Montreal Protocol
On Substances That Deplete
The Ozone Layer

UNEP

1998 Assessment Report
of the
Technology and Economic Assessment Panel

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The names, addresses and contact numbers of all members of the UNEP Technology and Economic Assessment Panel can be found in Annex B.
The opinions expressed are those of the Committee and do not necessarily reflect the views of any sponsoring or supporting organisations.

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ES Executive Summary

ES.1 Aerosol, Sterilants, Miscellaneous Uses and Carbon Tetrachloride

ES.1.1 Aerosol products (other than MDIs)

For aerosol products, other than metered dose inhalers (MDIs), there are no technical barriers to global transition to alternatives. The major issue remaining is the use of CFCs in Article 5(1) Parties and CEIT. The ATOC estimates that 1997 CFC consumption in the aerosol sector was less than 15,000 tonnes in Article 5(1) Parties and some CEIT, excluding MDI use.

The remaining use of CFCs in most countries – especially Latin America and South East Asia Pacific (SEAP) – is concentrated in the industrial/technical aerosols (principally electronics contact cleaners) and in non-MDI pharmaceutical products. In China, remaining consumption is mostly in non-MDI pharmaceuticals.

There is a declining trend in the use of CFCs in aerosols, and the pace of reduction is currently slow. However, it could accelerate if the specific problems of (1) availability of hydrocarbon aerosol propellants, (2) industrial/technical aerosols and non-MDI pharmaceutical products, and (3) conversion of small and very small CFC users, were resolved.

ES.1.2 Metered dose inhalers

Currently, approximately 500 million metered dose inhalers (MDIs) are used annually worldwide, using approximately 10,000 tonnes of CFCs. Non-Article 5(1) Parties that requested essential use nominations for MDIs are reported to have used 7,893 tonnes of CFCs in 1996.

There is international consensus that primary treatment of asthma and chronic obstructive pulmonary disease (COPD) should be by the inhaled route. Overall, use of inhaled medication is increasing because of increased disease prevalence. MDIs remain the dominant inhaled delivery system in most countries and for all categories of drugs.

Currently available alternatives to CFC-based MDIs are CFC-free MDIs, dry powder inhalers (DPIs), nebulisers, orally administered drugs and injectable drugs.

DPIs have been formulated successfully for most anti-asthma drugs. These inhalers are an immediately available alternative for a large proportion of patients, but they may not represent a satisfactory alternative to the pressurised MDIs for all patients or for all drugs.

DPI usage globally as a percentage of all inhaled medication is estimated to be around 17 percent. This figure varies considerably from country to country, e.g. currently from 85 percent in Sweden to less than 2 percent in the USA and there are no DPIs yet available in Japan. It seems unlikely that the uptake of DPIs in most countries will be at the levels seen in Scandinavian countries.

A number of pharmaceutical companies have introduced or plan to introduce a number of CFC-free MDIs. In the ATOC 1997 Update Report, projected timetables for the launches of HFC MDI products in both the European Union and the USA were included. More recent company specific data are available that indicate that a number of companies are well advanced with their reformulation programs. However, it would appear that the projected "best case" scenario is now not possible due to technical and regulatory delays.

It is likely that a wide range of reformulated products will be available in many developed nations and transition will be making good progress by the year 2000. Minimal need for CFCs for MDIs is envisaged by the year 2005 in non-Article 5(1) Parties. Remaining technical, patent, safety and regulatory issues for some commonly used drugs still make it difficult to predict the schedule for full phase-out with precision.

The ATOC does not believe that a rigid global transition strategy is appropriate in view of the widely differing circumstances of individual Parties. However, the Parties could consider the benefits of a "Global Transition Framework" which would underpin national strategies and ensure that they are complementary. Because the phase-out of CFC-containing MDIs in non-Article 5(1) Parties is anticipated in the next few years, the Parties may wish to recommend that Article 5(1) Parties and CEIT start work on preparing their national transition strategies.

In Article 5(1) Parties, the first control measure on the total consumption of CFCs commences in the year beginning 1 July 1999. Controls on CFCs make no allowance to permit exemptions for essential uses prior to the phase-out date of 2010. This will mean that MDI manufacturers in Article 5(1) Parties will be competing for CFC supply in their local markets with other users of CFCs. Parties may wish to consider a procedure by which non-Article 5(1) Parties that no longer need CFCs for their own use can continue to produce CFC MDIs for export for a limited period, as necessary.

Continued provision of MDIs in Article 5(1) Parties 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) Parties and will overlap with the importation and local production of CFC-free MDIs by multinational and national companies. Local production of CFC-free MDIs will require the transfer of new technologies and may require new licensing arrangements and transfer of intellectual property. This is true whether production is by a local producer, a multinational company or by a local producer in collaboration with a multinational company. The costs of local CFC-free inhaler production will involve capital costs and licensing arrangements.

In relation to Article 5(1) Parties, the ATOC suggests that Parties may wish to consider:

- the importance of maintaining adequate supplies of the necessary range of inhaled medications during transition in non-Article 5(1) Parties
- encouraging the introduction of CFC-free technologies into these countries
- encouraging these Parties to start work on preparing their national transition strategies.

ES.1.3 Sterilants

By the beginning of 1997, CFC-12 use in non-Article 5(1) Parties for 12/88 (a sterilant gas based on ethylene oxide (EO)), had virtually disappeared. There remain no technical barriers to the phase-out of CFCs in sterilisation, but in some Article 5(1) Parties there are indications of increased use of CFC-12 as a sterilant gas diluent.

In non-Article 5(1) countries, low temperature medical device sterilisation is being met by HCFC-diluent replacement sterilant gas, 8.5/91.5 EO/CO_2, and pure EO. In some European countries formaldehyde is also used. There are a variety of not-in-kind substitutes, but some of these substitutes may have materials compatibility problems or may be less robust processes. Not-in-kind substitutes include radiation (gamma and electron beam), plasma systems and liquid chemical systems. In other instances medical devices compatible with the steam process have been developed.

Global consumption of CFC-12 in this sector is very difficult to estimate since it is basically located in Article 5(1) Parties; it is estimated to be less than 1,500 tonnes. Estimated use of substitute HCFC replacement is thought to be less than 3,000 tonnes (some 90 ODP tonnes). CEIT and Article 5(1) Parties could convert to EO/HCFC-124 sterilant gas rapidly with reasonable cost and no changes in operating procedures.

ES.1.4 Miscellaneous Uses

CFCs have a number of miscellaneous uses, of which tobacco expansion is the most significant. It is difficult to estimate the 1998 worldwide use of CFC-11 to expand tobacco. Most countries have stopped or will shortly stop the use of

CFCs to expand tobacco. After 1998, China may be the only remaining country to use significant quantities of CFCs for this purpose. In 1996, 4050 tonnes were used in China compared with 900 tonnes in 1992. Based on the recent and planned installation of alternative carbon dioxide technology in China, declining use in this country is expected.

ES.1.5 Laboratory and Analytical Uses

Typical 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 agencies require specific use of the controlled substances.

Essential uses of 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.

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

It has been estimated that the total global use of controlled substances for these applications in non-Article 5(1) Parties will not exceed a maximum of 500 metric tonnes. Use in CEIT is unlikely to be more than a few hundred metric tonnes. Additionally, up to 500 metric tonnes could be used in Article 5(1) Parties for an estimated global consumption of 1,500 tonnes of controlled substances for laboratory and analytical uses.

TEAP has learned that the following specific uses have identified alternatives and substitutes and therefore do not require the use of ODS:

- testing of oil, grease, and total petroleum hydrocarbons in surface and saline waters and industrial and domestic aqueous wastes including the testing of water which is separated from oil and discharged from offshore drilling and production platforms
- testing of tar in road paving materials by dissolving tar and separating it from aggregate

- forensic fingerprinting.

ES.1.6 Carbon tetrachloride

CTC can be used:

- As a feedstock for the production of other chemicals. The 1997 Report of the Process Agents Task Force (PATF), offered the following definition of feedstock:

  "A controlled substance that undergoes transformation in a process in which it is converted from its original composition except for insignificant trace emissions as allowed by Decision IV/12."

- Used as a process agent. The 1997 Report of the PATF offered the following definition of process agent:

  "A controlled substance that because of its unique chemical and/or physical properties, facilitates an intended chemical reaction and/or inhibits an unintended chemical reaction.

  Note 1: Refrigeration, solvent cleaning, sterilisation, aerosol propellants and fire-fighting are not process agents according to this definition.

  Note 2: Parties need not consider use of ODS for foam blowing, tobacco puffing, caffeine extraction, or fumigation because these uses are already covered in other Decisions and/or by Technical Options Committee Reports."

- As a solvent. This includes simple solvent extraction such as caffeine extraction and palm oil extraction, and cleaning applications such as metal degreasing and textile spotting. Substitutes are commercially available and economic and, thus, these uses should be discontinued to protect the ozone layer as well as to safeguard the health and safety of people now using CTC.
- In miscellaneous applications such as fire extinguishers, as grain insecticide fumigant, and in an anti-helminthic agent (especially for the treatment of liver fluke in sheep). These uses also should be discontinued for the same reasons stated above.
- As a laboratory chemical.

In the past, data on both CTC production and consumption have been difficult to obtain. The new UNEP data reporting formats will enable the collection of much clearer data and a more detailed analysis of CTC applications. Indeed, total CTC production data including production for feedstock use is well known for 1996 and was reported to UNEP as 203,820 ODP tonnes.

ATOC has estimated atmospheric emissions of CTC to be 41,000 tonnes (-25 percent, +50 percent) for 1996. The primary source of atmospheric CTC emissions is from the use as a feedstock to produce CFCs. This has been estimated to be between 27,500 and 29,100 tonnes for 1996 (67-71 percent of total emissions). The majority of the emissions from feedstock use originate from CFC production in Article 5(1) Parties and CEIT (25,700 to 27,300 tonnes, 64-67 percent of total emissions).

Atmospheric CTC levels have declined as a result of the CFC phase-out by non-Article 5(1) Parties. However, they will only fall significantly in the near future if CFC and CTC the use Article 5(1) Parties is phased out at a faster pace than required by the Montreal Protocol. Otherwise use of CFC and CTC will remain frozen until 1 January 2005 and CTC emissions will remain unchanged until that time.

There are a number of measures, which could lead to reductions in CTC emissions to the environment:

- Closure of CFC manufacturing facilities in Article 5(1) Parties and CEIT with accelerated introduction of alternatives.
- Conversion of facilities using CTC as process agents in Article 5(1) Parties to alternatives.
- Use of improved emission control technology in CTC and CFC manufacturing facilities in Article 5(1) Parties and CEIT.
- Use of improved containment and emission control technology in Article 5(1) Parties and CEIT manufacturing facilities using CTC as process agents.

The ATOC wishes to point out that projects to phase out solvent uses of CTC are eligible for financing under the Multilateral Fund. The ATOC further believes that in some cases eligible solvent uses have been presented to the Multilateral Fund incorrectly as process agent uses and, therefore, have not been funded.

ES.2 Economics Options Committee

ES.2.1 Introduction

The theme of the 1998 Assessment Report of the Economic Options Committee (EOC) is progress made towards full implementation of the Montreal Protocol control schedules. The analyses address economic aspects of the implementation process, including assessments of the essential elements of national policy regimes. Updates on economic aspects of selected controlled substances, trade issues, and “lessons learned” from the Montreal Protocol experience are presented.

The policy challenge is to design and implement policy regimes that are appropriate to national institutional capacities, industrial structure and trade patterns with respect to ODS production and consumption. Evidence suggests that there is ample scope for more extensive use of market-based instruments to improve the cost-efficiency of implementation

ES.2.2 Implementation: Article 5(1) Parties

The issues facing Article 5(1) Parties include compliance, inter alia, with their first control target for Annex A, Group I chlorofluorocarbons (CFCs). Studies addressing this issue conclude that virtually all Article 5(1) Parties will comply with 1995-1997 “freeze level”. To meet subsequent control measures for 2002 and beyond, the Article 5(1) Parties will need to improve compliance by the small and medium-sized enterprises (SMEs), including the informal sectors. The use of market-based instruments is likely to be more effective than command-and-control policies in raising compliance levels by the SMEs and the informal sector. The quality of data reporting and management has important implications for assessing compliance. Recent studies highlight the need to improve data quality and management. Case studies for China and India highlights China’s increasing use of market-based instruments in contrast to India’s more extensive reliance on command-and-control measures.

ES.2.3 Implementation: CEITs

CEITs have had trouble in complying with the control schedules and paying their assessed contributions to the Multilateral Fund. Overall, significant progress in reducing the ODS consumption has been achieved by the CEITs. However some Non-Article 5(1) CEITs, most significantly the Russian Federation, failed to comply with the January 1, 1996 phase-out target for Annex A and Annex B substances. A formal extension for Russian compliance, although requested, was not granted leaving Russia in breach of the Protocol. This matter has not been resolved. However, by encouraging the funding of Russian phase-out projects through the GEF and ad hoc donors, the Parties have kept open a channel for influencing and participating in the design, implementation and monitoring of Russian responses to its Protocol obligations. The problems that Russia faces in switching out of ODS consumption also apply to other CEITs. These are principally difficulties in obtaining funds for switching production to non-ODS substances at a time when industrial prospects are poor and capital is extremely scarce. At the same time, the option of closure is very unattractive when unemployment is already very high.

ES.2.4 The Use & Cost Effectiveness Criteria of the MLF and GEF

The role and application of cost-effectiveness thresholds continue to evolve as the Executive Committee takes decisions on new concepts of investment projects such as “umbrella projects”, “terminal umbrella projects” and “sector approach projects” (e.g., the Halon Sector Plan in China). Further developments are likely as the Executive Committee progresses in its work on the application of cost-effectiveness criteria to projects designed to phase out ODS production capacity in the Article 5(1) Parties.

ES.2.5 Methyl Bromide

The Non-Article 5(1) Parties, in aggregate, are well within reach of the required 25 percent reduction in consumption by January 1, 1999 for methyl bromide. However, most of the overall decline in methyl bromide consumption has occurred in the United States while several other non-Article 5(1) Parties have not yet achieved significant reductions. Therefore, it appears that some Parties may have not achieved significant reductions, and will face difficult challenges in meeting the 25 percent reduction target. The 20 percent reduction target for Article 5(1) Parties by January 1, 2005 is unlikely to cause concern, if technical innovation and investment projects progress as expected.

ES.2.6 HFCs and HCFCs

There are trade-offs between the benefits of using HFCs and HCFCs for ozone protection and the environmental costs associated with their emissions. Economic analyses can go some way in providing appropriate frameworks for assessing these cost and benefits. However, not all costs and benefits can be quantified and economic analysis alone may not be sufficient to guide decisions on alternatives that might have widely different distributions of costs and benefits.

ES.2.7 Halons

China is using market-based instruments to improve economic efficiency in the implementation of the Halon Sector Plan. The main economic instruments are a tradable production quota system and a bidding system for MLF grants. The results of this initiative were (1) economic efficiency improved; (2) significant environmental benefits were achieved; and (3) the cost of the phase-out to the Multilateral Fund was reduced by about 27 percent compared with normal project-by-project approach. Based on this experience, China is moving quickly to apply this approach to other ODS sectors, e.g., for the CFC production sector plan, the solvent sector plan and the tobacco sector plan.

ES.2.8 International Trade Issues

The trade provisions of the Montreal Protocol have undoubtedly reduced international trade in controlled substances as intended. At the regional level, there is quantitative evidence that trade flows in relevant product groups have been impacted by the Protocol.

Unrestricted trade in second-hand ODS-using equipment can create problems. The attraction for Article 5(1) Parties is low initial cost, however the derived demand for ODS for recharge and the costs of disposal drive up long term costs, and can create additional ODS emissions.

ES.2.9 Transferability of Lessons Learned from the Montreal Protocol

"Lessons learned" and their possible transferability to the design and implementation of other international environmental agreements are updated from the 1994 EOC Assessment Report. Important lessons include the: (1) *role of science;* (2) *role of independent, objective technical experts;* (3) *role of co-operation;* (4) *role of equity;* (5) *economic costs;* (6) *similarities and differences;* and (7) a*pplication of "lessons learned*".

ES.3 Foams Technical Options Committee

ES.3.1 Technology Status

Zero-ODP alternatives are the substitutes of choice in many applications including packaging, cushioning (flexible) and certain rigid thermal applications. No single solution has emerged from transition, and thus, choices must be retained to allow optimal solutions for given applications, producer-specific and country-specific circumstances.

The development of liquid HFC replacements for HCFC-141b continues for thermal insulating polyurethane, polyisocyanurate and phenolic foams. HFC-245fa and HFC-365mfc, liquid HFCs, are being actively developed as zero-ODP, near drop-in replacements for HCFC-141b. It is anticipated that both of these products will be commercially available around the beginning of 2002. No toxicity issues have been identified. Uncertainty, however, over cost, availability and the long term environmental management of greenhouse gases is slowing development. For polystyrene and polyolefin insulating foam, the most likely long-term candidates are CO_2 (liquid carbon dioxide), HFC-152a, HFC-134a, or blends thereof.

Pentane-based technologies for rigid polyurethane foams continue to evolve. Technical properties including thermal insulation and lower density have been improved with the use of blends of cyclopentane with iso-pentane or with iso-butane. These gains, have also led to improved cost competitiveness for hydrocarbon blown products.

Whichever types of blowing agent are chosen, an increasing trend in the development of newer technologies is the use of optimised blends. These often combine new and existing materials and are typically low or, most commonly, zero ODP. Blends are preferred because they more closely match the performance of the original CFC technologies. This trend is seen in most sectors. It appears that use of single blowing agent systems has ended in several foam applications.

ES.3.2 Transition Status

Global use of ozone depleting substances in rigid foams has decreased by almost 75 percent since reaching a peak in 1989. All CFC use in Non-Article 5(1) countries (except for some CEIT) has been eliminated. As of 1997, HCFC use represents less than 20 percent of the total rigid foam sector use of ozone depleting substances, as measured in ODP tonnes. There is very little, if any, use of HCFCs in non-rigid foam sectors.

For Article 5(1) Parties, CFC phase-out is technically feasible around the year 2001 provided Multilateral Fund projects are implemented without delay. However, the foam sector is growing very rapidly in a number of Article 5(1) countries. In addition to expanded CFC use among manufacturers who have not yet completed transition, some new operations are starting up with CFC technology. In some Article 5(1) countries this market growth and related CFC use outpaces the phase-out progress. It may be difficult in these countries to meet applicable phase-out deadlines.

ES.3.3 Transition Barriers

Some CFC and HCFC users are reluctant to finalise a transition strategy until there is greater certainty concerning the availability and suitability of HFCs long-term CFC replacements. Depending on the situation of the individual foam manufacturer, some technically viable alternatives may not be economically viable owing to high cost of capital investment, and the sensitivity of unit foam costs to blowing agent costs.

In Article 5(1) countries, CFC-11 continues to be widely available and is generally much cheaper to use than the currently available alternatives. Another factor constraining a more rapid phase-out is that very few alternatives are manufactured in Article 5(1) countries. The technical options for low volume CFC consumers in Article 5(1) countries are also limited because funding cannot cover the capital costs of, for example, hydrocarbon or CO_2 (liquid carbon dioxide). Given the advantage of using existing equipment with liquid HFCs, once the uncertainties in price and availability are clarified these substitutes may serve as a cost-effective replacement in

Article 5(1) countries in some applications. Consistent use of safe practices by manufacturers during storage, production and transportation of products—especially extruded polystyrene sheet—manufactured with flammable blowing agents continue of to be of concern.

ES.4 Halons Technical Options Committee

Extensive R&D into new liquid and gaseous halocarbon replacements for halons and into the use of new and existing alternative approaches has resulted in the availability of a wide range of options. This has led to the almost complete cessation of use of both halon 1211 and halon 1301 in non-Article 5(1) and in many Article 5(1) Parties for new installations across most applications, as well as to significant retrofitting. Those systems that remain are substantially non-emissive in normal circumstances; emissions due to testing and training have been virtually eliminated; and recovery of agent during servicing and decommissioning is routine. Based on these achievements, the cessation date for halon production in non-Article 5(1) Parties was successfully brought forward to January 1994. Only a single Essential Use production exemption has been approved, in the special case of halon 2402.

Despite this success, concerns remain. Vastly dominant amongst these is continuing significant halon 1211 in Article 5(1) Parties. Technology transfer is required, especially for high quality ABC powder manufacture as an alternative to halon 1211 and for hydraulic and installation design for fixed systems alternatives to halon 1301. New National Standards for alternatives will help in reducing costs. Countries with Economies in Transition require implementation of effective halon recovery and recycling, establishment of a halon 2402 management program and a continuing process of information dissemination and awareness improvement.

Two other halons, 1011 and 1202, were much less widely used. Increases in atmospheric concentrations of halon 1202, recently reported in scientific journals, cannot be explained by use as a fire extinguishant. Halon 1202 was only used as a fire extinguishant on a few aircraft types that are longer produced. Parties may wish to examine the possibility that inadvertent production and release of halon 1202 during halon 1211 production in Article 5(1) countries is the source of these atmospheric concentrations.

The needs of “Critical Users” who still require halon 1301 - including, at present, aviation and some defence, oil and gas, and shipping - are being met by management of the existing inventory. They are in approximate balance (within the estimating error) with the rate at which agent is coming onto the market as systems reach the end of their useful life and are decommissioned.

It is important to ensure that this balance is maintained, that the halon retains its asset value, and that it finds its way to the Critical Uses. Until there is a clear surplus of halon 1301, widespread destruction cannot be recommended.

Efforts to minimise emissions continue to be imperative, especially bearing in mind that near term emissions are more damaging to the ozone layer than later ones. It should be noted that total ODP weighted emissions of halon 1211 and halon 1301 from Article 5(1) countries now exceeds those from non-Article 5(1) countries. It is expected that Article 5(1) country halon emissions will increase significantly until production ceases.

ES.5 Methyl Bromide

MBTOC addresses the technical feasibility of chemical and non-chemical alternatives for the current uses of MB. Of the 1996 global MB production of 71,425 tonnes, quarantine and pre-shipment (QPS) use was 15,000 tonnes and equivalent to 22 percent of global fumigant use. QPS use is exempt from control and is an emissive use unregulated under the Protocol and moreover, this use appears to be increasing for both developing and developed countries.

ES.5.1 Soil Fumigation

MB as a soil fumigant is the single largest use category accounting for about 75 percent of global use. In spite of the widespread use of MB as a soil fumigant MBTOC did not identify a single crop that cannot be produced successfully without MB.

ES.5.2 Durable Commodities

Durable commodities include grains, dried fruits and beverage crops, and non-foods such as wood products and tobacco. Approximately 13 percent of the global consumption of MB is used for treating durable commodities and about 3 percent for structures. The principal alternatives are phosphine, heat, cold and contact pesticides. In many cases, integrated pest management procedures can replace MB. MBTOC did not identify any existing alternatives for some non-QPS uses but these are likely to consume less than 50 tonnes per annum.

ES.5.3 Perishable Commodities

Perishable commodities include fresh fruit and vegetables, cut flowers, ornamental plants, fresh root crops and bulbs. About 9 percent of global MB consumption is used for disinfestation of perishable commodities, with about half used for disinfestation of fruit for quarantine purposes. Post-entry alternative treatments are particularly problematical as they have neither been developed and approved for treating products entering via multiple air and sea ports, and nor would they be easy to implement.

ES.5.4 Article 5(1) Parties Perspective

Based on official data, Article 5(1) Parties consumed 15,350 - 17,500 tonnes of MB per annum, equivalent to 23-26 percent of global consumption. Some have greatly reduced their consumption or even officially phased out MB, while others have substantially increased their usage and in some cases production. Demonstration projects currently being implemented in a number of countries will curb this increase and ultimately encourage phase out.

ES.5.5 Quarantine and Pre-shipment (QPS)

MBTOC noted there is some inconsistency in the interpretation of the terms ‘quarantine’ and ‘pre-shipment’ that may lead to some Parties incorrectly exempting this use. In addition, multiple MB applications are being used when a single application just prior to shipment would meet QPS requirements.

ES.5.6 Emission Reduction

There has been some limited further research into the development of recovery and recycling systems for MB, mostly directed at recovery from commodity fumigation. Only a few special examples of recovery equipment are in current commercial use.

