.

The way forward

Emissions from feedstock and process agent uses in Article 5(1) Parties require special attention from the Montreal Protocol Parties. Close co-operation of the Technology and Economic Assessment Panel with the Science Assessment Panel will be required to better estimate inadvertent emissions and more closely examine their implications.

1.3 Rigid and Flexible Foams TOC

Current status

The phase-out of ODS in the foam sector has forced the industry to innovate faster than ever before. The first technology transition in the early 1990s led to the introduction of transitional substances such as HCFCs as well as the increasing use of hydrocarbons and other non-ODSs. This transition step is still taking place in Article 5(1) countries. Meanwhile, attention in non-Article 5(1) countries is on phasing out transitional HCFCs. This is concentrating attention on the emerging HFC-based technologies as well as the further optimisation and use of hydrocarbon and CO_2 technologies, which are continuing to gain market share in several sub-sectors.

The phase-out of CFC use in the polyurethane flexible foam sector is now largely complete, even in Article 5(1) countries, although some small discontinuous processes still represent a challenge. In the flexible sector there has been little use of transitional technologies.

In the appliance polyurethane rigid foam sector, there has been a tendency to switch in one-step transition to hydrocarbons. The exception is the market in North America, which over the coming months is likely to move substantially to HFC use, as HCFC-141b is phased-out in the United States. CFC usage has been all but phased out in the construction foam markets, although transitions out of HCFCs are proving difficult within the smaller site-applied products such as spray foam.

The use of CFCs in foams has been reduced by over 90% since its peak in 1988 and HCFC use is also in decline from its peak in 2000. For the first time, the ozone depleting impact arising from new consumption of each class of blowing agent -if and when emitted- has become comparable in magnitude.

What is left to be achieved

Liquid HFC blowing agents have been commercially introduced and work is ongoing to define responsible use criteria in the light of the significant global warming potential of these materials. Nonetheless, HFCs can be used responsibly in many applications where they offer additional energy efficiency benefits or particular product/process safety.

The plight of the small- and medium-sized enterprises (SMEs) also remains to be addressed. This is most severe in non-Article 5(1) countries where no transitional assistance exists. However, even in Article 5(1) countries, there is continuing concern that uncertainty over the future supply of alternatives is delaying phase-out of CFCs. This is particularly an issue for plants where cost-effectiveness considerations dictate the use of transitional technologies.

As annual consumption of ODSs decreases, the focus is shifting towards the management of emissions from delayed release sources such as closed cell foams. Both Japan and Europe have already taken steps related to resource recovery and ODS destruction from appliances. However, recovery of ODSs from buildings is likely to pose a more significant and costly challenge. This may be a further driver towards HC or CO_2 options or wider changes in building practice to facilitate recovery. Progress in this area will also have valuable benefits for the new generation of foam technologies.

The way forward

For SMEs and particularly low volume users, there is no economically feasible solution unless the financial implications of investments are overcome. In many foam sectors, the alternative blowing agents are hydrocarbons, which are less expensive than HFC blowing agents but require expensive investments to satisfy safety requirements. A solution might be interest-free loan schemes, even in non-Article 5(1) countries, where the investment cost is repaid from savings in blowing agent expense. However, no such schemes are yet being considered.

The technical and economic feasibility of the recovery of blowing agents from foam at end-of-life will continue to be an area of significant study over the next few years. The requirements of the Montreal Protocol and most national implementation procedures provide little economic incentive. However, recovery and destruction would be economic if credit was given to mitigation of greenhouse gas emissions also, in addition to the direct benefit to the ozone layer. Regulatory or trading schemes would have to reclassify ODS destruction to engage the necessary economic drivers.

1.4 Halons TOC

Current status

Halon fire extinguishants are no longer necessary in virtually any new installations, with the possible exceptions of engine nacelles and cargo compartments on commercial aircraft and crew compartments of combat vehicles. The very high cost of replacing many existing halon systems with substitutes, replacements or other alternative fire protection measures continues to be a major impediment to eliminating continued use of halons.

Although potential alternatives exist for both engine nacelles and cargo bays of commercial aircraft it is disturbing to report that new airframes are still being designed and certified with halons as the required fire extinguishant due to regulatory requirements. Parties may wish to consider requesting the International Civil Aviation Organization (ICAO) to act with the TEAP HTOC as a co-ordinating body in development of a timely plan of action to eliminate regulatory requirements for halons on new airframes. Airframe Certification Agencies and Airframe Manufacturers may want to participate in this effort.

What is left to be achieved

Some Parties have enacted regulations requiring existing halon systems to be decommissioned and the halons from these systems destroyed. Although most halon 1211 and a portion of halon 1301 in inventory will not be required to meet future needs such measures require careful planning to ensure that sufficient stocks of halon 1301 remain available to meet future critical needs of both Article 5(1) and non-Article 5(1) Parties. Users that have critical halon needs should consider making arrangements to ensure a secure supply, either individually or in partnership with other critical users. This effort would likely include obtaining the additional halon necessary to meet their future requirements and expansion of existing or construction of new secure storage facilities that would include necessary leak prevention and monitoring measures.

The way forward

An alternative to the creation of large halon stockpiles would be a decision to allow Parties to earn credits for destroyed or converted halon by technologies approved by the Parties. These credits would be eligible to be carried forward for possible future critical uses to be approved (Article 1, Paragraph 5, read with Article 7, allows credits for production. However, since the control measures are for each year, the credit is in the year of destruction and not for future use). Such a provision would be an incentive to collect and destroy halons, would deter emissions from halon banks which may be found surplus to requirements, and could help eliminate the reluctance to retrofit of existing applications that results from the current oversupply of halon. A bolder market-based strategy to achieve these objectives could be trading in credits obtained by destruction of halons or allowing such credits to be used for essential/critical uses of other ODS.

The HTOC will invite TEAP and its other TOCs to consider the potential advantages and disadvantages of such an approach to other ODS use sectors. In 2003, the Halon Technical Options Committees will further explore options to reduce halon emissions.

1.5 Methyl Bromide TOC

Current status

Production of MB for controlled uses was reported to be about 62,757 metric tonnes in 1998; it was reduced to at least 49,566 tonnes in 1999 and at least 46,055 tonnes in 2000. Non-Article 5(1) countries have reduced controlled MB consumption by about 56% from the 1991 baseline, in advance of the Protocol requirements. Controlled MB consumption in Article 5(1) countries rose from about 8,460 tonnes in 1991 to about 17,600 tonnes in 1998. Based on Ozone Secretariat data reported so far, Article 5(1) MB consumption was reduced to about 16,440 tonnes in 2000. Between 1998 and 2000, national MB consumption fell by more than 20% in some Article 5(1) countries.

The decline in total global consumption of MB is attributed largely to reductions for soil fumigation. This has been achieved mainly by the adoption of transitional strategies, such as replacing MB used alone with MB/chloropicrin mixtures, and to a lesser extent by adoption of alternatives, principally alternative fumigant mixtures and soil-less culture systems. Alternatives adopted for durable commodity and structural treatments are principally phosphine fumigations and, in specific situations, heat treatments.

By December 2002 the Multilateral Fund (MLF) had approved a total of 232 MB projects in more than 63 countries. This included 44 demonstration projects for evaluating and customising alternatives, 38 projects for phasing-out MB and 150 other projects for information exchange, awareness raising, policy development and project preparation. Further MB replacement activities have been funded directly by Article 5(1) countries and/or agricultural producers, bilateral assistance and the Global Environment Facility.

With two exceptions (control of ginseng root rot and stabilisation of high-moisture fresh dates), the completed demonstration projects, for all Article 5(1) locations and all crops or situations tested, identified one or more alternatives comparable to MB in their effectiveness in the control of targeted pests and diseases. In many cases, combined techniques have provided more effective results than individual techniques, particularly when they are part of an integrated pest management (IPM) program.

Projects in Article 5(1) countries have demonstrated that a similar range of alternatives to those in non-Article 5(1) countries can be successfully adopted. Differences in costs and resource availability can lead to a preference for different alternatives in Article 5(1) compared to non-Article 5(1) countries. Demonstration projects showed that it is feasible to introduce the tested alternatives into Article 5(1) countries and adapt them successfully within 2-3 years, in some cases even including registration of pesticide products.

Systems for recapture of methyl bromide based on activated carbon absorption have recently been commercialised. The driving force has been local regulations on air quality to protect workers and the general community. MB recapture is not likely at present to be used on farms in a significant way. Practically, the scope for recovery of MB after fumigations is likely to be restricted to treatments carried out in enclosures, i.e. space fumigations, particularly QPS-related, of commodities, structures and transport, with subsequent destruction of the captured MB.

What is left to be achieved

MBTOC could find no existing technical alternatives for about 3200 metric tonnes of MB per annum used for non-QPS treatments. This implies that there are existing alternatives for more than 93% of year 2000 consumption of MB, excluding QPS. However, some of these alternatives may not be available in practice as a result of various constraints, particularly lack of registration for use on the particular crop or foodstuff to be treated. Significant effort must now be undertaken to register and implement these alternatives and to optimise their use. Some countries have registered some alternatives in recent years and some large volume consuming countries are currently considering registration for certain alternatives. There is the possibility that further registrations for use will be completed prior to the 2005 phase-out in some non-Article 5(1) countries.

With regard to Decision IX/5(1e), experience with demonstration and investment projects to date, such as those supported by the Multilateral Fund, indicates that the many technical, climatic, social and economic barriers to MB alternatives present in diverse Article 5(1) regions can be successfully overcome. The commercial availability of certain alternatives for some applications in Article 5(1) countries is of continued concern.

Adapting the alternatives to the specific cropping environment and local conditions of particular Article 5(1) countries is essential to success. For example, local materials such as coconut coir and rice hulls have made it possible to adapt substrate systems that would normally have required know-how and technically-demanding materials (e.g. rockwool) not widely available in Article 5(1) countries.

The way forward

MB alone, or in mixtures with chloropicrin, is still being used for preplant soil disinfestation to manage the range of crop/pathogen complexes reported in the 1998 Report. The major crops for which MB is still widely used in some regions include: cucurbits, pepper, tomatoes, perennial fruit and vine crops, ornamentals, strawberry fruit and turf. MB may also be used in the production of propagation material for forests, fruit and vine crops, strawberries, ornamental trees and tobacco.

Although significant progress in developing alternatives to MB has been made since the publication of the 1998 report, the complexity of soil pathogen and weed problems in different countries and the diversity of environments in agriculture require the continuing development and adaptation of non-chemical and chemical methods. Further investment in research and technology transfer will be necessary to implement alternative pest management systems effectively in all countries.

TEAP reported previously that QPS use is increasing in some countries and estimated that approximately 22% of MB consumption was used for QPS treatments. Following Decision XI/13, MBTOC will, *inter alia*, report on the feasibility of alternatives in 2003. MBTOC noted more than 300 examples of alternatives to MB approved for quarantine treatment of perishables and more than 70 approved as QPS treatments for durable commodities. There is scope for the further development of alternatives in the QPS area.

On the basis of 70% recapturable MB, fitting of recapture and destruction equipment to QPS commodity treatments could prevent about 7,000 metric tonnes of MB emissions entering the atmosphere. Existing and anticipated MB projects are due to lead to the phase-out of 10,000 tonnes of MB before about 2008 in Article 5(1) countries.

1.6 Refrigeration, AC And Heat Pumps TOC

Current status

In the last decade, the refrigeration, air conditioning and heat pump industry made tremendous technical progress and complied with the Montreal Protocol through phasing out CFCs and, in several applications, HCFCs as well. The mobile air conditioning and the domestic refrigeration industries have shifted rapidly from CFC-12 to non-ODS refrigerants. Other applications, such as chillers and commercial refrigeration, have shifted from CFCs to HCFCs and HFCs or other fluids.

The requirement to phase out CFCs and eventually other ODS, along with considerations to reduce global warming impacts, has spurred unprecedented transitions. Differences in timing and in choosing options between countries have been influenced by regional and national regulations. The primary solutions for new equipment are summarised below by application:

- *domestic refrigeration*: HFC-134a and isobutane (HC-600a),
- *commercial refrigeration*: HCFC-22 and mainly R-404A in supermarket systems, HCs in some self-contained units as well as in a few indirect systems, and to a small extent carbon dioxide (R-744),
- *industrial refrigeration*: ammonia (R-717), HCFCs, HFCs and to some extent carbon dioxide for low temperature,
- *transport refrigeration*: HFCs for the majority of applications,
- *stationary air conditioning equipment*: HCFC-22 (in about 90% of the equipment), with the remainder using the currently produced HFCs and HFC blends, and, to a lesser extent, HCs,
- *chillers*: HCFCs (primarily HCFC-22 in small and HCFC-123 in centrifugal chillers), HFCs (primarily HFC-134a and, in smaller equipment, also blends), and much less commonly ammonia and HCs,
- *heat pump water heaters*: HCFC-22, HFC-134a, propane (HC-290), R-410A, and to some extent carbon dioxide,
- *mobile air conditioning*: HFC-134a for virtually all new vehicles (being the global choice).

The above solutions are also being applied in Article 5(1) countries, where in several sectors the conversion is not complete, however, the number of conversions is steadily increasing. There still is a certain amount of new equipment manufactured with CFCs, also in domestic, but particularly in commercial and transport refrigeration.

What is left to be achieved

World-wide, a significant amount of installed refrigeration equipment still uses CFCs and HCFCs. As a consequence, service demand for CFCs and HCFCs remains high. The refrigerant demand for these service needs is best minimised by preventive service, containment, retrofit, recovery and recycling. Recovery at decommissioning or scrapping of equipment, not only in the case of refrigerators, is an important topic, which receives increasing attention now that the non-Article 5(1) ODS consumption has been restricted to essential uses. The first step in addressing the refrigerant conservation topics cited above is through training of installers and service technicians, together with certification and regulations. Countries where programs have been successful have had comprehensive regulations requiring recovery and recycling.

The way forward

Current developments concentrate on increasing use of HFCs as well the non-fluorocarbon options mentioned above in most sectors, with emphasis on optimising system efficiency (COP) and reducing emissions of high-GWP refrigerants. A high degree of containment, in fact, applies to all future refrigerant applications, either for decreasing climate impact or for safety reasons. Additional research and development is ongoing all over the world (i) to enhance the development status and the quality of the equipment using the current alternatives, and (ii) to investigate the potential of other long term in-kind and not-in-kind solutions, seeking both lower environmental impact including higher energy efficiency and improved safety characteristics.

1.7 Solvents, Coatings And Adhesives TOC

Current status

The achievements of the Solvents, Coatings and Adhesives Technical Options Committee (STOC) have further consolidated its past work, while examining new developments in terms of replacement technologies, market evolutions, solvents toxicology etc. In particular, the STOC has assessed the market potential for n-propyl bromide in the light of concern for ozone depletion and health impacts from human exposure. It has also given particular attention to the specific needs of Article 5(1) countries. Almost a total phase-out of the use of Annex A, Annex B and Annex C, Group III controlled solvents has now been achieved in non-Article 5(1) countries. There are still a few cases of users relying on stockpiled or recycled materials, but these stocks must be exhausted in the near future. A very small amount of ODS solvents has been necessary for a few Essential Use Exemptions granted by Parties. The STOC believes that the unexpected 1,1,1-trichloroethane emissions measured in Europe probably come from landfills where drums of used solvents may have been dumped many years ago. In addition, HCFC-141b is being rapidly phased out as a solvent in the European Union and the USA. Subsidiaries and suppliers of multinational companies in Article 5(1) countries have long ago finished their phase-out and the MLF has completed a few major solvents projects. However, very few projects have been completed with small and medium enterprises (SMEs) and users (SMUs) consuming less than 5 ODP tonnes of solvents. There are many thousands of such users, consuming a major part of the remaining usage.

What is left to be achieved

There is much left to be achieved in the Solvents Sector. Effort is still required to phase out ODS solvents in Article 5(1) countries, and especially the small- and medium-sized users (SMUs). In particular, there is concern about the use of carbon tetrachloride (CTC) for solvent applications by both large and small enterprises in some countries. A few important CTC projects are currently being developed by the Implementing Agencies, but these represent only a fraction of the total consumption. One other obstacle that has been identified is illegal imports into, mostly, Article 5(1) countries that have already enacted restrictive legislation. These may represent a considerable proportion of baseline quantities, in some cases, and, of course, are not reported. This, and other factors, may mean that the total global OD solvents consumption is currently significantly higher than is reported.

The way forward

Delaying the phase-out of production and imports of Annex A and Annex B solvents will involve greater difficulty and larger costs than doing it now. This will inevitably cause hardship, especially for the many SMEs. The STOC is developing an e-mail and Internet infrastructure that will allow National Ozone Units (NOUs) to obtain detailed expert technical information free-of-charge, for rapid response in each sub-sector. This report is the first step with stand-alone, sub-sectoral chapters, for easy translation into languages, each with e-mail addresses of experts for consultation. The STOC also needs to address the increasing use of HCFC-141b solvents in Article 5(1) countries, sometimes as substitutes for non-OD solvents. There are no technical barriers to a total and immediate phase-out of the use of CTC, CFC-113, 1,1,1-trichloroethane and HCFC-141b solvents in nearly all applications.

1.8 Collection, Reclamation and Storage Task Force

The Task Force on Collection, Reclamation and Storage (TFCRS) assessed use patterns, associated emissions and aspects of collection and storage of ODS from all relevant use sectors. The assessment takes into account the different situations in Article 5(1) Parties, where production takes place for the Article 5(1) Parties (under "Basic Domestic Needs") and the situation of non-Article 5(1) Parties, some of which are still manufacturing. The TFCRS Report also presents an overview of ODS inventories and their management in the different sectors and provides first estimates of historic and actual emission patterns from the different use sectors.

(a) Types of Emission

ODS can be emitted at various stages in the lifecycle of production, distribution, use, and disposal. Emission estimates for any given year need to account for early emissions of recently 'consumed' ODS as well as delayed emissions of historically used ODS. This is because emissions from both developed and developing countries will continue for many years after the phase-out of ODS production.

Because the TFCRS Report addresses management of ODS currently in use, it categorises sectors based on emissions profiles. Solvents, aerosol products (including MDIs), methyl bromide and flexible foams emit ODS soon after initial use, and for a relatively short period of time. The report terms these "early emissions." Refrigeration and air conditioning equipment, rigid foams and halon equipment emit small quantities of ODS over very long periods of time after initial use. The timeframe over which these uses emit ODS range from years to decades. The report terms these "delayed emissions."

The main focus of the TFCRS Task Force was on uses with delayed emissions, because those are uses that have the largest inventories of ODS and offer the greatest opportunities to destroy or recycle large quantities of ODS.

The focus for early emissions is on non-Article 5(1) Parties essential uses and on current and/or recent use in Article 5(1) Parties. The focus for delayed emissions is on inventories of ODS originating from sustained non-Article 5(1) and the increasing inventories present in the same applications in Article 5(1) Parties.

(b) Technical feasibility of Collection, Recovery & Storage

It is technically feasible to collect and recover all ODS retained in inventories. In refrigeration and halon equipment the ODS is already contained in readily accessible containers. In the case of other applications, the ODS can be in locations which are much more difficult to access (e.g. cavity wall rigid foam insulation).

For many rigid foams including those contained in refrigerators, the recovery and destruction steps can be combined and the decision may be made that it is more cost-effective to directly incinerate a product containing the ODS than to extract the ODS for subsequent destruction.

It is technically feasible to recover methyl bromide used as a post harvest, structural or transport fumigation (about 26 % of current methyl bromide uses, including for QPS) for destruction. The surplus methyl bromide can be adsorbed and then directly treated for destruction either chemically or by incineration.

(c) Inventories and Collection Potential

It is has been known for quite some time that the ODS inventories stored in delayed emission applications are substantial. This assessment has better quantified these amounts. Inevitably, the assessment has involved a combination of 'top-down' and 'bottom-up' modelling and will be the subject of continuous refinement as more information emerges.

- Between 350,000 and 400,000 ODP-tonnes of CFCs are estimated to be contained in refrigeration equipment in 2002;
- 1.25 million ODP-tonnes of CFC-11 are predicted to remain in installed foams in year 2010 with the majority in non-Article 5(1) countries;
- 450,000 ODP-tonnes of halon 1301 and 330,000 ODP-tonnes of halon 1211 are installed in fire fighting equipment in year 2002.

However, it is important to recognise that not all of this material will be accessible for collection and recovery, since decommissioning at end-of-life needs to take place first. The annual quantities of refrigerants potentially available for destruction are estimated to be around 9,000 ODP-tonnes. The quantities of blowing agents expected to be recovered from domestic refrigerators, are expected to reach a rate of between 10,000 and 11,000 ODP-tonnes per annum with the currently installed recovery capacity. This could be increased by further investment but is likely to require additional local legislation. Sizeable amounts of halon 1211 could be collected for subsequent destruction.

(d) Economic Implications of Collection, Recovery & Storage

The TFCRS report has not made a detailed assessment of the costs of collection, recovery and storage at the global level, since the range of technical options available and the cost of local logistics are highly variable. Economic feasibility is demonstrated by examples of established commercial infrastructures. These exist in several sectors and in several regions of the world. The recovery of blowing agents from refrigerator cabinets costs approximately US$60-100 per kg of CFC-11. The cost equates to approximately US$25-35 per tonne of CO_2 equivalent. This is well within the range of investments being considered for CO_2 emission abatement in other sectors.

(e) Barriers to Collection, Recovery & Storage

There are many barriers to the application of effective collection, recovery and storage. Examples of these can be listed as follows:

Lack of appropriate legislation and infra-structures to ensure end-of-life decommissioning;

Financial resistance where the 'polluter' (manufacturer or owner) has to pay;

Installations of rigid construction foam can be within building structures that prohibit effective collection;

Waste transportation management restricts movements within some countries and internationally.

(f) Conclusions

The collection, recovery and storage of ODS is technically feasible and economically viable.

The adoption of such measures depends to a large degree on the regulatory structures, the collection and recovery infrastructures and the way in which the financial burden is allocated.

Executive Summaries of all 2002 TOC Assessment Reports

2. Executive Summary of the 2002 Assessment Report of the Aerosols, Sterilants, Miscellaneous Uses and CTC TOC

2.1 Aerosol products (other than MDIs)

There are no technical barriers for the transition to alternatives for aerosol products other than MDIs. However, some consumption of chlorofluorocarbons (CFCs) in aerosols still remains in Article 5(1) countries and countries with economies in transition (CEIT). The remaining main uses for CFCs in these countries have been identified as:

- Non-MDI medical aerosols such as local anaesthetics, throat sprays, nasal sprays, wound sprays, vaginal products and traditional Chinese medicines.
- Industrial/technical aerosols such as electronics cleaners, spinnerette sprays, anti-spatter sprays and tyre inflators.
- Personal hygiene products filled in small volume cans.
- Insecticide and disinfectant sprays for use aboard aircraft.

The Aerosols Technical Options Committee (ATOC) estimates that the consumption of CFCs in the non-MDI aerosol sector was approximately 4,300 tonnes in 2001 in Article 5(1) countries and CEIT. This represents less than 1 percent of the propellants used in aerosol products in 2001, and a 71 percent reduction in CFC consumption from 1997 (14,700 tonnes). For the first time, ATOC can report that CFC consumption in the non-MDI aerosol sector in Article 5(1) countries and CEIT has reduced to below that consumed for global CFC MDI manufacture.

The most progress has taken place in the Russian Federation where, as a result of the closure of CFC production facilities, use of CFCs in aerosol products, other than MDIs, has dropped from 7,800 tonnes in 1997 to 200 tonnes in 2001, representing a 97 percent reduction.

China and India have signed stepwise phase-out plans for CFC production, but the effect of these on the aerosol products sector is not yet apparent. In China the use of medical aerosols is increasing and new CFC-propelled products, including traditional Chinese medicines, continue to be developed. Lack of locally produced alternative pharmaceutical-grade propellants impedes their reformulation.

Comprehensive CFC consumption data for aerosol products is difficult to obtain. An estimation showing a regional break down of CFC consumption for 2001 is as presented in Table 2-1.

Table 2-1 *CFC consumption in non-MDI aerosols in 2001 (tonnes)*

ASEAN Countries*	700
China	1,800
South Asian Countries**	400
Latin America	400
Middle East, Africa	400
Russian Federation	200
Other CEIT and CIS***	400
Total	4,300

* Brunei, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam
** Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka
*** CIS: Successor States of the former Soviet Union

Specific actions from governments and their national ozone officers will be needed to achieve final phase-out. The reformulation of the non-MDI medical aerosol products and industrial/technical aerosols may require technical and financial assistance. In the case of medical aerosols approval by national health and drug authorities will be required, after pharmacological and toxicity tests and clinical trials. Currently, more expensive products result if the new replacement products require the use of HFCs.

HFCs should be used in applications where either pharmaceutical or non-flammable propellants are required, but their high price and high global warming potential will limit their usage in aerosol products.

Hydrocarbons are the principal substitutes for CFCs used in aerosols. Suitable mixtures of *n*-butane, *iso*-butane, and propane are called hydrocarbon aerosol propellants (HAPs). Hydrocarbons are highly flammable and care is required during storage, transfer and filling. Where HAPs supplies were available at reasonable cost, transition out of CFCs has already taken place.

It is important to stress that in the process of replacing CFCs in the aerosol industry of Article 5(1) countries and CEIT, every effort should be directed to ensure that safety standards at the manufacturing plant and at the consumer level are maintained.

The declining trend in the use of CFCs in aerosols has accelerated. There still remain the following problem areas: HAPs availability; conversion of small and very small CFC users; industrial/technical aerosols; and non-MDI pharmaceutical products.

2.2 Metered dose inhalers

Asthma and chronic obstructive pulmonary disease (COPD) are the most common chronic diseases of the air passages (airways or bronchi) of the lung and are estimated to affect over 300 million people world-wide. These illnesses account for high health care expenditure, cause significant loss of time from work and school and COPD in particular, is responsible for premature death. There are two main categories of treatment for asthma and COPD: bronchodilators (also called acute relievers) and anti-inflammatory medication (also called controllers or preventers).

A metered dose inhaler (MDI) is a complex system designed to provide a fine mist of medicament for inhalation directly to the lungs. MDIs contain either CFCs or more recently HFCs as propellants. Total reported use of CFCs for non-Article 5(1) countries manufacturing MDIs for asthma and COPD has fallen by 33 percent from a peak of 8,906 tonnes in 1997 to 5,983 tonnes in 2001. ATOC estimates that a total of 7,500 tonnes of CFCs were used world-wide for MDI manufacture in 2001, including an estimated 1,500 tonnes used in Article 5(1) countries.

The major alternative methods to CFC MDIs for drug delivery include:

HFC MDIs **–** At least one HFC MDI is available in over 60 countries, and 30 countries have both bronchodilator and preventative drugs approved and used in that country. The number of HFC MDIs used world-wide has increased from 10 million in 1998 to an estimated 110 million in 2002.

Dry powder inhalers (DPIs) **–** DPIs have been successfully formulated for most inhaled therapies, and are widely available. They are easy to use and are preferred by many patients. Their use has increased to 27 percent of inhaler units world-wide as new devices and formulations are introduced in new markets.

2.3 CFC transition

The rate of transition from CFC MDIs to CFC-free products has varied from country to country. Even when new products have been introduced, the rate of their uptake has varied. This has occurred for a number of reasons including price considerations, differences in medical practice and patient preferences. Brand-by-brand transition has generally occurred at comparable prices but its success is influenced by the above factors. In the European Union, the ratio of CFC MDIs to HFC MDIs to DPIs was approximately 1:1:1 in 2001.

It is clear that the development of HFC MDIs and their registration and launch into the market is only partially effective in transition. Parties may wish to consider official action (e.g. a target and timetable approach) to achieve CFC MDI phase-out.

There has been a lack of awareness by healthcare providers regarding the need for change from CFC to CFC-free inhalers. In developed countries already advanced in their transition process, multinational pharmaceutical companies have been more effective than governments and NGOs in educating healthcare providers. This may also prove to be the case in developing countries and CEIT.

In several countries there is a large proportion of generic or locally produced CFC MDIs that are priced significantly lower than the brand name CFC MDIs and HFC alternatives. Since payors (patients, purchasers, health authorities, insurance companies etc.) will continue to favour lower priced medicines, countries will have to address the means to have payors accept the CFC-free alternatives.

2.4 CFC manufacture

There are currently three producers of pharmaceutical-grade CFC-11/12 in the European Union. One important producer in the Netherlands will be allowed to continue CFC manufacture until 2005, and a second producer of CFC-11/12 in the European Union is currently modifying its CFC production to enable the manufacture of pharmaceutical-grade CFCs for supply to the United States. At the current time, no CFC production has been approved as pharmaceutical-grade from CFC manufacture in Article 5(1) countries.

Future CFC requirements are difficult to predict and there are a number of uncertainties in projecting CFC volume requirements:

- When CFC-free reformulation programmes will be completed;
- The introduction and uptake of CFC-free alternatives;
- The national determinations of non-essentiality;

- The dynamics of the market share between remaining CFC products and alternatives; and
- The role of existing CFC stockpiles and their transfer between MDI manufacturers.

The further into the future that a company projects its CFC requirements, the greater is the uncertainty. The ATOC believes that where possible, just in time production should be continued. If final campaign production is required, the Decision to initiate should be taken as late as possible, compatible with guaranteed supply (see *UNEP, Report of the Technology and Economic Assessment Panel, April 2002, Volume 1* for further discussion of the timing of campaign production).

Although the satisfactory storage of pharmaceutical-grade CFCs for extended periods, e.g. 3-5 years under controlled conditions appears possible, it is not clear that some product would not be lost. Nevertheless, it is not unreasonable to assume that up to 3000 tonnes of CFCs could be the total needed to meet the cumulative United States' requirements for MDI production after 2005. As MDI producers in the United States held an inventory of close to 2000 tonnes at the end of 2001 and other storage facilities exist, storage of this size should not pose great operational problems. Similar considerations may hold for other regions/countries. (Refer to the *UNEP, Report of the Technology and Economic Assessment Panel Task Force on Collection, Recovery and Storage 2002* for further information).

2.5 Article 5(1) countries and CEIT

Multinational pharmaceutical producers provide the vast majority of MDIs in most Article 5(1) countries and CEIT. In some countries (e.g. Brazil, Mexico), local manufacture accounts for some MDIs, while the majority comes from multinational producers. In a few countries (e.g. People's Republic of China, Cuba and India), local manufacture, including that of multinational plants operating in these countries, supplies the majority of MDIs to the market. Continued provision of MDIs in Article 5(1) countries and CEIT will depend either upon import of products, or local production. The local production of CFC MDIs is likely to continue for some time after cessation of their use in non-Article 5(1) countries and will overlap with the importation of CFC-free MDIs by multinational companies (the introduction of the latter will require approval by regulatory authorities).

It is important that countries collect accurate basic data on inhaler use if effective transition plans are to be developed. If such data already exist, the ATOC is not aware of them. Since price is such an important factor, the price of CFC alternatives will be a major barrier to transition, unless they are no more expensive than comparable CFC products.

Those countries with CFC MDI manufacture by local companies will require an interventionist transition policy. This may require assistance with the development of alternative formulations, modification of manufacturing plant and fulfilling of regulatory obligations for marketing. This assistance may vary, depending on whether local manufacture is undertaken independently, or under a licensing agreement. As has been the case in developed countries, an evaluation of whether reformulation of a specific drug is technically feasible may be needed. This and similar aspects of transition policy will require input by appropriate pharmaceutical and technical experts in order to ensure optimal use of any development funding.

Most countries do not have local manufacture of CFC MDIs and supply of MDIs is wholly or largely by import. In those countries, national transition policies may be less interventionist, as in many developed countries. Experience in developed countries, where the supply of CFC MDIs comes from import by multinational companies, is that CFC alternatives can be introduced promptly where it is feasible within the regulatory framework of a country (e.g. Canada).

In Article 5(1) countries, this transition is occurring as a part of the overall phase-out of CFCs (with a 50 percent reduction from baseline levels in CFC consumption for basic domestic needs in 2005). Competition for supply of CFC between all uses may compromise supply of CFCs for MDIs. Therefore, ATOC strongly recommends that in order to protect patient health, MDI transition strategies be developed now, especially by those countries with local MDI manufacture. The development of transition policies could be facilitated by a series of regional workshops.

2.6 Sterilants

Use of EO/CFC blends for sterilisation has been successfully phased out in most non-Article 5(1) countries and in some Article 5(1) countries. Although it is difficult to estimate, it is believed that the global total use of CFCs in 2001 for this application is less than 500 metric tonnes. Remaining world-wide use can be easily substituted, as there are a number of viable alternatives.

EO/HCFC mixtures that replace EO/CFCs are mostly used in the United States and in countries that allow venting of HCFCs to the atmosphere. The European Union has legislation restricting the use of HCFCs in emissive applications such as sterilisation. In 2001, the estimated use of HCFC replacement mixtures is thought to be less than 1,700 metric tonnes (some 50 ODP tonnes). Use has been reduced to almost one half of 1998 figures by using less mix per steriliser load, and by hospital conversion to other technologies.

Hospital units are now used more efficiently due to hospital consolidation. When several hospital sites become part of a single institution, they shut down their under-utilised sterilisers, and concentrate EO/HCFC sterilisation in one hospital. Alternative technologies to which hospitals have converted include: use of more steam-sterilisable devices; more single-use devices; pure ethylene oxide sterilisers; and other methods that will sterilise or disinfect some of the low temperature devices used in hospitals. These other low temperature processes are vapour phase hydrogen peroxide-plasma, steam-formaldehyde (in parts of Europe and South America), and liquid phase peracetic acid.

Sterilisation of medical devices can be performed in industrial settings with large outputs of the same item (such as manufacturers of syringes and droppers) and in hospitals with much smaller outputs, but with a great diversity of items. Process requirements for these two settings are very different.

Quality health care is dependent upon sterility of medical devices. Validation of processes for the intended application is important to avoid either materials compatibility problems or deficiencies in the level of sterility. Not every process/sterilant will be compatible with all products. The nature and size of items to be sterilised will vary according to the user. Some items are more robust than others with regard to temperature and radiation. Thus, a number of different processes can be used, and each will offer specific advantages.

2.7 Miscellaneous uses

Ozone depleting substances have a number of miscellaneous uses of which tobacco expansion is the most significant. China is believed to be the only remaining country to use significant quantities of CFC-11 for tobacco expansion, using about 1,000 ODP tonnes per year. According to decisions taken by the Executive Committee, a stepwise phase-out is planned by about 2007. Based on this and the planned installation of alternative carbon dioxide technology in China, declining use in this country can be expected.

Most remaining miscellaneous uses are believed to represent only small amounts of CFC use. Miscellaneous uses are difficult to identify and to obtain good data on volume and use patterns. With the phase-out of CFCs in developed countries for non-essential uses, the use of CFCs in miscellaneous uses in, for example, leak detection or solar panels, is most likely almost non-existent.

2.8 Laboratory and analytical uses

Typical laboratory and analytical uses include: equipment calibration; extraction solvents, diluents, or carriers for specific chemical analyses; inducing chemical-specific health effects for biochemical research; as a carrier for laboratory chemicals; and for other critical purposes in research and development where substitutes are not readily available or where standards set by national and international agencies require specific use of the controlled substances.

Essential uses for ODS for laboratory and analytical uses were authorised by the Parties to the Montreal Protocol, Decision VI/9(3). Manufacture as highly pure chemicals for final marketing in small, labelled containers was to discourage non-essential use. The Decision by the Parties allows marketing in blends including blends with more than one controlled substance.

Decision VI/9(3) also requires that Parties report on each controlled substance and, that used or surplus ODS be collected, recycled and/or destroyed. Other relevant Decisions include: Decision VII/11, Decision VIII/9(4), Decision IX/17, Decision X/19 and Decision XI/15. This latter Decision eliminated three uses from the global exemption: the testing of oil, grease and total petroleum hydrocarbons in water; testing of tar in road-paving materials; and forensic fingerprinting. Three Parties required an emergency exemption for the testing of oil, grease and total petroleum hydrocarbons in water for the year 2002.

A number of Parties have now reported on the use of controlled substances for analytical and laboratory uses. The European Community, Australia, the Czech Republic and the United States have adopted licensing systems in order to manage supplies into these applications. These systems license supplies to the distributors of controlled substances into the laboratory and analytical sector. Registration of the many of thousands of small users in this sector is generally impracticable.

Although only few data are available for laboratory and analytical uses, it can be estimated that the total global use of controlled substances for these applications in non-Article 5(1) countries will not exceed a maximum of 500 metric tonnes. Use in CEIT is unlikely to be more than a few hundred metric tonnes. An estimate of Indian use of CTC of 150 metric tonnes as a laboratory reagent would indicate that up to 500 metric tonnes could be used for analytical and laboratory uses in Article 5(1) countries. An estimate for global use of controlled substances for laboratory and analytical uses is 1,500 metric tonnes. This will reduce as the major uses are phased out through the implementation of Decision XI/15.

In its April 2002 Report (Volume 1), the Technology and Economic Assessment Panel (TEAP) recommended a workshop on the elimination of controlled substances in laboratory and analytical uses. Such a workshop could assemble and document the methods that have enabled the phase-out of uses under Decision XI/15 and identify remaining uses and their potential substitutes.

2.9 Carbon tetrachloride

Carbon tetrachloride (CTC) remains a widely available and used chemical. The main uses are:

- as a feedstock for the production of other chemicals, primarily CFC-11 and CFC-12;
- as a process agent (uses are detailed in the *UNEP, Report of the Technology and Economic Assessment Panel Process Agent Task Force, 2001*);
- as a solvent;
- as a laboratory or analytical chemical; and
- in miscellaneous applications.

The primary source of atmospheric emissions of CTC is manufacturing plants that use CTC as a feedstock to produce CFCs. These will decline in line with the phase-out of CFC production. Substantial reductions have been achieved recently through closures of CFC production facilities in Brazil and the Russian Federation. Significant emissions result from process agent, other uses, and inadvertent emissions.

CTC consumption in Article 5(1) Parties has been reported to the United Nations Environment Programme (UNEP) as 22,934 ODP tonnes in 1999 and 15,487 ODP tonnes in 2000. CTC consumption in non-Article 5(1) Parties has been reported to UNEP as 2,040 ODP tonnes in 1999, rising to 4,205 ODP tonnes in 2000. These data exclude reports by Parties of negative consumption, which originate where a Party destroys CTC or uses it as a feedstock and do not include data for 2000 from China.

CTC consumption for process agents and other uses in non-Article 5(1) Parties is low. Decision X/14 limits the ‘make-up or consumption’ of CTC to 4,501 tonnes and emissions to 220.9 tonnes. CTC consumption for process agents in Article 5 (1) Parties has proved very difficult to estimate. In particular, a number of different applications for CTC have been reported without conclusive evidence to determine whether these applications are indeed process agents. The TEAP, in its Assessment of the Funding Requirement for the Replenishment of the Multilateral Fund for the Period 2003-2005, assumed that around 8,000 ODP tonnes are used as process agents in uses approved by Decision X/14, but acknowledged that several thousand tonnes could be used in China in uses not approved by Decision X/14.

The estimate of consumption from laboratory and analytical uses of 1,500 tonnes in previous reports remains valid.

If the limit for non-Article 5(1) Parties, and the data reported to UNEP for CTC consumption are used, then the global CTC consumption/“make-up” for process agent, laboratory and analytical and other uses can be estimated as a maximum of 25,000 tonnes. These estimates should improve as a result of studies taking place in India and China to identify and quantify CTC use as a process agent.

3. Executive Summary of the 2002 Assessment Report of the Rigid and Flexible Foams TOC

3.1 Introduction

Historically, the blowing agent selection made by the foam plastics manufacturing industry was based heavily on CFCs. This was particularly the case in closed cell insulating foams. An assortment of CFCs and other ozone depleting substances (Doss), including CFC-11, CFC-12, CFC-113, CFC-114, and methyl chloroform were used in numerous foam plastic product applications. However, the effect of the phase-out process has been to create further diversification.

The first technology transition in the early 1990s led to the introduction of transitional substances such as HCFCs as well as the increasing use of hydrocarbons and other non-ODSs. This transition is still taking place in Article 5(1) countries. In non-Article 5(1) countries, particularly in Europe and North America, attention is now firmly focused on the second phase of technology transition out of the transitional substances. This transition is concentrating attention on the emerging HFC-based technologies, although it should be stressed that much consideration is still being given to the optimisation of hydrocarbon and CO_2 technologies[1] and these technologies are gaining market share in several sectors.

As before, this report details for each foam type the technically viable options available by each foam type to eliminate CFC and other ODS use as of 2002. However, by way of departure from previous reports, this review concentrates primarily on the transition status by product group and region and on issues affecting transition. Coverage of technical options per se is now located for information purposes within the appendices only.

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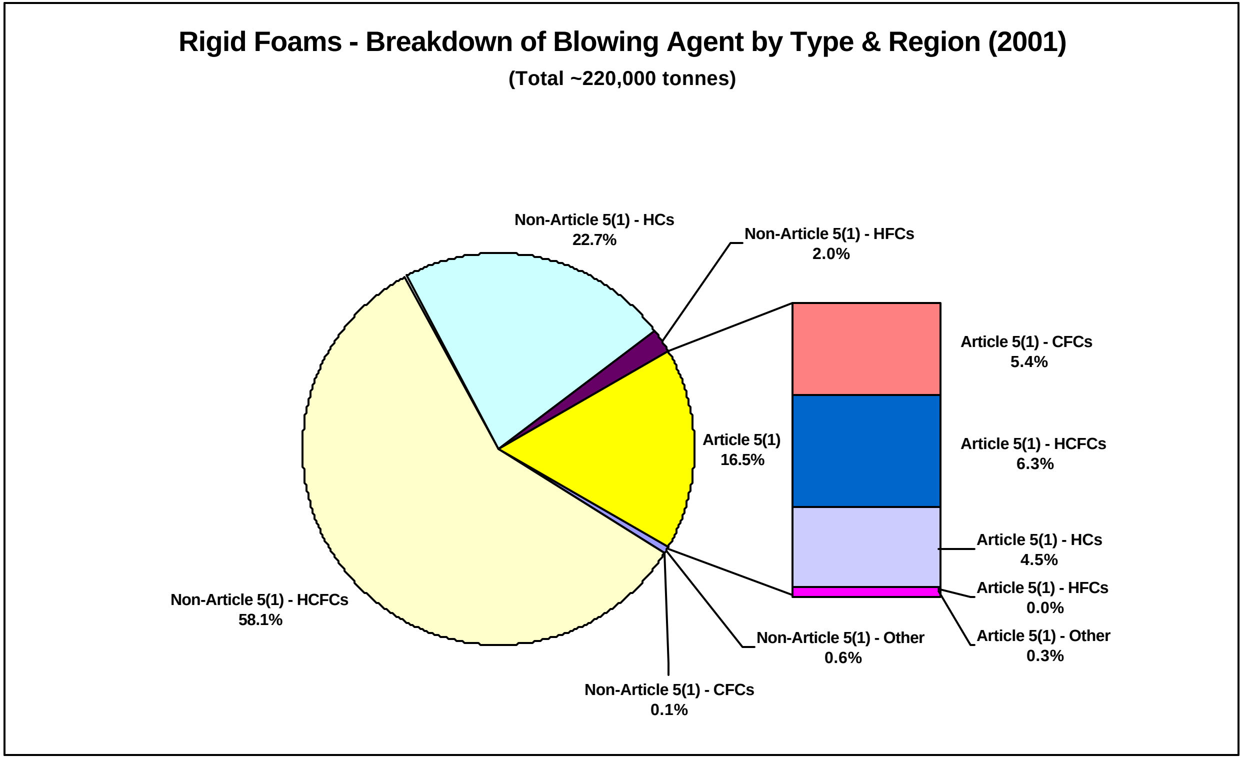
[1] Carbon dioxide or CO_2 as a blowing agent in polyurethane foam can be chemically generated from the reaction between water and isocyanate but also added in both polyurethane and other foams as an auxiliary blowing agent in liquid or gas form. The different options are hereafter referred to as CO_2 (water), CO_2 (LCD) or CO_2 (GCD).

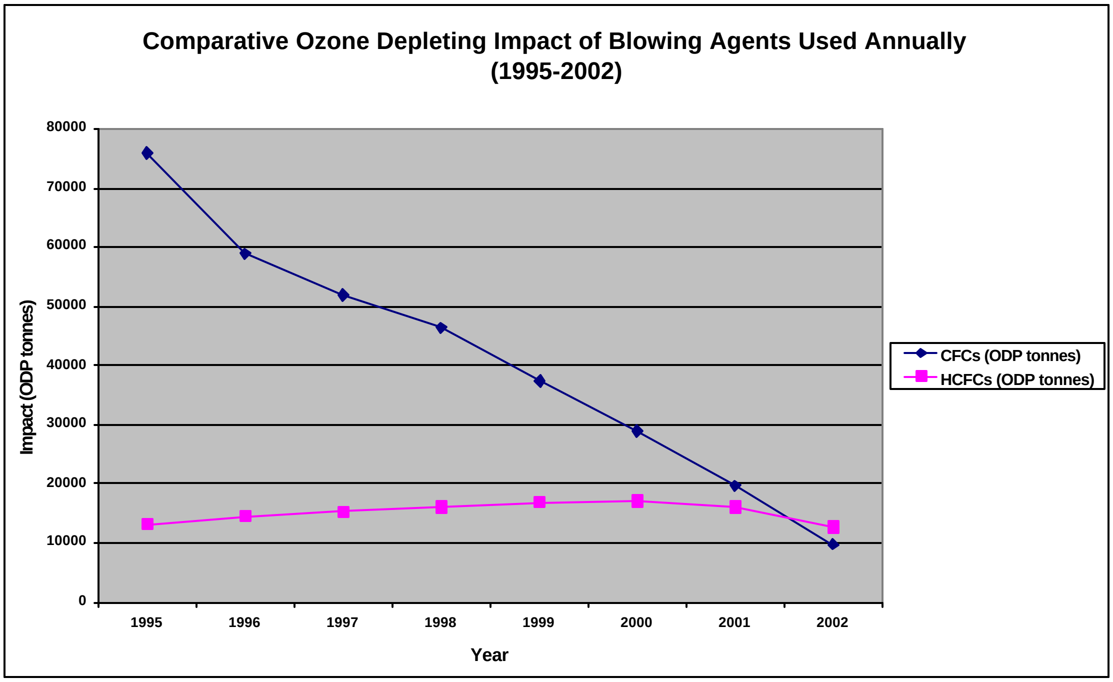
3.2 Transition Status

- Several developing countries are approaching final phase-out of CFC use in the foam sector. However, delays in other developing countries have limited progress and are threatening compliance.
- Several developed countries are currently occupied with the management of HCFC phase-out strategies. Approaches vary by region and a variety of challenges are being faced, both in terms of the readiness of replacement technologies and the uncertainty surrounding future product requirements and standards.
- The technical acceptability of hydrocarbons, particularly in polyurethane formulations, has expanded as several previous shortcomings have been overcome. In several key sectors market penetration now exceeds 50%.
- The commercial introduction of new HFC blowing agents has taken place and HFC-245fa and HFC-365mfc are now readily available in key transitional markets. There is now also a better view of how HFCs will ultimately be used in practice. However, issues remain concerning non-flammable blends and these are receiving attention. Issues of responsible use are continually being reinforced to ensure that emissions of HFCs are minimised.
- In this respect, focus has also increased on end-of-life management of foamed products. Because of their long application lifetimes (up to 50 years), it has been recognised that significant ‘banks’ of ODSs still exist and, in many cases, can be managed. Actions are already underway in Europe, Japan and elsewhere in this regard.
- The market share of insulation foams continues to grow against alternative insulation materials because of their excellent insulation efficiency and structural integrity. Increased concerns over climate change will continue to drive this growth further.