ES.5.7 Alternatives to Methyl Bromide

MBTOC could find no existing alternatives to MB for about 2500 tonnes of MB per annum used for non-QPS treatments. Existing alternatives are those non-chemical or chemical treatments and/or procedures that are technically feasible for controlling pests, thus avoiding or replacing the use of MB. Based on this relatively small consumption, MBTOC considered there are existing alternatives for more than 95 percent of the current tonnage of MB, excluding QPS. Significant effort must now be undertaken to transfer these alternatives to as many locations as possible and optimise the conditions under which they can be most effective.

ES.6 Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee

ES.6.1 Introduction

CFC production has been phased out in the non-Article 5(1) countries, and phase-out is underway in the Article 5(1) countries. In both the non-Article 5(1) and the Article 5(1) countries, HCFCs and HFCs have been the primary substitutes for CFCs. In many applications, alternatives to HCFCs have become commercially available, mainly as blends of HFCs. As a result, HFCs have currently gained a large share of the replacement market. A rational approach to phase out HCFC consumption should allow a minimum time period to permit the industry to develop and commercialise alternatives; and a rational phasing in of new equipment in order to avoid high obsolescence costs. For the short term, the transitional HCFCs still form a valid, global option for refrigeration and AC equipment. However, for the long term, there remain (in addition to various non vapour compression methods) only five important different refrigerant options for the vapour compression cycle:

- hydrofluorocarbons (HFCs, HFC-blends with 400 and 500 number designation);
- ammonia (R-717);
- hydrocarbons and blends (HCs, e.g. HC-290, HC-600, HC-600a etc.);
- carbon dioxide ($CO_{2,}$ R-744);
- water (R-718).

None of the above refrigerants is perfect, and all have both advantages and disadvantages that should be considered by governments, equipment manufacturers and equipment users. For example, HFCs have relatively high global warming potential, ammonia is more toxic than the other options, and ammonia and hydrocarbons are flammable to certain extents. Appropriate equipment design, maintenance and use can mitigate these concerns, though sometimes at the cost of greater capital investment or lower energy efficiency. Energy efficiency relates directly to global warming and greenhouse gas emissions. Therefore, it remains an important issue for all refrigeration technologies, and should be considered along with the other factors described above.

Next to ozone depletion, global warming is the main environmental issue governing the selection of refrigerant technologies for the near-, mid- and long-term. Although this issue is not covered by the Montreal Protocol, it nevertheless forms an important criterion in the ongoing “environmental acceptability” discussion. Interest in ammonia and the hydrocarbons is stimulated, at least in part, by the fact that the HFCs are greenhouse gases for which emissions may be controlled in future. However, safety aspects also imply stringent emission controls for ammonia and hydrocarbons. Similarly, energy efficiency research is partly spurred by the role of energy production in carbon dioxide emissions. The five refrigerant options described above are in different stages of development or commercialisation; HFCs are widely applied in many sectors, ammonia and hydrocarbons enjoy growth in sectors where they can be easily accommodated, and for certain applications, CO_2 equipment is under development and the first demonstration components have reached the market. Equipment using water has been developed and may see some increase in limited applications. Work is being done by several committees in developing standards to permit the application of new refrigerants, and it is the intent of companies to reach worldwide accepted limits in those different standards.

ES.6.2 Global CFC and HCFC Production and Consumption

CFC production in the non-Article 5(1) countries shows a decrease from 866 to 53 ODP-ktonnes in the years 1986 and 1996, respectively. The total aggregated production volume in Article 5(1) countries seems to have stabilised over the period 1994-1996. CFC production in all Article 5(1) countries amounted to 109 ODP-ktonnes in 1996. The total global CFC production available for consumption in the Article 5(1) countries in the year 1996 was on the order of 145-150 ODP-ktonnes. If Article 5(1) countries were to continue producing on the order of 110 ODP-ktonnes annually, exports by non-Article 5(1) Parties could be rapidly reduced. This is because Article 5(1) consumption is expected to decrease due to project implementation and national measures being implemented by many Article 5(1) Parties.

HCFC production increased from about 12.7 ODP ktonnes in 1989 to about 30.8 ODP ktonnes in 1996 in countries, which have facilities belonging to the AFEAS manufacturer group. According to the 1996 manufacturers' data, the largest ODP consumption of HCFCs was not in refrigeration and air conditioning, but in the foams sector (HCFC-141b). HCFC global consumption is expected to decrease from 412 to 163 ktonnes between the years 1998 and 2015, respectively. HFC-134a production has shown a continuous growth over the period 1990 -1996, with a consumption of about 74 and 84 ktonnes in the years 1995 and 1996, respectively, which represents growth percentages of 45 and 13 percent. Annual HFC-134a consumption for all applications in 2015 is forecast to be 207 ktonnes. This represents an increase of about 250 percent between 1997 and 2015; this figure includes 174 ktonnes for the use of HFC-134a in refrigeration and A/C. The same growth percentage also applies for the consumption of other HFCs in the 1997-2015 period (forecast consumption of 133 ktonnes in 2015). These growth estimates should be considered against a substantial decrease in HCFC consumption over the period 1997-2015.

ES.6.3 Domestic Refrigeration

All manufacturers in non-Article 5(1) countries have transitioned from CFC-12 to non-ODS refrigerants in new domestic refrigeration equipment. Transitions in the Article 5(1) countries are occurring faster than the Montreal Protocol requirements. Preferred alternatives were assessed considering safety, environmental, functional and performance requirements. Broad based

OEM refrigerant alternatives have narrowed to HFC-134a and HC-600a. Both can provide safe, reliable and efficient domestic refrigerators and freezers. Analysis of regional requirements and consumer - selected product differences provides insight into refrigerant selections. Field repair complexity is expanding with the introduction of new refrigerants which involves several potential issues and OEMs should be consulted regarding proper repair procedures for their equipment. Equipment design for use with CFC-12 should be carefully assessed for safety prior to undertaking drop-in repair, particularly when using flammables. There is a significant difference in field repair rates between developed and developing countries, at approximately 2 percent and 10 percent, respectively. Differences result from use environment, extended life and uncertain power service, aggressive transport conditions and deficient service training. The premium value of capital goods relative to labour expense in many countries promotes component rebuilding by small, decentralised service shops. This has the strategic consequence of extending the use of obsolete materials and components. CFC-12 continues to globally dominate the aftermarket service demand. Energy efficiency of domestic refrigeration is a subject of accelerating interest. Retirement and replacement of less efficient older units and extended application of conventional state of the art technology could result in large reductions in global energy consumption.

ES.6.4 Commercial Refrigeration

Commercial refrigeration includes a wide range of equipment. While the refrigeration capacity of centralised systems in supermarkets varies typically from 20 kW to 1000 kW, stand-alone equipment capacities are comparable to domestic equipment. Stand-alone equipment traditionally used CFC-12; most new equipment uses HFC-134a. Several manufacturers in Denmark, India, Sweden and the UK have introduced small commercial equipment using various hydrocarbons. The expected more rapid HCFC phase-out in Europe has led to the choice of R-404A and R-507A in new, centralised systems. In some European countries certain industries are supplying units that either use ammonia or hydrocarbons. However, HFC blends as economically preferred refrigerants form the usual choice, due to safety considerations and initial costs. A number of units have been installed to evaluate the advantages and the drawbacks of indirect systems (using a secondary circuit with heat transfer fluids), and new concepts for direct expansion using water cooling, now in operation, are also being evaluated. Other developmental efforts are focused on improving energy efficiency, minimising charge size, and minimising refrigerant emissions. The early CFC phase-out in some Article 5(1) countries and their level of refrigerant consumption (which can be up to 50 percent of the overall country CFC consumption), provide incentives for both system owners and repair shops to replace CFC-12 with low- or non-ODP refrigerants.

ES.6.5 Industrial Refrigeration and Cold Storage

Most industrial systems are custom made and erected on site. Therefore, the refrigerant choice has to be evaluated on a case-by-case basis, whether it concerns a new installation or the retrofit of an existing one. Ammonia and HCFC-22 are currently the most commonly used refrigerants for industrial refrigeration including cold storage and food processing; it is expected that ammonia will increase its importance in the future. In these sectors CFCs have been replaced by new systems using ammonia, HCFC-22 and HFCs, where the currently used HFCs are HFC-134a, R-404A and R-507A. The blend R-410A is expected to become the leading HFC in future.

Hydrocarbons and CO_2 are applicable for specific applications. Retrofit activities in the industrial sectors have been lower than expected several years ago, although the various retrofit options, i.e., HCFC-22, HCFC blends and HFCs have proven to be viable solutions. In a certain number of cases retrofit cannot be performed due to economic or technical reasons, and the systems have to be replaced. Compared to industrial refrigeration, cold storage and food processing is a more important sector in the Article 5(1) countries; the refrigerants used are, to a certain degree, CFCs as well as the substitutes HCFC-22 and ammonia.

ES.6.6 Air Conditioning and Heat Pumps (Air Cooled Systems)

Air cooled air conditioners and heat pumps ranging in size from 2 kW to 420 kW comprise the vast majority of the air conditioning market. Nearly all of these units use HCFC-22 as working fluid; this represents an inventory of approximately 423 ktonnes of HCFC-22. There has been significant progress made in developing HCFC-22 alternatives for this category of products. Hydrocarbon refrigerants might also be suitable replacements for HCFC-22 in some categories of products: air-to-water heat pumps and possibly very low charge level air-to-air systems. Article 5(1) Parties will have a significant need for the transfer of reclamation and retrofit technologies in the air conditioning sector. At least one retrofit candidate for HCFC-22 is commercially available: the HFC-blend R-407C.

ES.6.7 Air Conditioning (Water Chillers)

The continuously growing number of water chillers for air conditioning, in service around the world, uses refrigerants including fluorocarbons (CFCs, HCFCs, HFCs), ammonia and hydrocarbons. The chillers employing the fluorocarbons dominate in terms of the installed base and new production, due to relatively low initial costs. Because HCFCs and HFCs are relatively similar to the CFCs physically and chemically, they can often replace the CFCs in new and existing chillers with less extensive modification of chillers and equipment rooms than are required for other replacement refrigerants.

However, the ammonia and hydrocarbon chillers are enjoying some growth, particularly in Northern Europe. The largest chillers, those with the highest cooling capacity, employ centrifugal compressors, where the smaller chillers have traditionally employed reciprocating piston compressors. Today, these are being complemented, and in come cases replaced, by screw and scroll compressors. The principal changes that have occurred since the 1993-1995 period are (i) the phase-out of the use of CFC-11 in existing chillers has been significantly slower than forecast in 1994, (ii) the use of ammonia in new systems has grown more rapidly than anticipated in 1994, (iii) very low emission chillers are now being installed by all manufacturers, and (iv) hydrocarbon chillers have been introduced on several regional markets.

ES.6.8 Transport Refrigeration

Transport refrigeration includes refrigeration in ships, railcars, containers and road transport equipment; it also includes refrigeration and air conditioning on merchant ships, buses and railcars. Most systems that used CFCs in 1994 have been retrofitted or scrapped, except for refrigerated containers and trucks, due to the large existing CFC fleets. Particularly in all segments of transport refrigeration, the emission rate can be significant, due to the rough operating conditions; therefore containment and maintenance are very important together with system design improvement. Nearly all shipboard systems use HCFC-22 but HFCs offer the preferred future option. Apart from HFCs, there is limited work on alternatives including hydrocarbons, ammonia, air-cycle and CO_2 for new systems in transport refrigeration. About half of the refrigerated containers and road vehicles still use CFC-12 today, but retrofit options, mainly HCFCs and HFCs, are fully available (only in some cases hydrocarbon options exist).

ES.6.9 Automotive Air Conditioning

By the end of 1994, all automobile manufacturers had converted mobile air conditioning systems to HFC-134a. Existing vehicles with CFC-12 air conditioning are expected to be phased out due to “old age” by the year 2008. The major issues remaining are to encourage the Article 5(1) Parties to phase out CFC-12 in motor vehicles as soon as possible and prevent unnecessary emissions during servicing. Accordingly, automobile manufacturers and their international associations have provided information on available retrofit technology, recovery and recycling of refrigerant, service technician training, and current service and retrofit trends; this has already been used in several Article 5(1) country Refrigerant Management Plans. Manufacturers of HFC-134a systems are working to improve their designs to minimise refrigerant charge and refrigerant emissions, and to maximise total system energy efficiency. Hydrocarbons and CO_2 have been proposed as possible long-term replacements for HFC-134a and are being evaluated. New vehicles are expected to be equipped with HFC-134a until an alternative is developed and commercialised that offers comparable performance, reliability and safety characteristics, and an economically viable global warming advantage.

ES.6.10 Heating Only Heat Pumps

It is estimated that the total existing heating-only heat pump stock in the residential, commercial/industrial and district heating sectors is roughly 1.7 million units, with a total heating capacity of about 13,300 MW. The corresponding figures for industrial heat pumps are 8,500 units with a total heating capacity of 3,000 MW. Virtually all heat pumps are in use in the developed countries. HFCs are the most important alternative refrigerant for heat pumps, both for retrofit and in new installations: HFC-134a is applied in medium/large capacity units as a replacement for CFC-12, where R-404A, R-407C and R-410A are the most promising HFC blend alternatives to replace HCFC-22. So far, the number of heat pump retrofits has been lower than expected. Ammonia has in the recent years attained a small, but growing market share in medium and large capacity heat pumps in Northern Europe; propane, propylene and certain hydrocarbon blends are being used in a limited number of residential heat pumps, mainly in Europe. In addition, the use of CO_2 is being evaluated and components for CO_2 have been developed.

ES.6.11 Refrigerant Conservation

Refrigerant conservation is critical both to maintaining the stock of existing CFC equipment and to minimising any environmental (e.g., global warming) or safety (e.g., flammability) impacts that may be associated with the transition away from ozone-depleting substances. Parties may wish to consider taking measures to encourage conservation. Measures successfully applied in the past have included financial incentives and regulations making containment compulsory. In Article 5(1) countries, important first steps include tightening up systems by finding and repairing leaks, and recovering refrigerant when opening the system for service. To be effective, conservation technologies must be matched by technician training and, in some cases, adaptation of technology. Replacing CFCs in new and existing equipment; ending the purchase of CFC equipment; and conservation through recovery, recycling and leak reduction are all steps that could be taken in the short term by Article 5(1) Parties in order to meet the initial 1999 control measures.

ES.7 Solvents, Coatings and Adhesives Technical Options Committee

ES.7.1 Non-Article 5(1) Party Progress

Industries in non-Article 5(1) countries have successfully complied with the production phase out of ozone-depleting solvents, which occurred nearly two years ago. A small quantity of ozone-depleting solvents is still produced for post-phase-out Essential Uses Exemptions.

Over the past four years the number of Essential Use Exemption Nominations for OD-solvents has decreased significantly, and only a few of these requests have granted by the Parties. The users of ozone-depleting solvents have been quite successful in the phase-out, however several industries still rely on them. Aqueous cleaning methods have been successful for many applications and indications are that a large percentage of users [about 50 - 60 percent] have made the transition to this alternative.

However, in several applications such as precision cleaning where factors such as high reliability, compatibility and short cycle time (e.g., fast, spot-free drying) are required, users are converting to alternative solvent processes. Many of these alternative solvents are more expensive on a per kilogram basis and do not possess many of the desirable properties of the original ozone-depleting cleaning solvents.

The number of new ozone friendly solvents is quite small and the projection for continued research into new solvents is not high. Cost of research, time for governmental approval and user acceptance continue to be major concerns for developers. Continued dependency on stockpiled OD solvents and ongoing enthusiastic attendance at conferences and workshops provide evidence that interest in more economical and effective alternatives still remains.

An additional issue worth mentioning is the cost of solvent alternatives. Unlike the ozone-depleting solvents, the alternatives market is made up of many suppliers with numerous alternatives, many of which are variations or blends marketed under trade names of the same alternative. This dispersed nature of this market has made the economics of scale that were realised in the past, impossible today. Therefore, alternatives in general remain expensive relative to the OD solvents they replace, particularly those for speciality uses.

The STOC continues to be aware of new solvents offered in the market that have ODPs and lack complete toxicological assessment. The rush to promote these alternatives has been such that this information is being overlooked and minimised.

ES.7.2 Article 5(1) Parties Progress

Although the phase-out effort is going well in developed countries, many unique challenges remain for Article 5(1) Parties. These Parties have an allowance under the Protocol to produce per capita quantities of ODS for their domestic use, some have very large populations, and industrial development is a high domestic priority. As a result, ODS production in these countries could easily cancel out much of the progress made during the first ten years of the phase-out. Thus, the STOC's primary concerns should be the rapid reduction in overall ODS demand by targeting SMEs and eliminating carbon tetrachloride solvent use.

Another challenge is providing awareness and training on both the ozone-depletion problem and solvent sector alternatives.

The freeze in OD solvent production at mid-1999 levels, and production phase-down over the next ten years, pose extremely difficult challenges to many users in Article 5(1) countries. The apparent ease by which the non-Article 5(1) Parties phased out may not be replicated in Article 5(1) countries. The challenges include: the inability to accurately identify products containing ODS, the inability to identify end users, a complex distribution chain, and lack of communications and infrastructure needed to translate technical information into local languages, and distribute the information to large numbers of small and medium size enterprises. Additional challenges include the higher cost of some alternatives, capital costs of new cleaning and waste treatment equipment, and operating costs of alternative processes. Fortunately, most of these costs are eligible for funding through the MLF. A brief description of progress and challenges in some sub-sectors is given below:

- *Metal cleaning* - A speedy phase-out in the metal cleaning sub-sector is hampered by the large number of small users, most of whom are undercapitalised. Trichloroethylene, perchloroethylene, dichloromethane and hydrocarbons (e.g. mineral spirits) do not deplete the ozone layer and offer low operative costs. The undercapitalised metal cleaning enterprises can use them as alternatives for rapid phase-out, provided they take proper workplace exposure, safety and waste solvent disposal measures. Part of this sub-sector is involved with maintenance cleaning, which is not generally addressed by seminars or other outreach programmes. Much large scale metal cleaning has traditionally been done by aqueous or semi-aqueous processes, where the equipment and waste treatment requirements are easily justified by the volumes processed.
- *Precision cleaning* - In precision cleaning applications, users have been aggressively implementing alternatives due to critical end-use requirements. Isopropyl alcohol has turned out to be the preferred choice for many precision cleaning applications because of its good cleaning property (although it does not have a high soil loading capability) and its low cost. However, in some cases users are still searching for solutions to precision cleaning of parts that are especially vulnerable to residues or reactions, or that have unusually stringent cleanliness, cycle time or compatibility criteria. In many of these cases an alternative solvent is the preferred choice.

ES.7.3 Small and Medium Size Enterprises (SMEs)

One of the major problems yet to be resolved is the phase-out of controlled solvents in SMEs, which collectively consume the greatest volume of OD solvents. The SME problem, though common everywhere, assumes serious proportions in Article 5(1) countries. However, some situations are easier to manage, such as Malaysia, Thailand, Indonesia and Mexico, where almost all the SMEs are clustered in one region. Here, SMEs have successfully implemented a phase-out program, mainly through the concept of umbrella projects. In countries like China and India, the SMEs are distributed over a wider range of regions and the immensity of the task of user identification becomes almost impossible.

The SMEs problem is compounded by the fact that some of the alternatives to OD solvents are not produced in Article 5(1) countries, and must be imported. As a result, price and availability become barriers to widespread implementation.

Projected authorisations from the MLF for SME solvents projects can also be difficult to establish. The high cost per kilogram of OD solvents phased out in SME projects as typically above threshold values, due to the capital and operating costs of most replacement processes.

Despite these difficulties, the rate of phase-out rate of OD solvent phase-out by the SMEs has been encouraging, especially in Article 5(1) countries. However, the magnitude of the global ODS phase-out task that remains is significant.

ES.7.4 Carbon Tetrachloride Use in Article 5(1) Parties

Since the last report, the STOC has become aware of very significant use of carbon tetrachloride (CTC) in various cleaning processes in Article 5(1) countries. It is being used in simple open containers which presents not only a serious threat to the health of a large number of workers due to its proven toxic effects, but also to the ozone layer, because of its very high ODP. Such cleaning operations are also coupled with significant spillage of CTC on the floor where it enters the soil, even through cement or concrete, and often contaminates ground water, often a major source of public drinking water. There are a large number of small users in Article 5(1) countries using CTC under very emissive conditions and they have limited resources for change. Developed countries are presently spending large sums to clean soil and groundwater that was contaminated by such practices in the past, and these practices are now illegal in the developed countries.

Some medium and large enterprises use CTC in inadequately sealed vapour degreasing machines, with equal risk to the environment and worker health and safety. It is the preferred solvent for metal cleaning as it is the cheapest, easily obtainable in many countries and is a very efficient as a degreaser.

CTC is widely used in some countries for the dry cleaning of textiles. One STOC member recently witnessed the use of CTC in an old, leaky, rotary drum machine. The clothes removed from the machine were still quite damp with the solvent, but they were immediately passed to workers for pressing with both hand irons and rotary calender machines. The long-term health effects on these operators resulting from dermal absorption and inhalation of CTC are significant.

The committee consensus is that such cleaning processes using CTC must be avoided for many reasons. This is especially true because non-OD alternatives (notably, trichloroethylene and perchloroethylene) that would improve the effects of worker exposure are readily available and could be easily implemented, provided suitable equipment is available. These solvents are not ideal, but they do offer a simple and immediate alternative to ODS, and offer an improvement to workers.

ES.7.5 HCFCs

HCFCs are transition substances that meet the needs of some limited and unique applications where non-OD alternatives have not been identified. These include:

- cleaning delicate materials such as cultural heritage and archival property
- cleaning assemblies or components with sensitive materials or particular soils
- cleaning certain oxygen systems
- cleaning where explosive or flammable conditions are possible
- as a carrier of oil in precision applications.

In countries where HCFCs are prohibited, enterprises may, in certain specific cases, select perfluorinated carbons (PFCs) as an adjunct to specialised cleaning systems. PFCs have extremely long atmospheric lifetimes and have potent global warming potentials (GWPs) and should therefore be avoided where possible.

The Committee does not recommend the use of HCFC-141b to replace 1,1,1-trichloroethane as a solvent. HCFC-141b has an ozone-depletion potential (ODP) comparable to 1,1,1-trichloroethane and is not technically suitable for many cleaning applications.

It is estimated that HCFC-141b and HCFC-225 together will not replace more than 1 percent of global CFC-113 uses unless HCFC-225 becomes a substitute for CFC-113 in dry cleaning, which could increase use to approximately 5 percent. In some countries, HCFC producers are engaged in aggressive marketing efforts. However, only about 5 percent of CFC-113 solvent use (excluding dry-cleaning, which may increase use) may be replaced with HCFC-141b. It is estimated that HCFCs overall may replace only about 1-5 percent of 1986 CFC-113 and 1,1,1-trichloroethane as a short term transitional substances in situations where no other alternatives are currently available.

ES.7.6 Brominated Solvents

Recently, two brominated OD solvents have been commercially introduced: chlorobromomethane (CBM) and n-propyl bromide (nPB). These two substances are also blended into solvent mixtures that are sold under many trade names. They are being marketed as substitutes for non-ozone depleting solvents (trichloroethylene and perchloroethylene) and ozone-depleting solvents (HCFCs, CFC-113 and 1,1,1-trichloroethane).

The UNEP Scientific Assessment Panel recently assigned chlorobromomethane (CBM) an ozone-depleting potential of 0.15, which is comparable to that of 1,1,1-trichloroethane. Additionally, CBM has significant toxicological concerns. The STOC does not recommend the use of CBM as a solvent alternative.

Likewise nPB is ozone depleting. The Committee does not recommend this solvent as a substitute for other OD solvents. This view is further substantiated by the fact that non-OD solutions exist for all cleaning applications for which nPB is being promoted.

ES.7.7 Military Progress

Military organisations in most developed countries have eliminated virtually all uses of OD solvents. The majority of military solvent uses are identical to those found in the commercial sector, and implementation of ODS alternatives in both sectors is virtually complete.