The chart below illustrates the overall status of transition for Article 5(1) and non-Article 5(1) countries in the rigid foam sector as at 2001.

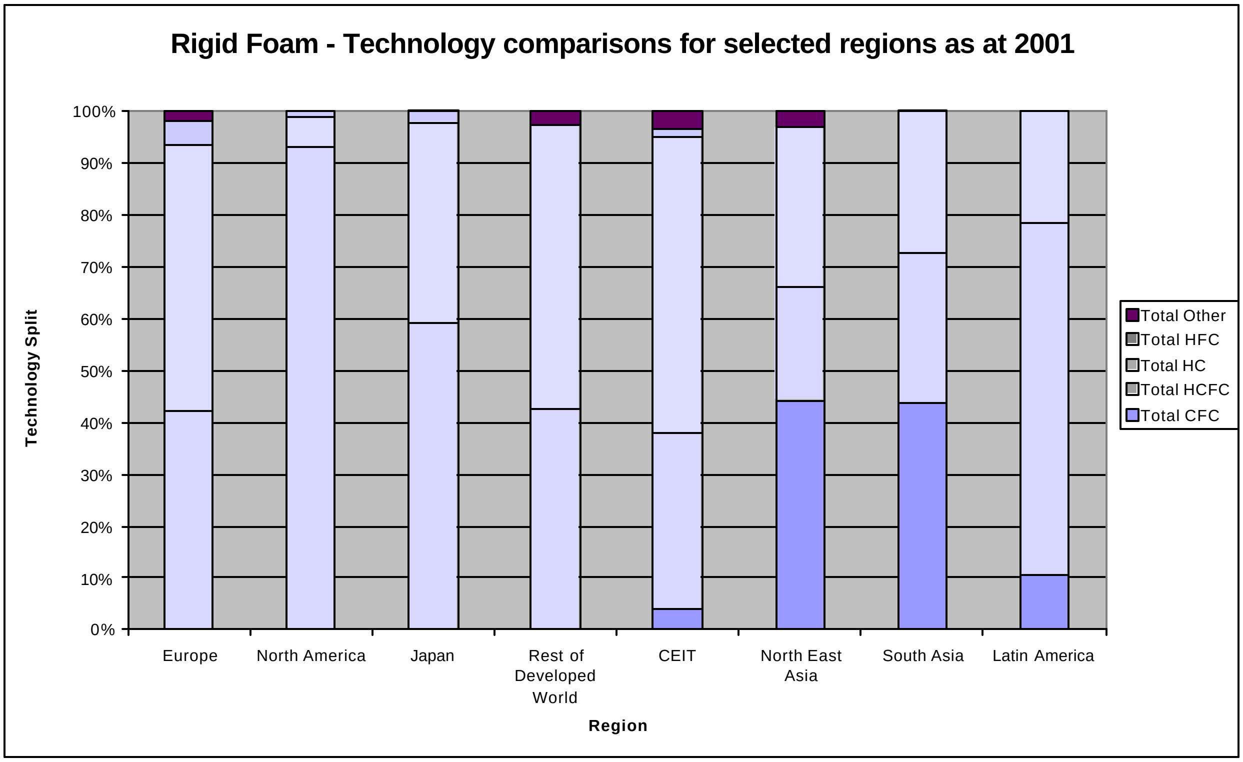


This chart suggests that, for the first time, the ozone depleting impact of HCFC-based blowing agents is approaching that of on-going CFC use. The following graph illustrates the trend further.



However, the convergence is caused primarily by the on-going phase-out of CFCs rather than any further growth in HCFC use. As can be seen, this peaked in 2000.

The following graph provides further analysis of some of the regional variations in phase-out progress and in preferred technology options:



Zero ODP alternatives are currently the substitutes of choice in many foam types and applications. The major zero ODP applications are:

- extruded polystyrene sheet with CO_2 (LCD), hydrocarbons and, under certain circumstances, HFC-134a and/or HFC-152a;
- polyolefin with hydrocarbons;
- polyurethane packaging with CO_2 (water or LCD);
- flexible polyurethane slabstock for cushioning with methylene chloride or CO_2 (water or LCD) and flexible moulded polyurethane with CO_2 (water, LCD or GCD), and methylene chloride (hot cure only);
- extruded polystyrene rigid insulation foams with CO_2 (LCD), alone or with organic secondary blowing agents, HFC-134a /152a blends, HFC-134a and even HCs in specific Japanese markets;

- polyurethane rigid insulation foams where energy efficiency and fire safety requirements can be met with hydrocarbons, HFC-134a, or CO_2 (water);
- polyurethane rigid insulating foams, especially in SMEs where insulating value, end product fire performance or processing safety considerations are important, and can be met with HFCs-245fa or -365mfc (and blends);
- phenolics foams with HFC-245fa or HFC-365mfc (and blends) and, in some cases, hydrocarbons
- polyurethane integral skin where skin quality requirements can be met with CO_2 (water), HFC-134a, or hydrocarbons.

However, during this transitional period, the choices are expected to vary with time and country status as shown in the following tables:

Foam Type	**CFC Alternatives**		
	Currently in Use (2000/2001)	**Anticipated in 2005-2010 period**	
		Developed Countries	**Developing Countries**
Polyurethane: Rigid			
Domestic Refrigerators and Freezers	HCFC-141b, HCFC-141b/22, HCFC-142b/22 blends, hydrocarbons, HFC-134a	HFC-245fa, HFC-134a, hydrocarbons	HCFC-141b, hydrocarbons
Other Appliances	HCFC-141b, HCFC-22, HCFC-22/HCFC-142b	CO_2 (water), HFC-134a, hydrocarbons, HFC-245fa, HFC-365mfc/HFC-227ea	HCFC-141b, CO_2 (water), hydrocarbons
Reefers & Transport	HCFC-141b, HCFC-141b/-22	HFC-245fa, HFC-365mfc/227ea	HCFC-141b
Boardstock	HCFC-141b, HCFC-141b/-22	Hydrocarbons, HFC-245fa, HFC-365/HFC-227ea	N/A
Panels – Continuous	HCFC-141b, HCFC-22, HCFC-22/HCFC-142b	HFC-134a, hydrocarbons , HFC-365mfc/HFC-227ea	HCFC-141b
Panels – Discontinuous	HCFC-141b,	HFC-134a, hydrocarbons, HFC-365mfc/HFC-227ea	HCFC-141b
Spray	HCFC-141b	CO_2 (water), HFC-245fa, HFC-365mfc	HCFC-141b
Blocks	HCFC-141b	Hydrocarbons, HFC-365mfc/HFC-227ea	HCFC-141b
Pipe	HCFC-141b	CO_2 (water), cyclopentane	HFC-141b
One Component Foam	HCFC-22	HFC-134a or HFC-152a/ Dimethylether/propane/butane	HFC-134a or HFC-152a/ Dimethylether/propane/butane
Polyurethane: Flexible			
Slabstock and Boxfoam	HCFCs are not technically necessary for this end use	CO_2 (water, LCD), methylene chloride, variable pressure, LCD, special additives	CO_2 (water), methylene chloride, variable pressure, LCD, special additives
Moulded	HCFCs are not technically necessary for this end use	Extended range polyols, CO_2 (water, LCD, GCD)	CO_2 (water, LCD, GCD)
PU Integral Skin	HCFC-141b, HCFC-142b/-22	CO_2 (water), HFC-134a, -245fa, -365mfc/227ea, hydrocarbons	CO_2 (water), HFC-134a, hydrocarbons
PU Miscellaneous	HCFC-141b, HCFC-22/CO2	CO_2 (water)	CO_2 (water)

Table 3-1 *– Alternatives for Polyurethane Foams*

Foam Type	CFC Alternatives		
	Currently in Use (2000/2001)	Anticipated in 2005-2010 period	
		Developed Countries	**Developing Countries**
Phenolic	HCFC-141b	Hydrocarbons, 2-chloropropane, HFC-365mfc/227ea, HFC-245fa	HCFC-141b, hydrocarbons
Extruded Polystyrene			
Sheet	Primarily hydrocarbons, HCFCs are not technically required for this end use	CO_2 (LCD), hydrocarbons, inert gases, HFC-134a, -152a	Hydrocarbons, CO_2 (LCD)
Boardstock	HCFC-22, HCFC-142b	CO_2 (LCD) or with HC blends, hydrocarbons (Japan only), HFC-134a, HFC-152a and HC blends	HCFC-142b, HCFC-22
Polyolefin	HCFC-22, HCFC-142b		

***Table 3-2** – Alternatives for Other Foams*

3.3 Issues Affecting Transition

The issues affecting transition are review in detail within Chapter 2 of this Report. They encompass factors in both Article 5(1) and non-Article 5(1) environments. There are several common elements and these often focus on SMEs. Key points to highlight at this stage are:

- There is concern in some specific sectors about whether HFC technologies can be validated, including safety considerations with “non-flammable” blends, in time to support HCFC phase-out within the existing regulatory frameworks because of extended approval times and changing product requirements

- The financial constraints of SMEs remain key factors in many transition strategies, both in developing and developed countries

- There remains concern among users about the possibility of a supply/ demand imbalance for HCFC-141b once the phase-out in developed countries takes place. This extends to the maintenance of adequate geographic supply chains.

- The sustained availability of CFC-11 at low prices continues to hinder phase-out.

3.4 Other Significant Issues

The long historic use of CFCs in rigid foams, the long product lifetimes and the slow release rates of blowing agents continue to point to the existence of a significant bank of future CFC and HCFC emissions. As noted under the Transition Status review earlier in this Summary, this is not only an issue arising from earlier practices, but is also impacting decisions about current and future product use. This may result in a greater consideration of insulation product design in buildings to facilitate removal at end-of-life and to encourage re-use of the building element wherever possible. These issues have been identified previously by the Foams Technical Options Committee (FTOC) both in its own reports and those of relevant TEAP Task Forces and are addressed in Appendix 4 of the FTOC Assessment Report.

For the first time in this Report, and in the interests of information dissemination, Appendix 2 in the FTOC Assessment report gives a comprehensive overview of the physical and chemical characteristics of the blowing agents together with issues that need to be considered when handling them. The Technical Options Committee hopes that this will be a valuable further dimension for readers.

4. Executive Summary of the 2002 Assessment Report of the Halons TOC

4.1 Introduction

The following sector summaries show the remarkable progress that has been made to significantly reduce the need for halons and discuss the current state of co-operative or individual arrangements to ensure adequate stocks of halons to meet future needs:

4.2 Military

The military sector has shown leadership in, and devoted considerable effort to, the identification, development and testing of suitable halon alternatives, with much of the benefit transferring to the civilian and commercial sectors. As a result of this effort, much progress has been made and HTOC is unaware of any new facilities or new designs of military equipment that now require the use of the halons. The conversion of systems in existing, in-service equipment is more challenging, but conversion programmes are underway or completed for several important applications. In other cases, very significant technical, economic and logistical barriers to conversion remain. To maintain Parties' levels of national security, and the safety of military personnel, halon systems may need to continue in service for the remainder of the operational life of the equipment concerned. Halon use by the sector is well managed. Many organisations have established dedicated halon storage and recycling facilities to support Critical Use equipment for as long as is necessary. Future Essential Use production of additional quantities of any halon for the military sector should therefore not be necessary.

4.3 Civil Aviation

The aviation industry continues the search for acceptable replacements for halon, and in the meantime has eliminated or reduced emissions in testing, training, maintenance operations and use in ground facilities. Progress has been achieved and for some applications, including systems for lavatory waste receptacles and portable fire extinguishers, approved replacements are available. However, for the majority of in-flight applications, including systems for engine nacelles and cargo compartments, progress has been slow due to a combination of factors. These range from industry and government reluctance to incur additional risk or expense associated with new systems, to the need for extensive training of personnel. An active programme of work to find suitable approaches for these remaining areas continues, co-ordinated for the commercial aviation industry by an International Aircraft Systems Fire Protection Working Group open to all interested parties.

Until these projects reach successful conclusions, aircraft will continue to require halon for their fire protection and Airworthiness Certification. To meet the needs of new and existing airframes certified with protection systems based on halon, recycling, conservation and banking of halon, will be necessary for their minimum expected life of some thirty years. It is strongly recommended that commercial airlines and other aviation users continue to implement discharge minimisation procedures and individually or collectively establish measures to meet their long-term needs for recycled halons.

In existing aircraft, changeover to approved halon free lavatory waste receptacle fire protection systems and portable fire extinguishers should be implemented in a timely manner.

Given the important technical considerations, logistical needs and financial implications, and to ensure the safety of the aircraft crew and passengers, the International Civil Aviation Organisation (ICAO) would be an appropriate body to co-ordinate the development of a timely plan of action to eliminate the need for use of halon on new airframes. Certifying Agencies, Airframe Manufacturers and Operators will likely wish to participate in this effort. Aircraft Operators may also wish to consider asking ICAO for assistance in developing a co-ordinated program to put in place and manage an assured supply of halon to meet the ongoing needs of existing airframes certified on the basis of halon fire protection.

4.4 Merchant Shipping

The status of halons in merchant shipping must be viewed in two different contexts: existing ships already equipped with halons and new ships that are not permitted to employ halons. At the centre of this halon subject is the International Maritime Organization (IMO), which has been the cohesive force to address the halon issue in both contexts. In that regard, IMO

- enacted an international ban on the use of halons aboard new ships on international voyages, nearly 2 years before the halt of production of halons in non-Article 5 countries.
- developed and published approval guidelines and test methods for the systems using halon alternatives on shipboard applications.
- developed recommended procedures for ships with discharged / depleted halon systems to safely move from one port to another where system replenishment is possible.
- established, distributed and has maintained an international listing of halon agent replenishment sources for ships needing a system recharged.

It is important that the marine industry closely monitors the change in availability of replenishment halon around the world. This is a dynamic situation and it will only be through pre-planning that owners and authorities can prepare for the eventuality of a future halon shortage. Parties to the Montreal Protocol, in conjunction with the International Maritime Organization, may wish to consider specific programs directed to owners of vessels to emphasise the need for continued international Cupertino to prepare for this potential problem.

4.5 Oil and Gas Production

The use of halon 1301 systems in this industry for explosion prevention (inertion) has been focused on inhospitable locations such as the Alaskan North Slope in the United States and the North Sea in Europe where facilities have had to be enclosed due to the harsh climatic conditions. The process areas in the production modules and the pumping stations face a constant threat from methane gas and crude oil leaks that can lead to potentially explosive atmospheres. Halon 1301 has been the agent of choice for mitigating this threat. When reviewing protection measures brought about by the phase out of halon there are two distinct cases to consider, existing facilities and new facilities. Halon supplies are only a consideration for existing facilities, as new facilities are not being designed to use halon.

In regions/countries where regulatory actions have forced the decommissioning of halon 1301 systems, companies are either stockpiling the resulting surplus (if permitted) or are relying on government/private halon ‘banks’ to supply their ongoing needs. In some cases, regulations require a company to submit their halon requirements to a ‘critical use’ review board to determine whether or not they can obtain necessary supplies.

In regions/countries without regulatory controls on halon use, there currently appears to be no compelling reasons to stockpile halon as demand is being met from recycled supplies. Companies are making opportune buys as halon comes to market at reasonable cost, and larger corporations are generally maintaining stocks at the 3 to 5 year level. However, the industry should plan for the long term to ensure that supplies of recycled halon are available to it for as long as will be needed.

4.6 Explosion Suppression

In the past, halons were used to suppress explosions in industries such as Aerosol Fill Rooms, Grain Silos, Paper Production and Milk Powder Processing plants. Halon 1301, halon 1211 and halon 1011 have all been used as explosion suppression agents. For all known applications alternatives have been developed and tested. As a result all new explosion suppression systems no longer rely upon halons.

Explosion suppression systems for Aerosol Fill Rooms are a special case. In the past, halon 1301 was the standard suppression agent used in North America, whereas aqueous systems were employed in Europe. Since approximately 1996, the standard agent for new systems in North America has been water. Retrofit activity from halon 1301 to water in North America has occurred but only to a limited extent, and significant conversion has not been undertaken. This is due to the very high cost of replacement of the entire existing system in the facility with a new aqueous based system.

4.7 Countries with Economies in Transition (CEIT)

The same technical issues and current status of selected uses of halons outlined in this Report also apply to all CEIT from a technical point of view. However, the difference is in the higher economic cost to retrofit existing halon based fire protection systems with alternatives, in particular in CIS.

The installed capacity of halon 2402 in the Russian Federation is sufficient to assure that enough halon 2402 can be removed and recovered to meet the needs of critical applications. Quantities should be sufficient to meet the critical needs of the Russian Federation and those CIS requiring halon 2402 for critical applications. Parties may wish to encourage the Russian Federation government to allow export of recycled halon 2402 to help meet critical needs in CIS.

There should be no further need for an “Essential Use” exemption for any halon in CIS. However, all CEIT governments should advise their “critical user sectors” to make appropriate efforts to obtain supplies of recycled halons to support their needs. Recovery and recycling of halon 2402 as well as halon 1211 and 1301 is of particular importance in the Russian Federation.

The need for technical training and assistance to CIS to facilitate the transfer of halon based fire protection towards long-term, sustainable fire protection alternative solutions continues.

4.8 Article 5(1) Countries

Halon consumption in Article 5(1) countries has been reduced significantly over the past few years. Based on the current trends, the agreements between the Multilateral Fund (MLF) and Article 5(1) countries, and the halon production figures for the year 2002, it seems certain that production of halon 1211 will stop in China by 2005, and the only remaining 1211 production may be a few hundred tonnes in South Korea. Similarly, total production of halon 1301 in China and

South Korea will also be reduced to less than 300 tons from 2005 and until 2009 due to reduced demand.

Three activities have contributed to this accelerated phase-out achievement in Article 5(1) countries. Firstly, halon management and banking projects have substantially reduced the demand for halon in over 35 of the larger halon consuming Article 5 countries. This has been achieved through a combination of awareness creating activities, promotion and transfer of substitute fire protection technologies, training courses for the fire protection industry, and halon recovery and recycling. Based on agreements with the Multilateral Fund, those countries will stop import of new halons by 2005 and will be able to cover future needs for halons through recovered and recycled halons. The second major activity that has enabled the accelerated phase-out of halons in Article 5(1) countries is the China Halon Sector Plan. The financial support provided by the MLF will result in the closure of halon 1211 production by 2005 and will reduce the allowed production of halon 1301 to no more than 150 tonnes annually from 2006 onwards. The third activity is the halon phase-out program for India, which has allowed India to accelerate its halon phase-out. As part of the MLF support to India, both halon production facilities in India have been dismantled.

While the demand for new halons has been reduced to close to zero, it is also necessary to recognise that Article 5(1) countries, like non-Article 5 countries, will be depending on the availability of recycled halons for critical uses after 2005. It is noted that critical uses in Article 5(1) countries are the same as in non-Article 5(1) countries and new technologies are suitable for new installations. As funds for capital expenditures are often scarce in Article 5(1) countries, retrofit of existing halon systems poses a particular challenge. Any assessment of global demand for recycled halons should therefore also include the demand in Article 5(1) countries after 2005. A real or perceived shortage of recycled halons could lead to the need for additional production of new halons.

4.9 Summary of progress

The following table provides a summary of the extraordinary progress that has been made in the development of alternatives, replacements and new fire protection approaches.

Current Status of Selected Uses of Halons		Halon Type	Alternative Availability for Existing Use	Impediments to Retrofit of Existing	Alternatives Available for Next Generation	Impediments to Next Generation
Military Uses						
Facilities	Command Centre	1301	Alternatives Available	Cost $$	Alternatives Available	None
	Research Facility	1301	Alternatives Available	Cost $$	Alternatives Available	None
	Computer Centre	1301	Alternatives Available	Cost $$	Alternatives Available	None
	Electrical Compartment	1301	Alternatives Available	Cost $	Alternatives Available	None
Airfield	Crash Rescue Vehicle	1211	Potential Alternatives	Technical	Potential Alternatives	Technical
	Flight Line Portables	1211	Potential Alternatives	Technical	Potential Alternatives	Technical
Aircraft	Engine Nacelle	1301, 1211 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Auxilliary Power Unit	1301, 1211 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Dry Bay	1301, 1211 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Cargo Bay	1301	Potential alternatives	Technical	Potential alternatives	Technical
	Fuel Tank Inerting	1301	Potential alternatives	Technical	Alternatives Available	None
	Lavatory Waste Receptacle	1301	Alternatives Available	Cost $	Alternatives Available	None
	Portable Extinguisher	1301 or 1211	Alternatives Available	Cost $	Alternatives Available	None
Combat Vehicle	Engine Compartment	1301, 1211 or 2402	Alternatives Available	Cost $$	Alternatives Available	None
	Crew Compartmnent	1301 or 2402	Potential alternatives	Technical	Potential Alternatives Available	Technical
	Portable Extinguisher	1211 or 1301	Alternatives Available	Cost $	Alternatives Available	None
Surface Vessel	Machinery Space	1301, 1211 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Flammable Stores	1301 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Electrical Compartment	1301 or 2402	Alternatives Available	Cost $$$	Alternatives Available	None
	Command Centre	1301 or 2402	Alternatives Available	Cost $$$	Alternatives Available	None
	Flight Line/Hangar Portable	1211	Potential alternatives	Technical	Potential Alternative	Technical
Submarine	Machinery Space	1301 or 2402	Potential alternatives	Technical	Alternatives available	None
	Diesel Generator Space	1301 or 2402	Potential alternatives	Technical	Alternatives available	None
	Electrical Compartment	1301 or 2402	Potential alternatives	Technical	Alternatives available	None
Merchant Shipping						
Vessels	Machinery Space	1301, 1211 or 2402	Alternatives Available	Cost $$$	Alternatives available	None
Ground Transportation						
Railway	Locomotive Engine Compartment	1301	Alternatives Available	Cost $$	Alternatives Available	None
	Wagons with Occupied Vehicles	1301	Potential alternatives	Technical	Potential Alternatives	Technical
Commercial Aviaton						
Aircraft	Engine Nacelle	1301 or 2402	Potential Alternatives	Technical	Alternatives Available	Regulatory Barrier
	Auxilliary Power Unit	1301 or 2402	Potential Alternatives	Technical	Alternatives Available	Regulatory Barrier
	Cargo Bay	1301 or 2402	Potential Alternatives	Technical	Potential alternatives	Technical
	Lavatory Waste Receptacle	1301	Alternatives Available	Cost $	Alternatives Available	None
	Portable Extinguisher	1211	Alternatives Available	Cost $	Alternatives Available	None
Airfield	Crash Rescue Vehicles	1211 or 2402	Alternatives Available	Cost $$	Alternatives Available	None
	Flightline portable	1211	Alternatives Available	Cost $	Alternatives Available	None
Industrial Uses						
Explosion Prevention	Oil and Gas Pipeline Pumping Stations	1301 or 2402	Potential Alternatives	Technical	Alternatives Available	None
	Enclosed Oil and Gas Production Modules	1301 or 2402	Potential Alternatives	Technical	Alternatives Available	None
	Aerosol Fill Rooms	1301	Alternatives Available	Cost $$	Alternatives Available	None
	General Explosion Suppression	1011 or 2402	Alternatives Available	Cost $	Alternatives Available	None
General Fire Protection	Computer Room	1301	Alternatives Available	Cost $$	Alternatives Available	None

4.10 Conclusions

Halon fire extinguishants are no longer necessary in virtually any new installations, with the possible exceptions of engine nacelles and cargo compartments on commercial aircraft and crew compartments of combat vehicles. The very high cost of replacing many existing halon systems with substitutes, replacements or other alternative fire protection measures continues to be a major impediment to eliminating continued use of halons.