Very few Parties operating under Article 5(1) have provided information to TEAP regarding military ODS solvent uses and on their efforts to find alternatives. With the first control measure coming into force in 1999 for Article 5(1) Parties it is important that military organisations in these countries identify their uses, and begin planning their transition to alternatives. There is a wealth of experience in non-Article 5(1) Parties on specific military uses. Developed country militaries have approved a wide range of alternatives for specific military applications, and are willing to share this information with militaries from Article 5(1) countries in order to simplify the transition. UNEP IE is producing a set of guidelines that capture the experiences from developed country military organisations and offer a framework for Article 5(1) militaries to begin implementing programs to manage their ODS uses.

ES.7.8 Oxygen Systems

Most oxygen systems have components and assemblies with similar functions such as tubing, gauges, regulators, valves, thermal compensators and cylinders. A large variety of metallic and nonmetallic parts are used to fabricate the system devices.

The use of oxygen involves a degree of risk because oxygen vigorously supports combustion when in contact with many substances. Thus a high level of cleanliness is prerequisite for oxygen system components.

CFC-113 was the solvent of choice for many years in cleaning oxygen systems. This solvent displayed performance and safety characteristics that were uniquely suited for the cleaning of oxygen systems.

Progress has been made to introduce alternative cleaning methods without the use of CFC-113. For example, the US Navy and Lufthansa German Airlines have been using aqueous cleaning methods with no processing or operational problems. Some other organisations have started using HFE-7100, HCFC-225, HFC-43-10 and HFC-141b with certain limitations for components used in their oxygen systems. The acceptance of alternatives to CFC-113 by the industry has been slow because of stringent specifications requirements on the degree of cleanliness and its verification. These requirements in many cases have been arbitrarily fixed.

ES.7.9 Sub-Sector Progress

In the following sub-sectors progress has been made to perform almost all tasks without the use of controlled ozone-depleting solvents:

- Electronics cleaning
- Precision cleaning
- Metal cleaning
- Dry cleaning
- Adhesives
- Aerosols solvent products and
- Fingerprinting.

In many applications HCFCs, HFCs and HFEs have replaced the use of CFC-113 and methyl chloroform.

For further details, see the 1998 STOC-Report.

ES.8 Challenges for Article 5(1) and CEIT

Some unresolved issues raised in the past are still pending for both Article 5(1) Parties and CEIT. Several concerns are still to be fully addressed in order to assure the continued success of the Protocol. Some issues are common to both Article 5(1) Parties and CEIT but others are specific either to non-Article 5(1) CEIT or to Article 5(1) Parties, and they are discussed separately in the report.

ES.8.1 Article 5(1) Parties

Capacity to access the enormous amount of information now available varies in Article 5(1) countries. Internet access has made increased the rate at which information is transferred internationally. However, access and language remain barriers, especially for SMEs. It is also important to keep national and international experts informed of technical developments, as well as successes and failures of the technologies offered or transferred to Article 5(1) Parties to avoid unwise choices and implementation delays.

With the freeze of 1999 and the reductions mandated for 2005, Governments are faced with great challenges. Experience from developed countries indicates that strong leadership and commitment from government, industry and individuals is important to establish and maintain momentum. Support from the MLF to strengthen institutions is an important mechanism to educate decision makers and stakeholders in government, industry and the public. During project formulation and implementation, prompt reaction to requests to and from the Implementing Agencies and good cooperation between the Ozone Unit and the Implementing Agencies is also important to accelerating implementation. Data reporting is also important. Accurate consumption data by sector/sub-sector is not available from several Article 5(1) Parties. Many kinds of support, including institutional strengthening, capacity building, information exchange and training are important, but ultimate responsibility lies with Governments to make effective use of this support.

A major obstacle for several Article 5(1) Parties is the inadequacy of the regulatory structure to support the phase-out process. In several Article 5(1) countries the price of ODS is very low and imported alternatives are taxed. Therefore, enterprises which have MLF funded projects finalised may find themselves in a situation where high costs of non-ODS alternatives prohibit them to be competitive with enterprises which still have not converted to non-

ODS. In addition, fiscal cultures that rely on collecting taxes for imported machinery can pose potential problems for MLF projects. Resolving these tax issue adds to project implementation delays because of the need to waive taxes for equipment procured through the MLF.

Uncertainties regarding availability and cost of technology have been mostly resolved. The Montreal Protocol brought high levels of technical innovation and business opportunities. Market strategies were designed to respond to increased consumer awareness in developed countries as well as in several Article 5(1) countries. Environmentally friendly products and better public image by industry brought gains in competitive global and regional markets. Industry creativity, research efforts and cooperation among industry sectors, and widespread adoption of new technologies were successful in lowering costs.

There are now alternatives to replace almost all ODS uses. Therefore, the greatest challenge that remains is the implementation of projects in Article 5(1) countries and ways to address and reach out the large informal servicing sector. In general technology transfer has been very successful with mature, proven technology being transferred to Article 5(1) Parties. Still, even with these technologies, training remains an important part of the projects to assure that technologies are correctly adopted and adapted to local capacity.

It is possible to conclude that the Montreal Protocol has forced the replacement of several mature technologies by many new alternatives. In some cases, these new technologies were easy to identify and offered clear paybacks, as was generally the case in the aerosols sector. However, in other cases, replacements were not as evident, and a number of possible solutions are available and must be carefully evaluated in the context of each specific application.

ES.8.2 CEIT

Many of the 16 non-Article 5(1) CEIT are lagging behind phase-out schedule set by the Montreal Protocol. Their noncompliance was and is going to be discussed by the Implementation Committee and reported to the Parties. The ODS consumption of these countries is decreasing year by year; its quantity in 1998 might be in the range of 10,000-12,000 tonnes.

Some special circumstance hampering timely phase-out still exist in these countries:

- Most CEIT lack the trade and industry associations that typically exist in other countries. The absence of trade and industry associations hampers the phase-out because there is no network of experts and because there is no venue for reaching consensus.

- Information exchange, training and raising of public awareness is necessary to be continued and/or improved. GEF supported projects might serve as proper channel for such activities.
- Governments continue in most CEIT to be challenged to improve inter-agency co-ordination, to introduce or strengthen substantially license and custom control system for ODS and generally to improve enforcement of existing new regulatory measures.

GEF-supported ODS phase-out projects are being implemented or implementation will begin soon in non-complying countries. It can be expected that around 2001 compliance will be accomplished.

Several factors might however challenge the goal of full non-Article 5(1) CEIT compliance by that point of time. The most important ones are:

- To get those states which are not yet Parties to the Protocol involved in the process of the Protocol, including ratification of the Amendments (or of the London Amendment as a minimum);
- To agree on a Special Initiative for funding the phase-out of ODS production in the Russian Federation, and an early start of its implementation;
- That the latest extensive economic difficulties in the Russian Federation and in other CIS countries do not ruin the financial viability of recipient enterprises in these countries.

1 Introduction - Montreal Protocol Process

1.1 Montreal Protocol Developments

In 1981, in response to the growing scientific consensus that CFCs and halons would deplete the ozone layer, the United Nations Environment Programme (UNEP) began negotiations to develop multilateral protection of the ozone layer. These negotiations resulted in the Vienna Convention for the Protection of the Ozone Layer, adopted in March 1985. The Convention provided a framework for international co-operation in research, environmental monitoring and information exchange.

In September 1987, 24 nations, amongst which the United States, Japan, the Soviet Union, certain country members of the European Community, the developing countries Egypt, Ghana, Kenya, Mexico, Panama, Senegal, Togo and Venezuela, as well as the European Community, signed the Montreal Protocol on Substances that Deplete the Ozone Layer. The Protocol was open for signature during one year; 21 more countries signed it during this period, including 9 developing countries. The Montreal Protocol entered into force on January 1, 1989. This international environmental agreement originally limited production of specified CFCs to 50 per cent of the 1986 levels by the year 1998 and called for a freeze in production of specified halons at 1986 levels starting in 1992. By April 1991, 68 nations had already ratified the Protocol: these countries represented over 90 per cent of the 1991 world production of CFCs and halons.

A list of CFCs, halons and other substances as controlled under the original Montreal Protocol and its amendments decided after 1987 (1990, 1992 and 1997) is shown in Table 1.1 (the ODP values represent the current values mentioned in the Annex to the Montreal Protocol).

Shortly after the 1987 Protocol was negotiated, new scientific evidence conclusively linked CFCs to depletion of the ozone layer and indicated that depletion had already occurred. Consequently, many countries called for further actions to protect the ozone layer by expanding and strengthening the original control provisions of the Montreal Protocol, and they decided that an assessment should be carried out in the year 1989.

In June 1990, the Parties to the Montreal Protocol met in London, considered the data from the assessment reports, and agreed to Protocol adjustments requiring more stringent controls on the CFCs and halons specified in the original agreement. They also agreed to amendments placing controls on other ozone depleting substances, including carbon tetrachloride and 1,1,1-trichloroethane. In London, a new assessment was again decided, which was endorsed during the 3rd Meeting of the Parties in Nairobi, 1991; Parties also requested the assessments to be carried out in 1991 for consideration in 1992.

The London Amendment acknowledged the need for financial and technical assistance of the developing countries, and established an Interim Multilateral Fund (the magnitude of which would depend on the fact whether China and/or India would accede to the Protocol).

At their 4th Meeting in Copenhagen, Denmark, 1992, the Parties considered the assessment reports and took decisions that again advanced the phaseout schedules in non-Article 5(1) countries for most ozone depleting substances, including methyl bromide. They continued the financial mechanism and decided a new assessment to be carried out in 1994 (IV/13), for decisions by the Parties in their 1995 Meeting. At the 5th Meeting of the Parties in Bangkok, in November 1993, the Parties decided a replenishment of US$ 510 million for the period 1994-1996. At this 5th meeting, the Parties also decided that the feasibility of control schedules for HCFCs in the Article 5 paragraph 1 countries should be investigated (V/19). With the phaseout date approaching, the Parties discussed the definition of those uses of ozone depleting substances which could be classified as “essential uses” under the Montreal Protocol at their 6th Meeting in Nairobi, in 1994. At this 5th Meeting, the Parties also requested studies on the relative effects of accelerated HCFC and methyl bromide controls for the developed countries.

At the 7th Meeting in Vienna (November 1995) the Parties focused on the progress made in phasing out ozone depleting chemicals, and extensively dealt with the difficulties experienced by Countries with Economies in Transition (CEITs), in particular several successor states to the former Soviet Union. A reduction in the maximum permissible annual consumption of HCFCs (the “cap”) for the developed countries was decided (2.8% instead of 3.1%, as decided in Copenhagen). A control schedule for HCFCs for the Article 5(1) countries was agreed upon (a freeze by the year 2016 and a phaseout by the year 2040). Article 5(1) countries also agreed to freeze their methyl bromide consumption by the year 2005. The Parties, in decision (VII/34), requested a new assessment to be carried out by the Assessment Panels in the year 1998; they also requested a new study for the replenishment of the Multilateral Fund.

At their 8th Meeting in San Jose, Costa Rica, the Parties discussed the Replenishment of the Multilateral Fund, and decided a total funding of US$ 540 million for the period 1997-1999. Updated and more detailed Terms of Reference for the Technology and Economic Assessment Panel (compared to the original 1989 one) were decided and were given in an Annex to the Meeting Report (see below).

The 9th Meeting of the Parties, held in Montreal in September 1997, had not only to deal with a full agenda, but was also set to commemorate the 10th Anniversary of the Montreal Protocol (signed 16 September 1987). The 10th Anniversary of the Protocol was celebrated by the Meeting of the Parties in a separate session (on 16 September, the International Day for the Preservation of the Ozone Layer); a Tenth Anniversary Colloquium was also organised, that highlighted the achievements under the Protocol in separate sessions on natural sciences, social sciences and technology. The most important topics dealt with by the Meeting of the Parties were related to a strengthening of control measures on HCFCs and methyl bromide; they also considered trade restrictions, a licensing system for imports and exports of controlled substances and several other issues. A phaseout schedule for methyl bromide for both the developed and the developing countries was decided (phaseout in 2005 and 2015, respectively, the latter dependent on the results of a review study to be carried out in 2003); no further changes to HCFC controls were decided (see Table 1.2, for the control schedules valid after the Montreal Meeting of the Parties). The outcome of the 9th Meeting in Montreal clearly shows that the focus of the ozone layer protection under the Montreal Protocol has shifted from the strengthening of control schedules towards managing the use of controlled substances, and towards managing non-compliance (also in data reporting).

The 10th Meeting of the Parties, to be held in Cairo in November 1998, will consider quarantine and preshipment uses of methyl bromide, exports of controlled substances to Article 5 Parties, imports of products, the use of process agents and a number of other issues. This meeting also will formally request a study for the determination of the Replenishment of the Multilateral Fund for the period 2000-2002.

The present status (October 1998) is that the Montreal Protocol has been ratified by 167 countries, Parties to the Protocol (the Vienna Convention has been ratified by 168 countries, Equatorial Guinea has only ratified the Convention). The London Amendment has been ratified by 123 Parties and the Copenhagen Amendment by 80 Parties. The Montreal Amendment has been ratified by 2 countries (Canada and Chile) and will enter into force on 1 January 1999 provided that at least 20 instruments of ratification, acceptance or approval have been deposited (or, if this is not the case, 90 days after this requirement has been fulfilled).

1.2 The UNEP Technology and Economic Assessment Panel

Four Assessment Panels were defined in the original Montreal Protocol as signed 1987, i.e. Assessment Panels on Science, and on Environmental Effects, a Technical Assessment and an Economics Assessment Panel. The

Panels were established in 1988-89; their Terms of Reference can be found in the Meeting Report of the 1st Meeting of the Parties, held in Helsinki in 1989. Under the Technical Assessment Panel five Subsidiary Bodies, the so called Technical Options Committees were defined (see Meeting Report Helsinki). The Technical and Economics Assessment Panels were merged after the Meeting in London in 1990 to the Technology and Economic Assessment Panel. At the Meeting in Copenhagen, it was decided that each Assessment Panel should have up to three co-chairs, with at least one from an Article 5(1) country. After the discussions on methyl bromide held at the meeting in Copenhagen, the Methyl Bromide Technical Options Committee was founded at The Hague in early 1993. Since 1993, the UNEP Technology and Economic Assessment Panel (TEAP) has 7 standing Technical Options Committees (TOCs):

1. Aerosols, Sterilants, and Miscellaneous Uses Technical Options Committee
2. Foams Technical Options Committee
3. Halons Technical Options Committee
4. Methyl Bromide Technical Options Committee
5. Refrigeration, AC and Heat Pumps Technical Options Committee
6. Solvents, Coatings and Adhesives Technical Options Committee
7. Economics Options Committee

Where, originally the Panels were considered as the bodies that should carry out assessments pursuant to Article 6 under the Montreal Protocol (at least every four years), it is particularly the TEAP that has become a “standing advisory group” to the Parties on a large number of Protocol issues. The evolving role of the TEAP -and its Technical Options Committees and other temporary Subsidiary Bodies- can be explained by the fact that the focus of the Montreal Protocol has shifted from introducing and strengthening control schedules (based upon assessment reports) to the control of the use of controlled chemicals and to compliance with the Protocol. This implies the study of equipment, of use patterns, of trade, imports and exports etc. A number of specific aspects studied by the TEAP and its TOCs are described below.

The Parties in Copenhagen took a number of decisions which concern the work of the Technology and Economic Assessment Panel and its Committees. A decision (IV/13) on “Progress” requested the TEAP and its TOCs to annually report on progress in the development of technology and chemical substitutes. This decision was re-evaluated and restated in the meeting in

Vienna, in 1995 (VII/34). As a result, progress reports have been conceived annually by the TEAP and its Committees; they were submitted to the Parties in the years 1993 – 98 as part of the annual report of the TEAP (next to the progress reports, the annual reports deal with a large variety of issues on the basis of which Parties have taken certain decisions in the 1993-98 period).

In 1995 a Task Force on CEIT Country Aspects reported to the Parties the specific circumstances of countries with economies in transition (CEITs) with respect to the compliance with the Montreal Protocol. In Vienna, the Parties requested (VII/34) an update report by the end of 1996. This update report was compiled by the TEAP Task Force in the course of 1996 and submitted to the Meeting of the Parties in that same year. It formed an adequate background information for a number of discussions by the Implementation Committee in dealing with non-compliance issues, particularly from countries from the Commonwealth of Independent States, as well as the Baltic countries.

In 1995, a TEAP Working Group on Process Agents drafted a report which was extensively reviewed and submitted to the Open Ended Working Group. On the basis of the information provided, the Parties took a decision "Continued Use of Controlled Substances as Chemical Process Agents after 1996" (VII/10) which allowed to consider the use of process agents as feedstock use for a limited number of years. However, the Parties preferred to further consider the process agent issue after this first report and requested an update report. As a result, a new Process Agent Task Force under the TEAP was established which conducted several meetings in which a report was drafted; this was submitted to the Parties as part of the TEAP April 1997 annual report. Since no further decisions were taken at that stage, the Parties have taken up this issue again in 1998 and are requesting a new report on process agents from a TEAP Task Force in the year 2001.

The 7th Meeting of the Parties in Vienna requested the TEAP to also prepare a report for submission to the 8th Meeting of the Parties, to enable the Parties to make a decision on the appropriate level of the 1997-1999 replenishment of the Multilateral Fund for the implementation of the Montreal Protocol. The Parties directed the TEAP to take into account a large number of aspects of the Montreal Protocol, including all relevant decisions, and to consult with the Executive Committee of the Multilateral Fund and other relevant sources of information during the composition of the report. A Replenishment Task Force was established under the TEAP; this Task Force prepared a report which was part of the June 1996 annual TEAP report. This replenishment report formed the basis for discussions which led to a final decision on the Replenishment of the Multilateral Fund at a level of US $ 540 Million, which decision was taken at the Meeting of the Parties in San Jose, Costa Rica.

In Vienna the Parties also requested the Technology and Economic Assessment Panel *"(e) with regard to its organisation and functioning: (i) proceed with efforts to increase participation of Article 5 country experts, subject to budgetary constraints and to improve geographical and expertise balance; (ii) present procedures and criteria for the nomination and selection of members of the Technology and Economic Assessment Panel; (iii) request the secretariat to appoint a small advisory group from both Article 5 and non-Article 5 Parties to meet with the Technology and Economic Assessment Panel and to report back to the Parties on progress made; and (iv) report to the Parties at the thirteenth OEWG in 1996, including a description of member expertise highlighting relevance, affiliation, country of residence....its methods of operation, including appointment of members to subsidiary bodies, promotion to chair.....options proposed for restructuring the Technology and Economic Assessment Panel and its Technical Options Committees and Working Groups......."*(VII/34). As a result, the Panel met twice with the "Informal Advisory Group", the IAG, chaired by Dr. Kozakiewicz from Poland; the Informal Advisory Group reported back to the Parties that good progress was made in the organisation and functioning of the Panel, and that restructuring of the TEAP was proceeding. As a result, the Panel presented its updated Terms of Reference to the Parties (these are part of the meeting report of the 8th Meeting of the Parties to the Montreal Protocol in Costa Rica, 1996). The TEAP also presented, in each of its annual reports (1996, 1997 and 1998) a disclosure of interests of all its members and an overview of its membership. Currently (status October 1998) the Panel has 23 members (of which three co-chairs) from 17 countries; almost 48% is from Article 5(1) and CEIT countries. The seven Options Committees have at least two co-chairs, one from a developed and one from an Article 5(1) country; both co-chairs are automatically member of the Technology and Economic Assessment Panel.

In Vienna, the Parties also requested *"to offer the assistance of the Scientific, Environmental Effects and Technology and Economic Assessment Panels to the SBSTA, the Subsidiary Body on Science and Technology under the UNFCCC, as necessary"* (VII/34). The current status is that the SBSTA adopted a paragraph under "Methodological Issues; Emission Inventories" at its 8th Meeting in Bonn, 2-12 June 1998, which states: *"The SBSTA recognised that methodological issues arising from the (Kyoto) Protocol including, for example, guidance for estimating and reporting hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride, need to be evaluated.... The SBSTA encouraged the Secretariat to continue its close collaboration with other relevant bodies such as the Technology and Economic Assessment Panel of the Montreal Protocol on Substances that Deplete the Ozone Layer, on technical and methodological issues."*

The request made by the Parties in Vienna on "Control Measures Concerning Halons and Other Measures" (VII/12) was considered by the TEAP and its

Halon Technical Options Committee (HTOC); the TEAP and its HTOC subsequently reported to the Parties in the June 1996 annual report. On the "Availability of Halons for Critical Uses" (VIII/17), the TEAP and its Halon Technical Options Committee reported in the April 1997 annual report. In 1996 and 1997, the Parties requested the TEAP to report on questions relating to the feasibility of, and problems with the early decommissioning of halon systems (VIII/17 and IX/29). TEAP and its HTOC reported on this issue in the April 1998 annual report and elaborated on allocated production, annual emissions and inventories, specifically for Western Europe, Australia, North America and Japan.

As a response to a request made in Vienna, 1995, to describe "Options for a Transitional Strategy for MDIs" (VII/34), the TEAP and its Aerosols TOC updated the 1994 information and provided the Parties with it in the June 1996 annual TEAP report. Parties requested more information on the transition in 1996 via "Promotion of Industry's Participation on a Smooth and Efficient Transition Away from CFC-based MDIs" and "Measures to Facilitate a Transition, etc." (VIII/10 and 11); the TEAP and its Aerosols TOC extensively reported on this transition strategy in the April 1997 annual report. In Montreal in 1997, the Parties requested the Technology and Economic Assessment Panel to continue the work on the transition strategy and to submit the final report to the 10th Meeting of the Parties (IX/19). In response to the above mentioned requests by the Parties, the TEAP and its Technical Options Committee issued the "Final Report on Issues Surrounding a Transition to Non-CFC Containing Treatments for Asthma and COPD and National Transition Strategies" in its April 1998 annual report.

In response to requests of Parties on "Trade in Methyl Bromide" (VII/7) and on "Critical Agricultural Use Exemption of Methyl Bromide" (VII/29) information on methyl bromide was provided in the June 1996 annual report. More information was contained in the April 1997 annual report as a response to requests from the Parties concerning information on "Control of Trade in Methyl Bromide with Non-Parties" and "Critical Agricultural Uses of Methyl Bromide" (VIII/15 and 16). At their 7th meeting in Vienna, 1995, the Parties requested a "Review of Methyl Bromide Controls" (VII/8) and requested the TEAP to prepare a report to the 9th Meeting of the Parties, in order to enable them to consider further adjustments to the control measures on methyl bromide. A Methyl Bromide Task Force also prepared a report on the economic feasibility of alternatives to methyl bromide, which report formed part of the 1997 annual TEAP report. The information provided by the TEAP formed the basis for decisions concerning adjusted control schedules for methyl bromide for both the developed and the developing countries. These decisions were taken at the 9th Meeting of the Parties to the Montreal Protocol (the 10th Anniversary Meeting) in Montreal in 1997. As a result, the control schedules for the different substances as currently valid are given in Table 1.2.

As part of the reporting on "Progress" by the TEAP, it was felt necessary to give more information on the use of flammable refrigerants, since this issue has become gradually more important since the introduction of flammable refrigerants in domestic equipment in the years 1992-1993. A subcommittee out of the TOC Refrigeration reported on the use of flammable refrigerants to the TEAP in 1997, and the report has been part of the TEAP 1997 annual report.

The 1995 Vienna Meeting of the Parties to the Montreal Protocol reconvened the Scientific, Environmental Effects and Technology and Economics Assessment Panels. The three international panels were requested to update their reports on:

- the scientific findings and observations regarding stratospheric ozone depletion and related phenomena and issues;
- the environmental and public health effects of stratospheric ozone depletion;
- the technical feasibility and earliest possible date in each of the major ODS use sectors, of reducing emissions and phasing out production and consumption of controlled (ozone depleting) substances and the related anticipated economic concerns.

The Parties decided "*to request the three Assessment Panels to update their reports of November 1994 and submit them to the Secretariat by 31 October 1998 for consideration by the Open-ended Working Group and by the Eleventh Meeting of the Parties to the Protocol in 1999.".* Together with the Science and Environmental Effects Assessment reports, the 1998 TEAP assessment report and the 1998 TOC assessment reports forms the direct response to the above mentioned decision.

The 1998 Technical and Economic Assessment study has been carried out by the Technology and Economic Assessment Panel and its seven Technical Options Committees. The seven Committees consisted of more than 300 experts from a large number of countries (for a list see the membership list in this report). The 1998 Technical Options Committees consist of several members of the 1991 and 1994 Committees and additional new experts, to provide the widest possible international participation. Much attention was paid to adequate participation by technical experts from Article 5(1) and CEIT countries, dependent upon budgetary constraints. The Technical Options Committee reports have been subject to a limited peer review before final release. The final version of the reports will be distributed internationally by UNEP and will also be available on the Internet at: **http://www.teap.org**

1.3 Adjustment of the focus of TEAP and TOC operations

During the last ten years, the Technology and Economic Assessment Panel and its Technical Options Committees have exhaustively evaluated emerging options to replace ODSs in virtually every application. In many such applications there is now a wide choice of environmentally acceptable and cost-effective options. Whilst the Technology and Economic Assessment Panel retains a broad overview of the technical, practical and economic progress of phase-out, it can be argued that some de-emphasis could be justified within those technical options committees where many environmentally acceptable options already exist and further technical enhancement is unlikely. This would still allow the TEAP to maintain an overview while the remaining TOCs can focus on those areas where technological progress is still rapid.

Overall, there is an opportunity to streamline and re-focus the operation of the TEAP and its TOCs after the 1998 assessment process, and Parties may wish to consider the advantage of authorising the TEAP:

1. To strengthen the membership of TOCs in those sectors where either the applications have inadequate technical options or where there is rapid technical progress; and
2. To dissolve TOCs in those sectors where applications need to be de-emphasised because adequate options are available and technical progress to further evaluate these options is slow; and to retain two or three members from these sectors to serve on the TEAP and as needed organise a temporary Task Force of experts, to respond to special requests from the Parties; and
3. To shift to “advisor status” currently serving TOC experts in sub-sectors that have matured and evolve only slowly.

A refocus of the TEAP and its TOCs should also make it possible to better consider the special circumstances of Article 5(1) and CEIT countries. Within the framework outlined above, TEAP and its TOCs may have more possibilities to undertake and stimulate technology co-operation, particularly via the organisation of workshops and conferences.

Table 1.1
Annex A – Controlled substances

Annex A:	**Controlled substances**	
Group	**Substance**	**ODP***
Group I		
$CFCl_3$	CFC-11 (Trichlorofluoromethane)	1.0
CF_2Cl_2	CFC-12 (Dichlorodifluoromethane)	1.0
$C_2F_3Cl_3$	CFC-113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	0.8
$C_2F_4Cl_2$	CFC-114 (1,2-Dichlorotetrafluoroethane)	1.0
C_2F_5Cl	CFC-115 (Chloropentafluoroethane)	0.6
Group II		
CF_2BrCl	halon 1211 (Bromochlorodifluoromethane)	3.0
CF_3Br	halon 1301 (Bromotrifluoromethane)	10.0
C_2F2Br_2	halon 2402 (Dibromotetrafluoroethane)	6.0

* These ozone depleting potentials are estimates based on existing knowledge and will be reviewed and revised periodically.

Table 1.2
Annex B- Controlled Substances

Annex B:	**Controlled substances**	
Group	**Substance**	**ODP**
Group I		
CF_3Cl	CFC-13 (Chlorotrifluoromethane)	1.0
C_2FCl_5	CFC-111 (Pentachlorofluoroethane)	1.0
$C_2F_2Cl_4$	CFC-112 (Tetrachlordifluoroethane)	1.0
C_3FCl_7	CFC-211 (Heptachlorofluoropropane)	1.0
$C_3F_2Cl_6$	CFC-212 (Hexachlorodifluoropropane)	1.0
$C_3F_3Cl_5$	CFC-213 (Pentachlorotrifluoropropane)	1.0
$C_3F_4Cl_4$	CFC-214 (Tetrachlorotetrafluoropropane)	1.0
$C_3F_5Cl_3$	CFC-215 (Trichloropentafluoropropane)	1.0
$C_3F_6Cl_2$	CFC-216 (Dichlorohexafluoropropane)	1.0
C_3F_7Cl	CFC-217 (Chloroheptafluoropropane)	1.0
Group II		
CCl_4	Carbon Tetrachloride	1.1
Group III		
$C_2H_3Cl_3$*	1,1,1-Trichloroethane* (methyl chloroform)	0.1
	* This formula does not refer to 1,1,2-trichoroethane	

Table 1.3
Annex C: Group I - Controlled Substances

Annex C: **Group**	**Controlled substances** **Substance**	**# of isomers**	**ODP ***
Group I			
$CHFCl_2$	HCFC-21 **	1	0.04
CHF_2Cl	HCFC-22 **	1	0.055
CH_2FCl	HCFC-31	1	0.02
C_2HFCl_4	HCFC-121	2	0.01-0.04
$C_2HF_2Cl_3$	HCFC-122	3	0.02-0.08
$C_2HF_3Cl_2$	HCFC-123	3	0.02-0.06
$CHCl_2CF_3$	HCFC-123 **	-	0.02
C_2HF_4Cl	HCFC-124	2	0.02-0.04
$CHFClCF_3$	HCFC-124 **	-	0.022
$C_2H_2FCl_3$	HCFC-131	3	0.007-0.05
$C_2H_2F_2Cl_2$	HCFC-132	4	0.008-0.05
$C_2H_2F_3Cl$	HCFC-133	3	0.02-0.06
$C_2H_3FCl_2$	HCFC-141	3	0.005-0.07
CH_3CFCl_2	HCFC-141b **	-	0.11
$C_2H_3F_2Cl$	HCFC-142	3	0.008-0.07
CH_3CF_2Cl	HCFC-142b **	-	0.065
C_2H_4FCl	HCFC-151	2	0.003-0.005
C_3HFCl_6	HCFC-221	5	0.015-0.07
$C_3HF_2Cl_5$	HCFC-222	9	0.01-0.09
$C_3HF_3Cl_4$	HCFC-223	12	0.01-0.08
$C_3HF_4Cl_3$	HCFC-224	12	0.01-0.09
$C_3HF_5Cl_2$	HCFC-225	9	0.02-0.07
$CF_3CF_2CHCl_2$	HCFC-225ca **	-	0.025
CF_2ClCF_2CHClF	HCFC-225cb **	-	0.033
C_3HF_6Cl	HCFC-226	5	0.02-0.10
$C_3H_2FCl_5$	HCFC-231	9	0.05-0.09
$C_3H_2F_2Cl_4$	HCFC-232	16	0.008-0.10
$C_3H_2F_3Cl_3$	HCFC-233	18	0.007-0.23
$C_3H_2F_4Cl_2$	HCFC-234	16	0.01-0.28
$C_3H_2F_5Cl$	HCFC-235	9	0.03-0.52
$C_2H_3FCl_4$	HCFC-241	12	0.004-0.09
$C_3H_3F_2Cl_3$	HCFC-242	18	0.005-0.13
$C_3H_3F_3Cl_2$	HCFC-243	18	0.007-0.12
$C_3H_3F_4Cl$	HCFC-244	12	0.009-0.14
$C_3H_4FCl_3$	HCFC-251	12	0.001-0.01
$C_3H_4F_2Cl_2$	HCFC-252	16	0.005-0.04
$C_3H_4F_3Cl$	HCFC-253	12	0.003-0.03
$C_3H_5FCl_2$	HCFC-261	9	0.002-0.02
$C_3H_5F_2Cl$	HCFC-262	9	0.002-0.02
C_3H_6FCl	HCFC-271	5	0.001-0.03

* Where a range of ODPs is indicated, the highest value in the range shall be used for the purposes of the Protocol. The ODPs listed as a single value have been determined from calculations based on laboratory measurements. Those listed as a range are based on estimates and are less certain. The range pertains to an isomeric group. The upper value is the estimate of the ODP of the isomer with the highest ODP, and the lower value is the estimate of the ODP of the isomer with the lowest ODP.

** Identifies the most commercially viable substances with ODP values listed against them to be used for the purposes of the Protocol.

Table 1.4
Annex C: Group II - Controlled Substances

Annex C: Group	**Controlled substances Substance**	**# of isomers**	**ODP ***
Group II			
$CHFBr_2$		1	1.0
CHF_2Br	HBFC-22B1	1	0.74
CH_2FBr		1	0.73
C_2HFBr_4		2	0.3-0.8
$C_2HF_2Br_3$		3	0.5-1.8
$C_2HF_3Br_2$		3	0.4-1.6
C_2HF_4Br		2	0.7-1.2
$C_2H_2FBr_3$		3	0.1-1.1
$C_2H_2F_2Br_2$		4	0.2-1.5
$C_2H_2F_3Br$		3	0.7-1.6
$C_2H_3FBr_2$		3	0.1-1.7
$C_2H_3F_2Br$		3	0.2-1.1
C_2H_4FBr		2	0.07-0.1
C_3HFBr_6		5	0.3-1.5
$C_3HF_2Br_5$		9	0.2-1.9
$C_3HF_3Br_4$		12	0.3-1.8
$C_3HF_4Br_3$		12	0.5-2.2
$C_3HF_5Br_2$		9	0.9-2.0
C_3HF_6Br		5	0.7-3.3
$C_3H_2FBr_5$		9	0.1-1.9
$C_3H_2F_2Br_4$		16	0.2-2.1
$C_3H_2F_3Br_3$		18	0.2-5.6
$C_3H_2F_4Br_2$		16	0.3-7.5
$C_3H_2F_5Br$		8	0.9-1.4
$C_2H_3FBr_4$		12	0.08-1.9
$C_3H_3F_2Br_3$		18	0.1-3.1
$C_3H_3F_3Br_2$		18	0.1-2.5
$C_3H_3F_4Br$		12	0.3-4.4
$C_3H_4FBr_3$		12	0.03-0.3
$C_3H_4F_2Br_2$		16	0.1-1.0
$C_3H_4F_3Br$		12	0.07-0.8
$C_3H_5FBr_2$		9	0.04-0.4
$C_3H_5F_2Br$		9	0.07-0.8
C_3H_6FBr		5	0.02-0.7

* Where a range of ODPs is indicated, the highest value in the range shall be used for the purposes of the Protocol. The ODPs listed as a single value have been determined from calculations based on laboratory measurements. Those listed as a range are based on estimates and are less certain. The range pertains to an isomeric group. The upper value is the estimate of the ODP of the isomer with the highest ODP, and the lower value is the estimate of the ODP of the isomer with the lowest ODP.

** Identifies the most commercially viable substances with ODP values listed against them to be used for the purposes of the Protocol.

Table 1.5
Annex E: - Controlled Substances

Annex E:	**Controlled substance**	
Group	**Substance**	**ODP**
Group I		
CH_3Br	Methyl bromide	0.6

Table 1.6
Summary of control measures for Annex A: Group I controlled substances under the Montreal Protocol

Note: An Article 5(1) Party is a party classified at a meeting of the parties as a developing country and whose annual per capita consumption of Annex A and Annex B substances are below the limits set in Article 5 of the Montreal Protocol.

Annex A – Group I: Chlorofluorocarbons

Applicable to production and consumption

Non-Article 5(1) Parties		*Article 5(1) Parties*	
Base level	1986	Base level	Average of 1995-97
Freeze	July 1, 1989, and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	Freeze	July 1, 1999, and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
75 percent reduction	January 1, 1994, and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	50 percent reduction	January 1, 2005, and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
100 percent reduction	January 1, 1996 (with possible exemptions for essential uses), and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	85 percent reduction	January 1, 2007 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
		100 percent reduction	January 1, 2010 (with possible exemptions for essential uses) and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).

Table 1.7
Summary of control measures for Annex A: Group II controlled substances under the Montreal Protocol

Annex A – Group II: Halons

Applicable to production and consumption

Non-Article 5(1) Parties		*Article 5(1) Parties*	
Base level	1986	Base level	Average of 1995-97
Freeze	July 1, 1992, and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	Freeze	July 1, 2002 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
100 percent reduction	January 1, 1994 (with possible exemptions for essential uses), and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	50 percent reduction	January 1, 2005 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
		100 percent reduction	January 1, 2010 (with possible exemptions for essential uses) and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).

Table 1.8
Summary of control measures for Annex B: Group I controlled substances under the Montreal Protocol

Annex B – Group I: Other fully halogenated CFCs

Applicable to production and consumption

Non-Article 5(1) Parties		*Article 5(1) Parties*	
Base level	1989	Base level	Average of 1998-2000
20 percent reduction	July 1, 1993 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	20 percent reduction	July 1, 2003 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
75 percent reduction	January 1, 1994 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	85 percent reduction	January 1, 2007 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
100 percent reduction	January 1, 1996 (with possible exemptions for essential uses), and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	100 percent reduction	January 1, 2010 (with possible exemptions for essential uses), and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).

Table 1.9
Summary of control measures for Annex B: Group II controlled substances under the Montreal Protocol

Annex B – Group II: Carbon tetrachloride

Applicable to production and consumption

Non-Article 5(1) Parties		*Article 5(1) Parties*	
Base level	1989	Base level	Average of 1998-2000
85 percent reduction	July 1, 1995 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	85 percent reduction	July 1, 2005 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
100 percent reduction	January 1, 1996 (with possible exemptions for essential uses), and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	100 percent reduction	January 1, 2010 (with possible exemptions for essential uses), and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).

Table 1.10
Summary of control measures for Annex B: Group III controlled substances under the Montreal Protocol

Annex B – Group III: 1,1,1-trichloroethane (methyl chloroform)

Applicable to production and consumption

Non-Article 5(1) Parties		*Article 5(1) Parties*	
Base level	1989	Base level	Average of 1998-2000
Freeze	July 1, 1993 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	Freeze	July 1, 2003 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
50 percent reduction	January 1, 1994 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	30 percent reduction	January 1, 2005 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
100 percent reduction	January 1, 1996 (with possible exemptions for essential uses), and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	70 percent reduction	January 1, 2010 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
		100 percent reduction	January 1, 2015 (with possible exemptions for essential uses), and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).

Table 1.11
Summary of control measures for Annex C: Group I controlled substances under the Montreal Protocol

Annex C – Group I: HCFCs

Applicable to production and consumption

Non-Article 5(1) Parties		*Article 5(1) Parties*	
Base level	1989 HCFC consumption + 2.8 percent of 1989 CFC consumption	Base level	2015 consumption
Freeze	1996	Freeze	January 1, 2016
35 percent reduction	January 1, 2004	100 percent reduction	January 1, 2040
65 percent reduction	January 1, 2010		
90 percent reduction	January 1, 2015		
99.5 percent reduction	January 1, 2020, and thereafter, consumption restricted to the servicing of refrigeration and air-conditioning equipment existing at that date.		
100 percent reduction	January 1, 2030		

Table 1.12
Summary of control measures for Annex C: Group II controlled substances under the Montreal Protocol

Annex C – Group II: HBFCs

Applicable to production and consumption

Non-Article 5(1) Parties		*Article 5(1) Parties*	
100 percent reduction	January 1, 1996 (with possible exemptions for essential uses).	100 percent reduction	January 1, 1996 (with possible exemptions for essential uses).

Table 1.13
Summary of control measures for Annex E controlled substances under the Montreal Protocol

Annex E: Methyl bromide

Applicable to production and consumption

Non-Article 5(1) Parties		*Article 5(1) Parties*	
Base level	1991	Base level	Average of 1995-98
Freeze	July 1, 1995 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	Freeze	July 1, 2002 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).
25 percent reduction	January 1, 1999 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	20 percent reduction	January 1, 2005.
50 percent reduction	January 1, 2001 and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).	100 percent reduction	January 1, 2015 with possible critical use exemptions.
70 percent reduction	January 1, 2003, and 10 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).		
100 percent reduction	January 1, 2005 with possible critical use exemptions and 15 percent of base level production allowed to be produced additionally to meet the basic domestic needs of parties operating under Article 5(1).		

2 Recent Global Production and Consumption Data and Estimates for Near Future Usage of Fluorochemicals

2.1 Introduction

This chapter provides data on the global production and consumption for CFCs over the period 1986-1996 and for 1989-1996 for HCFCs. Consumption is defined in the Montreal Protocol. These data have been assembled from chemical manufacturer sources (submitted to the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS) and from data submitted to UNEP by both non-Article 5(1) and Article 5(1) Parties to the Montreal. Much more information has become available since the 1994 TEAP Assessment, reducing the need for extrapolation compared with earlier versions.

The text highlights uncertainty about specific data.

The CFC and HCFC production and consumption has been allocated between:

- the group of all Article 5(1) Parties,
- certain non-Article 5(1) Parties belonging to the OECD group (defined as OECDnA5 in this report, which are the Western European countries, the 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 Central and Eastern European countries).

Using data from several sources (mainly confidential information from fluorocarbon manufacturers) preliminary estimates are given for the global use (and developed country use in several cases) of HCFCs and HFCs during the next twenty years. Section 2.2 describes the data sources for CFC and HCFC production and consumption. Section 2.3 presents available data and makes some observations regarding the use of CFC and HCFC chemicals up to 1996. Section 2.4 presents some estimates for the future use of fluorocarbon chemicals (particularly HCFCs and HFCs).

Halon production estimates are the aggregate from various sources, including CEFIC published data for production in non-Article 5(1) countries, production estimates from HTOC members from Article 5(1) halon producing countries and published estimates of halon production in another Article 5(1) country. Further details are provided in Section 3.8.

2.2 Data Sources for CFC and HCFC Production and Consumption

CFC and HCFC production data from the companies that comprise the AFEAS group have been independently audited. These companies are primarily located in the OECDnA5 group of countries (see definition in section 2.1), however; production in Argentina/Brazil/Mexico/Venezuela is also included. (See the report "Production, Sales and Atmospheric Release of Fluorocarbons through 1996, AFEAS, Washington, D.C., 1996.)

The AFEAS group also reports an estimation of global production and sales of CFCs, and relies on UNEP data for an estimation of the share of the AFEAS HCFC production and sales in the global production.

The UNEP report "Production and Consumption of Ozone Depleting Substances," issued in September 1997 presents data on consumption and production for each of the Parties through 1995. UNEP/OzL.Pro9/ImpCom/20/3 presents updated information for the year 1995 and also for the year 1996. The September 1997 UNEP report was updated and corrected for inconsistencies by the end of July 1998, and submitted to the Refrigeration, AC and Heat Pumps TOC. The latter document presents the most current and thorough information available from the UNEP Ozone Secretariat.

From a combination of sources, reasonably reliable trends for CFC and HCFC production and consumption up to 1996 can be derived. Country programmes have not been taken into consideration, since most do not present data up to 1996.

2.3 Data analysis

2.3.1 CFC production 1986 - 1996

Table 2.1 presents a summary of the information for the production of CFCs from AFEAS and UNEP sources as specified above.

CFC production data published by AFEAS shows a decrease from 895 (1986) to 77 ODP-ktonnes in the year 1996. The AFEAS group contains some companies in Article 5(1) countries. The Article 5(1) production data included by AFEAS can be determined via the UNEP production data. In this way it is possible to calculate the production data for the companies from the developed countries that belong to the AFEAS group (defined as OECDnA5 data, see section 2.1). Subtracting UNEP production data for a country from total AFEAS data yields production data for the OECDnA5. The results show production has decreased from 866 in 1986 to 53 ODP-ktonnes in 1996.

Production data for several groups of countries can be determined using UNEP data. Although there have been fluctuations (after making corrections for the years when data were not submitted) in the production in South and Central America, 1996 consumption is comparable to 1989-1992 production. On the other hand, production in China, India, and Korea has increased, from 41 ODP-ktonnes in 1992 to 85 ODP-ktonnes in 1996. However, the total Article 5(1) CFC production seems to have stabilised over the period 1994-1996.

Total global production as reported to UNEP has sharply decreased, from 1071 ODP-ktonnes (1986) to 160 ODP-ktonnes in 1996.

The OECDnA5 production derived from AFEAS is lower than OECDnA5-production data reported to UNEP for the years 1986-1990 and comparable for the years 1991-1995. However, 1996 production reported to UNEP for the OECDnA5 group is significantly lower (36%) than the production that can be derived via the AFEAS data. The reason for this inconsistency is uncertain.

Total Article 5(1) CFC production amounted to 109 ODP-ktonnes in 1996. OECDnA5 CFC production was estimated at 40-45 ODP-ktonnes for the year 1996. Of this amount a maximum of 8 ODP-ktonnes is for essential uses (including laboratory and analytical applications) and the remainder is for export. This implies that 145-150 ODP-ktonnes production of CFCs was available for consumption in Article 5(1) or available for illegal import to non-Article 5(1) countries.

2.3.2 CFC consumption 1986-1996

CFC consumption data have been derived for groups of countries from data submitted to UNEP. These groups include four South American Article 5(1) Parties, China, India, Korea, and a group defined as “other” Article 5(1) Parties produce CFCs.

Table 2.2 shows the CFC consumption data for the period 1986-1996. Chart 2.1 also presents consumption data of CFCs for 1986, 1992, and 1996. Consumption in Article 5(1) Parties except for China/India/Korea is relatively constant. China/India/Korea show a growth from 1986 through 1995 and a decrease in 1996 (mainly due to a sharp decrease in consumption reported by China).

Total consumption reported to UNEP is in reasonable agreement with Table 2.1 for all non-Article 5(1) and Article 5(1) Parties—consumption of 166 ODP-ktonnes in 1996 and production of 160 ODP-ktonnes for 1996.

The OECDnA5 group reports 8 ODP-ktonnes consumption for 1996, which can be attributed to essential use consumption (this is in agreement with production for essential use discussed earlier in this section).

Consumption for Argentina/Brazil/Mexico/Venezuela is at the same level as production. This implies that these countries will export only small quantities, probably only to other countries in the region.

Production in China/ India/ Korea was smaller than the demand through 1995; this would imply imports from non-Article 5(1) Parties in the order of 0-14 ODP-ktonnes during 1994-1996. It appears that the 30-35 ODP-ktonnes exported from non-Article 5(1) Parties in recent years was largely to Article 5(1) Parties other than China/India/Korea.

The reports indicate that of the total 1996 Article 5(1) consumption of 143 ODP-ktonnes, 109 ODP-ktonnes are produced in these countries. This implies exports of 36 ODP-ktonnes from non-Article 5(1) Parties to Article 5(1) Parties. This is consistent with the figures from 2.3.1. Figure from previous years indicate exports by non-Article 5(1) Parties of 59 ODP-ktonnes (1995), 53 ODP-ktonnes (1994), 71 ODP-ktonnes (1993).

If Article 5(1) Parties continue to produce approximately 110 ODP-ktonnes during 1997-99, non-Article 5(1) exports may decrease rapidly as Article 5(1) Parties will also reduce consumption after 1999, as required by the Protocol.