Although potential alternatives exist for both engine nacelles and cargo bays of commercial aircraft it is disturbing to report that new airframes are still being designed and certified with halons as the required fire extinguishant due to regulatory requirements. Parties may wish to request the International Civil Aviation Organization (ICAO) to act with the TEAP HTOC as a co-ordinating body in development of a timely plan of action to eliminate regulatory requirements for halons on new airframes. Airframe Certification Agencies and Airframe Manufacturers will want to participate in this effort.

Some Parties have enacted regulations requiring existing halon systems to be decommissioned and the halons from these systems destroyed. Although most halon 1211 and a portion of halon 1301 in inventory will not be required to meet future needs such measures require careful planning to ensure that sufficient stocks of halon 1301 remain available to meet future critical needs of both Article 5(1) and non-Article 5(1) Parties. Users that have critical halon needs should consider making arrangements to ensure a secure supply, either individually or in partnership with other critical users. This effort would likely include obtaining the additional halon necessary to meet their future requirements and expansion of existing or construction of new secure storage facilities that would include necessary leak prevention and monitoring measures.

An alternative to the creation of large halon stockpiles would be a decision to allow Parties to earn credits for destroyed or converted halon by technologies approved by the Parties. These credits would be eligible to be carried forward for possible future critical uses to be approved (Article 1, Paragraph 5 allows credits for the year of destruction and not for future use). Such a provision would be an incentive to collect and destroy halons, would deter emissions from halon banks which may be found surplus to requirements, and could help eliminate the reluctance to retrofit of existing applications that results from the current oversupply of halon. A bolder strategy to achieve these objectives could be, through market-based approaches, such as trading in credits to be obtained by destruction of halons or allowing such credits to be used for essential/critical uses of other ODS.

The HTOC will invite TEAP and its other TOCs to consider the potential advantages and disadvantages of such an approach to other ODS use sectors.

In 2003, the Halon Technical Options Committees will further explore options to reduce halon emissions.

5. Executive Summary of the 2002 Assessment Report of the Methyl Bromide TOC

5.1 Introduction

The Methyl Bromide Technical Options Committee (MBTOC) was established by the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer to identify existing and potential alternatives to methyl bromide (MB). This Committee, in particular, addresses the technical feasibility of chemical and non-chemical alternatives for the current uses of MB, apart from its use as a chemical feedstock.

MBTOC reports to the Technology and Economic Assessment Panel (TEAP) which advises the Parties on scientific, technical and economic matters related to the control of ozone depleting substances and their alternatives. MBTOC members have expertise in the uses of MB and its alternatives. At December 2002 MBTOC had 34 members; 10 (29%) from developing and 24 from developed countries and coming from 9 Article 5(1) and 10 non-Article 5(1) countries respectively.

5.2 Mandate and Report Structure

Under Decision XI/17, taken at the ninth Meeting of the Parties to the Protocol in 1997, the Parties requested the Assessment Panels, to update their 1998 Assessment reports and submit them to the Secretariat for consideration by the Open-Ended Working Group and by the fifteenth Meeting of the Parties in 2003.

This MBTOC 2002 Assessment reports on MB usage; the quantities produced and consumed; existing and potential alternative treatments for uses as a soil fumigant; as a fumigant of durable commodities and structures; and as a fumigant for quarantine and pre-shipment (QPS).

In addition, the report provides sections in response to Decision IX/5(1e) and also on methods for reducing MB emissions. Decision IX/5(1e) notes that, in the light of an assessment to be made by the Technology and Economic Assessment Panel, the Meeting of the Parties shall decide in 2003 on further specific interim MB reductions in Article 5(1) Parties for the period beyond 2005. To aid this assessment, information is provided on the extent to which alternatives have been tested and evaluated in Article 5(1) countries, and the results of demonstration projects which examined efficacy with respect to target pests, ease of application, availability, relevance to climatic conditions, soils and cropping patterns found in Article 5(1) regions.

5.3 General Features of Methyl Bromide

MB is a fumigant that has been used commercially for more than 50 years to control pests such as fungi, bacteria, soil-borne viruses, insects, mites, nematodes and rodents. It has sufficient phytotoxicity to control many weeds and seeds in soils. MB is used mostly for soil fumigation, a lesser amount is used for disinfestation of durable and perishable commodities and some is used for disinfestation of buildings, ships and aircraft, and other miscellaneous uses. It has well established uses for quarantine and pre-shipment treatment of a diverse range of pests and diseases.

It has features that make it a versatile material with a wide range of potential applications. In particular, it is a gas that is quite penetrative and usually effective over a broad range of temperatures. Its action is usually sufficiently fast and it airs rapidly enough from treated systems to cause relatively little disruption to commerce or crop production.

Methyl bromide was listed under the Montreal Protocol as an ozone depleting substance in 1992. Control schedules leading to phase-out were agreed in 1995 and 1997. There are a number of concerns apart from ozone depletion that have also led countries to impose restrictions on its use. These concerns include residues in food, toxicity to humans and associated operator safety and public health, and detrimental effects on soil biodiversity. In some countries, pollution of surface and ground water by MB and its derived bromide ion are also concerns.

5.4 Production and Consumption

The latest year for which production and consumption estimates are available is 2000. MBTOC used primarily the data reported by Parties to the Ozone Secretariat to estimate total production and consumption. Data gaps were filled by using data from the previous reported year.

MB production trends

Global MB production for all uses (including QPS and feedstock) in 1998, as reported to the Ozone Secretariat, was about 75,200 metric tonnes. Ozone Secretariat reports indicate that global MB production for controlled uses (i.e. excluding QPS and feedstock) was at least 62,750 tonnes in 1998. This data set is not complete and other sources indicate that it was somewhat higher. Production for controlled uses was reported to be at least 49,560 tonnes in 1999 and about 46,050 tonnes in 2000. The reductions reflect primarily the production controls implemented in non-Article 5(1) countries. Most MB production occurs in the USA and Israel.

MB consumption trends

Parties reported MB consumption of about 60,200 tonnes in 1998 (excluding QPS), although some sources indicate higher consumption. On the basis mainly of Ozone Secretariat data, MBTOC estimated that, for controlled uses, at least 49,170 tonnes MB was consumed in 1999 and at least 45,360 tonnes in 2000. Although the data set is incomplete, the data at country level indicates MB consumption has been reduced in non-Article 5(1) counties in line with the Protocol requirements.

Controlled MB consumption in Article 5(1) countries rose from about 8,460 tonnes in 1991 to about 17,600 tonnes in 1998, representing an increase of 15% per year on average. However, since 1998 the consumption has decreased at an average rate of about 5% per year (1998-2000). Based on Ozone Secretariat data reported so far, MBTOC estimated the total Article 5(1) MB consumption to be around 16,440 tonnes in 2000. Between 1998 and 2000, national MB consumption fell by more than 20% in some Article 5(1) countries, but increased significantly in others.

As at December 2002, the Multilateral Fund had approved 38 MB phase-out projects that are designed to eliminate almost 8,000 tonnes of MB in Article 5(1) countries. The projects are scheduled to phase out about 75% of this before 2006. The speed of planned MB reductions depends on a variety of factors, such as the initial consumption level, MB uses/crops and national policies. In the 15 countries that plan full phase-out, MB is scheduled to be reduced at an average annual rate of about 22.5% per year, in a total of 4.4 years on average (range 3-6 years). This includes countries that are small, medium and large MB consumers.

A number of additional MB phase-out projects are under development by the MLF and other organisations. The existing and anticipated projects are due to lead to the phase-out of about 10,000 tonnes MB before about 2007, eliminating more than 50% of the peak consumption in Article 5(1) regions.

A MBTOC survey of ozone offices and national experts in 2001/2 provided information on the breakdown of MB uses in major MB-consuming countries. In 2000, an estimated 67% was used for soil and 33% for commodities/structures, including QPS.

5.5 Methyl Bromide Emissions

Under current usage patterns, the proportions of applied MB eventually emitted to the atmosphere are estimated by MBTOC to be 40 - 87%, 85 - 98%, 69 - 79% and 90 - 98% of applied dosage for soil, perishable commodities, durable commodities and structural treatments respectively. These figures, weighted for proportion of use and particular treatments, correspond to a range of 50 - 87% overall emission from agricultural and related uses, with a best estimate of overall emissions of 73%, or 40,515 metric tonnes based on production of 55,500 tonnes in 2000.

5.6 Methyl Bromide Control Measures

The current control measures, agreed by the Parties at their ninth Meeting in Montreal in September 1997, can be paraphrased as:

For non-Article 5(1) Parties operating under the Protocol (developed countries) a 25% cut in production and consumption, based on 1991 levels, from 1 January 1999, a 50% cut from 1 January 2001, a 70% cut from 1 January 2003 and phase out by 1 January 2005 with provision for exemptions for any critical uses. A freeze on MB production and consumption based on 1991 levels already applies from 1 January 1995.

For Parties operating under Article 5(1) of the Protocol (developing countries) a 20% cut in production and consumption, based on the average in 1995-98, from 1 January 2005 and phase out by 1 January 2015 with exemptions for any critical uses. There is also a freeze on MB production and consumption based on 1995-98 levels from 1 January 2002 which was agreed at the ninth Meeting of the Parties in 1997.

The Protocol provides an exemption under Article 2H para. 6 for all Parties for the amounts of MB used for QPS purposes. Additionally, certain uses of MB may be allowed exemptions from phase-out after 2005 if they are deemed to meet the criteria for ‘critical uses’ defined by the Parties.

5.7 Alternatives to Methyl Bromide

Definition of an alternative

MBTOC defined ‘alternatives’ as those non-chemical or chemical treatments and/or procedures that are technically feasible for controlling pests, thus avoiding or replacing the use of MB. `Existing alternatives’ are those in present or past use in some regions. `Potential alternatives´ are those in the process of investigation or development.

MBTOC assumed that an alternative demonstrated in one region of the world would be technically applicable in another unless there were obvious constraints to the contrary e.g., a very different climate or pest complex.

MBTOC is not required in its terms of reference to conduct economic studies on MB and alternatives. Additionally, it was recognised that regulatory requirements, environmental issues and social constraints may make an alternative unavailable in a specific country or region. MBTOC did not omit alternatives from consideration on such grounds.

Availability of alternatives

MBTOC could find no existing technical alternatives for about 3200 tonnes of MB per annum used for non-QPS treatments. Based on this relatively small consumption of MB and bearing in mind the above definition of an alternative, there are existing alternatives for more than 93% of current consumption of MB, excluding QPS. Significant effort must now be undertaken to transfer, register and implement these alternatives and to optimise their use.

While an alternative may be technically appropriate as an MB replacement for a given situation, it may not be available in practice. For example, registration is a major constraint affecting the availability of certain alternatives, particularly novel chemicals or chemicals applied to new uses. . In many countries, the pesticide registration process requires the generation of a substantial amount of health and safety data. The potential health and environmental risks must be assessed thoroughly and appropriate mitigation controls put in place before an alternative can be registered. Overall, the registration and approval process is often costly and protracted, with the outcome uncertain from the point of view of the potential registrants. In addition, the market size for a particular MB application may be too small to justify the commercial risk and investment involved. These problems are particularly noted where use on foodstuffs is involved and registration costs are high, such as with MB alternatives for many postharvest applications, including QPS. However, some countries have registered some alternatives in recent years and some large MB-volume consuming countries are currently considering registration for additional alternatives. There is the possibility that further registrations for use will be completed prior to 2005 phase-out in some non-Article 5(1) countries.

Alternatives for soil treatments

The reduction in consumption of MB for soil fumigation has been the major contributor to the overall reduction in global consumption of MB as most non-Article 5(1) countries have met or exceeded the 50% reduction schedules for soil use agreed under the Montreal Protocol.

Since the 1998 MBTOC Report, clearer trends have developed in the adoption of alternatives to replace MB as a preplant soil fumigant. These include alternatives that either provide broad-spectrum control of pests, diseases and weeds (e.g.

chemicals and their combinations, steam and solarisation) or cultural practices which avoid the need for MB.

MB used alone, or in mixtures with chloropicrin, is still being used for preplant soil disinfestation to manage a similar range of crop/pathogen complexes to those that were recorded in the 1998 Report. The major crops for which MB is still widely used in some regions include; cucurbits, pepper, tomatoes, perennial fruit and vine crops, cut flowers and bulbs, strawberry fruit and turf. MB may also be used in the production of propagation material for forests, fruit and vine crops, strawberries, ornamental trees and tobacco.

Although significant progress in alternatives to MB has been made since the 1998 report, MBTOC recognises that the complexity of soil pathogen and weed problems in different countries and the diversity of environments in agriculture require the continued development and adaptation of non-chemical and chemical methods. Further investment in research and technology transfer will be necessary to implement alternative pest management systems effectively in all countries.

Feasibility and adoption of alternatives to MB may be affected by local availability, registration status, market requirements, costs, labour inputs and efficacy against pests, disease and weed complexes and, in some cases, by reduction of crop yield or quality. Alternatives need to demonstrate sufficient efficacy and yields over several seasons, before confidence is obtained for their commercial use.

To date, reductions in the amount of MB used for soil disinfestation have been achieved mainly by the adoption of transitional strategies and to a lesser extent by adoption of alternatives in non-Article 5(1) countries. In Article 5(1) countries reductions have been made largely by adopting alternatives.

The main transitional strategies used include:

> MB/chloropicrin mixtures with lower concentrations of MB, the use of lower doses of MB and/or to a lesser extent the adoption of barrier films.
>
> Less frequent fumigation.

The major alternatives adopted to offset the use of MB include:

> Fumigants and other chemical pesticides applied alone or as mixtures. 1,3-dichloropropene (1,3-D) and mixtures of 1,3-dichloropropene/chloropicrin (1,3-D/PIC) are the most common fumigant alternatives being adopted, followed by metham sodium, dazomet and chloropicrin used alone. Combinations of 1,3-D, PIC, metham and dazomet, with or without additional herbicides and fungicides, or other non-chemical alternatives have been proven as effective as MB in research trials, but need further commercial validation.

Solarisation, alone or combined with biofumigation, has gained wider acceptance to replace MB in areas with hot climates and where it suits the cropping season and the pest and disease complex.

Steaming is being adopted for high value crops grown in protected agriculture e.g. greenhouses, particularly when quick turn around times are required or where fumigant use is impractical.

Soilless culture is a rapidly expanding cropping practice, primarily for protected agriculture, which has offset the need for MB, especially in some floricultural crops, vegetables and seedling production. In particular, flotation systems, based on soilless substrates and hydroponics, have replaced over 80% of MB for tobacco seedling production worldwide. The adoption of this technique is currently expanding into cut flower and some vegetable production.

Grafting, resistant rootstocks and resistant varieties are commonly used practices to control soilborne diseases in vegetables, flowers and fruit trees and are being more commonly adopted as part of an integrated pest control system. Although grafting is used widely to control specific diseases of many crops for which methyl bromide is still used, MBTOC did not have the data to determine the extent to which these practices have replaced MB for soil disinfestation.

In addition to the above specific technologies, integrated pest management (IPM) strategies have also been developed for control of pests, diseases and weeds using combinations of a range of other chemical and non-chemical alternatives. IPM strategies have been developed for specific pests, climatic regions and soil types but further development is required in many countries, before IPM can be expected to provide the broad spectrum control that is presently achieved by MB.

Potential alternatives include:

Methyl iodide, propargyl bromide and sodium azide which have each been demonstrated in research trials to be effective as direct replacements for MB in some cropping systems where MB is currently used.

Biological control agents, organic amendments, and incorporation of green manures into the soil, have been subjected to a considerable amount of research and have a role in integrated systems. Significant advances in the use of these techniques have been accomplished for the control of soilborne diseases in horticultural crops. There are specific crop/pest combinations where green manures have successfully replaced MB when combined with other methods, particularly solarisation.

MBTOC estimates that the reductions in MB consumption from 1991 baseline consumption for non-Article 5(1) Parties for soil fumigation result from mainly from transitional strategies (about 30% of the reduction), use of alternative fumigants and chemical treatments (10%) and use of soilless systems (5%). Other measures, steaming and solarisation, account for less than 1% of the present reduction in use, though they are important as alternatives in some particular situations.

Projects in Article 5(1) countries have demonstrated that a similar range of alternatives to those in non Article 5(1) countries can be successfully adopted. Costs and different resource availability can lead to preference for different alternatives in Article 5(1) compared to non-Article 5(1) countries.

Research has not yet determined conclusively that MB can be replaced in certain production systems to give similar outcomes, notably certain perennial crops and some other replant situations, and production of certain propagation materials meeting legislated requirements for pest-free status. Also, several diseases of certain crops are proving difficult to control, including root rot of ginseng in China and a soilborne virus (cucumber green mottle mosaic virus) in Japan. Since the 1998 Report, MBTOC has revised its estimate of the annual quantity of MB required for these difficult situations world-wide from 2500 to 3000t.

Alternatives for treatment of durables, wood products and structures (non-QPS)

Durables are commodities with a low moisture content that, in the absence of pest attack, can be safely stored for long periods. They include foods such as grains, dried fruits, cocoa beans, animal feeds and non-foods such as wood products, wool, cotton, and tobacco. Wood products include artefacts and other items of historical significance; unsawn timber, timber products and bambooware; wooden packaging materials and manufactured articles. All these commodities may sometimes be treated at present with MB for control of insects and other pests.

Structures include entire buildings and portions thereof, including mills, food production and storage facilities, and transport vehicles, including ships, aircraft, freight containers and other vehicles, These all may all sometimes be treated with MB to control stored product or wood destroying insects, rodents and other pests.

It is estimated that approximately 15% of the annual world non-feedstock usage of MB is for the disinfestation of durable commodities and about 2.5% for structures. MBTOC estimates that 5-10% of controlled MB usage for durables has been replaced since 1998.

There are several existing alternatives to MB for disinfestation of durable commodities and structures, though MB may be used in preference because of traditional practice, perceived reliability or speed of action, or for contractual reasons. The principal alternatives in use for durables are phosphine, heat, cold and contact pesticides; for wood products, they are sulphuryl fluoride, chemical wood preservatives, and heat; for structures, they include sulphuryl fluoride, and heat. The choice of appropriate alternatives is dependent on the commodity or structure to be treated, the situation in which the treatment is required, the accepted level of efficacy, the desired speed of action required and the cost, and registration status of alternatives.

There are a small number of current non-QPS uses of MB for which MBTOC did not identify any existing alternatives. For durables, these are: disinfestation of fresh chestnuts, disinfestation of fresh walnuts for immediate sale, stabilisation and disinfestation of high moisture fresh dates, elimination of seed-borne nematodes from alfalfa and some other seeds for planting, and control of organophosphate-resistant mites in traditional cheese stores. In treatment of mills and food processing facilities where IPM systems have not proved adequate, or are very difficult to implement, and where heat treatment is not feasible, it may be necessary to resort to occasional use of MB. In addition there is no recognised alternative for control of fungi in historical structures. The total requirement of MB for these uses is unlikely to exceed 150 tonnes per annum.

Phosphine is the only available in-kind alternative extensively used on durables. Cylinder-based formulations are now available in several countries. Phosphine has the potential to act as a direct substitute for MB in many situations but can also act as a component of an IPM process to avoid MB use. Its action against pests is much slower than MB, particularly at low temperatures. Insect populations are capable of developing resistance to phosphine more readily than MB. There are continued concerns over potential corrosion of some metals and electronic components that impact acceptability of phosphine as an MB alternative for some structural fumigations.

There are several other chemicals that may have some potential as alternatives for MB, but the small market size, and consequent poor return for investment for registrants, limits prospects for their availability. This is particularly a problem for durable and QPS treatments, due to the wide variety of commodities involved. In addition fumigants require specialist training to achieve adequate standards of safety and efficacy. Although hydrogen cyanide was once widely used for treatment of structures and durable commodities, its availability and limitations related to health and safety issues inhibit its immediate substitution for current uses of MB in many countries. Ethyl formate, carbon bisulphide, propylene oxide and ethylene oxide have been or are useful in selected situations. Sulphuryl fluoride is used for controlling wood destroying pests in residences, other buildings and wood products and registration is being sought in the US and Europe for commodities. Carbonyl sulphide is under consideration in Australia for registration for use on various durable commodities.

Treatment with controlled atmospheres (CA) based on carbon dioxide or nitrogen offers an alternative to fumigation for insect pest control, but while the growth of fungi is inhibited in the atmosphere, growth resumes after treatment. MB has been replaced in many countries by CA for disinfestation of artefacts. High pressure CO_2 acts even more rapidly than MB and is an alternative for some export situations, though installation costs are relatively high. CA at normal pressure is much slower acting than MB except at elevated temperatures.

Vacuum technologies using low cost plastic enclosures have recently been commercialised. These simple systems provide a means of holding an insecticidal low oxygen atmosphere at low cost, and also they aid the effectiveness of some fumigants.

Where registered for use, synthetic pesticides including contact insecticides and insect growth regulators may provide persistent protection against reinfestation. Dichlorvos where registered, can provide a rapid control of externally feeding insect stages in grain. Contact insecticides are not normally registered for use on processed food commodities or dried fruit, nuts and cocoa beans. Botanical compounds, such as plant powders, extracts and oils have minor and traditional applications as insecticides in Article 5(1) countries.

Physical methods of insect control, including mechanical measures during handling and processing, cold, heat and irradiation treatments, offer further potential as non-chemical alternatives in individual circumstances. Cold treatments are now used on their own in specific situations or, more commonly, as part of IPM systems for stored products and artefacts. Heat treatment technologies are increasingly used for structures and some commodities and match the speed of treatment afforded by MB and other fast-acting fumigants. Heating can also assist other treatments, for example fumigants, controlled atmospheres and inert dusts. Inert dusts such as those based on diatomaceous earth can provide effective pest control in dry grain and as part of an IPM program in structures.

Alternatives evaluated in Article 5(1) countries – Response to Decision IX/5(1e)

Several MB alternatives have been selected in Article 5(1) countries for extensive adoption as part of MB phase-out (investment) projects, following successful demonstration projects, and progress in MB reductions in Article 5(1) regions.

By December 2002 the Multilateral Fund (MLF) had approved a total of 232 MB projects in more than 63 countries. This included 44 demonstration projects for evaluating and customising alternatives, 38 MB investment projects for phasing-out MB and 150 other projects for information exchange, awareness raising, policy development and project preparation. Further MB replacement activities have been funded directly by Article 5(1) countries and/or agricultural producers, bilateral assistance and the Global Environment Facility.