Chart 2.1

1986, 1992 and 1996 CFC Consumption Data as Reported by UNEP

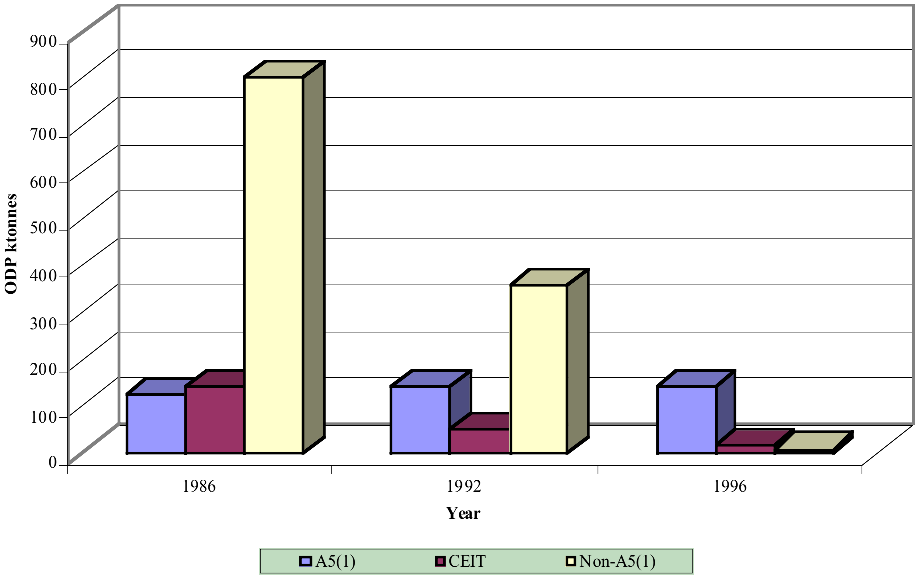


Table 2.1
Historic production data of CFCs, 1986-1996 (Sources UNEP and AFEAS) (ODP-ktonnes or ktonnes)

	1986	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
AFEAS									
AFEAS (kt)[1,2]	976	962	659	605	526	426	234	146	80
AFEAS (ODP-weighted)	895	859	587	544	481	405	221	136	77
UNEP [3] (ODP-weighted)									
Argentina,/Brazil/Mexico/Venezuela	29	24	25	27 (17)[4]	27(17)5	31	35	31	24
China/India/Korea	15	33	35 (21)[6]	40 (26)[7]	41	52	78	78	85
Total Article 5(1)(plus adjustments)	44	57	60	67	68	83	113	109	109
Eastern Europe	107	106	104	84	62	41	43	40	17
OECDnA5 group (incl. S. Africa)	920	879	613	527	461 (449)[8]	360	186	100	349
Total Production (UNEP)									
A5(1) and Non A5(1)	1071	1042	763	678	591	484	342	249	160
OECDnA5 group(UNEP)	909	869	607	522	4578	356	184	99	34
OECDnA5 gr. (AFEAS)	866	835	552	517	454	374	186	105	53
Unallocated	43	34	55	5	3	-18	-2	-6	-20
% OECDnA5 group (UNEP) in total	85	84	80	77	77	74	54	40	21

1 AFEAS normally reports non-weighted ODP production
2 AFEAS data includes production from OECDnA5 group countries and from Argentina/Brazil/Mexico/Venezuela
3 UNEP data contain inconsistencies or anomalies in some reporting years
(some adjustments need to be made for an adequate comparison)
4 Mexico did not report data in 1991 (estimated at 10 ktonnes)
5 Brazil did not report data in 1992 (estimated at 10 ktonnes)
6 India and Korea did not report data in 1990 (estimated at 14 ktonnes)
7 India and Korea did not report data in 1991 (estimated at 14 ktonnes)
8 Greece did not report data in 1992 (estimated at 12 ktonnes)
9 After corrections made by UNEP, 30 July 1998, from 39 down to 34 ktonnes

Table 2.2

Historic consumption data of CFCs, 1986-1996 (Source UNEP) (ODP-ktonnes)

UNEP [1]	**1986**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Argentina/Brazil/Mexico/Venezuela	29	25	26	25	17 [2]	23	28	25	25
China/India/Korea	41	63	42 [3]	50 [3]	81	82	88	92	73
Other Article 5(1) countries	54	53	41	40	52	49	50	51	45
Total Article 5(1) (UNEP data)	124	141	109	115	140	154	166	168	143
Central/Eastern Europe (Russian Federation) [4]	141 (100)	136 (99)	116 (99)	50 (39)	50 (37)	40 (30)	31 (23)	27 (21)	16 (12)
OECDnA5 group	788	740	497	436	352	279	149	67	8
Other non-Article 5(1)	17	15	7	5	8	8	3	3	0
Total Consumption (UNEP) Non A5(1)	958	897	626	493	412	329	183	97	23
Un-allocated [5]	12	6	6	2	2	2	0	0	-1
Total Consumption non- A 5(1) and A 5(1) (UNEP)	1070	1032	729	606	550	481	349	265	167
% OECDnA5 in total	73	72	68	72	64	58	43	25	5

1. UNEP data often lacks full data reporting, particularly from developing countries
2. Brazil did not report 1992 data
3. India and Korea did not report the 1990 and 1991 data
4. Consumption in Russia significantly changes after CIS has been formed; consumption reported by Russia is lower than estimated by the TEAP Task Force in 1995; the Task Force estimated for 1994 consumption by Russia of 34 kt and for all CIS and Baltics 42 ktonnes; estimates for Russia for 1990 and 1992 were 67 and 36 ktonnes, respectively
5. Separate totals calculated from UNEP country data; non-allocated implies the difference in the totals calculated and the official UNEP- totals

2.3.3 HCFC Production Data 1989-1996

Table 2.3 presents a summary of AFEAS and UNEP HCFC production data. HCFC-123 and -124 are not included in AFEAS data, due to AFEAS reporting criteria. However, HCFC-124 production could significantly increase if adopted as an interim replacement for HCFC-141b as a blowing agent.

AFEAS data shows an increase in HCFCs production from 12,743 ODP-tonnes in 1989 to 30,822 ODP-ktonnes in 1996. The increase from 1994 to 1995 was largely due to an increase in HCFC-141b production, and the increase from 1995 to 1996 was largely due to an increase in HCFC-22 production.

UNEP data shows production for several groups of countries. Argentina/Brazil/Mexico/Venezuela production did not increase from 1992-1995, but increased by 20% in 1996. 1997 data is not yet available. From 1989-1993, production in China/India/Korea increased sharply, but has since stabilised. As a result, the total Article 5(1) production data do not show significant changes from 1994-1996.

UNEP global production data show an increase from 24.7 ODP-ktonnes in 1994 to 26.3 ODP-ktonnes in 1996, a moderate increase of 6%. However, there are inconsistencies in data collection and reporting that may affect the accuracy of the figures. Data were corrected to account for the lack of Japanese data for 1994 and 1995, and the US government data reported by manufacturers differ from the data reported by UNEP.

Comparing the OECDnA5 group production data reported to UNEP with the OECDnA5 production data reported by AFEAS, there is reasonable agreement for the years 1989, 1993, 1994 and 1995 (less than 5% differences).

However, the production data reported to UNEP for the year 1996 is significantly lower than the data reported by AFEAS. HCFC production for OECDnA5 countries reported by UNEP for 1996 is about 15% lower than the one reported by AFEAS. It seems likely that the data submitted to UNEP are not complete, particularly since there is a decrease in HCFC ODP-weighted production from 1995 to 1996, which seems unrealistic. It may be that an update of the data reporting will explain these differences (the same type of inconsistency can also be observed for the year 1992, which has so far been impossible to explain).

The percentage of the global HCFC production that is taking place in the OECDnA5 group of countries amounts to 92-106%, according to UNEP and AFEAS based estimates.

2.3.4 HCFC consumption data 1989-1996

HCFC consumption data have been derived for groups of countries from data submitted to UNEP.

Table 2.4 shows the consumption data for HCFCs for the period 1989-1996. Chart 2.2 also presents consumption data of HCFCs for 1989, 1992, and 1996. Consumption of HCFCs has been increasing for almost the entire period 1989-1996. The consumption in the countries China/India/Korea is relatively constant during the period 1994-1996 (it cannot be predicted whether this trend will continue after 1996). For "other" Article 5(1) Parties, the increase in consumption is substantial during the period 1994-1996 (95 and 37% per annum increase, respectively). A reason for this sharp increase is difficult to explain it may be related to a conversion from CFCs to HCFCs (since CFC consumption in these countries has not increased, actually decreased during 1994-1996, however by a relatively smaller amount of 10%).

As can be observed, the total consumption in Article 5(1) Parties as reported to UNEP has always been substantially larger than the total production in Article 5(1) Parties (with smaller differences for China/India/Korea).

In this report, the total consumption data for all countries have been determined from data for country groups and from totals published by UNEP. If certain inconsistencies (particularly the non-data reporting by Japan in 1994 and 1995) are corrected for, some years production figures are larger than consumption figures (1993, 1994, 1996), for other years consumption figures are larger than the figures for production (1989, 1992, 1995) (6% larger). Table 2.4 shows that 1994 and 1995 consumption of HCFCs in the OECDnA5 group of countries is 83% of the global total consumption.

Assuming that production in Central and Eastern Europe is not exported to Article 5(1) Parties, 5 - 8 % of the HCFCs produced in non-Article 5(1) countries is exported to Article 5(1) Parties. This percentage seems reasonable when taking into account that the OECDnA5 group of countries consumes 83% of the global production (and Article 5(1) Parties have an 8-10% share in the global production).

Chart 2.2
Historic consumption data of HCFCs as reported by UNEP for 1989, 1992 and 1996

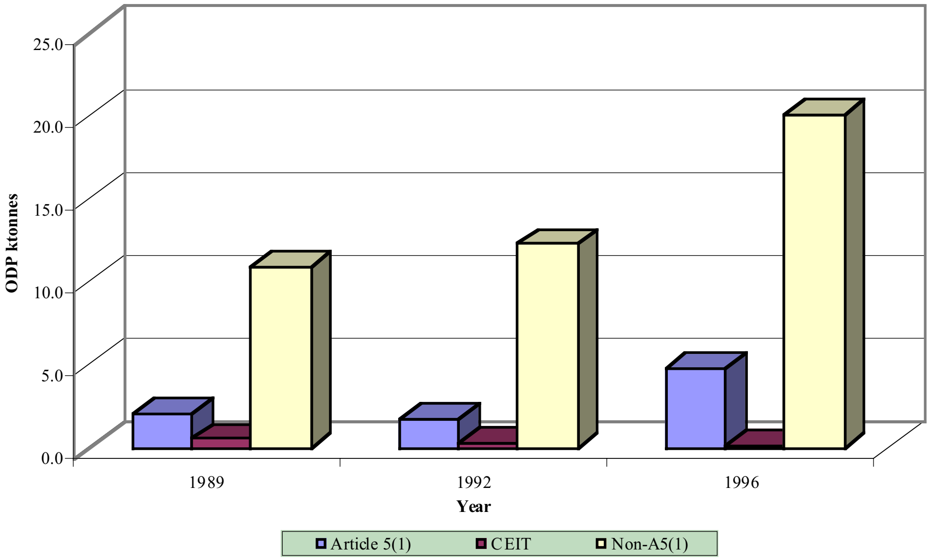


Table 2.3
Historic production data of HCFCs (tonnes or ODP-tonnes), 1989-1996 (sources UNEP and AFEAS)

	1989	1992	1993	1994	1995	1996
AFEAS						
AFEAS [1]	229825	289759	318134	359948	398430	435308
AFEAS (ODP-weighted)	12743	16969	20197	24618	28422	30822
UNEP [2] (ODP-weighted)						
Argentina/Brazil/Mexico/Venezuela	353	475	461	452	421	505
China/India/Korea	249 [3]	731	1212	1840	1877	1831
Total Article 5(1) (plus corrections)	602	1206	1673	2292	2298	2336
Eastern Europe	1084	267	172	198	184	74
OECDnA5 (including South Africa)	12181	12469	10078 [4]	20220	25335 [9]	26264 [9]
Total A5(1) & Non A5(1)	13867	13942	11923	22710	27817	28674
Total (UNEP) adjusted						
A5(1) & Non A5(1)	13867	13942	20875 [4]	27266 [5]	30180 [6 7]	28674
OECDnA5 group(UNEP)	12181	13232	18946	24689 [5]	27641 [6 7]	26264
OECDnA5 group(AFEAS)	12390	16494	19736	24166	28001	30317
Unallocated	-209	-3262	-790	523	-360	-4053 [8]
% OECDnA5 (UNEP) in total	88	95	91	91	92	92

1. AFEAS data includes production from OECDnA5 countries and from Argentina/Brazil/Mexico/Venezuela
2. UNEP data contain inconsistencies or anomalies in some reporting years (some adjustments need to be made for an adequate comparison)
3. China did not report data for 1989 (data have not been estimated)
4. USA did not report data for 1993 (data estimated in the OECDnA5 group total)
5. Japan did not report data for 1994 (data estimated from the 1993/96 profile)
6. Japan did not report data for 1995 (data estimated from the 1993/96 profile)
7. OECD data were corrected for the US contribution for 1995 (UNEP mentions 14893 ODP tonnes for 1995 where manufacturers submitted 12503 ODP tonnes to the US government)
8. The difference in 1996 may originate from incomplete data reporting to UNEP (1998 status)
9. After corrections made by UNEP, 30 July 1998, a reduction of 197 ODP-tonnes in 1995, and an increase of 680 ODP-tonnes in 1996

Table 2.4

Historic consumption data of HCFCs, 1989-1996 (Source UNEP) (ODP-tonnes)

	1989	1992	1993	1994	1995	1996
UNEP [1]						
Arg/Brazil/Mexico/Venezuela	418	423	642	769	971	866
China/India/Korea/	991	748	1407	2140	2392	2265
Other Article 5(1) countries	623	591	693	616	1203	1646
Total Article 5(1) (UNEP data)	2032	1762	2742	3525	4566	4777
Central/Eastern Europe (Russian Federation) [2]	564 (437)	316 (267)	258 (172)	228 (107)	259 (84)	195 (73)
OECDnA5 group	10605	12009	15727	21684 [3]	26780 [3]	19780 [4]
Other non-Article 5(1)	290	271	353	469	471	324
Total Consumption (UNEP) Non A5(1)	12152	12641	16392	18214	23338	20300
Non-allocated [5]	693	45	54	-4347	-4172	1
Total Consumption non- A 5(1) and A 5(1) (UNEP)	14184	14403	19134	21739	27904	25077
% OECDnA5 in total (UNEP)	75	83	82	84	83	79

1. UNEP data often contains a lack of reported data in several years, particularly from developing countries
2. Consumption in Russia significantly changes after CIS has been formed
3. Japan did not report data in 1994 and 1995 (estimated at 4170 ODP tonnes)
4. Decrease in consumption due to decrease in reported EC consumption from 1995 to 1996 (4494 ODP tonnes)
5. Separate totals calculated from separate UNEP country data; unallocated implies the difference in the totals calculated and the official UNEP- totals

2.3.5 HCFC consumption in sectors

According to the 1996 AFEAS data, the largest ODP consumption was in the foams sector (HCFC-141b). Table 2.5 shows some percentages for the different HCFC chemicals for the year 1996, taken from the 1996 AFEAS report. Chart 2.3 also presents consumption of HCFCs for 1996 by application as reported by AFEAS.

T able 2.5
1996 use of HCFCs in different sectors

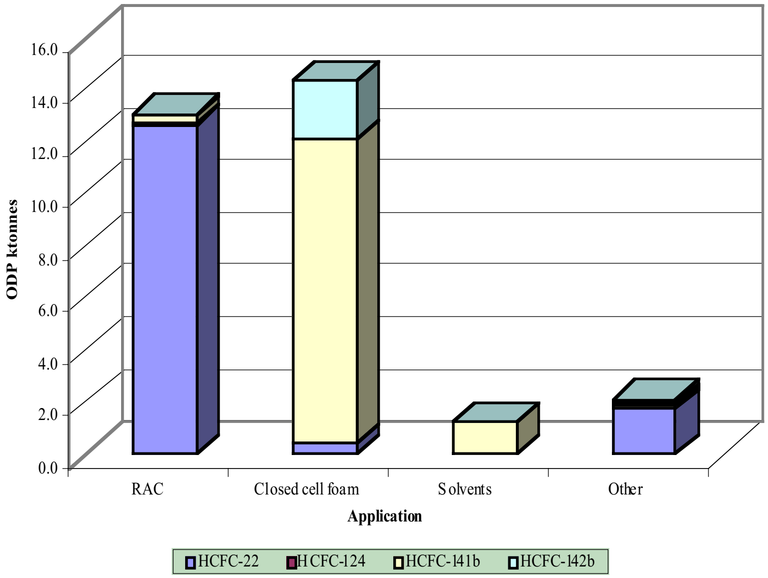
	HCFC-22	**HCFC-141b**	**HCFC-142b**	**HCFC-124**	**Total**
RAC	84.9%	2.2%	3.0%	48.3%	42%
Closed cell foam	3.0%	87.6%	91.8%		47%
Solvents		9.3%	-		4%
Others	12.1%	0.9%	5.2%	51.7%	7%
RAC	12670	288	72	52	13082
Closed cell foam	445	11644	2274	-	14363
Solvents	-	1240	-	-	1240
Others	1797	124	161	55	2137
Totals	**14912**	**13296**	**2507**	**107**	**30822**

Source: AFEAS - in percentages per HCFC and in ODP tonnes.

In ODP-tonnes, the largest use of HCFCs is in the rigid (closed-cell) foam sector. A comparable amount in ODP tonnes is consumed in the refrigeration and air conditioning sector, mainly due to the use of HCFC-22.

Partly based on this data and trends in production and consumption data described earlier, estimates can be made for future use. As a starting point, the production in AFEAS reported companies of 435 metric ktonnes, or 30.8 ODP weighted ktonnes can be taken.

Chart 2.3
Consumption of HCFCs by application for 1996 as reported by AFEAS



2.4 Estimates for future use of chemicals

2.4.1 HCFC chemicals

In this section, estimates are given concerning the future global consumption of HCFCs (and HFCs) by using:

- extrapolated data from fluorocarbon manufacturers;
- information from UNEP data reporting;
- data from the 1998 UNEP TOC Refrigeration and Foams Assessment Reports and from earlier TOC reports; and
- assumptions on the replacement of CFCs and HCFCs.

Efforts have been undertaken to estimate the global HCFC consumption for 1997-2015. Several manufacturers provided (on a confidential basis) their best estimates for the consumption of HCFCs (sometimes split up over different application areas). Data on the future consumption of HFCs were also submitted (on a confidential basis). Both data have been used to derive a “best guess” scenario for future global consumption of HCFCs and HFCs, by averaging the different forecasts. HCFC-123 and HCFC-124 production data could not be used since only one manufacturer produces these chemicals (not included in historic AFEAS data either).

The AFEAS reported HCFC production quantity was 435 metric ktonnes for all uses in 1996. Table 2.6 shows the estimated future HCFC use, both globally and for developed countries.

Table 2.6
Estimates of total HCFC consumption and
HCFC consumption in non-Article 5(1) Parties (ktonnes)

Year	**1997**	**1998**	**2000**	**2005**	**2010**	**2015**
Total Consumption	404	412	387	258	204	163
Developed Countries Total Consumption	323	330	293	155	80	55
Developed Countries Refrigeration / AC Consumption	126	231	214	118	60	40

This table also includes figures for the consumption in the non-Article 5(1) countries for refrigeration/AC

It should be noted that the differences between the values submitted by the different manufacturers were large. The values given in the table have been averaged over the data provided. For the years 2005-2015 lowest and highest estimates have therefore been discarded (the year 2015 has been selected since it is the year for when HCFC consumption should be reduced by 90% relative to the base allowable level under the Montreal Protocol). In this model the significant decrease in developed countries' consumption of HCFCs after 2000 has to been attributed to a phaseout in the production of closed cell foams using HCFC-141b. This aspect is well reflected in Figure 2.1 which illustrates the likely future regional trends in HCFC-141b use for rigid foams.

It should also be observed that the estimates for Article 5(1) consumption (from the difference between the global and the developed countries consumption) are larger than the capacity used for production in 1996, although not substantially. It is uncertain how Article 5(1) production capacity will grow during 1998-2010, if at all.

It should be noted that the HCFC consumption for refrigeration and A/C uses is assumed to remain at a level of 40 ktonnes in the year 2015 in the developed countries, which may be somewhat over-estimated.

The above model estimates are based upon an approach that takes into account recent experience from the market with certain likely reductions factored in (phaseout of HCFC-141b etc.) known at this stage.

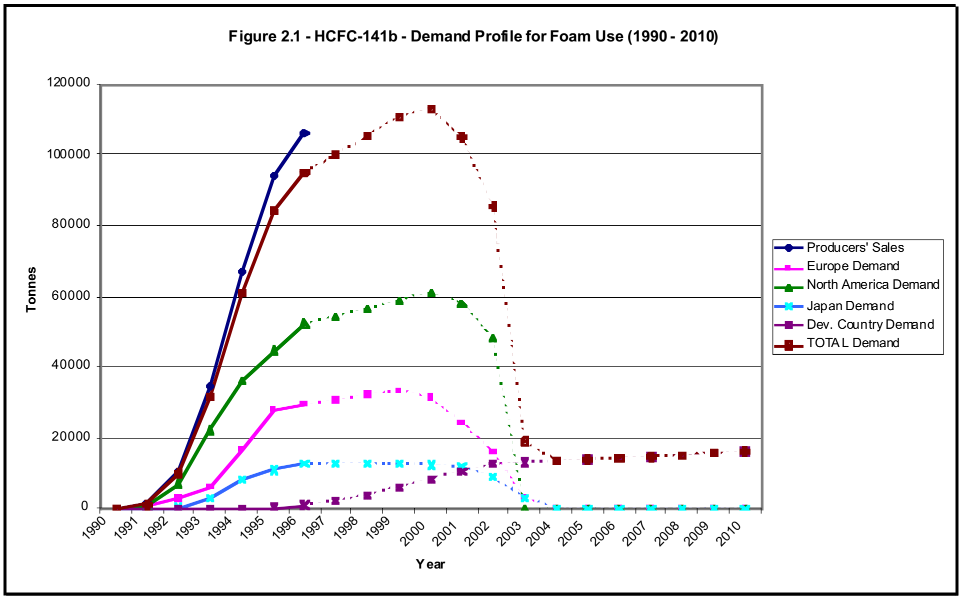


Figure 2.1 - HCFC-141b - Demand Profile for Foam Use (1990 - 2010)

2.4.2 HFC-chemicals

AFEAS, in its 1996 report, published data on the production of HFC-134a (in metric tonnes) and the volume of sales to the Refrigeration/AC sector. These are shown in Table 2.7.

Table 2.7
Historic HFC-134a production (ktonnes)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Total	0.2	2.2	6.4	26.5	50.4	73.8	83.7
Refrigeration/AC	0.08	2.1	6	24.5	46.1	61.3	71
% total Refrigeration/AC	41%	97%	93%	92%	92%	83%	85%

Where the table shows a continuous growth in HFC-134a production over the period 1990-1996, percentage growth for the years 1995 and 1996 were 45% and 13% respectively (with production of about 74 and 84 ktonnes). The major proportion is used in the refrigeration and air conditioning sector, although its share is slightly decreasing in 1995 and 1996 compared to previous years.

Several manufacturers have provided estimates of future consumption of HFC chemicals, both for HFC-134a and for other HFC chemicals (HFC blends in refrigeration, HFCs in foams and HFCs in other uses). Results are presented in Table 2.8, both for global total use and for global use in the refrigeration and A/C sector.

Table 2.8

Estimates for HFC consumption (ktonnes)

Year	**1997**	**1998**	**2000**	**2005**	**2010**	**2015**
Total HFC-134a	87	103	127	163	187	207
Total Refrigeration/AC HFC-134a (% in total)	69 (79%)	79 (77%)	99 (78%)	128 (79%)	154 (82%)	174 (84%)
Total other HFCs	10	18	29	77	110	133
Total Refrigeration/AC other HFCs (% in total)	9 (90%)	14 (78%)	22 (76%)	50 (65%)	74 (67%)	96 (72%)

Note: The table does not take into account consumption of HFCs such as HFC-152a

The figures show an increase of about 250% over the period 1997-2015 for the use of HFC-134a in all uses (from 87 to 207 ktonnes). The same growth percentages also apply to refrigeration and air-conditioning uses. These growth estimates should be considered against a decrease in HCFC consumption over the period 2000-2015. The use of HFC chemicals other than HFC-134a is also predicted to significantly increase over the period. For the refrigeration and air conditioning sector, the large expected increase in the use of "other HFCs" can be balanced against a decrease in the use of HCFC chemicals.

In Table 2.8, the consumption of certain HFCs such as HFC-152a, has not been included (although this may constitute 40 - 50 ktonnes for 1997-2015). Their consumption has not been reported due to an inadequate set of data.

2.5 Carbon Tetrachloride

2.5.1 Data Sources for CTC Production and Consumption

Data on CTC production and consumption have been difficult to obtain due to confusion over feedstock, process agent uses, and solvent uses (production plus imports of CTC should be equal to consumption plus feedstock uses plus exports).

Global CTC production had not been reported before the Montreal Protocol was ratified. Data collection under the Montreal Protocol provided information and a better understanding of the uses of this chemical. The main use of CTC is as feedstock in manufacturing CFC-11 and -12. This use is not regulated directly by the Montreal Protocol. It is possible to estimate some of the CTC feedstock use by using data provided by the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS) for the production of CFC-11 and -12 in countries that have companies reporting to AFEAS. Current new UNEP data reporting formats will enable the collection of much clearer data.

2.5.2 CTC Production

In its 1994 Assessment Report ATOC estimated that the production of CTC for feedstock use in countries that have companies that report to AFEAS as 493 kilotonnes in 1992. AFEAS estimated that 18-31% of global CFC production was not included in its report. From these figures the global 1992 CTC production can be roughly estimated as 660 kilotonnes.

1995 CTC production figures reported to UNEP add up to a global total of 99 ODP kilotonnes, but these do not include all CTC production for feedstock use, since some Parties reported production for feedstock uses and others did not. For 1996, UNEP figures were collected with the new formats and they now include production for both feedstock and non-feedstock uses. Total global production for 1996 can be confidently pegged at a total of 203.8 ODP kilotonnes. Of these, 113.3 ODP kilotonnes were produced in non Article 5(1) Parties and 90.5 ODP kilotonnes were produced in Article 5(1) Parties.

2.5.3 CTC Consumption

Estimating CTC consumption is more difficult than estimating production. The 1995 figures reported by Parties to UNEP are discussed in the 1998 ATOC Assessment Report as it seems that some Parties included feedstock uses as consumption, whereas in other cases negative consumption values are listed. Negative consumption values are to be expected for countries that either export CTC or that have large feedstock uses. From the 1998 ATOC Assessment Report it can be estimated that global consumption of CTC is less than 5 ODP kilotonnes; this figure does not include either Feedstock or Process Agent uses. It is comparable to previous estimates by the ATOC that non-Feedstock Use of CTC is about 3 to 5% of the CTC production. Non-Feedstock and non-Process Agent Uses of CTC include Laboratory and Analytical Uses, and other solvent uses.

2.6 Methyl Chloroform (1,1,1-Trichloroethane)

2.6.1 Data Sources for MCF Production and Consumption

UNEP has reported data provided by Parties for the period from 1989 to 1995; these figures are ODP weighted (methyl chloroform has an ODP of 0.1).

2.6.2 Production of MCF

UNEP 1989 figures report production of 63.6 ODP kilotonnes, of which 62.4 kilotonnes were manufactured in non-Article 5(1) Parties (98.1%) and 1.2 kilotonnes were produced in Article 5(1) Parties (1.9 %). In 1995, production had decreased to 11.5 ODP kilotonnes of which 11.4 ODP kilotonnes were manufactured in non Article 5(1) Parties (98.7%) and only 0.1 ODP kilotonnes were produced in Article 5(1) Parties (1.3 %) since production in Brazil was halted. With the 1996 phaseout in non-Article 5(1) countries, the production of MCF has been reduced further.

2.6.3 Consumption of MCF

UNEP figures for consumption in 1989 match reasonably those reported for production. Thus, a total consumption of 64.9 ODP kilotonnes were reported, of which 60.1 ODP kilotonnes were consumed in non Article 5(1) Parties (92.5%) and 4.9 ODP kilotonnes were consumed in Article 5(1) Parties (7.5 %). A significant consumption decrease took place between 1989 and 1995. However, the figures reported for consumption in 1995 are slightly larger than those reported for production for that year, which probably reflects the depletion of inventories. Figures for the 1995 global consumption are 15.6 ODP kilotonnes of which 12.8 ODP kilotonnes were used in non Article 5(1) Parties (82.2%) and 2.8 ODP kilotonnes were used in Article 5(1) countries (17.8%).

2.7 Methyl Bromide

2.7.1 Supply

Methyl bromide (MB) has a boiling point of 4°C under normal atmospheric pressure. It is normally supplied and transported as a liquid in pressurised steel cylinders or cans. Typically cylinders range in size from 10 - 200 kg capacity. There is also trade in larger cylinders of up to 18 t capacity and in small disposable steel cans, typically of 0.4 – 1 kg capacity.

Decision VIII/14 recognises supply in all of these forms as “trade in bulk.” MB is usually applied directly from the cans or cylinders in which it is transported; though it may also be decanted from large cylinders for direct application. Decanting is not permitted in some countries. Supply in small disposable cans may also be permitted in some countries.

2.7.2 Production

Estimates of MB production from 1984 to 1996 are given in Table 2.1. The table includes production figures previously reported by MBTOC together with estimates of production for chemical feedstocks. MBTOC did not obtain data on production in the Democratic Republic of Korea.

Table 2.9
Gross production of methyl bromide

Year	North America	Europe	Asia	China, India & Former USSR	Other	Total Production	Feedstock	Fumigant
1984	19,659	11,364	10,678		3,871	45,572	3,997	41,575
1985	20,062	14,414	9,743		4,054	48,273	4,507	43,766
1986	20,410	13,870	11,278		4,897	50,455	4,004	46,451
1987	23,004	15,339	12,816		4,531	55,690	2,710	52,980
1988	24,848	17,478	13,555		4,729	60,610	3,804	56,806
1989	26,083	16,952	14,386		5,149	62,570	2,496	60,074
1990	28,101	19,119	14,605		4,074	65,899	3,693	62,206
1991	31,924	18,020	17,396	3,160	6,260	76,760	4,071	72,689
1992	29,466	18,521	16,944	4,040	6,654	75,625	2,658	72,967
1993	30,723	18,286	17,185	1,500	6,463	74,157	3,000	71,157
1994	31,981	18,052	17,427	890	6,271	74,621	3,000	71,621
1995	28,965	16,350	15,784	2,078	5,680	68,857	2,458	66,339
1996	29,679	16,753	16,173	3,000	5,820	71,425	2,759	68,666

Data Sources:
1991 – 1996 Production for China, India & former USSR (MBTOC estimates)
1984 – 1992 Production for all other regions (MBTOC 1994 Assessment)
1993 – 1996 Production for all other regions (Consultancy Study for UNEPA by ICF)
1993 – 1994 Production for Feedstock (MBTOC estimates)
1995 - 1996 Production for Feedstock (Figures supplied to UNEP by Parties)

Global sales of MB, excluding China, India and former USSR, for major use sectors, were reported in the 1994 MBTOC Assessment. These data cover the 1984–1992 period.

Table 2.10
Methyl bromide production as reported to UNEP by the Parties

Party	**"Base"**	**1992**	**1993**	**1994**	**1995**	**1996**
France	3,649				3,294	4,458
Israel	24,500				24,213	23,678
Japan	5,627				5,270	5,015
Romania			4	21	36	18
USA	31,826			28,215	23,941	26,866
Ukraine	0				1,402	1,402
China						1,100
Total	65,602	0	4	28,236	58,156	62,537

Source: UNEP Data

2.7.3 Consumption and usage

2.7.3.1 Comparison of production with consumption

There are discrepancies the data on production and consumption that MBTOC was able to obtain from various sources. Parties to the Montreal Protocol report to UNEP figures for both production and consumption. In Table 2.1 figures for 1995 and 1996 are given that were obtained by ICF for a report commissioned by the US-EPA. A comparison between the various figures is given in Table 2.3. It can be seen that the discrepancies between the figures are not large, but that the reported production figures are lower than both reported consumption and production figures generated by ICF. Discrepancies are attributable to inventory changes, trade with non-Parties and differences in reporting procedures.

Table 2.11

Comparison of Production and Consumption Figures

Category of Information	**Source**	**1995**	**1996**
Gross Production figures	Reported by the Parties	58,155	62,537
Gross Production figures	Estimated by MBTOC and for US-EPA by ICF	68,857	71,425
Gross Consumption[1] figures	Estimated from data provided on official government letterhead	67,706	66,749
Gross Consumption[1] figures	Estimated from UNEP Ozone Secretariat data	67,743	64,910

[1] Based on import data including QPS in most cases.

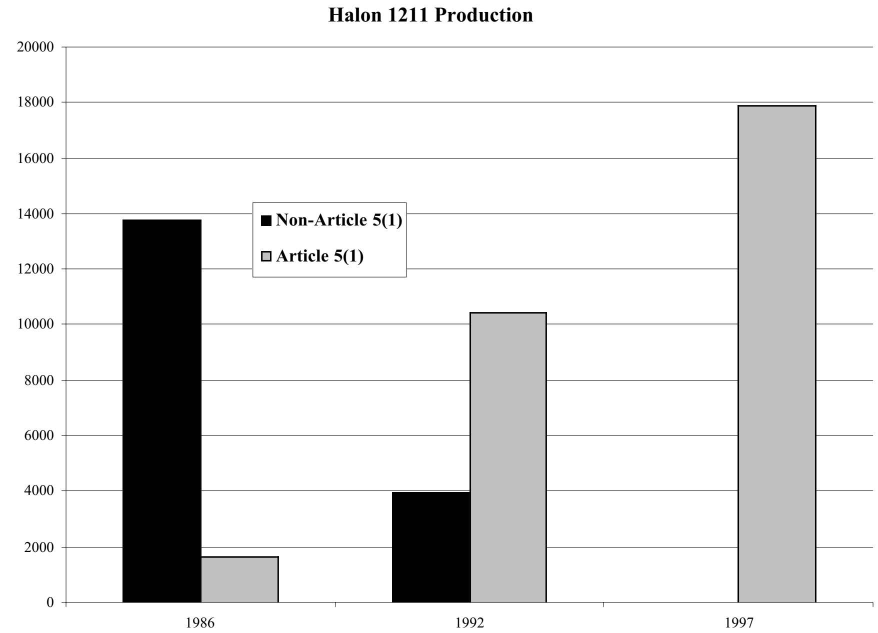
2.7.3.2 Usage by sector

MBTOC notes that there has not been a significant shift in consumption by sector from 1992 to 1998 and thus the proportions have remained approximately constant during that period. For the purposes of calculation, proportions of usage are the same as those provided in MBTOC (1995) which were 75% of MB use for soil treatment, 16% for fumigation of durable commodities and structures, and 9% for perishable commodities.

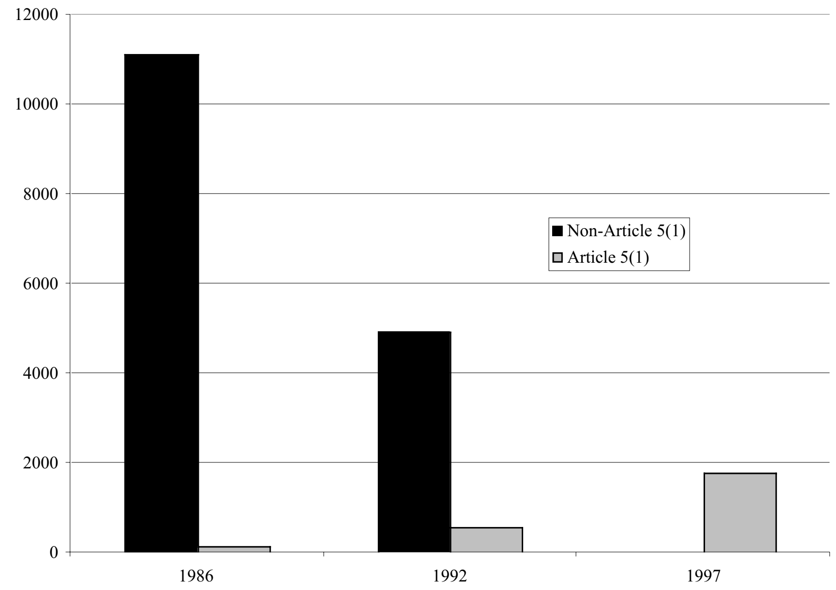
2.8 Halons

2.8.1 Halon production

Halon production estimates are the aggregate from various sources, including CEFIC published data for production in non-Article 5(1) countries, production estimates from HTOC members from Article 5(1) halon producing countries and published estimates of halon production in another Article 5(1) country. Preliminary data was presented in the Spring 1998 TEAP Report. Preliminary data did not include Article 5(1) production data. The most recent update now includes production data for Article 5(1) countries, as well as non-Article 5(1) countries. A complete data set is provided in the 1998 Assessment Report of the Halons Technical Options Committee.



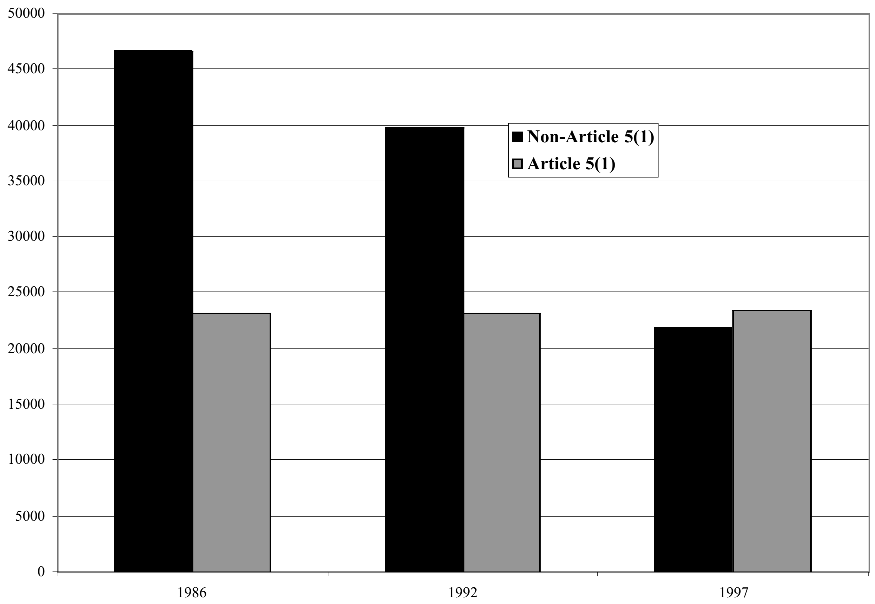
Halon 1301 Production



2.8.2 Halon Emissions

Halon emissions estimates were calculated using the updated computer program “Bank” developed by the Halons Technical Options Committee. Preliminary data was presented in the Spring 1998 TEAP Report. Preliminary data did not include Article 5(1) halon emissions. The most recent update now includes emission estimates for Article 5(1) countries, as well as non-Article 5(1) countries. Full calculations are provided in the 1998 Assessment Report of the Halons Technical Options Committee. The term “controllable emission” refers to the total of all halon emissions, except use on fires.

ODP Weighted Controllable Halon Emissions



3 Lessons learned and challenges for the future

This chapter describes the different technological stages in a process that has sought to control the consumption and, where possible, the emissions of environmentally damaging ozone depleting chemicals. It focuses on how control measures have been managed for CFCs, HCFCs and other halogen containing chemicals used in aerosols, foam blowing, fire fighting, fumigation, refrigeration and air conditioning, and for various solvent uses. It also looks at the generic challenges facing the process in future. Chapter 4 looks more specifically at the challenges facing Article 5(1) countries and Countries with Economies in Transition (CEIT).

3.1 The sector overviews

3.1.1 Aerosols

The aerosols sector accounted for about 60 % of the total use of CFC 11 and 12 in the mid 1970s. CFCs 113 and 114 were also used, but in much smaller quantities. CFCs served mostly as aerosol propellants, but in many cases also were used either as solvents or as active ingredients. They were contained as liquids under pressure inside the aerosol cans, and as propellants ensured a relatively constant pressure while the package was used. CFCs were particularly convenient because they were non-flammable and good solvents. The aerosol package has been successfully used in many applications. Examples include household and cosmetics products, industrial and speciality products that need to be non-flammable, and inhalers that provide small droplets of medication directly to the lungs.

3.1.2 Rigid and Flexible Foams

The rigid and flexible foams sector had made use of CFCs for very different reasons. In the flexible foam sector, the use of CFC-11 was adopted as an auxiliary-blowing agent to reduce densities and to allow greater control on the foam process. With flexible foam being open-celled, the usage was a transient and generally emissive one. Rigid foams, on the other hand, utilised CFCs primarily for their excellent thermal conductivity. This characteristic has made an intrinsically more expensive foam matrix extremely cost effective as an insulation material. The very nature of insulation foams made them primarily non-emissive uses.

3.1.3 Halons

Halons were first introduced into commercial use during the 1960s. They exhibit exceptional effectiveness in fire extinguishing and explosion prevention and suppression applications. They are clean, electrically non-conductive, and leave no residue. Halon 1301 has proven safe for human exposure at concentrations sufficient for fire extinguishing. This unrivalled combination of desirable properties led to the selection of these agents for many fire protection applications. Halon 1211, a vaporising liquid at room temperature, has been widely used in portable fire extinguishers, and to a lesser extent in fixed extinguishing systems for unoccupied areas. Halon 1301, a gas at room temperature, has seen widespread use in fixed systems throughout the industrial, commercial, marine, defence and aviation industries. Halon 2402, a low-boiling liquid, has primarily been used in the defence, industrial, marine, and aviation sectors in Russia and other countries of the former Soviet Union. Two other halons, halon 1011 and halon 1202, were much less widely used. Increases in atmospheric concentrations of halon 1202, recently reported in scientific journals, cannot be explained by use as a fire extinguishant. Halon 1202 was only used as a fire extinguishant on a few aircraft types that are no longer produced.

3.1.4 Methyl bromide

Methyl bromide (MB) is a highly versatile, broad-spectrum pesticide (fumigant) effective against rodents, insects, mites, nematodes, soil pathogens and weeds. It was identified and officially listed as an ozone-depleting substance (ODS) in 1992, later than CFCs and halons. The first control – a freeze in non-Article 5(1) countries – was agreed in the same year. Reduction and phase out schedules were agreed and accelerated at subsequent Meetings of the Parties.

3.1.5 Refrigeration and Air Conditioning

The refrigeration and air conditioning sector has historically utilised CFCs on a widespread basis. The specific heat transfer characteristics and relative safety in use had made CFCs the refrigerant of almost universal choice for over half a century. Because of its boiling point, CFC-12 was the prime refrigerant in most units. However, large centrifugal chillers utilised CFC-11; HCFC-22 was used for air conditioning and, in the form of the blend R-502, for low temperature refrigeration. In the late 1970's, much ahead of the Montreal Protocol, the non-ODP refrigerant HFC-134a was developed and thermodynamic properties were published. Commercialisation of this refrigerant was much accelerated after the Protocol entered into force. CFCs were (and are) being used -particularly CFC-12- in servicing in the developed and in Article 5(1) countries. A large part of the centrifugal chillers in operation -still- uses CFC-11. Recovery and recycle programs were first considered in the early 1980's when the global warming contribution of CFCs was -already- considered one of the most important environmental aspects.

3.1.6 Solvents, Adhesives and Coatings

The solvents, adhesives and coatings sector achieved phase-out in the non-Article 5(1) countries with apparent ease, however it is unlikely that this will be the case in Article 5(1) countries**.** The obstacles confronted in the Article 5(1) countries are lack of communication, and infrastructure, identification of SMEs, lack of financial resources, etc. and the availability of alternative options at affordable prices. The future phase-out actions should incorporate adequate measures to overcome these obstacles. A firm policy to regulate the market penetration of new solvents should take into consideration overall effects of these on other issues such as health and safety, environment degradation and climate change, etc. The "Protocol" process should take into consideration that for sustained development the technical options for industry must be based on long-term usage and not piece-meal solutions.

3.2 Experiences under an emerging regulatory framework

One of the problems in reporting individual sector experiences in one chapter is that the timeframe required to transition to alternatives and the specific technical challenges vary considerably. However, the experiences in each individual sector can be generally described in terms of four common stages:

1. The initial response
2. Intermediate actions
3. Longer term solutions
4. Future challenges

Each TOC considered these stages and summarised the lessons they considered important. These summaries will be found in sections 3.3 through 3.8 of this section. Common findings will be found in section 3.9 and conclusions will be found in section 3.10.

The regulatory framework that has emerged over the last 15-20 years in response to concern over the ozone layer is unique. It is the first time this large a proportion of the world's sovereign governments agreed to take concrete steps that would directly affect their industries, for the purpose of addressing a global environmental problem for which the underlying scientific understanding was still less than perfect.

The original Montreal Protocol, established in 1987, set out the first globally binding requirements for the control of production and consumption of ozone depleting substances, ODS. Previous actions, such as the Vienna Convention, concentrated on reporting only. The 1978 CFC aerosol ban in the USA was one of the few specific control measures taken prior to Montreal. The Protocol initially required only modest controls on the consumption of ODS. The immediate impact on Article 5(1) countries was minimal because of the grace period granted under the Protocol that delayed any controls for 10 years. However, the impact on developed countries was immediate. At the time of the Protocol, the market for CFCs and the other controlled substances was growing, and the consumption freeze represented a market decline in real terms for the chemical producers, and the other industries that were based on processes that used ODS. Early pronouncements by industry predicted that controls on ODS would, among other things, result in extraordinary costs to industry and the public, cause changes in lifestyle due to loss of important products in the marketplace, and put the public and the military at substantial risk due to the important fire protection role the halons performed. None of these predictions came to pass.

At the London Conference of the Parties in 1990, and subsequently at Copenhagen in 1992, the concept of a total phase-out was introduced for the first time. This change also indicated an inevitable acceleration of the control. Target dates of 2000 and 1996 were respectively agreed at the two conferences with the emerging evidence of Antarctic ozone holes spurring the process along. Perhaps, most importantly during this phase, there was the emergence of a discussion over the contribution of HCFCs both to ozone protection and ozone depletion. A famous debate took place in London concerning whether HCFCs constituted ‘part of the problem or part of the solution’. In reality, the question was not that simple - the answer was “both”. This culminated in the development of the London resolution, which called for responsible use of HCFCs as defined in four principles:

- Use of HCFCs only where no more environmentally acceptable alternative was available
- Use of the HCFC with the lowest ozone depletion potential
- Efforts required to minimise emission and to encourage recovery and recycling
- No use of HCFCs where CFCs were not previously used

This was followed in Copenhagen by the introduction of a consumption cap based on 1986 ODP weighted CFC consumption plus 1989 ODP weighted HCFC consumption. The CFC-based element of the CAP was initially set at 3.1% of the ODP weighted consumption of CFCs in 1986.

These elements had a significant impact on industries striving to phase-out CFC usage. There was some concern that premature control of HCFCs might slow CFC the phase-out. In reality, a more significant factor in slowing the process was the low price of CFCs during the production phase-down. Producers found it difficult to keep in step with the reduction in demand caused by the wholesale transition to alternatives in large application areas, such as aerosols. To avoid the situation in which economics would encourage, rather than discourage, transition to alternatives, several regions introduced substance or end-use controls to facilitate phase-out. In the USA it was the Clean Air Act, and in Europe it was regulation 3093/94.

These regulations were usually the result of substantial dialogue between user industries and regulators. Indeed, the enactment of the Montreal Protocol continues to be a testimony to the value of constructive dialogue between regulated parties, regulatory agencies and non-governmental organisations. This constructive dialogue has been further fostered by the TOC and TEAP structures.

Throughout 1990-96, Article 5(1) Party activities were characterised by establishment of the Multilateral Fund and the efforts to increase awareness of the problem amongst the industries likely to be affected. UNEP IE, the TEAP, the TOCs, National Ozone Units and regional trade associations have all made significant contributions to increasing awareness of the problem among stakeholders in Article 5(1) countries, and in promoting technical solutions. In addition, the development of the project fund and the involvement of the Implementing Agencies (UNDP, UNIDO and the World Bank) in project development and implementation were important to preparing Article 5(1) to integrate technical solutions into their industrial base. These issues are discussed in more detail in Chapter 4.

The most significant future challenge facing the Montreal Protocol is implementing the phase-out in Article 5(1) Parties. With economic development ambitions and significant portions of their industries still dependent on ODS, consumption could grow rather than decrease without a concerted effort to provide meaningful assistance.

3.3 The Aerosol Sector

3.3.1 The initial response

As noted previously, this sector was amongst the first to experience specific legislation back in 1978 with the US ban of CFCs. This made sense because aerosols constitute a totally emissive use of CFCs. Prohibiting the use of aerosols with CFC provided a significant reduction in CFC emissions without painful sacrifices. An additional, and possibly even stronger, factor in the aerosol experience was the familiarity that the general public had with the aerosol package. Once the voices of concern for the ozone layer were raised, public opinion eventually asked for the adoption of a fast phaseout schedule.

The closeness of a given product to the consumer is always a key factor in the rate of technology change and the direction it takes. Eventually, aerosol bans became the first step of most CFC phaseout programs, with the exemption of the EU where voluntary reductions were agreed with the industry.

However, in the 1970s the use of hydrocarbon propellants was already well known. Indeed, products such as paints had used these alternative propellants for years because they were cheaper than CFCs. The use of hydrocarbon propellants required some investment by aerosol fillers, not only to handle safely these flammable materials, but also to deodorise them to levels where the consumer could not notice the use of the new propellant. Hydrocarbons also have a lower density than CFCs, which forced aerosol producers to fill less weight per package size. Labels warning of flammability risks also became noticeable in many products. Precautionary measures had to cover storage and transport of finished goods.