MB phase-out projects approved to December 2002 are scheduled to eliminate major uses of MB in 35 Article 5(1) countries. The projects aim to achieve the widespread commercial adoption of alternatives that were found effective during demonstration projects and/or used in similar climates and conditions in other countries.

Demonstration projects have been carried out in Article 5(1) countries using a wide range of chemical and non-chemical alternatives, in diverse situations, climates, soil types and cropping systems, and for many different types of MB users, ranging from small producers with less than 0.5 ha, to medium and large producers, who produce under low, medium and higher levels of technical sophistication (which does not necessarily correlate with size of operation).

Twenty-nine demonstration projects evaluated and customised alternatives in the soil sector, covering all the MB-using major crops in Article 5(1) regions, (tomato, cucumber, pepper, strawberry fruit, melon, cut flowers, nurseries and tobacco seedbeds). About 16 of the projects (completed and on-going) evaluated alternatives for post-harvest uses of MB, such as on stored grains, pulses, peanuts, seeds and dates.

The completed demonstration projects to date show that for all locations and all crops or situations tested, except control of ginseng root rot and stabilisation of high-moisture fresh dates, one or more of the alternatives have proven comparable to MB in their effectiveness in the control of pests and diseases targeted in the projects in these Article 5(1) countries. In many cases, combined techniques have provided more effective results than individual techniques, particularly when they are part of an integrated pest management (IPM) program.

The results indicate that particular attention needs to be paid to appropriate, effective application methods. Adapting the alternatives to the specific cropping environment and local conditions is essential to success. For example, local materials such as coconut coir and rice hulls have made it possible to adapt substrate systems that would normally have required know- and how technically-demanding materials (e.g. rockwool)not widely available in developing countries. These demonstration projects also showed that the tested alternatives could be introduced into an Article 5(1) country and adapted successfully within 2-3 years, in some cases even including registration of pesticide products.

The main techniques found effective in demonstration projects and/or being implemented in follow-up investment projects for the main MB-using crops/uses are:

Tobacco seedbeds: The soilless float system is an effective MB alternative, applicable to most regions where tobacco is grown. Countries now implementing MB phase-out projects in tobacco have primarily chosen to adopt float systems. Their use is increasing in countries like Brazil, Cuba, Zimbabwe, Argentina, Macedonia and Croatia, and has very good potential in China. In some countries, effective results in tobacco seedbeds were also achieved with dazomet and dazomet + solarisation.

Cut flowers: Steam + IPM, metham sodium, substrates, and dazomet were all identified as effective alternatives to MB in diverse conditions. Countries implementing phase-out projects in the cut-flower sector have chosen to adopt these same treatments. Steam with organic amendments is used commercially in, for example, Colombia. Commercial adoption of substrates in greenhouse flower production is increasing in Colombia, Brazil, Ecuador and many other countries.

Tomato, cucumber, melon, peppers, eggplant and other vegetables: The demonstrations identified solarisation + biofumigation, solarisation + metham sodium or dazomet, and grafting as treatments with effects comparable to MB for the control of soilborne pests and diseases. Examples of commercial use include solarisiation + metham and solarisation + biofumigation in tomato and pepper production in Uruguay. Solarisation with biofumigation is widely used by tomato and cucumber growers in the Jordan Valley. Use of grafted tomato plants + IPM is now a common practice among farmers in Morocco and is being introduced in Lebanon. Countries who are implementing MB phase-out projects for vegetables/melons have chosen to adopt alternatives such as substrates, grafted plants, direct seeding, solarisation combined with fumigants or organic matter or biofumigation, and steam + biocontrol agents.

Strawberries (fruit production): Demonstrations identified metham sodium, dazomet, solarisation and combinations of these as effective alternatives to MB under Article 5(1) conditions. Solarisation alone or in combination with biofumigation or *Trichoderma* was reported as having high potential for commercial adoption in Turkey. Dazomet + 1,3-D and chloropicrin are being adopted commercially in some CEIT countries. Countries that are implementing MB phase-out projects in the strawberry sector have chosen to adopt alternatives such as solarisation combined with metham sodium or with manure and *Trichoderma*. Biofumigation + 1,3-D and steam have also been selected, the precise combination of techniques depending on the climate, the soil type and target pests, as for all other crops.

Banana and fruit trees: Dazomet has proved an efficient alternative to MB for controlling Moko disease of bananas. This chemical is now widely used commercially in banana plantations (e.g. in Colombia and the Philippines). Countries who are implementing MB phase-out projects for banana plan to adopt combinations of steam, 1,3-D, metham sodium or solarisation. For fruit trees Article 5(1) countries plan to adopt alternative fumigants + selected chemicals for replant problems, and steam or steam + biocontrols for fruit tree nurseries.

Stored products (durables): Many former storage uses of MB in Article 5(1) countries have already been replaced by phosphine, as noted in previous MBTOC reports. In most cases the current choice of alternative treatments lies between phosphine, carbon dioxide, combinations of these gases with raised temperatures and high or low pressures, other modified atmosphere systems, heating, and vacuum-hermetic treatments. While the limited choice at present is strategically undesirable, the range of available alternatives is expected to increase in future. However, the techniques available at present can achieve effective (non-QPS) disinfestation of almost all stored products without recourse to MB.

The completed demonstration projects identified one or more technically effective alternatives to MB for all the stored products tested, except high moisture fresh dates. Projects generally concluded that alternatives should be implemented together with integrated commodity management (IPM) programmes.

The projects found that phosphine was technically effective against target pests in stored wheat, maize, rice, peanuts for seed, spices and dried fruit. The demonstration project in Egypt concluded that phosphine (combined with improved gastightness) is an effective alternative for grains in bag stacks, silos and warehouses. Vacuum-hermetic treatments were found to provide an effective treatment for cocoa beans in Côte d'Ivoire. Modern hermetic storage has been recently adopted commercially in the Philippines for stored grains.

Countries that are implementing MB phase-out projects have chosen to adopt phosphine with integrated commodity management (ICM) for stored wheat, maize and peanuts. For dried fruits they have chosen carbon dioxide with raised temperature.

The projects described above show that substantial progress has been made in the identification of suitable alternatives in Article 5(1) countries. They indicate that it will be technically feasible for Article 5(1) countries to make substantial reductions in MB use. Experience with demonstration and investment projects to date, such as those supported by the Multilateral Fund, indicate that the many technical, climatic, social and economic barriers to MB alternatives can be successfully overcome in diverse Article 5(1) regions and that alternatives can be adopted within a relatively few years. Commercial availability of certain alternatives for application in Article 5(1) countries is of continued concern.

Alternatives to methyl bromide for quarantine and pre-shipment applications (perishables, durable commodities and structures)

Many perishable and durable commodities in trade or storage lose quality and value when they are attacked by pests such as insects, mites and fungi. These commodities may also carry pests and diseases that can be a threat to agriculture, health and the environment. There are a wide variety of QPS measures that can be taken so that any potential losses and risks can be mitigated, including fumigation with methyl bromide (MB) or the use of a range of alternatives to MB.

For quarantine and pre-shipment purposes, MB fumigation is currently a preferred treatment of commodities in trade world-wide, particularly for insect pest control, as it has a well-established, successful reputation amongst plant regulatory authorities. MB may also be approved for QPS treatments of snails, nematodes, other invertebrate pests, some fungi, and vertebrate pests. Mandatory MB treatments may be required if the pest present is of quarantine concern, and particularly if it is difficult to detect but there is a risk it is present. In some cases, MB may be used for devitalisation as well as for disinfestations (e.g. for some cut flower types). Quarantine pests, detected in a country or region previously free of them, can result in considerable cost caused by restriction of exports, eradication measures and implementation of disinfestation treatments if eradication is not achievable.

Article 2H exempts MB used for quarantine and pre-shipment (QPS) treatments from phase-out, while Decision VII/5(c) urges Parties to adopt recapture technology for QPS applications. The European Community is one of the few Parties that has placed conditions additional to those under the Protocol on MB consumed for QPS, including a cap on the amount that can be used and further reporting requirements. Japan has mandated application of coloured labels to the cylinders to differentiate MB used for QPS or non-QPS.

TEAP reported previously that approximately 22% of MB global consumption was used for QPS treatments. As requested by the Parties in Decision XI/13, MBTOC will *inter alia* undertake a survey in 2002 and report in the 2003 on the consumption and use of MB for QPS treatments.

MBTOC categorised thirteen different categories of alternative treatments such as heat, cold and irradiation that are approved by regulatory agencies as QPS treatments in one or more countries for disinfestation of perishable and durable commodities. Only a small proportion of commodities in commercial trade are treated in the export country using these alternatives as most countries have specific requirements for proving the efficacy for each commodity-pest combination. Post-entry alternative treatments used by the importing country are particularly problematical because many alternatives have neither been approved for treating a specific product on arrival, nor are they easy to implement. To solve this problem, development of a range of alternatives is urgently needed to cope with a large and highly varied volume of produce entering via multiple air and sea ports. Such treatments would need to be able to treat perishable commodities quickly to avoid congestion at busy ports and, for perishable commodities, allow the product to be placed on the market within a few hours of receival.

Alternatives to MB for quarantine treatments are difficult to develop and commercialise. The success of any replacement for MB depends on a number of factors that include: proven treatment efficacy; commodity tolerance; equipment design and commercial availability; regulatory approval, often including bilateral or multilateral agreements; cost competitiveness; and technology transfer, logistical capability and ease-of-use. Given all of these factors, the time from conception to implementation of an alternative disinfestation treatment as a quarantine treatment for perishable and durable commodities can vary from 2 to more than 10 years, depending mainly on the technical difficulties. On the other hand, a pre-shipment treatment that, by definition, target non-quarantine pests may require less time for implementation if the proposed treatment is non-chemical, but it could be equally as long as a quarantine treatment if registration for use on foodstuffs is necessary.

Existing alternatives to MB for QPS treatment of perishable and durable commodities are based on (1) pre-harvest practices and inspection procedures; (2) non-chemical (physical) treatments; and (3) chemical treatments.

For perishable products, pest control based on pre-harvest practices must describe the cultural techniques leading to pest reduction, they must have an agreement on the area of the pest-free zones, and be subject to inspection in order to receive certification. In these cases, regulatory approval depends on a number of factors including knowledge of the pest-host biology, evidence of commodity resistance to the pest, trapping and field treatment results, monitoring of pests and diseases, and careful documentation. Some countries must also maintain a pest-free zone free of pests by placing restrictions on the movement of commodities into the zone and/or by disinfesting vehicles and commodities that are categorised as high risk before or on entry.

Non-chemical treatments kill pests by exposure to changes in temperature and/or atmospheric conditions, or high energy processes such as irradiation and microwaves, or physical removal using air or water jets. Often a combination of these is required to kill pests or pest complexes because they can tolerate a single treatment. Chemical fumigation QPS treatments are often technically feasible for both perishable and durable foodstuffs, but the range of chemicals is limited at present mainly because companies are reluctant to make submissions for registration due to the high costs of demonstrating compliance with health and safety standards and small market for the product. For non-foodstuffs (e.g. timber, cut flowers) that require a lesser investment in testing, alternative chemical treatments may be less expensive to develop.

For each category of alternative to MB, MBTOC noted country-specific regulatory agency approval for specific perishable and durable commodities or several commodities within a class (e.g. citrus): 24 *heat* treatments for 15 perishable commodities (babaco, cucumber, citrus, mango, papaya, bell pepper, eggplant, grapefruit, melon, narcissus, pineapple, squash, sweet potato, tomato and zucchini) and 33 heat treatments for 12 durable commodities (animal feed, bagasse, bulbs, grain, maize, horseradish, museum artefacts, packing material, rice straw and hulls, seeds, tobacco and timber); 7 *chemical* treatments for perishable commodities (asparagus, bulbs, cut-flowers, ornamental material) and 7 chemical treatments for durable commodities (bamboo, bulbs, cocoa, cotton, dried fruit, hay, ship holds and seafreight containers, seeds and dried pods, tick-infested articles, timber and logs, tobacco and wooden artefacts; more than 240 *cold* treatments for 27 perishable commodities (apples, apricots, avocado, carambola, cherries, citrus, clemantines, durian, ethrog, grapes, grapefruit, kiwifruit, litchi, loquats, nectarines, oranges, papaya, peaches, pears, persimmons, plums, plumcots, pomegranate, pommelo, quinces, tangerines and Ya pears) and 4 heat treatments for durable commodities (items infested with insects in soil, hickory, museum artefacts and pecans); one example of *controlled atmospheres* for perishable products (apples) and 12 treatments for 13 durable products (cocoa, dried figs, cereals, dried fruit, furniture, grain, museum artefacts, nuts, pulses, rice, seeds, spices and tobacco); 10 *combination treatments* for perishable products (apricots, cherimoya, durian, limes, litchi, ornamentals, seeds for planting and tomatoes) and one combination treatment for a durable commodity (timber, as logs); 5 examples of *irradiation* of perishable and durable commodities (garlic, papaya, carambola, litchi, plums, wooden artefacts); 30 examples of *pest-free zones* for 9 perishable commodities (cucurbits, grapes, kiwifruit, immature banana, melons, nectarines, peaches, strawberries and tomatos); 6 examples of *pre-shipment inspection* for perishables (apples, apricots, cut-flowers, garlic, nectarines and vegetables); and three examples of the *systems approach* for perishables (apples, avocado and citrus). In summary, MBTOC noted more than 300 alternatives approved for quarantine treatment of perishables and more than 70 approved as QPS treatments for durable commodities.

Currently, there are no approved alternatives to MB for QPS for exports such as apples, pears, stonefruit and walnuts that are hosts to codling moth; for internal quarantine pests of berryfruit; for grapes infested with mites exported to some countries; for many root crops exported by countries if soil is present or pests of concern are detected on arrival; for cut-flowers (roses, carnations and statice) exported to Europe, USA, Scandinavia and Japan; for logs imported into the European Union potentially contaminated with oak wilt fungus; for ship hold disinfestation in most countries; and for seed-borne nematodes potentially infesting seeds for planting.

5.8 Reduction of Emissions from Methyl Bromide Use

Emissions from fumigation operations occur through leakage and permeation during treatment (inadvertent emissions) and from venting at the end of a treatment (intentional emissions). Estimates of the proportion of MB used that is released into the atmosphere vary widely because of: differences in usage pattern; the condition and nature of the fumigated materials; the degree of gas-tightness; and local environmental conditions. Some MB may also be converted to non-volatile materials making it incorrect to equate production with emissions.

Emission volume release and release rate to the atmosphere during soil fumigation depend on a large number of key factors. Of these, the type of surface covering and condition; period of time that a surface covering is present; soil conditions during fumigation; MB injection depth and rate; and whether the soil is strip or broadacre fumigated are considered to have the greatest effect on emissions. Under ideal conditions, when all these factors are controlled and impermeable films are used, emission volumes as low as 3% have been observed. It is unlikely, however, that these results will ever be repeated in the field due to the handling difficulties of laying plastic sheets during fumigation and leakage from the edges, tears, cracks and other events. The use of Virtually Impermeable Film (VIF) sheeting and reduced application rates of MB, offer the greatest potential for immediate reduction of emissions from soil fumigations during the interim phase-out period and for any post-phase-out critical use exempted treatments. Use of VIF has been mandated in the EU. However, elsewhere, cost and several non-air quality related environmental and health issues (recycling, disposal and possibility of increased bromide ion concentration in soil) are seen as barriers to their adoption.

For commodity and structural fumigations, techniques such as improved sealing of enclosures for decreasing MB leakage are in limited use world-wide. Their adoption is constrained particularly by lack of incentives, lack of promotion of relevant technologies and by perceived or real increases in costs and logistical problems. A high degree of containment is a prerequisite for efficient recovery of the used MB. Many facilities used for fumigating perishables, particularly for quarantine, already have a high standard of gastightness leading to very low leakage rates (often less than 5% of applied dosage).

There has been limited research into the development of recovery and recycling systems for MB. Systems reported on in the 1998 MBTOC report would have had high running costs associated with energy requirements and many would require a level of technical competence to operate, not normally found at fumigation facilities. Since then two systems based on activated carbon absorption have been commercialised. There are now several examples of recovery equipment in current commercial use. Adoption of these systems has been driven by considerations other than ozone layer protection, e.g. local air quality.

Practically, the scope for recovery of MB after fumigations is likely to be restricted to treatments carried out in enclosures, i.e. space fumigations of commodities, structures and transport, with subsequent destruction of the captured MB. At this time no system for recovery of MB from soil fumigation has been commercialised and there are no systems known to MBTOC under development. Furthermore, since the phase-out of MB for soil uses in non-Article 5(1) countries is imminent (2005), such systems are unlikely to be developed. In 2000, total space (durables, perishables and structures) treatments in Article 5(1) and QPS uses in non-Article 5(1) countries were 9,300 - 10,400 tonnes. On the basis of 70% recapturable MB, this corresponds to about 7,000 metric tonnes of emissions that could be prevented from entering the atmosphere by the fitting of recapture and destruction equipment.

Unlike some other ozone depleting substances where the interim needs of Article 5(1) countries can be met in part by banks of recycled material, it is unlikely that this method will be practical for MB. This is because some of the MB used in any application reacts and breaks down (it is not unusual to lose most of the MB applied in some more reactive commodities such as oilseed meals). Some Parties may not permit reuse of recaptured MB as it does not conform to their labelling requirements.

If recovery is to be recognised as an acceptable method of reducing MB emissions to the atmosphere, it will be necessary to set specifications on aspects of fumigation such as equipment efficiency and acceptable levels of emission.

6. Executive Summary of the 2002 Assessment Report of the Refrigeration, AC and Heat Pumps TOC

6.1 Refrigerants

This chapter summarises data for refrigerants and specifically those addressed in other sections. It discusses thermophysical (both thermodynamic and transport) properties as well as heat transfer, compatibility, and safety data. The chapter also provides similar information for heat transfer fluids (sometimes referred to as "secondary refrigerants") for air-conditioning, heat pump, and refrigeration systems.

The tabular data summaries are updated from prior assessments to reflect current data, from consensus assessments and published scientific and engineering literature where possible. The summaries address:

- refrigerant designations
- chemical formulae
- molecular mass
- normal boiling point (NBP)
- critical temperature (T_c)
- critical pressure (P_c)
- occupational exposure limits
- lower flammability limit (LFL)
- heat of combustion (HOC)
- safety classification
- atmospheric lifetime (τ_{atm})
- ozone depletion potential (ODP)
- global warming potential (GWP)
- control status

The summary tables also add new blends introduced since the 1998 assessment report. The new chapter clarifies the significance of between *modelled*, *semi-empirical*, *time-dependent*, and *regulatory* bases for Ozone Depletion Potentials (ODPs) and tabulates comparative *modelled* and *regulatory* values for controlled, single-compound refrigerants. The updated chapter adds guidance for ODPs and GWPs for regulatory reporting.

This chapter does not address the suitability, advantages, and drawbacks of individual refrigerants or refrigerant groups for specific applications; such discussion is addressed for specific applications where relevant in subsequent chapters.

6.1.1 Status of Refrigerant Data

The status of data for the thermophysical properties of refrigerants, which include both thermodynamic properties (such as density, pressure, enthalpy, entropy, and heat capacity) and transport properties (such as viscosity and thermal conductivity), is generally good and excellent for the most common alternative HFCs. Data gaps exist, however, for the thermodynamic and transport properties of blends and less-common fluids as well as the transport properties of many fluids (but especially so for blends). The data situation for the less-common fluids is more variable; there is a need to collect and evaluate the data for such candidates.

A major uncertainty for all of the refrigerants is the influence of lubricants on properties. The working fluid in most systems is actually a mixture of the refrigerant and the lubricant carried over from the compressor(s). Concerted research on the refrigerant-lubricant mixtures is in the early stages. It is complicated by the great variety of lubricants in use and by the often highly proprietary nature of the chemical structure of the lubricant and/or additives.

The updated chapter reviews the status heat transfer and compatibility data for refrigerants. It recommends further research of:

- further test data for shell-side boiling and condensation of zeotropic mixtures
- local heat transfer data determined at specific values of vapour quality
- microchannel heat exchanger refrigerant-side heat transfer data including flow distribution effects
- effects of lubricants on heat transfer, especially for hydrocarbons, ammonia, and carbon dioxide
- accurate plain tube and microfin tube evaporation and condensation data for hydrocarbons
- inside-tube condensation heat transfer data for carbon dioxide at low temperatures such as –20 °C
- heat transfer correlations for carbon dioxide supercritical heat rejection and two-phase evaporation

The chapter similarly outlines current understanding of materials compatibility data for refrigerant systems as well as safety data and classifications. It notes that efforts are underway to develop recommended refrigerant concentration limits for unplanned exposures and to improve flammability test methods and data.

6.1.2 Heat Transfer Fluids ("Secondary Refrigerants") for Indirect Systems

The expanded update adds information on heat transfer fluids (HTFs) — also referred to as *secondary refrigerants* — for indirect systems. Although HTFs have been used for many years in industrial applications, they have recently become more popular in commercial applications for the purposes of reducing the primary refrigerant charge and/or mitigating emissions of refrigerants that have notable environmental warming impact or when regulatory or safety constrains apply. HTFs are divided into two categories, namely single phase and phase-change fluids.

Single phase fluids are in common use and include the following chemical groups:

- Glycol solutions
- Salt solutions
- Synthetic oils
- Hydrofluoroethers

The use of phase-change fluids in indirect systems is becoming more popular due to favourable thermal and transport properties leading toward energetic benefits. The most common phase change fluids are carbon-dioxide and ice-slurries, although other suspensions such as water/ice-filled capsules, hydrophilic material slurries, and frozen emulsions have been considered, but these are largely in developmental stages. With the benefit of much greater heat capacities, and generally improved heat transfer coefficient associated with change of phase, they offer systems potential benefits from lower flow rates and pumping costs, smaller pipe sizes and heat exchangers.

6.2 Domestic Refrigeration

The transition from CFC refrigerants in new equipment is complete in non-Article 5(1) countries and is accelerating in Article 5(1) countries. The 15 to 25 year typical life span for domestic refrigerators results in older product manufactured using CFC-12 refrigerant still comprising the majority of units in the installed base. This in-turn significantly retards the rate of reduction in the demand for CFC-12 refrigerant in the servicing sector.

HC-600a and HFC-134a continue to be the dominant alternative refrigerant candidates to replace CFC-12 in new domestic refrigeration equipment. Both of these have demonstrated mass production capability for safe, efficient, reliable and economic use. In practice, similar product efficiencies result from the use of either refrigerant. Independent studies have concluded that other design parameters introduce more efficiency variation opportunities than is presented by the refrigerant choice. Comprehensive refrigerant selection criteria include safety, environmental, functional and performance requirements. A grossly simplified summary of relative considerations for these two refrigerants is:

- HC-600a is compatible with historically accepted mineral oils as a lubricant. Designs must take care to properly deal with the flammable nature of the refrigerant.

- HFC-134a uses moisture-sensitive polyolester oils. Manufacturing processes must take care to properly maintain low moisture levels. Long-term reliability requires more careful avoidance of contaminants during production or servicing compared to previous CFC-12 based designs.