Hydrocarbons could not offer a solution for products where flammability was an issue. In some cases, the use of methyl chloroform as a solvent was promoted, because when combined with a hydrocarbon propellant it produced a non-flammable aerosol. In other cases, especial exemptions were made for the use of CFC containing aerosols. This was the case of aerosol products used in aeroplanes, in mines, for the cleaning of live electrical equipment, and for many other uses such as pharmaceutical aerosols that are not metered dosed inhalers (MDIs) for oral inhalation.

In some developing countries where good quality hydrocarbon propellants were available it was possible to convert at almost the same pace as in the USA. This was the case for the major Latin American countries that had forbidden the use of CFCs in most aerosols by the early 1980s.

In the late 1980s with the advent of the Montreal Protocol, pharmaceutical companies manufacturing MDIs started looking at new chemicals that they could use as propellants and solvents. They knew that the adoption of new chemicals would be a decade long process due to strict regulations by health authorities, but at that time it appeared that there was enough time to conduct the necessary development and research.

3.3.2 Intermediate actions

The ozone crisis interrupted the continued growth of the aerosol sector. Despite its very fast change to non-ODS propellants the industry had to fight the perception that aerosols were damaging to the environment. The inclusion of methyl chloroform and HCFCs in the group of controlled substances limited the options to reformulate products. However, after some years of struggle, production figures returned to their previous levels. This was possible by the development of many water based formulations, the adoption of high boiling solvents, and the use of compressed gases and new propellants such as dimethyl ether, HFC-134a, and HFC-152a. Still some categories such as deodorants and antiperspirants never recovered their previous volumes.

It became evident that some developing countries had special problems to convert to hydrocarbon propellants. The main obstacle was difficulty to obtain hydrocarbon propellant of good quality (odour and pressure). In many cases this problem was compounded by the existence of many small and medium enterprises (SMEs) that lacked the equipment, space and knowledge to use flammable propellants. Conversion of these types of enterprises could require plant relocation and purchase of new filling equipment.

MDIs were recognised as the main CFC use in developed countries that would require Essential Use Allocations after 1996. Companies involved in the manufacture of MDIs face two distinct challenges; they need to secure sufficient CFCs to continue their production while they develop new medication that can safely replace CFC MDIs. These goals conflict to some extent. Phaseout in this case is hampered by the very essentiality of the end use. Thus, although ODS free alternatives exist for some drugs either as CFC free MDIs or as dry powder inhalers (DPIs), new equivalent CFC MDIs are still entering the market at lower prices than the ODS free products. Furthermore, reformulation has proved more difficult than originally anticipated.

3.3.3 Longer term solutions

CFCs and HCFCs are no longer used for aerosols in the developed countries, with the exemption of some countries with economies in transition (CIS) . The aerosol sector is currently reviewing its position with respect to hydrocarbons and HFCs, not so much as a result of concerns for the protection of the ozone layer, but rather as a response to new issues, such as global warming and particularly to controls of volatile organic compounds (VOCs). VOC controls exist in some states of the USA and emission levels have been agreed in the EU to reduce smog in urban areas. These issues have forced aerosol producers to change again their formulations to make them even more sound ecologically.

In developing countries these limitations do not exist. Still, aerosol producers need to recognise that some applications where safety issues have arisen may be better served by the judicious use of non flammable HFCs than by hydrocarbons. However, the price of the new HFCs is so high that it makes their adoption by markets in developing countries almost impossible. This applies to HFC-134a as a propellant and for HFC-43-10 mee as a solvent for the cleaning of live electrical equipment.

Reformulation of MDIs is expected to be virtually completed by the year 2005. CFC MDIs will be phased out by the implementation of national transition strategies that will take into consideration the unique circumstances of each country. Transition strategies will assure that the phasing out of CFC MDIs is conducted with minimum disruption for patients. The existence of several ODS free alternatives that allow the patient possibilities to chose the medicine that suits him best are desired generally. A Global Transition Framework could underpin national strategies and ensure that they are complementary.

3.3.4 Future challenges

There are no technical reasons to continue use of ODS in aerosols other than MDIs. Therefore, it is expected that ozone protection issues will not affect the aerosol industry once the remaining production in Russia and Ukraine, and in developing countries is phased out. Conversion in these first countries is funded by the GEF while for the latter is financed by the Multilateral Fund of the Montreal Protocol.

Availability and price of HFCs may delay the adoption of some speciality aerosol products for the industrial and pharmaceutical sectors in developing countries.

Total phaseout of all CFC MDI products may not be possible for all drugs. CFCs will not be available for small residual uses. Developing countries will not have Essential Use Allowances as it is expected that sufficient ODS free alternatives will be available by 2010. Transfer of new technology will be necessary for local production of CFC-free inhalers in developing countries and may require new licensing arrangements and transfer of intellectual property. The costs of such local production will thus involve capital costs and either multiple years or one off licensing arrangements.

3.4 The Rigid and Flexible Foams Sector

3.4.1 The initial response

The global foam industry is characterised by a relatively small community of medium sized companies. Accordingly, the challenge of dissemination is in no way as severe as that for the refrigeration and air conditioning sector. Nonetheless, the early period following the introduction of the Montreal Protocol was taken up with dissemination activities via conferences, trade associations and the use of other relevant channels. Additionally, the shape of the industry made it relatively easy to foster good working relationships with regulators in developed countries. The problem was rather more difficult with the less developed industries in developing countries. It was only the advent of the National Ozone Units and Country Programmes that started serious dialogue in these regions.

With no immediate replacement technologies to hand, the rigid foam sector began to look at reduced CFC formulations. It was found that the bulk of essential properties could be maintained with this approach although some compromises in long-term thermal performance were an inevitable consequence. For flexible foams, some application areas were found to be able to do without CFC-11 as an auxiliary blowing agent, albeit with the surrender of some density benefits. In addition, methylene chloride emerged as a possible drop-in replacement in some applications.

All of these actions were seen to be consistent with the partial phase-out of CFCs proposed in the 1987 Montreal Protocol. However, the introduction of total phase-out targets in London and Copenhagen required a more significant response.

3.4.2 Intermediate actions

The debate, which took place on the role of HCFCs over this period (i.e. part of problem vs. part of the solution), was critical for the insulation foam industry. The need to retain optimum thermal performance in insulation materials was a major consideration. In addition, concerns about the fire performance of these building products were another factor that acted against the uptake of the alternative hydrocarbon blowing agents.

In this light, one of the more surprising developments was the selection of hydrocarbons in European building insulation. No particular consumer pressure could be cited here although national objectives in Germany and elsewhere were clearly a major factor. In this context, it is interesting to note that the German fire standards at that time were much more lenient than in some other parts of Europe. In addition, the method used for classifying thermal performance grouped both HCFC blown foams and hydrocarbon blown foams into the same category despite significant differences in performance. Accordingly, the adoption of hydrocarbon blown foam caused no market disadvantage. This development epitomises the relevance of local standards and building codes to the direction taken for alternatives. In North America and certain parts of Europe, fire codes for buildings have, until recently, brought into question the adoption of hydrocarbon blown foams. Similarly, there has been a continuing debate in the domestic appliance sector over the ability of hydrocarbons to meet the increasing energy efficiency requirements of these units. In these areas, the emergence of the relationship between the phase-out of ozone depleting substances and the need to optimise solutions from a climate change perspective first began to emerge.

For non-insulating foams, several options outside of HCFCs began to emerge and where some degree of end use control was enforced (e.g. Reg. 3093/94 in Europe and SNAP in the USA); the use of HCFCs for such foams was prohibited with the exception of some integral skin safety formulations.

In the rigid insulating foam sector, the need for longer-term alternatives was beginning to emerge and some discussion over liquid HFCs was surfacing. This was spurred on by the agreement of phase–out dates for key HCFCs. The European foam industry identified that a phase-out of HCFC-141b would be desirable by 2004 and was willing to commit to this date provided that liquid HFCs were available for succession. In addition, the industry was keen to avoid unnecessary restrictions on supply ahead of that date because of the sensitivity of foam costs to blowing agent prices.

For developing countries, the Multilateral Fund was beginning to initiate foam projects for fruition during the mid 1990s. Bearing in mind the low level of market development for building insulation in many of the developing country regions, the focus of many of these projects was in flexible foams and also appliances. The latter is a particularly growing area in China and other parts of the Asian sub-continent. The availability of hydrocarbon technology in Europe provided the Fund with the opportunity to avoid the use of HCFCs in many initial projects. However, as the size of the remaining projects has reduced, the logistics and cost effectiveness of hydrocarbon solutions has diminished.

3.4.3 Longer term solutions

Safety has been a key concern also in some developing country projects, with more than one foam project in the thermoplastic sheet foam sector being negated by the incidence fires in factories when using hydrocarbon blowing agents. This remains an on-going issue and requires addressing through better training and more appropriate selection of technology.

A substantial proportion of the insulation foam industry in the developed countries remains reliant on the successful introduction of liquid HFCs, such as HFC-245fa and HFC-365mfc. However, concerns over cost, availability and the long-term environmental strategy for managing greenhouse gases under the Kyoto Protocol are all providing concerns. These concerns are, of course, also passing through to parties in developing countries even though there is no pressure to phase-out HCFC usage until 2040 in these parts. Perhaps a point of more immediate concern to developing country users of HCFCs is the availability of supplies after the developed countries have phased out use in 2004. There is currently little production in developing countries (with the exception of China) and the European Union is already proposing production controls to limit exports from 2004 onwards. Bearing in mind that the over-capacity in developed countries at present is unlikely to stimulate significant licensing activity in the next five years, the signals are clearly mixed for those currently still using CFC-11 as their prime blowing agent.

3.4.4 Future challenges

As noted previously, for the foam sector, the concern rests very significantly with the availability of liquid HFCs such as HCFC-245fa and HFC-365mfc. Again future policy on HFCs in unclear because of the inclusion of these materials within the Kyoto Protocol. However, the basket approach taken in that Protocol does, at least, allow for the consideration of energy efficiency factors through the TEWI concept. Some regulators are now beginning to realise the potential significance of insulation materials in the fight against carbon dioxide emissions and in view of the high efficiency of HFC blown foams there may be a unique role for these materials, particularly in the all-important retrofit activities.

An additional issue that is brought into focus by the Kyoto Protocol, is the potential value in controlling future emissions of CFCs from foams. The insulation sector in particular has a significant bank of CFCs which, although being released slowly from installed components, is still likely to have substantial further impact if allowed to be released at the end of life. Although the size of this impact varies with the application and its anticipated life cycle, the need for, and potential value of, appropriate destruction technologies is a key aspect of consideration for future policy. In order to provide some incentive to Parties in this regard, it may still be appropriate to consider Kyoto Protocol ‘credits’ against appropriate destruction achievements. This, of course, is not the same as including CFCs and HCFCs as part of the base line in the original Protocol and thereby decreasing the overall value of reduction targets. In the end, a Party’s individual strategy on such measures would be driven by the cost-effectiveness of the measure against other greenhouse gas reduction measures.

These, and other, aspects of the future phaseout process in foams make the sector an important element for further study in the years that lie ahead. Emphasis on the inter-relationship between the Kyoto and Montreal Protocols is vital for the well being of the insulation industry in general and the foam industry in particular. While the Kyoto Protocol must surely remain the ‘home’ of emission controls of the type proposed here, it is believed that the TEAP and Foam TOC could have a substantial role to play in providing advice on the potential value and appropriate application of any such measures.

3.5 The Halons Sector

3.5.1 The initial response – reduce unnecessary emissions

The initial response of the fire protection community was to ensure that technical requirements did not contribute to mandating unnecessary emissions from the use of halons. In 1986 the fire protection community began to concentrate on measures that would ensure reliability of halon 1301 systems without the need to discharge test new installations. A door fan test was developed to determine leakage from protected spaces, new piping requirements included new test methods, stringent requirements for testing detection and control systems all made it possible to provide confidence without the need of a discharge test. Work to include these requirements began in 1986 – before the Montreal Protocol was signed.

In many countries an internal inspection of the pressure vessel used to contain the halon 1211 in a portable fire extinguisher was required on a regular schedule (e.g. every 7 years). Technical requirements were changed to require that the halon 1211 was recovered and recycled during this procedure. As well the development of alternative training procedures significantly reduced the emissions of halon 1211.

It should be noted that halons extinguish fires chemically, with bromine acting as a catalyst. The fire extinguishing reaction unfortunately has strong similarities to the reaction that destroys ozone. This has posed a particular challenge in attempts to develop halon alternatives. This was perhaps the only use of an ODS where a chemical reaction was the primary benefit. In most other cases ODS were used for particular physical properties such as boiling point, heat of vaporisation, solubility, etc.

3.5.2 Intermediate actions – use other existing alternatives

Although halons offered advantages over other fire protection choices, the environmental disadvantage of halons began to be considered one of the important factors in selecting the most suitable fire protection choice for a particular application and for its long-term viability.

As new technology halon alternatives did not appear until 1994 the choice was to accept the possibility of greater collateral damage from the extinguishing agent. Water sprinklers became the fire protection system choice for many computer facilities instead of a halon 1301 system.

Dry chemical extinguishers or the appropriate use of a water extinguisher or a carbon dioxide extinguisher were proven alternatives to the use of halon 1211. In Europe, North America, South America, Australia and Japan the manufacture of dry chemical portable was a well established, proven technology. In other parts of Asia, including India and China, a tradition and expertise in the manufacture of dry chemical extinguishers was yet to be established and the manufacture of halon 1211 portable fire extinguishers grew rapidly.

3.5.3 Longer term solutions

In 1994 halon production was phased out in non-Article 5(1) countries. Essential halon needs were met by the use of recycled halons in countries where the fire protection community, often in partnership with government, had implemented halon management procedures. Also in 1994 new technology alternative agents for fixed systems became commercially available. Inert gases, halocarbon alternatives and fine water mist systems provided alternatives for many applications where halon 1301 had previously been the preferred choice. Work continued to find alternatives to halon 1301 for civil and military aviation, crew compartments of tactical military vehicles and in explosion prevention use in occupied areas.

By 1996 new technology alternatives were commercially available for portable fire extinguishers.

Limited production of halon 2402 continued in Russia. The disruption caused by the transition to a new economy seriously damaged effort to establish halon recycling and management programs. Although a 90% reduction was achieved there was no global supply of halon 2402 to meet essential and critical needs within the Russian Federation. As a result the Parties granted an Essential Use production exemption to the Russian Federation to meet essential halon needs. It is expected that the need for an Essential Use exemption by the Russian Federation will end by the year 2000.

3.5.4 Future challenges

Production of halon 1211 in India ceased in 1998, however production of both halon 1211 and halon 1301continues in China and South Korea. It has been reported that halon 1211 production in China has now reached levels close to total global production of 1986. The possibility that inadvertent production and release of halon 1202 during halon 1211 production in China is also of concern.

The Russian Federation and other states of the former USSR continue to struggle to meet their commitments.

There remain continuing essential and critical uses, almost all of which relate to halon 1301, whose needs must be met by recycling and reusing existing material. At present, the majority of the agent for this purpose is being found from the continuing process of decommissioning of existing installations, most commonly when the protected asset has naturally reached the end of its useful life; as the number of remaining halon installations dwindles - a process further accelerated by the increasing political encouragement to replace halon proactively in existing installations - this source of agent for reuse will diminish and eventually disappear. Not all long term Essential and/or Critical Users appear to be aware of this inevitable development, and some may therefore be inadequately prepared in terms of assessing their projected needs and making appropriate provision to ensure that they will be supported. Unless and until it is apparent that there is a clear surplus of agent for these needs, widespread destruction of halon 1301 cannot be recommended.

It continues to be essential to minimise emissions as far as possible in accordance with the implications of the Report on Scientific Assessment of Ozone Depletion, which identifies the benefits attainable "if halons presently contained in existing equipment were never released to the atmosphere". This applies with equal force to existing installations (whether in Critical Uses or not), to the servicing and decommissioning processes, and to repositories. Also clear from the Scientific Assessment is that, while all emissions are undesirable, those which take place in the immediate future occur while the ozone layer is at its most depleted and therefore most vulnerable, and thus may have a greater impact than those which are delayed by some years or even decades. Actions which cause increased emissions in the short term, where the alternative is safe retention of stored halons in installed systems, or which bring forward in time a potentially emissive transaction, should be carefully assessed with this in mind.

3.6 The Methyl Bromide Sector

3.6.1 The initial response

3.6.1.1 Controls pre-dating Montreal Protocol measures

Prior to methyl bromide (MB) being brought under the Montreal Protocol it was already being regulated by governments as a toxic chemical and pesticide, and these controls are still in place today.

The World Health Organisation's safety guide lists MB as a 'highly toxic gas' (WHO IPCS 1994). Normally MB has to be officially registered as a permitted pesticide before it can be sold or used within a country. In many countries the pesticide regulations restrict the uses of MB to specific crops or situations. Due to poisoning accidents in the past, many countries issue permits allowing only licensed operators to use it. Imports of MB are often monitored or recorded under hazardous substance controls and international guidelines on the use of pesticides.

During the 1970s and 1980s several governments took steps to reduce environmental pollution from pesticides. In some cases the registration of MB as a permitted pesticide was allowed to lapse by the suppliers. In other cases governments phased out many uses of MB as a result of concerns about the safety of agricultural workers and local communities, localised air contamination, water contamination, and/or residues in food. In the early 1980s, for example, fruit, vegetable and flower production in the Netherlands depended very heavily on MB, but a national programme was established and all soil uses were phased out by 1992. Acting on WHO information about toxicity, Bahrain identified alternatives and decided not to issue any more permits for importing MB. In 1983 a regional government in Italy prohibited use of MB and promoted alternatives in an intensive horticultural zone near Lake Bracciano, because of concerns about water contamination.

3.6.1.2 *Quarantine uses of methyl bromide*

There was also some limited activity to replace MB used for quarantine purposes in this period. Ethylene dibromide (EDB) a fumigant used extensively for fruit fly control in tropical fresh commodities, was banned or restricted for safety reasons in many countries. This led to increased dependence on MB. However, MB was not able to substitute for many uses of EDB and safety studies indicated that regulators might limit or ban MB at a future date. This led some quarantine researchers in New Zealand, Hawaii and parts of the USA to develop some alternative quarantine techniques such as heat, cold, chemical dips and systems approaches.

3.6.1.3 *First Protocol controls*

The WMO Scientific Assessment in 1991 noted that MB was a major contributor to stratospheric bromine. MB's ODP was estimated to be 0.5-0.6. The scientists noted that MB displays a very much larger ODP over short time scales because of its short lifetime and the destructive power of bromine[1] (WMO 1991).

TEAP carried out an interim assessment of MB in 1992 identifying potential alternatives and noting that use of the fumigant had increased about 5% per year since 1984 (UNEP 1992). Scientific model calculations suggested that emissions from MB fumigation could account for 5-10% of observed ozone losses (UNEP 1992). The Parties listed MB as an ozone-depleting substance in 1992 and agreed that non-Article 5(1) country countries would freeze consumption in 1995.

The Parties established the Methyl Bromide Technical Options Committee

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[1] An atom of bromine in the stratosphere is estimated to destroy about 60 times more ozone than an atom of chlorine (WMO 1998).

(MBTOC), which produced a full Assessment in 1994 (MBTOC 1995) listing a range of alternatives currently available or at a late stage of development for the majority of MB uses. The report stressed the importance of not-in-kind alternatives and integrated pest management approaches (IPM, ie. combinations of treatments targeting specific pests).

3.6.1.4 *Stakeholder response*

Much of the MB industry opposed controls or action as they believed that the scientific evidence supporting MB as an ozone depleting substance was insufficient and, moreover, there were no alternatives. TEAP noted in 1995 that users and producers of MB had been reluctant to commercialise and implement alternatives. TEAP also noted that success factors for eliminating controlled ODS in the past included changes in industry attitude, chemical suppliers' support for ozone protection, national regulations and company leadership in developing alternatives.

A small number of companies took a leadership role in commercialising alternatives. For example, Insects Limited and Fumigation Services and Supply, a major US pest control company headed by Mr David Mueller, led the commercial adoption of alternatives to MB for treating commodities such as grains and for treating large food processing buildings.

However, with the exception of Denmark and the Netherlands, very few countries actively promoted the adoption of alternatives between 1992 and 1995. Substantial efforts commenced only after controls were put in place under the Montreal Protocol in 1995.

3.6.1.5 *MB recycling and re-use*

For some ODS, capture-recycle-reuse has been important. But in the case of MB this has generally been less feasible and more expensive compared to introducing alternatives.

MBTOC's 1994 Assessment reviewed technical aspects of recovery and recycling . Most of the potential recovery and recycling systems are complex and expensive to install compared with the cost of the fumigation facility itself. Some systems would have high running costs associated with energy consumption. Many would require a level of technical competence to operate that would not normally be found at fumigation facilities. In addition US pesticide authorities indicated that impurities in recycled MB would make it unlikely to be approved for re-use on food commodities.

Several pilot scale recycling facilities were constructed, based on various concepts for recovery and recycling of MB. However, none of them is in full commercial use. The MB recycling facility set up at the Port of San Diego cost about $1.5 million to install, had high energy costs and was eventually de-commissioned due to technical problems. Today, there remain only a few examples of recovery equipment in current commercial use worldwide.

3.6.2 Intermediate actions

3.6.2.1 Controls on methyl bromide

In 1995, the Parties agreed controls on MB for non-Article 5(1) countries consisting of a stepwise reduction leading to phase out by 2010. In 1997, the Parties accelerated the phase out date to 2005 and agreed to a freeze for developing countries by 2002 leading to a phase out by 2015.

3.6.2.2 Activities leading to MB reductions

The growth in MB consumption has been halted in industrialised countries. Some developing countries have also reduced MB consumption. Technically, reductions have been achieved by:

- Adopting or adapting alternatives
- Using MB less frequently (eg. by using cleaner practices to prevent build-up of pests; or monitoring for pests to determine whether fumigation is necessary)
- Using MB more efficiently (eg. combining it with other fumigants; or reducing permitted application rates)

A variety of activities in different countries led to these changes; examples include the following:

- Dissemination of information to agricultural sectors about how to use alternatives; agricultural extension (advice) services
- Amendment of pesticide regulations to restrict conditions of use (eg. safety buffer zones around fumigation sites; limiting MB soil fumigations to one year in two; requiring permits for each MB fumigation)
- Use of pesticide regulations to prohibit specific MB uses or to ban imports
- Raised prices of MB due to import taxes and voluntary user levies
- Government programmes promoting companies that can supply alternative services and products
- Amendments to existing agricultural subsidies, grants and loans to discourage use of MB and encourage use of alternatives
- Public awareness raising and consumer groups' demands for labels to identify products grown with/without MB
- Policies of supermarkets and wholesale purchasing companies which restrict MB use or require use of alternatives (eg. supermarket IPM

protocols which prevent growers using MB for some crops and restrict use for other crops)

3.6.2.3 Multilateral Fund projects

During 1997 and 1998 the Multilateral Fund (MF) and bilateral aid provided technical and financial assistance for preparation or implementation of more than 50 demonstration projects, as well as information materials and workshops. The MF guidelines strongly encourage policy dialogue and the development of national legislative frameworks to assist the phase out process. The first results are expected in 1999. The range of alternatives already in use means that projects should focus on transferring, combining and optimising existing techniques.

3.6.3 Longer term solutions

The range of existing and potential alternatives to MB continues to increase. Phase-out has been accepted by some users and more governments are starting to develop plans or activities to assist the process.

3.6.3.1 Alternatives: a new twist to an old tale

Most of the alternatives are not new but combinations of older techniques integrated in new ways to control the wide range of pests previously controlled by MB.

Integrated pest management strategies, developed in agriculture to reduce the environmental impact of pesticides in general, are very important. The shift to IPM systems is also part of an international change in agriculture promoted by some farmers, agriculturalists, governments and purchasing companies such as supermarkets.

Most of the alternatives are based more on improved skills and knowledge than equipment (technology), so training will become very important in this third stage.