No significant new technology options are expected to emerge which will significantly alter options for conversion to ozone-safe refrigerants in the remaining Article 5(1) countries still using CFC-12 in new equipment. All required technologies are mature and readily available; availability and prioritisation of capital resources are dictating conversion timing. Current technology designs typically use less than one-half the electrical energy required by the units they replace. This reliable performance is provided without resorting to higher cost or more complex designs. Anticipated enhancements with leading edge technologies will provide further incremental improvements in unit performance and/or energy efficiency. In some cases this efficiency will be provided at the cost of increased complexity or reduced tolerance to abnormal conditions. Government regulations and voluntary agreements on energy efficiency and labelling programs have demonstrated effectiveness in modifying product offerings in several countries.

6.3 Commercial Refrigeration

Commercial refrigeration types of equipment are very different in term of size, mainly depending on the country and the kind of shops. Commercial refrigeration equipment consists of 3 main different system types.

- *Stand-alone equipment* includes integrated display cases, ice machines, vending machines, and an array of small equipment installed in stores or public areas in developed countries as well as in many Article 5(1) countries. It is estimated that there are, 44.7 million units in this category world-wide. Refrigerant charges range between 0.2 and 1 kg. HFC-134a is the usual refrigerant replacing CFC-12. HCs (HC-600a and HC-290) are now being used in some European countries. Beverage and ice cream vending machines are estimated at 14.7 million units. Several large food and beverage companies have indicated that they will refrain from using HFCs within a few years where suitable alternatives are available. HFC-134a is clearly the dominant option at present.
- *Condensing units* are typically installed in specialised shops. The refrigerant charge varies between 1 and 5 kg, and the estimated global number is on the order of 32.5 million. The refrigerant of choice depends on the temperature

range required. Both HFC-134a and the HFC blend R-404A are the preferred options for medium temperatures , and R-404A for low temperatures. Due to safety concerns, HCs are not a common option for the charge amount normally present in condensing units.

- *Centralised systems* are installed in super- and hyper-markets. The estimated number of supermarkets where a wide range of refrigerating capacities is installed is estimated as 340,000; this number includes 18,000 hyper-markets, i.e., very large supermarkets. In centralised systems, the refrigerant charge varies from 100 kg up to 2,000 kg. The refrigerating system is installed in a machinery room and the refrigerant circulates between this machinery room and the display cases installed in the sales area. The choice of refrigerants largely depends on national regulations.

- CFC-12 is still being used in Article 5(1) countries, but new supermarkets in these countries use the same refrigerant as is used in non-Article 5(1) countries. HCFC-22 is still widely used in the United States, but R-404A is gaining market share in the USA. In Europe, the use of HCFC-22 in new equipment has been banned since 1 January 2001. R-404A is the preferred choice there. In Japan CFC-12 has been replaced by HFC-134a and sometimes by R-407C.

- In Europe, indirect systems are receiving more and more attention in order to limit the refrigerant charge (whatever the type of refrigerant) or to allow the use of ammonia or hydrocarbons. CO_2 is being evaluated as a heat transfer fluid or as a low temperature refrigerant. Several hundred of indirect systems have been installed in the last four years, especially in Northern Europe.

- The energy consumption of both direct and indirect systems is being evaluated. However, the reference base varies widely as there are many variables such as the size of sales areas, the type of display cases (with or without doors), the control system, and the climatic zones, etc. Particularly at the medium temperature level, well-designed indirect systems may show equal or even slightly better energy consumption compared to the usual, centralised direct systems.

- It should be mentioned that indirect systems need a more complex and a more expensive design. The initial costs are higher, whereas currently the operating costs and the maintenance costs are still being evaluated. For large store companies, the initial costs still form the main driver; it is for this reason that centralised direct expansion systems still form the most common technology for supermarkets.

6.4 Large Size Refrigeration (Industrial, Cold Storage and Food Processing)

The applications covered in this chapter are industrial refrigeration, cold storage, food processing and large industrial heat pumps. The major concern for the systems , which are described in this chapter, is the reduction of energy consumption. The systems are mainly custom made and often erected on site. As a refrigerant, ammonia (NH_3) is used in approximately 75-85% of the current installations followed by HCFC-22, CFCs and HFCs.

Industrial Refrigeration covers a wide range of cooling and freezing applications, including chemical and pharmaceutical industries, petrochemical, oil and gas industries, metallurgical industry, plastic moulding, civil engineering, sports and leisure facilities, industrial ice making, air liquefaction and others.

Food Processing is one of the fastest developing industries in the world. Food processing covers a wide range of cooling and freezing applications, including the processing and storage of meat, fish, cheese, beer, eggs, fruits and vegetables. Refrigeration is used to preserve food from harvest, catch or slaughter, through processing, transport, storage and distribution to retail sales and markets.

Cold Storage is related to both raw materials and finished products in a food processing factory. Modern cold storage warehousing typically consist of a one level building with elevated loading banks for the rational handling of full pallets.

In 2000, the world-wide consumption of frozen food was 30 million tonnes. The United States accounts for more than half of this, with more than 63 kg per capita. The average figure for the European Union (EU) is 25 kg and for Japan 16 kg. Chilled foods form 10 -15 times the frozen product quantity. Total quantity of temperature controlled products is estimated at 350 million tonnes (1995), where the annual growth is estimated as 5 %.

Most systems use NH_3 with a tendency emerging to reduce the charge through indirect systems using brines or cascade systems using refrigerants. Beside traditional brines “ice slurries” have been introduced as a new option (in breweries first). It is expected that the market share will increase for such systems where a reduction of refrigerant charge is required. At low temperatures (below –40 to –45°C) a clear global trend can be observed towards cascade systems, where CO_2 is used in the low temperature stage of the system. Particularly in Europe, large cascade systems with cooling capacities of several MW have been built utilising NH_3/CO_2 cascade systems. For new systems no CFCs or HCFCs have been used. In applications, where, for various reasons, NH_3 cannot be utilised, HFCs are used.

The retrofit of industrial refrigeration plants is difficult due to the fact that these are custom made installations. Most existing systems that use CFCs and HCFC-22 are still in operation, although in some special cases end-users have already converted HCFC-22 systems to operate on CO_2 or NH_3.

In Article 5(1) countries the use of NH_3 is not so common as in the developed countries, but there is a significant number of –mostly old- systems still in operation. Systems based on HCFC-22 have been installed there more often, with CFC units to a much lesser extent.

6.5 Transport Refrigeration

Transport refrigeration includes refrigeration in ships, fishing vessels, containers, road transport equipment and railcars. For transport air conditioning only merchant ships and railcars are covered.

Most systems which still used CFCs in 1998 have been retrofitted or scrapped and the remaining uses are concentrated on old refrigerated containers and trucks with a short remaining operational lifetime, yet the existing CFC fleet remains still significant.

In ships, most existing systems use HCFC-22, though R-407C and R-404A/R-507 are options already used today in Europe for new systems. For the future, R-410A is expected to play an important role.

On merchant ships most systems use HCFC-22, and CFC use is reducing significantly since 1998. R-404A/R-507 is dominating new systems, and fishing fleets and naval vessels form a significant part of this sector.

Out of the about 550,000 refrigerated containers fleet, only a small portion still uses CFC-12, and some may be in use beyond the year 2003. They could be retrofitted with an interim solution to cope with their remaining lifetime. For new units HFC-134a and R-404A predominate the market. Besides, some development of carbon dioxide based units has started.

There are about 1,200,000 refrigerated road vehicles in use. Half of these still use CFC-12 or R-502. Current production uses HFC-134a, R-404A, or HCFC-22 (to a lesser extent) and some units with R-410A are available. Research and tests of hydrocarbon, solar and cryogenic systems with liquid air or liquid carbon dioxide are in progress.

Numbers of refrigerated railcars and swap-bodies remain relatively small.

Railcar air conditioning is moving from HCFC-22 with relatively high leakage rates to R-134a or R-407C, which require specific attention for system containment. Railcar air conditioning exhibits increasing market penetration.

Generally, HFCs offer today the preferred future options for new systems, though there is development work on alternatives including hydrocarbons, ammonia, air cycle and CO_2.

HFC and HC retrofit options exist for systems in use. Application of some of these could be restricted by local legislation in some countries.

There is a need to concentrate on containment, training and efficiency issues, and to accept the imminent restrictions on HCFC use in some countries.

6.6 Air Conditioning & Heat Pumps (Refrigerant-To-Air)

Globally, air-cooled air conditioners (including heat pumps) comprise a vast majority of the air conditioning market. Air-cooled air conditioners fall into four categories: window-mounted, non-ducted split residential and commercial, ducted split residential, and ducted commercial air conditioners. Nearly all air-cooled air conditioners manufactured prior to 2000 used HCFC-22 as a working fluid.

It is estimated that 131 million window-mounted and through-the-wall air conditioners are in operation globally—containing an installed HCFC-22 bank of approximately 85,000 tonnes. During this assessment period, there has been a significant shift away from the use of window-mounted air conditioners to non-ducted split residential air conditioners as the entry-level air conditioning product in developing countries--particularly in Asia. An estimated 158 million non-ducted or duct-free Split air conditioners are installed world-wide—containing a refrigerant bank of 199,000 tonnes. An estimated 60 million ducted split residential air conditioners are currently in service world-wide. The total estimated inventory of HCFC-22 in the installed population of ducted systems has been estimated to be 164,000 tonnes. Approximately 19 million air-cooled Ducted Commercial Split and Packaged air conditioners and heat pumps are installed world-wide containing and estimated refrigerant bank of 101,000 tonnes.

Since the last assessment, the primary non-ODS refrigerants used in these products have been R-407C, R-410A and to lesser extent HC-290. A significant shift to non-ODS alternatives has been observed in Europe and Japan. A shift of approximately 5% has been observed in the US. In the remainder of the world there has been minimal conversion to non-ODS alternatives in air conditioning applications. A rough estimate would indicate that globally 85 to 90% of the air-cooled air conditioners and heat pumps currently produced globally still use

HCFC-22 as the refrigerant. HFC refrigerants and hydrocarbon refrigerants, to a lesser extent, will have the greatest impact on the industry transition for the next 10-15 years.

The primary retrofit refrigerant is the zeotropic blend, R-407C. Hydrocarbon refrigerants are viewed as unlikely retrofit options because of high cost and complexity of safely retrofitting existing HCFC-22 systems.

Demand for HCFC-22 may continue to increase until approximately 2005 and gradually decline as developed countries expand their usage of non-ODS alternatives to meet regional and Montreal Protocol phase-out dates.

Most of the technology required to phase-out ODS substances in developing countries has been developed and is slowly being transferred to the Article 5(1) countries. As the penetration of these technologies increases, costs will fall, resulting in increased conversion to non-ODS refrigerants in the developing countries.

6.7 Chillers and Heat-Pump Water Heaters

Chillers, also known as water chillers, cool water or heat transfer fluids for air conditioning and process cooling. The heat removed is rejected to ambient air in air-cooled chillers or to water in water-cooled chillers.

Heat pump water heaters are reversible chillers capable of drawing heat from an air or water source and using it for service (sometimes indicated as sanitary) supply or for hydronic heating systems employing convectors, fan coils, or other heat exchangers.

New Equipment since 1998

In, general, the types of available equipment have not changed since 1998, but there have been subtle changes in the relative importance of various refrigerants. CFCs are decreasing in importance as the older machines are phased out in the developed countries and are being replaced largely by HCFCs and HFCs. There is some growth of machinery using non-ODS refrigerants, primarily ammonia, hydrocarbons in small machines, and CO_2 in some heat pump water heaters. In chillers employing positive displacement compressors, reciprocating compressors are being displaced by screw compressors (above 140 kW) or scroll compressors (below 140kW).

Options to Replace Current Systems

The technological options available to the systems designer or machine purchaser have not changed substantially since 1998. The most significant changes have been:

1. Increases in efficiency,
2. Elimination of production of HCFC-22 centrifugal machines,
3. Migration from HCFC-22 towards towards HFCs in screw and large scroll chillers,
4. Softening of the absorption chiller market,
5. Growing chiller industry in some developing countries (especially China and Korea),
6. Decreased optimism for the prospects for CO_2 except in water-heating applications, and
7. Less optimism for the commercial viability of new low pressure refrigerants R-236fa and R-245fa.

Market Characteristics

The market for centrifugal and large screw chillers is divided among the USA (40%), Asia (25%-30%), and smaller percentages in Europe and the Middle East. The market for smaller positive displacement chillers is much larger in numbers and in market revenues world-wide than for the other chiller types. The market for absorption chillers is concentrated in Japan, China, and Korea. The market for heat-pump water heaters is growing and is found primarily in Western Europe and Japan.

Developing Countries / Technology Transfer

Chillers are technologically sophisticated machines. In developing countries, they are normally first seen in large hotels, resorts, well-funded industries, commercial buildings, and hospitals. As the economy grows, so does the use of chillers.

Some developing countries have developed domestic production capacity for chillers, largely as a result of joint venture technology transfer. This is perhaps most noticeable in China, but also in India and some Latin American countries. The joint venture partner companies are typically Japanese, Korean, or American.

6.8 Vehicle Air Conditioning

Vehicles (cars, trucks, and buses) built before the mid-1990's used CFC-12 as the refrigerant. Since then, in accord with the Montreal Protocol, new vehicles with A/C have been equipped with HFC-134a, a zero ODP chemical, as the refrigerant. As a result, HFC-134a has now replaced CFC-12 as the globally accepted mobile A/C (MAC) refrigerant and the industry is busy expanding global production to meet the increasing demand. By 2008, almost all vehicles on the road are expected to be using HFC-134a and the transition from CFC-12 will be complete.

HFC-134a is considered a potent greenhouse gas and, due to concerns about emissions of HFC-134a from MAC systems, vehicle makers and their suppliers are reducing their system leakage and improving energy efficiency, and are searching for a replacement refrigerant. In the timeframe 1998-2002, the leading potential replacement refrigerant has been carbon dioxide (R-744) for which many global vehicle manufacturers and suppliers have demonstrated prototype cars. Recently, the use of HFC-152a (with a global warming potential less than one-tenth that of HFC-134a) has been proposed and publicly demonstrated in two prototype car systems.

On-site recycling of refrigerant at service shops has been proven to be quite effective for HFC-134a systems; a full 60% of the original charge can be recycled and reused during service. Combining this with service frequency scenarios allows an estimation of the current and future refrigerant emissions from MAC systems. Such emission estimates can be useful when calculating the cost benefit analysis of proposed changes.

6.9 Refrigerant Conservation

Refrigeration conservation is an effort to extend the life span of used refrigerant by establishing efforts to recover, recycle, and reuse refrigerants. Refrigerant conservation is now a major consideration in refrigerating system design, installation, and service. The benefits of refrigerant conservation include not only environmental protection, but they also include a decreases on the dependency on newly manufactured refrigerant. Refrigerant conservation has several basic elements:

- proper design and installation of new refrigeration and air-conditioning equipment so as to minimise actual or potential leaks;
- leak-tighten existing refrigeration and air-conditioning systems so as to reduce emissions;
- improve service practices, including use of refrigerant recovery equipment and technician training; and

- safe disposal techniques that provide for refrigerant recovery for systems at the point of final disposal.

There has been a great deal of success in the creation and implementation of conservation programs since the 1994-1998 assessment, most visibly in the creation of governmental regulations to restrict the use or reuse of CFCs and mandate training for service technicians.

Developed countries have begun to see the results and consequences of conservation programs. The Japan End-Of-Life Appliance Recycling And Destruction Technologies Program has been established to reduce emissions of ozone-depleting refrigerants. European Union countries have established programs mandating recovery, mandating service technician training, forbidding CFC top-off, forbidding reuse of CFCs, and mandating the use of non-HCFC refrigerants in new equipment. The United States has seen an increase in the number of service technicians certified and the amounts of refrigerant reclaimed and placed back into commerce.

Developing countries have the opportunity to leverage the knowledge gained from developed countries during their implementation of conservation programs. If a government plans to create a program to recover, recycle, and reclaim refrigerant or phase-out the use of CFCs, the government must establish economic assessments that make owners of systems take conservation efforts or enforce government requirements by means of financial or other penalties. Developing countries have also seen increases in the number of certified technicians and establishment of conservation programs. For example, Brazil is implementing several reclaim centres capable of handling recovered refrigerant. Several African countries have seen an increase in the use of portable recovery equipment in their efforts to reduce emissions of ozone-depleting refrigerants.

When establishing refrigerant conservation controls, governments must also establish disposal means for systems. The government should include means of properly disposal of refrigeration and air-conditioning systems. Refrigerant containers pose a problem, in that efforts must be implemented to recover remaining refrigerant (commonly called the can heel) at the point of container disposal.

Governments should also be proactive in combating illegal imports and the establishment of illegal markets for CFCs that can be a by-product of conservation efforts. Governments should include training of customs officials as a part of their conservation efforts.

7. Executive Summary of the 2002 Assessment Report of the Solvents, Coatings And Adhesives TOC

7.1 Introduction

The 2002 report is considerably different from previous reports of the Solvents Technical Options Committee (STOC). The physical structure has been designed so that each sub-sector has a self-contained chapter that summarises new, essential, information and the technology choices available. It is intended that these individual chapters may be extracted for copying to interested parties, while remaining short enough for translation into local languages and subsequently distributed. To achieve this, the older technological details are not as complete as in previous editions. Readers requiring a more complete treatise are referred to the 1998 report.

Committee members have observed progress being made in phasing out ODS throughout the world. While great progress has been made in developing countries, there have been some challenges in Article 5(1) countries, where the final phase-out will occur over the next few years.

There are no substantial technical barriers to phasing out ODS. Alternatives are available that will meet the needs of all solvent users with very few exceptions.

There is still limited use of CFC-113 and 1,1,1-trichloroethane (methyl chloroform) in solvents applications in non-Article 5(1) countries; these are being met with stockpiled products and recycled material. Eventually, these will run out and alternatives will need to be implemented. Most enterprises in this situation have plans and will make the conversion once the supply of controlled materials is terminated.

The major obstacles in eliminating ODS use are in Article 5(1) countries and a separate chapter is devoted to this subject. The main barrier in overcoming such obstacles in these countries is communication and education of suitable alternatives.

The question as to what can be done to assist in the complete phase-out of ODS in developing countries has been studied, resulting in the following remarks:

Greater co-operation would be beneficial between the STOC and other international and national organisations, including within UNEP.

Parties may wish to consider new measures to ease the financial burden of the numerous small and medium users (SMUs), which represent the majority of emissions in the sector.

Since the phase-out of the widely used CFCs and 1,1,1-trichloroethane in non-Article 5(1) countries, a number of new solvents that claim to be direct replacements have been marketed. The critical parameter for alternatives has been, and continues to be, that they should be non-ozone depleting. A notable exception is that of some hydrochlorofluorocarbons which possess small ozone-depletion values. These chemicals are Annex B Group 1 compounds and are scheduled to be phased out. Several promising alternatives have emerged from a review of historical data and by conducting new research. However, no single solvent or process was found to be a direct replacement for the CFCs and 1,1,1-trichloroethane. Hydrofluoroethers, hydrofluorocarbons, and hydrochlorofluorocarbons are among the organic solvents most widely used as substitutes. These materials have advantageous properties for many applications. Aqueous techniques are used in many cases. These are not the only acceptable alternatives. Descriptions of these and other alternatives are reported in this Assessment and in previous editions of the UNEP Solvents Technical Option Committee Assessment Reports. The potential user has the responsibility of evaluating and assessing an alternative as it applies to the specifics of the application.

Reference to n-propyl bromide (nPB) is limited. More details of this solvent are found in Appendix 1. Its use is not recommended at this time. New chemical solvents and processes are evaluated as they are marketed. However, a major break-through is rather unlikely in the near future.

7.2 Sub-sectors

Each sub-sector, which may cover a range of applications, is treated in a separate chapter.

7.2.1 Electronics Defluxing

Ozone-depleting solvents (ODS) use in the electronics industry is a major source of emissions although the only significant use is in defluxing. This process removes the residues from the soldering operation to ensure maximum reliability and consistent performance. Several technologies may be used to achieve this but the selection is not always easy. The list of methods provides basic advice, but it is by no means exhaustive. Further details can be found in the 1998 and earlier Solvents Technical Options Committee Assessment Reports. In many cases, the advice in this chapter will be sufficient for enterprises to short list the technologies down to two or even one. From there, qualification testing will be required to select the most suitable materials, equipment, and processes. In most cases, it is possible to reduce production costs of the overall soldering and cleaning (if any) processes. This is therefore a candidate application to significantly reduce ODS emissions rapidly and effectively in many Article 5(1) countries.

7.2.2 Precision Cleaning

Since the phase-out of the widely used CFCs and 1,1,1-trichloroethane in non-Article 5(1) countries, a number of new solvents that claim to be direct replacements have been marketed. Unfortunately, no single solvent or process was found to be a direct replacement for the CFCs and 1,1,1-trichloroethane. Hydrofluoroethers, hydrofluorocarbons and hydrochlorofluorocarbons are among the organic solvents most widely used as substitutes. These materials have advantageous properties for some applications. Aqueous techniques are used in some cases. New chemical solvents and processes are evaluated when they are marketed. However, it is unlikely that a major breakthrough can be expected in the near future.

7.2.3 Metal Cleaning

Metal cleaning is a surface preparation process that removes organic compounds such as oils and greases, particulate matter, and inorganic soils from metal surfaces. Metal cleaning prepares parts for subsequent operations such as further machining and fabrication, electroplating, painting, coating, inspection, assembly, packaging or further treatment such as heat treatment for surface modification. Parts may be cleaned several times during the manufacturing process. Almost all metal cleaning operations include solvent conservation and recovery practices and the use of alternative cleaning processes including alternative solvents and their blends contained solvent cleaning systems, low flash point solvents, co-solvent systems, aqueous cleaners, emulsion cleaners, mechanical cleaning, thermal vacuum de-oiling, liquid carbon dioxide, and no-clean alternatives.

Alternatives to CFC-113 and 1,1,1-trichloroethane must be selected and optimised for each application given the varying substrate materials, soils, cleanliness requirements, process specifications, and end uses encountered in metal cleaning. There is still a significant use of carbon tetrachloride in various cleaning processes in developing countries. These uses have been identified primarily where a low cost, non-flammable, and simple cleaning process is required, such as metal cleaning applications. While many alternatives seem obvious to improve worker exposure, total cost including environmental concerns, should be considered for any alternative.

Most of the CFC-113 and 1,1,1-trichloroethane used in metal cleaning applications can be replaced by existing alternatives in accordance with the Montreal Protocol.

Developing countries should be able to closely follow the same scenario as the smaller companies in the developed countries. They may have an additional lag time in their own smaller industries. Each developing country will have somewhat different scenarios depending upon their unique industry structure, quantum of ODS in use, and the selection of a suitable alternative.

7.2.4 Dry Cleaning

The dry cleaning industry has been deploying ozone depleting solvents, CFC-113, and 1,1,1-trichloroethane, in specialised segments. CFC-113 was used primarily for delicate fabrics and those with sensitive dyes and trimmings. 1,1,1-trichloroethane was used mostly in the leather and suede applications in North America and, to a limited extent, for general dry cleaning elsewhere. It is believed that developed countries have completely phased out these solvents and switched over either to existing solvents, such as perchloroethylene, or to some of the new solvents mentioned in this report and its prior editions. There is no evidence to suggest that 1,1,1-trichloroethane was ever used in developing countries as a dry cleaning solvent, and very little, if any, CFC-113.

7.2.5 Adhesives

While there is no drop-in replacement for 1,1,1-trichloroethane in adhesive bonding products, a variety of solvent-based and non-solvent adhesives provide high performance for specific applications. In many cases, changes to previous operating procedures must be made, but in general, these changes are not very restrictive. Careful selection of available alternatives is important to adequately meet performance, cost, regulatory, and worker health criteria.

7.2.6 Aerosols

HCFC-141b had emerged as a lead replacement candidate for CFC-113, CFC-11, and 1,1,1-trichloroethane since the non-Article 5(1) countries phase-out in 1996 in aerosol formulations as an active ingredient or as a solvent. However, HCFC-141b has an ozone-depletion potential about equal to that of 1,1,1-trichloroethane, therefore its use has been phased out in Europe since the beginning of 2002 and is scheduled in the United States at the end of 2002. The replacement solvents include petroleum distillates, water-based products, organic solvents, HFCs, and HFEs. However, the use of HCFC-141b may continue in Article 5(1) countries until its scheduled phase-out date of 2040.

7.2.7 Miscellaneous Uses

There are numerous miscellaneous industrial and laboratory applications that are not addressed in this report. Relatively small quantities of CFC-113, 1,1,1-

trichloroethane, and carbon tetrachloride are employed in most of these applications. In many cases, the alternatives are readily available but their selection and validation may require extensive effort. In other areas, some ODS are still necessary, even though significant progress has been made towards a complete phase-out.

7.3 Article 5(1) Countries

A review of the challenges that the phase-out of ODS is facing in developing countries shows that suitable alternatives have to be chosen for CFC-113, 1,1,1-trichloroethane, and carbon tetrachloride. HCFCs are the ODS which need to be phased out in the future. Substitutes and alternatives have been identified throughout the world and are generally readily available for incorporation into existing processes. The major drawbacks to the implementation are access to information and knowledge about what are the acceptable alternatives and the economic and environmental considerations associated with them. Details of the alternative technologies are addressed in other chapters in this report dealing directly with the alternatives available for each application. Previous versions of the Solvents Technical Options Committee assessment reports also provide further information.

The major efforts to complete the transition away from ODS in developing countries are dependent on the areas cited above, namely, 1) availability of information, 2) financial and economic needs to assist in the conversions, and 3) enforcement of current regulations.

7.4 Appendices

Four appendices and a glossary in the STOC Assessment Report give additional useful information that is common to most of the applications. The first summarises the current situation regarding n-propyl bromide, with a recommendation of cautious use until there is clarification on the open questions of its effect on the ozone layer and its toxicity. Appendix 2 provides information on the proper use of halogenated solvents, particularly the non-ozone-depleting chlorinated solvents, based on known science, as well as policy decisions. Appendix 3 is an update on regulations introduced or proposed in Europe, Japan and the United States of America since the publication of the 1998 Assessment Report. Appendix 4 tabulates the principal properties of typical ozone-depleting and non-ozone-depleting solvents. The Glossary defines the most common technical terms used in this document.

8. Recent Global Production and Consumption Data for Fluorochemicals

8.1 Introduction

This section provides data on global production and consumption of CFCs during the period 1986-2000, during 1989-2000 for HCFCs and during 1990-2000 for HFC-134a. As defined by the Montreal Protocol, consumption equals production plus imports minus exports (minus destruction). Data sources have included those assembled from chemical manufacture sources as overseen by the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS) and their independent accountant, Grant Thornton. These CFC, HCFC and HFC data are from participating companies headquartered in developed countries. CFC and HCFC data were used as contained in the report Production and Consumption of Ozone Depleting Substances under the Montreal Protocol 1986-2000, April, 2002 /Pro02/ and in UNEP/OzL.Pro/14/3, dated 18 October, 2002. Data has also been included from UNEP as appearing in Production and Consumption of Ozone Depleting Substances 1986-1999 published by the Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn /GTZ01/. CFC production and consumption data have also been compared to the data in the TEAP Progress Report 2002, Volume 2, Replenishment of the Multilateral Fund for the period 2003-2005 /TEA02/.

The accuracy of HFC data from AFEAS is excellent as virtually all HFC-134a production takes place in contributing companies. It should be recognised that this is the only global source of such data as there is no jurisdiction for reporting of HFCs. However, AFEAS data accuracy for HCFCs is significantly lower reflecting the reality that most of the AFEAS reporting is from developed countries and developing countries are assuming a growing portion of production for these compounds. As such, UNEP is more accurate in capturing this information than AFEAS. The data accuracy of AFEAS reporting of CFCs has low value at this point as the majority of production is currently in Article 5(1) Parties. Developed country production is limited to that used for essential uses or export to Article 5(1) markets. UNEP data are the prime source of quality information for CFCs.

CFC and HCFC production and consumption has been presented as from:

- the group of Article 5(1) Parties
- certain non-Article 5(1) Parties belonging to the OECD group (defined as OECDnA5 in this report, which are Western European countries, USA, Canada, Japan, Australia and New Zealand; this has been done since the OECD group also contains Article 5(1) Parties) and
- other non-Article 5(1) Parties which includes the ones in Central and Eastern Europe.

8.2 Data Analysis

CFC Production Data (1986-2000)

Table 8-1 provides data for production for the period 1986-2000. For the non-Article 5(1) Parties such production has dropped from 909 to 53 ODP ktonnes over these years- a reduction of 94%. Remaining production is to meet domestic essential use exemptions and for export to Article 5(1) Parties. This production appears to have stabilised at about 50 ODP ktonnes however; this will likely decrease further with shut down of Russian production of CFCs, which was 25 ktonnes in 2000. Over the time period 1986-2000, the CFC production has increased in Article 5(1) countries from 44 to 73 ODP ktonnes representing an increase of 66%. Such production actually peaked in 1996 with minor declines over the next few years. Again this seems to be currently decreasing as projects to shut down CFC production facilities are being implemented. Production in China, India, Argentina and Venezuela will decrease further in the future as CFC production is being decreased in accordance with the Montreal Protocol schedules and in accordance with agreements with the Executive Committee of the Multilateral Fund. CFC production in Eastern Europe has dropped some 76% during the period from 107 to 26 ODP ktonnes, which is expected to drop to zero after 2000.

Overall, the reduction to date from all sources has been from 1071 ODP ktonnes to 126 ktonnes or 88%. Some error is likely in these reported amounts, as there is no accounting for any illegal production activity, which is suspected but not documented.

AFEAS data, once the most accurate of all sources, is no longer of value for deriving production data for CFCs. AFEAS companies now account for ca. 27% of all global CFC production and the UNEP data are far more reliable for any analyses of this product family.

CFC Consumption Data (1986-2000)

Data for CFC consumption have been prepared by clustering Argentina, Brazil, Mexico and Venezuela, a second grouping of China, India and Korea and a third group of Article 5(1) other. Data are separated for Central and Eastern Europe and then finally OECD non-Article 5(1) Parties. These data are presented in Table 8-2 along with a figure illustrating the total annual consumption for Article 5(1) and the total consumption of all Parties.

Total consumption by all Parties has dropped during this period from 1070 ODP to 138 ODP ktonnes. Much of this 87% decrease occurred by 1996 concurrent with the phase-out of CFC consumption in the developed world. Since that time, the rate of decrease is slight amounting to about 18% over the 1996-2000 period. Consumption in Argentina, Brazil, Mexico and Venezuela has levelled at about 21 ODP ktonnes/yr. (but is assumed to further decrease with the Brazil phase-out plan in place). The consumption of China, India and Korea doubled between 1986 and 1995 peaking in that year. It has since dropped

51% to 45 ODP ktonnes in 2000 as transitions are occurring to alternative products. Production in China and India exceeds consumption indicating that they serve as a source of CFCs for use by other Article 5(1) Parties.

CFC consumption in non-Article 5(1) countries has decreased to only 5 ODP ktonnes/yr. for essential uses. The remaining consumption of about 26 ODP ktonnes in Central and Eastern Europe where consumption has dropped 74% since 1986. There has been good agreement between production and consumption numbers, which can be seen when comparing Tables 8-1 and 8-2.

HCFC Production Data (1989-2000)

Data for HCFC production are presented in Table 8-3 and Figure 8-3. Summarised are both AFEAS and UNEP data representing HCFC-22, -124, -141b and -142b. Absent from AFEAS data are any references to HCFC-123 due to AFEAS reporting criteria requiring a minimum of three producers. Regulatory decisions in Europe ban HCFC use in new equipment and foams etc. after 2003; they are only allowed for servicing. US regulations concerning HCFC use as blowing agents following HCFC-141b phase-out now suggest that HCFC-124 will not find appreciable use outside refrigeration and air conditioning applications.

AFEAS data show an increase in production from 1989 from 12,743 ODP-tonnes levelling out over the period 1997-2000 at about 30,000 ODP-tonnes. HCFC-141b has increased in volume each year and has accounted for most of this increase. HCFC-22 grew from 12,075 ODP-tonnes in 1989 to a peak of 14,918 ODP-tonnes in 1996. Production then decreased slightly to a total of 13,411 ODP-tonnes in 2000. This reduction of 10% is a reflection of reduced demand from beginning conversions from HCFC-22 in refrigeration and air conditioning applications to non-ODS substitutes and to improved practices in HCFC-22 use.

Production in Argentina, Brazil, Mexico and Venezuela peaked in 1997 and has since dropped to the same level in 1999 as in 1989, and to 274 ODP-tonnes in 2000. At only 274 ODP-tonnes, production in these countries does not constitute a major global supply source (this in contrast with their tripling of the HCFC consumption from 1130 to about 3000 ODP-tonnes in the year 2000).

China, India and Korea made sharp increases in 1993 and 1994 and then again in 1999. The total increase was from 249 ODP-tonnes in 1989 to 5013 ODP-tonnes in 1999 and to 6713 ODP-tonnes in the year 2000 (of which about 6000 ODP-tonnes are produced in China. Korea did not report any production in 2000. This may be an anomaly, because of the fact that it did report production in 1999). If one compares it to the consumption, see below, it makes China and India exporters of HCFC chemicals at about 1300 ODP-tonnes per year. The almost 30-fold increase has made particularly China (and to a lesser extent, India) a significant source of HCFCs.

The agreement of UNEP and AFEAS data has improved significantly indicating more complete reporting by Parties to UNEP. Note that AFEAS data include production in Argentina, Brazil and Mexico but do not account for China, India and Korea, as the AFEAS companies do not have production facilities in these Parties.

With increased production activity in China, India and Korea of HCFCs, their production in OECDnA5 countries has dropped from a former 94% to a 2000 level of 83%.

HCFC Consumption Data (1989-2000)

HCFC consumption data are included in Table 8-4. There is generally very good agreement between the consumption and the production data. Exceptions exist for 1994 and 1996 where consumption is significantly lower than either production data from AFEAS or UNEP. As the AFEAS and UNEP data are consistent, and the consumption data are created from a bottom-up summation of Parties' submissions to UNEP, it is likely that there was incomplete reporting of consumption for 1994 and 1996 from Parties.

Total consumption for all Parties has increased on a fairly continuous basis (except for 1996 during which there was a dip; however, this was a year for which data reported might be incomplete). Consumption between 1989-1999 increased from 14,184 to 37,097 ODP-tonnes, and to 37,712 in 2000, which implies a total increase of about 160% for the years 1989-2000. Growth in Argentina, Brazil, Mexico and Venezuela was from 418 to 1799 ODP-tonnes, and to about 3,000 ODP tonnes, a very significant increase, i.e. almost a doubling in one year. This suggests business growth based on alternatives to CFCs. HCFC consumption in Central and Eastern Europe decreased during 1989-1999 by 36%; however, significant increases during 2000 suggest transition from CFC use.

Consumption in China, India and Korea increased from 991 to 5355 ODP-tonnes or 540% over the period 1989-2000. The increase had appeared to peak in 1995 with declines during following years. There were dramatic increases in HCFC consumption between 1998, 1999 and 2000 going from 1756 to 5355 ODP-tonnes in just two years.

Non-Article 5(1) consumption has grown from 12,152 to 25,281 ODP-tonnes or 108% during the period 1989-2000. It appears that after the consumption has peaked at about 27000 ODP-tonnes in these countries that a decrease has started, shown by the consumption of 25,281 ODP-tonnes in the year 2000. This is likely the result of the implementation of regulations on HCFC use in Europe, where it is or will be prohibited in all types of foams and in charging new refrigeration and AC equipment. Also, specific end uses for certain HCFCs have been phased out in the U.S. which may have further limited the overall demand.

Over the period 1989-1999, the portion of HCFCs consumed by OECDnA5 Parties has averaged about 80% of the total. Most recently, this has fallen to 61% in 2000 largely due to consumption growth in China, India and Korea and a significant reduction in such use in non-Article 5(1) Parties in 2000. It is expected that the proportion of HCFC global consumption in all Article 5(1) countries will increase as the HCFC use restrictions will have serious impacts on the consumption in Europe and the U.S. These will force users to convert to non-ODS alternatives to HCFCs. It is notable that AFEAS data, provided by major producers mainly in developed countries, represents 83% of total consumption for the year 2000.

HCFC Consumption in Different Sectors

A sectoral analysis of HCFC use based on AFEAS data input is provided in Table 8-5. These data represent about 86% of global consumption. The largest consumption of HCFCs was in the closed cell foam application as blowing agents and represents 53% of all HCFC on an ODP-weighted basis. This was due to the use of HCFC-141b. This application is declining and will be phased out in Europe and will also have been phased out in the US by the end of 2002. Therefore, total consumption in this sector should be decreasing shortly. This will be somewhat offset by growth in developing countries.

Use in refrigerants was nearly as large on an ODP-weighted basis with 47% of the total. The vast majority of this was from HCFC-22 with minor amounts from the use of HCFC-124 and HCFC-142b mostly as components in refrigerant blends. It is expected that blends will grow somewhat in the future, as these are service replacements, which can be used for CFC installations with minor modifications.

HFC-134a Production

Data for the production of HFC-134a is available from the AFEAS database. AFEAS companies represent nearly 100% of the commercial supply of HFC-134a with only developmental quantities currently (year 2000) being produced in China, India and Korea. The data appear in Table 8-6.

Production has increased rapidly and consistently to meet growing HFC-134a demand as a replacement for what were formerly CFC applications. There was a distinct break in this trend with the 2000 data, which were 1% lower than that for 1999. There appears to be both a slowing of replacement growth rate as well as a significant downturn in business activity both contributing to this change in growth pattern. Production has increased to a current annual rate of 132 ktonnes. Of this, about 111 ktonnes or 84% of the total is for refrigeration.

Data are not yet available for other HFCs due to AFEAS collection criteria. There are regulatory oversight groups collecting global HFC production and/or consumption data at this time. It is uncertain how such information will be reported in the future as the Kyoto Protocol addresses emissions rather than production or consumption.

8.3 Concluding Remarks

Production Summary

Tonnes	**1989**	**1995**	**1999**	**2000**
CFCs	1,032,000	265,000	146,000	138,000
HCFC	257,891	338,230	449,236	451,066
HFC-134a		73,800	133,700	132,000
ODP-tonnes				
CFC	1,032,000	265,000	146,000	138,000
HCFC	2,032	4,566	9,539	11,932
Total	1,046,184	292,904	183,097	175,213
Reduction	-	72%	82%	83%

(CFC ODPs=1.0, for HCFCs, 1995-2000 an average ODP of 0.082 has been applied; for 1989 the ODP of HCFC-22 has been used)

CFC use has dropped 87% globally since 1989 largely due to the phase-out of its use in developed countries. With the current cap in Article 5(1) countries and reductions in use during the rest of this decade, this use will continue to drop. HCFC production has increased but has levelled off. It is expected that this will begin a downturn, as use in developed countries will be reducing due to current regional and national regulations that are even more restrictive than those of the Montreal Protocol. The latter will mandate reductions in consumption of 35% in developed countries in 2004. This will be slightly offset due to expected Article 5(1) party increases as HCFCs play an important role in facilitating CFC phase-out in those countries. HFC-134a has emerged as the key agent in replacing CFC use in many applications. Its production has levelled due to improved product stewardship in selection of uses, minimisation of emissions during use, and, in certain regions, recovery and recycle. The net impact of these activities is to reduce the net ozone depletion by about 83% as compared to the levels seen in 1989.

Table 8-1

Historic Production Data of CFCs- (Sources UNEP and AFEAS) – (ktonnes)

	1986	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
AFEAS													
AFEAS (ktonnes)	976	962	659	605	526	426	234	146	80	57	52	42	36
AFEAS (ODP-weighted)	895	859	587	544	481	405	221	136	77	56	52	42	36
UNEP (ODP-weighted)													
Argent/Braz/Mex/Venez	29	24	25	27 (17)	27 (17)	31	35	31	24	26	20	23	13
China/India/Korea	15	33	35 (21)	40 (26)	41	52	78	78	85	74	81	75	60
Total Article 5.1 (plus adj)	44	57	60	67	68	83	113	109	109	100	101	98	73
Eastern Europe	107	106	104	84	62	41	43	40	17	27	14	18	26
OECDnA5 (incl S. Africa)	920	879	613	527	461 (449)	360	186	100	34	35	32	32	27
Total Production (UNEP)													
A5.1 and Non A5.1	1071	1042	777	678	591	484	342	249	160	159	147	148	126
OECDnA5 group (UNEP)	909	869	607	522	457	356	184	99	34	49	46	50	53
OECDnA5 gr. (AFEAS)	866	835	552	517	454	374	186	105	53	57	52	42	36
%OECDnA5 group	85	83	78	77	77	74	54	40	21	31	31	34	42
Total Article 5.1 (plus adj)	44	57	60	67	68	83	113	109	109	100	101	98	73
Eastern Europe	107	106	104	84	62	41	43	40	17	27	14	18	26
OECDnA5	909	869	607	522	457	356	184	99	34	49	46	50	53

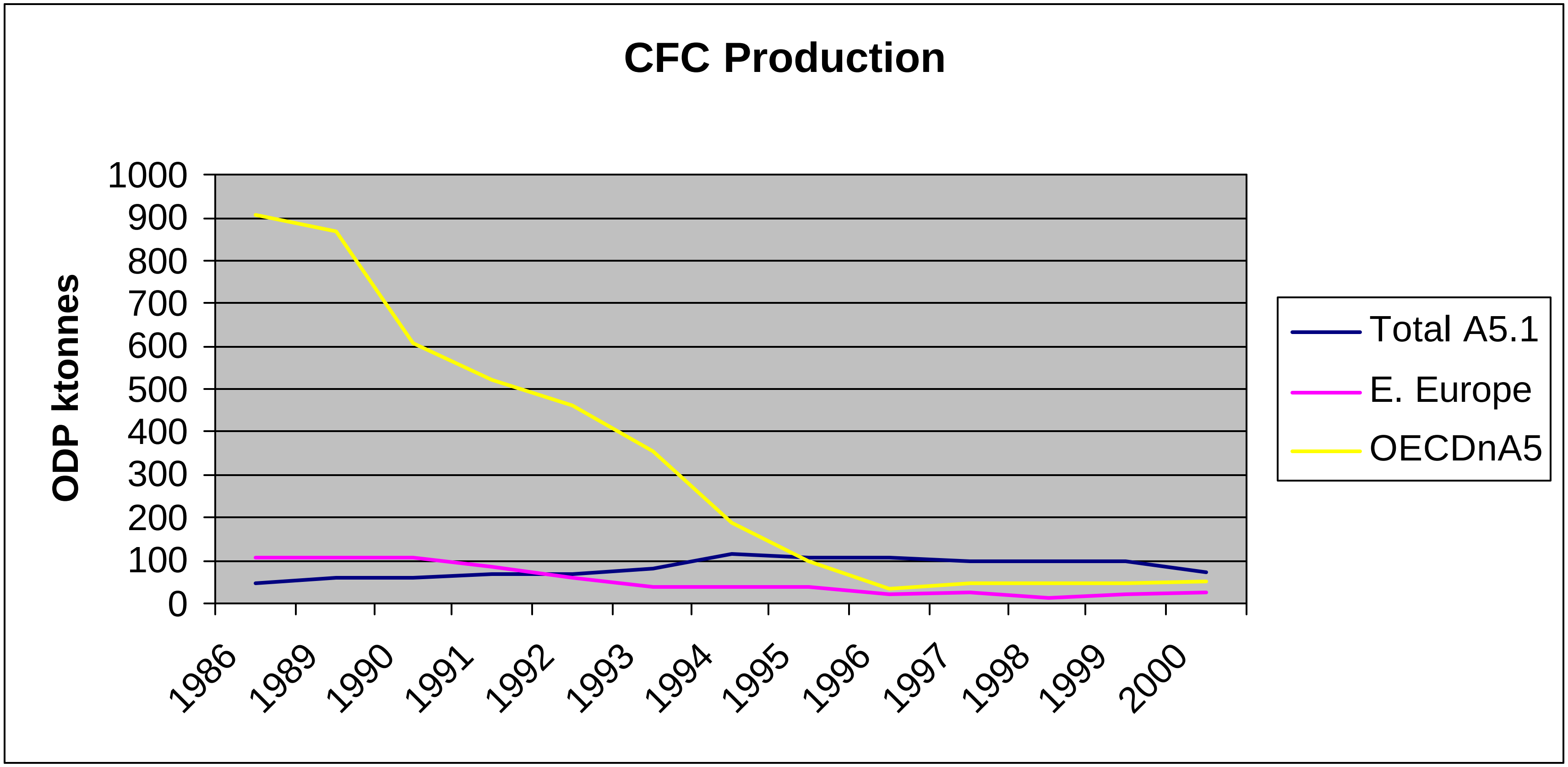

CFC Production
ODP ktonnes
1000
900
800
700
600
500
400
300
200
100
0
1986
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Total A5.1
E. Europe
OECDnA5

Table 8-2

Historic Production Data of CFCs, 1986-2000 (Source UNEP) – (ODP ktonnes)

	1986	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Argentina/Brazil/Mexico/Venezuela	29	25	26	25	17	23	28	25	25	21	20	21	18
China/India/Korea	41	63	42	50	81	82	88	92	73	58	61	55	45
Other A 5.1 countries	54	53	41	40	52	49	50	51	45	64	56	45	45
Total Article 5.1 (UNEP data)	124	141	109	115	150	154	166	168	143	143	137	121	108
Central/Eastern Europe (Russian Fed)	141 (100)	136 (99)	116 (99)	50 (39)	50 (37)	40 (30)	31 (23)	27 (21)	16 (12)	14	15	17	26
OECDnA5 group	788	740	497	436	352	279	149	67	8	7	7	8	5
Other non-Article 5.1	17	15	7	5	8	8	3	3	0	0	0	0	0
Total Consumption (UNEP) Non A5.1	958	897	626	493	412	329	183	97	24	21	22	25	30
Total Consumption (UNEP)	1070	1032	729	606	560	481	349	265	168	164	159	146	138
% OECDnA5 in total	74	72	68	72	63	58	43	25	5	4	4	5	4

	1986	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Total Article 5.1 (UNEP data)	124	141	109	115	150	154	166	168	143	143	137	121	108
Total Consumption (UNEP)	1070	1032	729	606	560	481	349	265	168	164	159	146	138

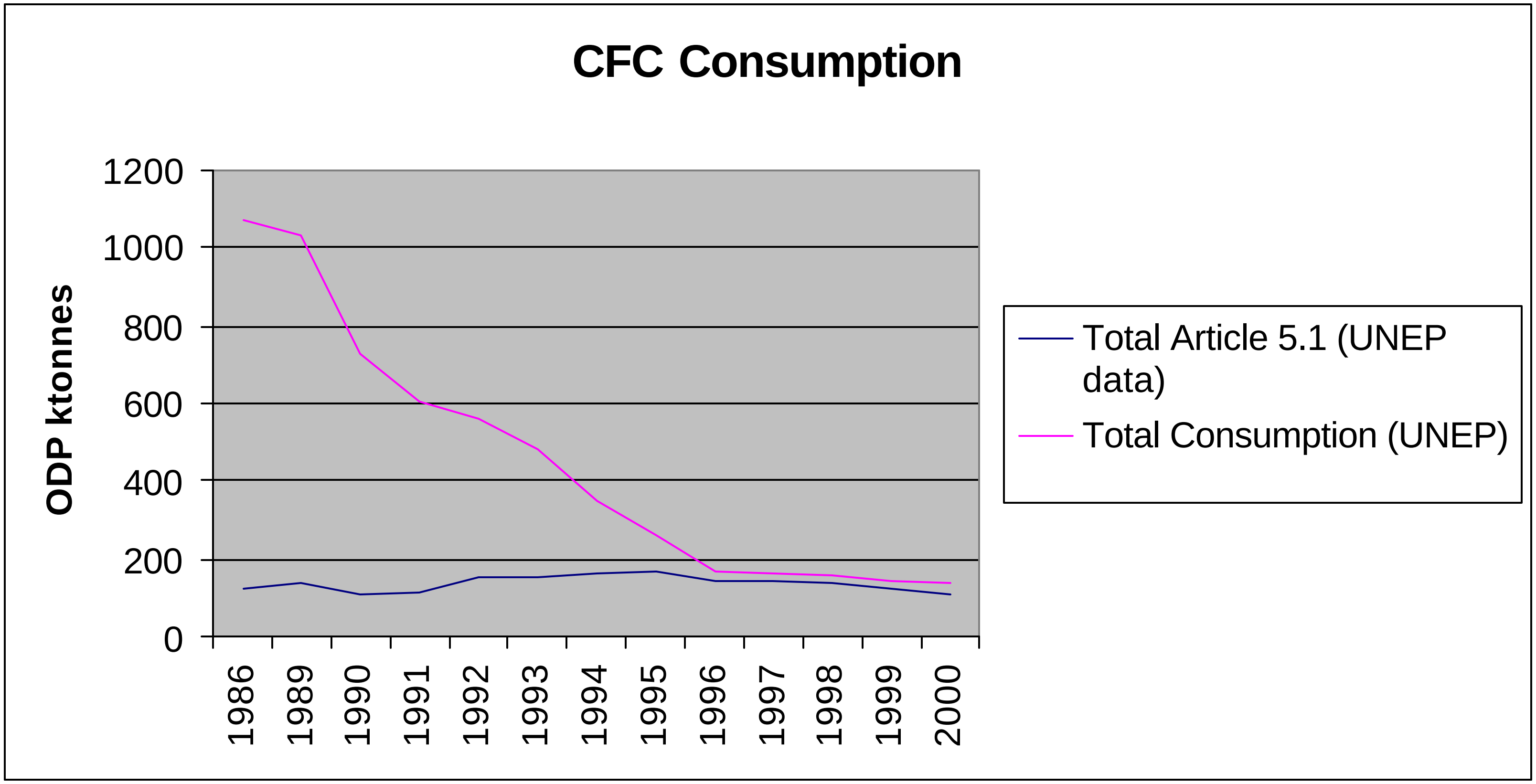

CFC Consumption
ODP ktonnes
1200
1000
800
600
400
200
0
1986
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Total Article 5.1 (UNEP data)
Total Consumption (UNEP)

Table 8-3

Historical Production Data of HCFCs (Sources UNEP and AFEAS) (tonnes)

	1989	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
AFEAS										
AFEAS	229825	289759	318134	359948	398430	435308	418424	432762	430151	422555
AFEAS (ODP-weighted)	12743	16969	20197	24618	28422	30822	29305	31069	31263	30847
UNEP (ODP-weighted)										
Argentina/Brazil/Mexico/Venezuela	353	475	461	452	421	505	523	439	372	274
China/India/Korea	249	731	1212	1840	1877	1831	1526	1522	5013	6713
Total Article 5.1	602	1206	1673	2292	2298	2336	2653	1960	5385	6987
Eastern Europe	1084	267	172	198	184	74	72	67	146	169
OECDnA5 (including S. Africa)	12181	12469	10078	20220	25335	26264	27143	30621	30676	30240
A5.1 & Non A5.1	13867	13942	20875	27266	30180	28674	29868	32648	36207	37228
OECDnA5 Group (UNEP)	12181	13232	18946	24689	27641	26264	27143	30621	30676	30240
OECDnA5 group (AFEAS)	12390	16494	19736	24166	28001	30317	28782	30630	31263	30847
% OECDnA5 (UNEP) in total	88	95	91	91	92	92	91	94	86	83

	1989	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
AFEAS (ODP-weighted)	12743	16969	20197	24618	28422	30822	29305	31069	31263	30847
Total Article 5.1	602	1206	1673	2292	2298	2336	2653	1960	5385	6987

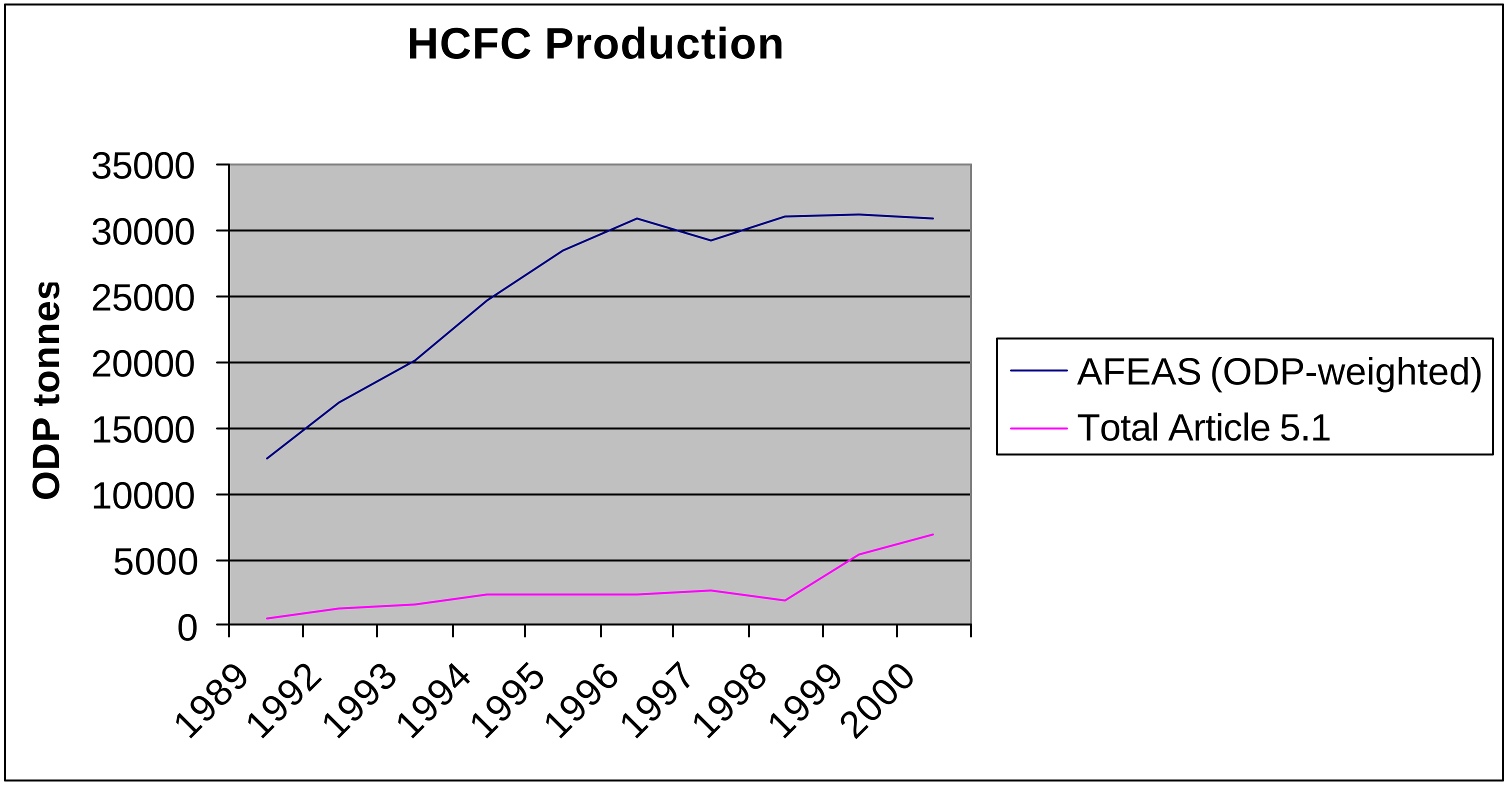

HCFC Production
ODP tonnes
35000
30000
25000
20000
15000
10000
5000
0
1989
1992
1993
1994
1995
1996
1997
1998
1999
2000
AFEAS (ODP-weighted)
Total Article 5.1

Table 8-4

Historic Consumption of HCFCs, 1989-2000 (Source UNEP) (ODP-tonnes)

	1989	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
UNEP										
Arg/Braz/Mex/Venez	418	423	642	769	971	866	1017	1130	1799	3023
China/India/Korea	991	748	1407	2140	2392	2265	1516	1756	4871	5355
Other Art 5.1 countries	623	591	693	616	1203	1646	3383	3442	2869	3554
Total Art 5.1 (UNEP data)	2032	1762	2742	3525	4566	4777	5941	5311	9539	11932
Central/Eastern Europe	564 (437)	316 (267)	258 (172)	228 (107)	259 (84)	195 (73)	345	304	362	586
OECDnA5 group	10605	12009	15727	21684	26780	19780	23788	27080	26995	24695
Other non-Art 5.1	290	271	353	469	471	324	134	42	165	
Total consumption (UNEP) non A5.1	12152	12641	16392	18214	23338	20300	24268	27427	27523	25281
Total Art 5.1 (UNEP data)	2032	1762	2742	3525	4566	4777	5941	5311	9539	11932
%OECDnA5 in total (UNEP)	75	83	82	84	83	79	80	84	74	68
Total consumption (UNEP)	14184	14403	19134	21739	27904	25077	30209	32793	37062	37213

	1989	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Total nonA5.1	12152	12641	16392	18214	23338	20300	24268	27427	27523	25281
Total Art 5.1 (UNEP data)	2032	1762	2742	3525	4566	4777	5941	5311	9539	11932
Total consumption (UNEP)	14184	14403	19134	21739	27904	25077	30209	32793	37062	37213

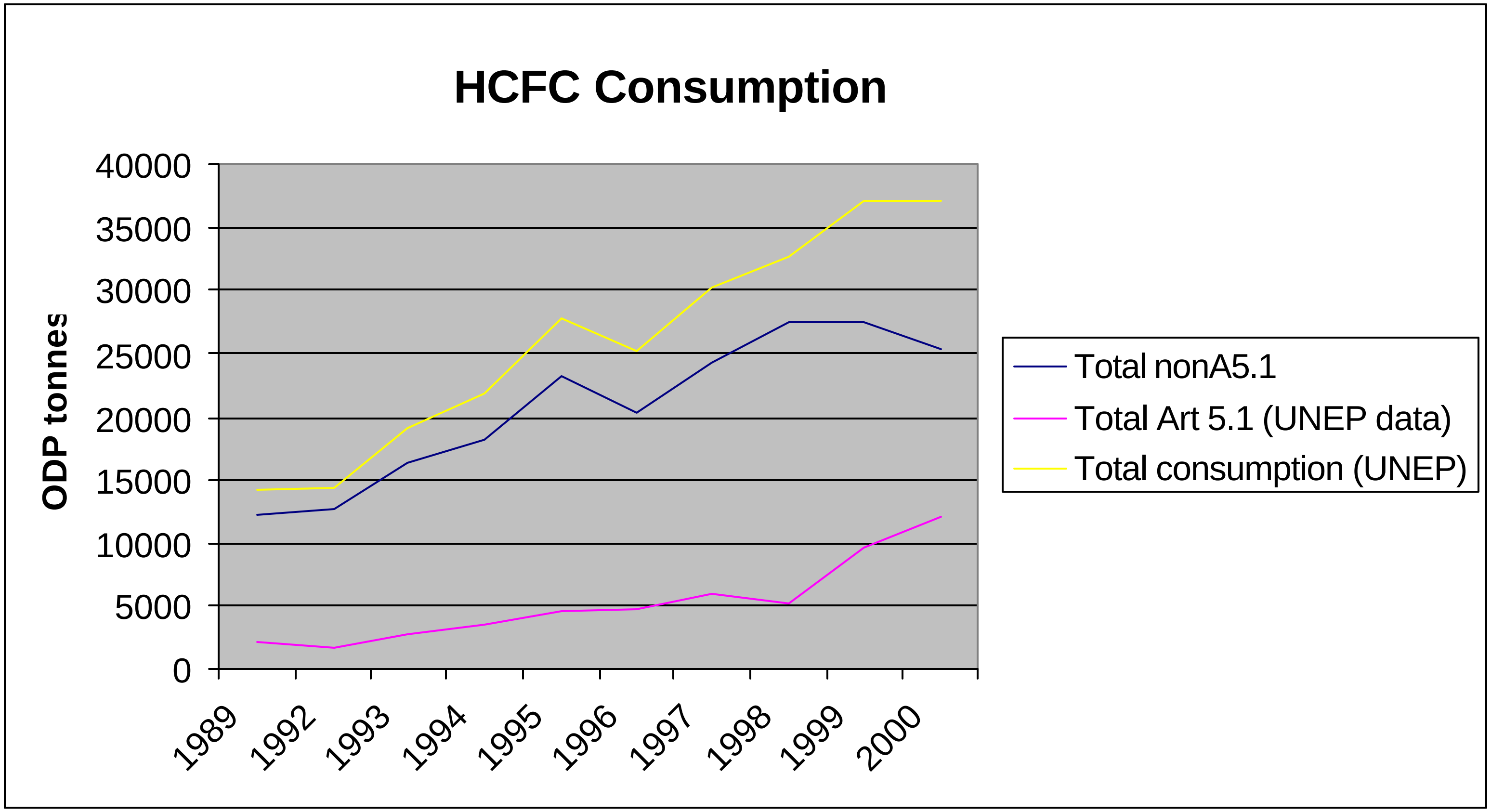

HCFC Consumption
ODP tonnes
40000
35000
30000
25000
20000
15000
10000
5000
0
1989
1992
1993
1994
1995
1996
1997
1998
1999
2000
Total nonA5.1
Total Art 5.1 (UNEP data)
Total consumption (UNEP)

Table 8-5

1999 use of HCFCs in different sectors

	HCFC-22	**HCFC-141b**	**HCFC-142b**	**HCFC-124**	**Total**
RAC	91.7%		2.1%	76.9%	41%
Closed cell foam	3.4%	91.2%	97.4%		53%
Solvents		8.8%	0.1%		4%
Others	4.8%		0.3%	23.1%	2%
RAC	12739		60	50	12849
Closed cell foam	474	13272	2686	0	16432
Solvents		1278	4		1282
Others	667	9	7	15	698
Totals	**13880**	**14559**	**2757**	**65**	31261

Source: AFEAS in percentages per HCFC and in ODP tonnes

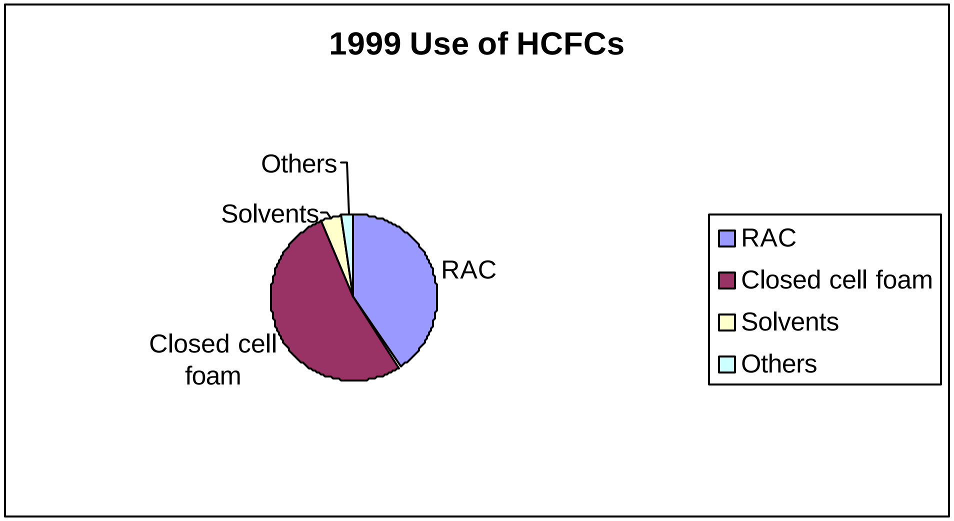
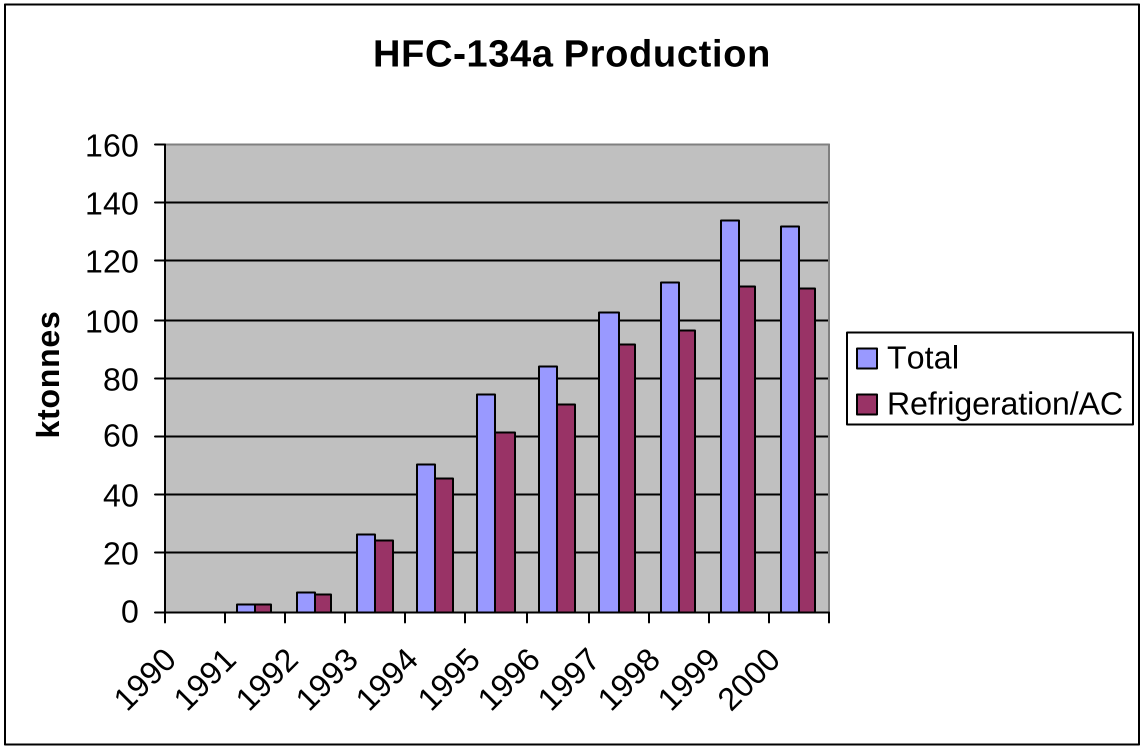


Table 8-6

Historic HFC-134a production (ktonnes)

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Total	0.2	2.2	6.4	26.5	50.4	73.8	83.7	101.9	112.2	133.7	132
Refrigeration/AC	0.08	2.1	6	24.5	46.1	61.3	71	90.9	96.6	111.2	110.7
% total RAC	40%	95%	94%	92%	91%	83%	85%	89%	86%	83%	84%



9. TEAP Member Biographies

9.1 TEAP Members

The following contains the background information for all TEAP members as at 31 December 2002. Note that in 2003, Members Jorge Corona and Mohinder Malik will retire from TEAP.

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Radhey S. Agarwal, Co-chair of the Refrigeration, Air-conditioning, and Heat Pumps Technical Options Committee, is the Deputy Director (Faculty) and Professor of Mechanical Engineering at the Indian Institute of Technology (IIT Delhi), Delhi, India. IIT Delhi makes in-kind contribution for wages. Costs of travel, communication, and other expenses related to participation in the TEAP and its Refrigeration TOC are paid by UNEP's Ozone Secretariat.

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Paul K. Ashford, Co-chair of the Rigid and Flexible Foams Technical Options Committee is the principal consultant of Caleb Management Services. He has over 20 years direct experience of foam related technical issues and is active in several studies concerning future policy for the foam sector. His funding for TEAP activities, which includes professional fees, is provided under contract by the Department of Trade and Industry in the UK. Other related non-TEAP work is covered under separate contracts from relevant commissioning organisations including international agencies (e.g. UNEP DTIE), governments and trade associations.

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Jonathan Banks, Co-chair of the Methyl Bromide Technical Options Committee, is a private consultant. He currently has contracts with Environment Australia and the Australian Quarantine Inspection Service related to methyl bromide and use of alternatives. He is an honorary fellow with the CSIRO Stored Grain Research Laboratory, a government/industry funded research laboratory engaged in finding improved ways of protecting stored grain, including developing and commercialising alternatives to methyl bromide. His funding for TEAP and MBTOC activities is through an Epson Australia Fellowship, a competitive fellowship administered by Environment Australia.

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Walter Brunner, Co-chair of the Halon Technical Options Committee, is a partner in the consulting firm envico, Zurich, Switzerland. He operates the halon registry and the halon clearinghouse under contract from the Swiss Government. The Government of Switzerland funds his participation in the Halons Technical Options Committee (HTOC) and TEAP.

Mr. Jorge Corona (resigned from TEAP 1 January 2003)
(Senior Expert Member)
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Jorge Corona is in charge of foreign relations of the Environmental Commission of Camara Nacional de la Industria de Tranformacion (CANACINTRA), National Chamber of Industries, Mexico City. Communications, wages and miscellaneous expenses are covered personally. Travel expenses are paid by the Ozone Secretariat. From 1997, communications and other expenses are being covered by the Ozone Secretariat. During recent years, Jorge Corona has worked for UNEP, UNDP and ICF on a consultancy basis.

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Ahmad Gaber, Co-chair of Solvents, Coatings and Adhesives Technical Options Committee, is Professor of Chemical Engineering, Cairo University. He is also the President of Chemonics Egypt, an Egyptian environmental management consulting firm. The UNEP Ozone Secretariat pays travel, communications and other expenses.

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Lambert Kuijpers, Co-chair of the Technology and Economic Assessment Panel and Co-chair of the Refrigeration, Air-conditioning and Heat Pumps Technical Options Committee, is based in Eindhoven, The Netherlands. He is supported (through the UNEP Ozone Secretariat) by the European Commission and this has been continued for the year 2002/2003. This applies to his activities related to the TEAP and the TOC Refrigeration, which includes in-kind contributions for wages and travel expenses. UNEP also funds administrative costs on an annual budget basis. In addition to activities at the Department "Technology for Sustainable Development" at the Technical University Eindhoven, other activities include consultancy to governmental and non-governmental organisations, such as the World Bank, UNEP DTIE and the French Armines Institute. Dr. Kuijpers is also an advisor to the Re/genT Company, Netherlands (R&D of components and equipment for refrigeration, air-conditioning and heating).

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