3.6.3.2 Measures that assist phase out

From experience with other ODS and experience to date on MB, the following combination of measures would assist countries in introducing alternatives and phasing out MB in a timely manner:

- Government programmes to promote industry leadership, encouraging farmers and pest control companies to adopt or optimise alternatives, and encouraging, exporters, supermarkets and purchasing companies to change policies, specifications or contracts on MB use;
- Strong policy frameworks at national level, such as regulations setting

reduction dates and phase out dates for specific uses of MB;

- Amendments to pesticide regulations to ban or restrict specific MB uses and place substantially tighter conditions on use;
- Import taxes and other measures to increase MB prices, and use of the revenue for training farmers and others to use alternatives;
- Adjustment of the conditions for receiving existing agricultural grants and loans so they no longer encourage or require MB use but actively encourage adoption of alternatives;
- Statutory and voluntary labelling of products produced with or without MB, including government-backed eco-label systems; labelling of MB containers with information about ozone-depletion and contacts for information about alternatives;
- Use of existing extension services of governments and agricultural agencies, as a channel for disseminating information, on-farm demonstration, training and advice about existing alternatives;
- Bringing farmers and specialists who use successful alternatives to discuss techniques with farmers in regions using MB;
- Government programmes to assist local companies (especially SMEs in rural areas) to supply and market alternative products and services.

3.6.3.3 Multilateral Fund assistance

The roles of the Multilateral Fund, bilateral and other agricultural assistance programmes are expected to change from a focus on demonstrations to a focus on regulatory frameworks, training, investment projects and other activities to ensure the adoption of alternatives. Since alternatives adopted in non-Article 5(1) country and developing countries will be similar, the reduction and phase out in non-Article 5(1) country countries is expected to lead to earlier phase out in developing countries.

3.6.3.4 MB manufacture and technology transfer

There will need to be more focus on limiting and phasing out the production of MB, especially in countries where production has been rising rapidly. The Parties will need to develop new tools and measures for addressing this issue. Related to this issue is the transfer of MB-related technology from non-Article 5(1) to certain Article 5(1) countries. However, intensive efforts to introduce and optimise alternatives in selected Article 5(1) countries would resolve both problems.

3.6.4 Future challenges

We can expect the following issues to become pertinent as we move closer to phase out:

3.6.4.1 Illegal imports

As with other ODS, we can expect that additional regulations and measures will have to be introduced to prevent illegal production or imports of MB based on measures developed for other ODS.

3.6.4.2 Exemptions

Parties will want to ensure that the criteria for exemptions are applied fully and consistently. Exemptions for MB will need to be reviewed after the first year of operation to ensure they being applied consistently by Parties, and to ensure that exemptions comply with the agreed criteria. Emergency use, for example, is likely to require further clarification and guidance.

3.6.4.3 Quarantine and pre-shipment

The MBTOC 1998 Assessment noted that the volume of MB used for QPS in 1996 accounted for about 22% of global use, while in 1991 it accounted for about 18%. Some of the increase is probably due to increased volumes of international trade. Some may be due to non-QPS use being inaccurately classified as QPS due to inconsistent interpretation of the definition. The MBTOC 1998 Assessment has provided information that will assist parties with accurate categorisation of uses.

MBTOC has identified some QPS uses for which there are currently no technically feasible alternatives. However, MBTOC has also identified a range of non-MB techniques which have already been approved by Regulatory Agencies as quarantine treatments for specific commodities/pests/ countries. It is therefore feasible to develop and get approval for further non-MB quarantine treatments.

The QPS exemption discourages research on the development of alternatives for quarantine treatments as most Parties have given them a lower priority than areas subject to control under the Montreal Protocol. At the same time Parties may wish to note that the time for development of quarantine treatments can take 3 to 12 years, depending on the extent of research to demonstrate efficacy and national policies for approving treatments.

Given the relatively large volume of MB that is now consumed for QPS, the probability that this will increase further in the future, and the fact that the QPS exemption discourages the development of alternatives, Parties may wish to consider limiting increases in QPS use by removing the exemption and replacing it with an exemption system consistent with Critical Use procedures under the Protocol. The text of Decision IX/6 follows:

Text of critical use exemption for methyl bromide
(Decision IX/6)

To apply the following criteria and procedure in assessing a critical methyl bromide use for the purposes of control measures in Article 2 of the Protocol:

(a) *That a use of methyl bromide should qualify as "critical" only if the nominating Party determines that:*

  (i) *The specific use is critical because the lack of availability of methyl bromide for that use would result in a significant market disruption; and*

  (ii) *There are no technically and economically feasible alternatives or substitutes available to the user that are acceptable from the standpoint of environment and health and are suitable to the crops and circumstances of the nomination;*

(b) *That production and consumption, if any, of methyl bromide for critical uses should be permitted only if:*

  (i) *All technically and economically feasible steps have been taken to minimize the critical use and any associated emission of methyl bromide;*

  (ii) *Methyl bromide is not available in sufficient quantity and quality from existing stocks of banked or recycled methyl bromide, also bearing in mind the developing countries' need for methyl bromide;*

  (iii) *It is demonstrated that an appropriate effort is being made to evaluate, commercialise and secure national regulatory approval of alternatives and substitutes, taking into consideration the circumstances of the particular nomination and the special needs of Article 5 Parties, including lack of financial and expert resources, institutional capacity, and information. Non-Article 5 Parties must demonstrate that research programmes are in place to develop and deploy alternatives and substitutes. Article 5 Parties must demonstrate that feasible alternatives shall be adopted as soon as they are confirmed as suitable to the Party's specific conditions and/or that they have applied to the Multilateral Fund or other sources for assistance in identifying, evaluating, adapting*

and demonstrating such options.

3.7 The Refrigeration and Air Conditioning Sector

3.7.1 The initial response

The initial Montreal Protocol control of 50% consumption reduction could be met with relative ease by the refrigeration and air conditioning sector. This strategy included:

- reducing emissions by making refrigeration equipment more leak resistant;
- introducing additional HCFC refrigerants which would require only modest changes to the equipment and could be phased in relatively quickly. In this scenario HCFCs were considered as part of the solution - key CFC replacements;
- introducing long term replacement chemicals that are non-ozone depleting (e.g., HFC-134a).

Of these three, reducing emissions from existing systems through improved maintenance was by far the most important, both in terms of creating awareness among technicians, and in the quantity reduced emissions.

This initial focus on “good practice” methods in refrigeration was inevitable in view of the uncertainty surrounding refrigerant substitutes at that time. Each of the options described above, as well as a discussion of the state of alternatives available at the time, can be found in the 1989 Refrigeration, AC and Heat Pumps Assessment Report.

3.7.2 Intermediate actions

The focus changed once the Parties decided to phase-out CFC consumption, and established a control schedule for phasing-out HCFCs (London in 1990 and Copenhagen in 1992). Improved maintenance procedures were no longer adequate, and HCFCs were no longer the appropriate technical path for alternatives. They now had to be supplemented with a more concerted effort to institutionalise recovery and recycling, and more investment in the development of alternative refrigerants. Because new refrigerants appeared likely to be more expensive then the CFCs, “good practice” measures became important for economic, as well as environmental reasons. So, during this intermediate period, the options can be summarised as:

- reduction of emissions and adequate containment procedures;
- introduction of stringent recovery and recycling schemes;
- rapid introduction and evaluation of non-OD refrigerants and refrigerant systems (HFCs, hydrocarbons, other non-ozone depleting alternatives);

- emphasis on retrofitting existing equipment;
- emergence of blends (some containing HCFCs) for the purpose of extending the service life of existing CFC based refrigeration.

The availability of new chemicals and blends became the major issue in this phase of the process. The combination of the decision to consider HCFCs only transitional substances, and the emerging threat of illegal imports,made it difficult for producers of alternatives to make good strategic decisions. As a result, progress slowed. An additional factor that complicated decision making was the emergence of energy efficiency as an important issue to the climate change issue, and expectation of a future "Montreal Protocol-like" treaty to control greenhouse gas emissions.

Also during this phase, the domestic refrigeration sub-sector came under pressure from environmental groups that sought to advance the use of "natural refrigerants" by influencing appliance producers and consumers. These non-fluorocarbon, flammable refrigerants such as iso-butane, are being proposed for use both as refrigerant fluids, and as blowing agents for the insulating foams used in domestic refrigerators. From the industry perspective, this involved discontinuing the use of the existing component concepts and necessitated changes in the design of refrigeration system components. These decisions had direct impacts on investment decisions, and the profitability and market share of individual companies. Initially, there were safety and toxicity concerns over the use of flammable refrigerants in households. However, the concept eventually gained wider acceptance as engineered solutions were shown to be able to manage this hazard. Barriers to wider use of flammable refrigerants include the need to revise relevant codes standards applicable to the construction of domestic appliances.

The "best practices" and technical alternatives adopted in developed countries are also technically and economically feasible in Article 5(1) countries. In this phase of the process, technology transfer and the supporting financial mechanisms were becoming very important to reduce the future dependence of Article 5(1) Parties on obsolete CFC-based technologies. The options described here, as well as their applicability to Article 5(1) countries, are discussed in more detail in the 1994 Refrigeration, AC and Heat Pumps Assessment Report.

3.7.3 Longer term solutions

Now that the production phase-out in developed countries is reality, the non-technical barriers to phase-out in Article 5(1) countries are more evident. The major obstacle appears to be the widespread availability of ozone depleting chemicals from local production, and the general global over-supply. A problem for the refrigeration sector is that a new system typically have 30 to

40 year economic life. To avoid premature retirement of capital, the equipment requires either a lifetime supply of ODS refrigerant, or an alternatives that can be adopted without significantly modifying the equipment. In addition, systems modified to accept alternative refrigerants, usually do so at the expense of energy efficiency, increasing greenhouse gas emissions. The solution is to work to facilitate the CFC phase-out in Article 5(1) countries as quickly as possible. The options listed here are appropriate to sustaining good environmental performance from the refrigeration sector in developed countries, and to the rapid conversion to non-ODS alternatives in Article 5(1) countries:

- improve performance of HFC based direct cooling equipment;
- introduce equipment based on hydrocarbons and ammonia;
- introduce equipment with non-ozone depleting chemicals in a first loop and heat transfer fluids in a secondary loop;
- introduce equipment using not-in-kind technologies;
- develop carbon dioxide systems for heat pumps and air conditioning;
- develop the air cycle for air conditioning purposes;
- develop non-HCFC based chillers, including the use of water as refrigerant;
- continue to introduce new non-OD replacement refrigerants in the short term.

The key issues have shifted from availability of alternatives, to the introduction of new refrigeration concepts, These include equipment that requires a small refrigerant charge (whether HFCs or other non-OD chemicals) or uses refrigerants that require significant design changes (such as carbon dioxide or water). These new concepts must perform at an acceptable energy efficiency and have an acceptable risk of return based on the investment needed to develop and commercialise the equipment. However, a lack of standards, and continuing uncertainties regarding the market value of energy efficiency in relation to speculative investments needed to achieve it present new uncertainties to the marketplace.

With an increasing number of options and more rapid phase-out schedules in several developed countries, the technologies available for Article 5(1) countries to choose from are becoming more diverse, and choosing correctly is a concern. One of the main objectives of this report is to provide Article 5(1) Parties with an overview of how policies and procedures developed countries used to meet the challenges of the Montreal Protocol in the Refrigeration, AC and Heat Pumps sector, and of the technologies that have proved most successful for specific applications.

3.7.4 Future challenges

In order to end the use of ODS, regulations that affect the choice of refrigerant by owners of existing equipment will become particularly important. Two main types of regulations have been proposed - ‘placement on the market’ or “use” bans. Some believe that ‘placement on the market’ bans will be more effective than use bans because they will not discourage the practice of internal recycling. The risk of a use ban is that it will make existing stock of CFC-12 a liability and will encourage the unscrupulous to release this to the atmosphere. In summary, this phase of the process is likely to be characterised by:

- potential continued production of controlled substances authorised under the Protocol essential use procedures; however, the criteria is difficult to satisfy for refrigeration and air conditioning applications;
- potential continued servicing via trade in recovered substances are permitted under the Montreal Protocol;
- national control schedules restricting specific uses of certain chemicals, necessitating the refrigeration sector to accelerate the introduction of new concepts in many developed countries;
- refinements to Multilateral Fund guidelines to recognise the importance of (i) a social and physical infrastructure to deal with the refrigerant bank (recover, recycle and reclaim), (ii) retrofit and replacement options.

The refrigeration sector has a large bank of CFCs (and HCFCs) which are likely to have a substantial impact on future emissions. This implies that the sector remains an importnat one for studies and analysis in the years to come. This also applies to TEAP and Refrigeration TOC studies. In fact, the same considerations apply as given under 3.4.4 for the foams sector.

At this stage, chemical alternatives are readily available. The primary limiting factor is the rate at which investments can be made to complete retrofits and procure new equipment.

3.8 The Solvents Sector

In this section different stages in the phase-out process are described and how the industry has so far managed to come into line with the control of production and consumption of solvents as defined in the Montreal Protocol. It also looks at achievements in general and draws attention to the challenges to be faced.

3.8.1 The initial response

The Montreal Protocol came into force in January 1989 and defined the measures that Parties must take to limit production and consumption of CFC-113.

CFC-113 because of its unique properties was the main solvent used for diversified applications e.g., general metal cleaning, electronic, precision, non-metallic parts, aerosols, adhesives, finger printing, dry cleaning, etc. The impending phase-out schedule spurred an intensive activity in many developed countries. Substitute solvents and processing technologies started emerging. Some industries switched on to the use of methyl chloroform as in 1987 it was not a controlled substance. HCFC based solvents with various ODPs started penetrating in the market. Carbon tetrachloride use as solvent in developed countries was being eliminated due to its known carcinogenicity - but it was being used widely in developing countries.

3.8.2 Intermediate actions

At the Meetings of the Parties in London (1990) and Vienna (1992) the concept of total phase-out was introduced and the control schedules to achieve this objective were defined.

Production and consumption phase-out dates for developed countries were fixed for year 1996 and year 2000 respectively. HCFCs were classed as transition solvents. These tight schedules accelerated the phase-out process in developing countries. The suppliers of solvents involved themselves in extensive research and development to take a lucrative share of market needed alternatives. The implementation regulators, the producers and users interfaced closely to facilitate the phase-out process. Many new alternative materials and technologies started emerging. The users were devoting lot of resources for development work to adopt new options for their uses. The high volume users were in a better position to introduce new alternatives relatively easier. The cost of this change compelled users to refine and streamline their practices for achieving higher economy. Industries also integrated in their operations conservation and recovery practices, particularly for higher cost consumables.

“No-Clean” methods were accepted by a large sector of the electronic industry and aqueous cleaning methods got established in different industries.

One of the main challenges in adoption of new options was to establish the compatibility of consumables with the materials to be processed. Higher operational safety demands for plants and equipment such as for aircraft, and space shuttles, submarines, nuclear energy, transportation, etc., the effective specification and regulatory requirements had to be complied with.

Large resources were allocated by many organisations to accomplish this. The TEAP and its TOCs provided a channel for collecting information on innovative solutions and its dissemination to those organisations needing it.

The Protocol also spurred well-focussed activity to bring the existing specifications into line with the industrial demands for greater flexibility. The concept of product end quality and not the route that is followed for intermediate process steps became acceptable to many organisations.

The production phase-out of controlled solvents has progressed smoothly and only small quantity of these permitted for essential use nominations is produced further. Consumption phase-out in general is progressing satisfactory although several industries still relied on the use of CFC-113 and methyl chloroform.

3.8.3 Longer term solutions

The developed countries have achieved the production phase-out and very small quantity of CFC-113 and methylchloride is produced to meet the essential use exemption requirements. Alternatives such as HCFCs, HCFs and HFEs have established themselves in the market but very low emission levels demands for worker safety or environment degradation need high capital investment. In addition some of these have an ODP and global warming effects or both.

It must be noted that introduction of alternative solutions in industry requires high investment for establishing compatibility of the solvents with so many different substrates and its adaptability for production. The production equipment often requires extensive capital investment. Once a production system is established its displacement becomes very tedious.

The high cost of some of these alternatives as compared to CFC-113 has opened the way for market penetration for new substances. STOC is aware that brominated solvents such as nPB and CBM are being used and these have an ODP and incomplete toxicological assessment data.

Stock piled and recycled ozone-depleting solvents are being used by some industries but their availability and increasing prices shall be faced be the users as the shelf life of stockpiles comes to an end. This shall provide an opportunity for new solvents.
The developing countries have made a relatively good start to introduce ozone friendly technologies but big challenges are confronted by various sectors. Companies with joint international ventures and large domestic industries should be in a position to comply with the phase-out schedules. SMEs on the

other hand pose a very serious challenge in countries with large aggregate population and strong consumer goods industries.

STOCs interface with some countries has identified that lack of resources and awareness of available viable options, weak infrastructures for supply and communication and lack of training shall have to be surmounted.

Carbon tetrachloride is being used widely and often in open pans and tanks for various tasks. The other two easily available alternatives, viz., perchloroethylene and trichloroethylene are being used in equipment with deficient emission controls. Such methods have serious health hazards for the operator and ground water contamination.

No-clean processing techniques have also been adopted by a large segment of the electronic industry in the developing countries.

3.8.4 Future challenges

The phase-out in developing countries should now be the top priority for the Protocol process. Ways and means are to be established so that alternative solvents and associated technologies are available to the users at affordable price. SMEs in developing countries shall need concerted assistance in improving awareness and training in the use of alternatives. The alternative options must incorporate personnel safety and environment improvement measures.

The “Protocol“ may wish to establish a mechanism by which new substances with ODP and possibly with other deleterious effects are not offered as replacements for OD solvents.

The future technical options should be based on inclusion of broad environmental degradation, global warming and worker health issues.

For developing countries technology transfer efforts should be intensively strengthened.

3.9 Common Themes

One important factor that characterised the phase-out process in the 1990-96 period was the rapid proliferation of technological solutions that entered the market place. This was perhaps a testimony to the overall utility of CFCs rather than an inevitable consequence of any such phase-out programme. Another plausible lesson is that industry will respond with technological innovation when the problem and end point are well understood, but the path to achieve the end point is left to the technical experts from industry who understand that business is rewarded by those who offer solutions to society's problems. However, the fact that the number of alternatives exceeds by a large margin the number of original CFC applications presents a challenge for Article 5(1) countries, and for the TEAP when asked for definitive pronouncements regarding which technical solution is best for a given situation. End users must become more knowledgeable about the options and make their own decisions. The ultimate responsibility and accountability for their decisions is theirs alone.

An additional observation is that the rate and direction of technology change appears to be heavily influenced by the proximity of the general public to the problem and their ability to make a positive contribution. For example, in domestic appliances, the use of hydrocarbons for both the insulation foam and refrigerant elements has been more extensive than could have been conceived at the start of the process. This is because the public was made aware of the problem, and of the environmental befits of hydrocarbons for this application.

On the supply side, the excess of CFC production capacity in Article 5(1) Parties and the fact that there is little indigenous production of HCFCs will continue to cause significant price disincentives to phase-out. This problem is being addressed at one level by the imposition of the CFC production freeze in 1999 and the subsequent phase down of production. However, the availability of HCFC licences for developing country producers is likely to remain extremely limited for the foreseeable future. This arises, at least in part, from the fact that HCFC uptake in developed countries was less than the producers had envisaged (e.g. rigid foams in Europe) and there continues to be global over-capacity as a result. No existing producer is therefore going to wish to contribute to further over capacity at this stage.

In addition, the uncertainty over future alternatives highlighted in section 3.3 will continue to be a barrier to change, although the foam industry in most developed countries remains committed to phasing out HCFC use in 2004 (with the major exception of HCFC-22 and HCFC-142b in the USA).

3.10 Conclusions

For the benefit of future such Protocols, the following lessons have been learned:

- Collective global action can be achieved in defined market segments.
- Leadership and constructive engagement, by governments, corporations and individuals, are essential keys to success.
- The pace of technological innovation is much faster and much less expensive than originally anticipated, despite the fact that early trials often provide poor initial results and subsequent technical offerings improve

rapidly.

- The process of replacement tends to create a proliferation of alternative options.
- The pace of action is strongly related to the proximity of a product/service to the general public.
- There are substantial regional differences affecting the choice of alternative - there are no silver bullets, and no “one-size fits all” solutions.
- The step-wise production and consumption cuts inevitably cause major fluctuations in the supply and demand balance.
- The implications on chemical prices are highly significant and can heavily disrupt phase-out processes.
- Conflicting environmental objectives can emerge requiring a judgement to be made on their relative importance. There is no perfect solution - everything involves compromise.
- Future environmental policy on possible alternatives needs to be made clear and as early as possible if the phase-out process is to maintain its momentum.
- Continuing to disseminate educational materials are a vital part of the process to avoid misinformation; and delay or inappropriate action based on misinformation.

4 Challenges for Article 5(1) Parties and Countries with Economies in Transition, CEIT

4.1 Introduction

Developing countries that are Parties to the Montreal Protocol and annually consume less than 0.3 kg of Annex A Group I substances per capita are classified under Article 5(1) of the Montreal Protocol. As such they qualify to receive assistance under the Multilateral Fund. Eight (8) Parties out of the 27 countries with economies in transition (CEIT), that changed from from centrally planned systems to market oriented systems, are classified under Article 5(1). CEIT Parties not classified under Article 5(1), qualify for financing by the Global Environment Facility (GEF).

As of October 1998 there are 168 Parties to the Montreal Protocol, of which 112 Parties are classified as operating under Article 5(1). This number includes the 8 Parties mentioned which are part of the CEIT, namely, Bosnia and Herzegovina, Croatia, Georgia, Moldova, Romania, Slovenia, Macedonia and Yugoslavia.

Most of non-Article 5(1) Parties have complied with the phase-out deadlines, but many CEIT Parties are lagging behind the phase-out schedule prescribed under the Montreal Protocol. The Executive Committee of the Multilateral Fund has to date approved projects worth (US)$760 million in more than 100 developing countries to phase-out about 110,000 tonnes of ozone depleting substances. The Global Environment Facility has approved ozone depleting substances phase-out projects by grants amounting to (US)$108 million in CEIT, which will phase-out about 33,000 tonnes.

Control measures are mandatory to Parties that have signed and ratified the Montreal Protocol; these Parties must comply with the Montreal Protocol ODS control obligations. Some unresolved issues raised in the past are still pending and several concerns are still to be fully addressed in order to assure the continued success of the Protocol. Some issues are common to both Article 5(1) Parties and CEIT but others are specific either to non-Article 5(1) CEIT or to Article 5(1) Parties, therefore the chapter will address them separately.

4.2 Challenges for Article 5(1) Parties

The Parties asked the Technology and Economics Assessment Panel (TEAP) to address concerns of Article 5(1) Parties. This section gives an update on issues raised in previous TEAP reports and presents challenges for the near future.

4.2.1 Information Exchange and Training

In its 1991 and 1994 Reports, TEAP emphasised that the barriers to rapid ODS phaseout were more informational and administrative than technical and economic. It also said that public awareness, information exchange and training were a prerequisite for both industry and government to be prepared before real progress in phasing out ODS could be achieved. In the initial years of the Protocol a lot of work was done to identify information needs and to create an effective communication system for ODS phaseout. It was stressed in the TEAP report that the ODS phaseout depended to a significant degree on the level of awareness on the issue by industry and its clients.

In the initial years of the Protocol, Implementing Agencies of the Montreal Protocol built their internal capacities to support phaseout activities and began to work closely with Article 5(1) Parties and industries. A great number of successful projects funded by the Multilateral Fund resulted in local and regional exchange of information and training. TEAP and its Options Committees have taken advantage of its expert meetings in different regions of the world to actively organise and/or participate in sector specific conferences and workshops to add to the information exchange network of the Montreal Protocol. Furthermore, UNEP's networking activities to train Governmental officials helped to increase awareness and to prepare Governments to eliminate ODS.

Capacity to access the enormous amount of information now available varies in developing countries. Internet access has made possible to increase the transfer of information to countries that have access to it, but still there is the need to have information to reach potential users, especially SMEs, by different communications media, and in many cases in their national languages.

National expertise has increased enormously due to the Montreal Protocol network that has used several pathways for information exchange, including the Implementing Agencies, the Multilateral Fund Secretariat, Governments, Industries and Industry Associations, Universities and the TEAP and its TOCs. Several TEAP and TOC members are now involved with Montreal Protocol project preparation and implementation tasks.

In several Article 5(1) Parties, in most of the sectors there are many small- and medium-sized enterprises (SMEs). It has been somewhat difficult to bring these enterprises into the implementation of the Montreal Protocol. There is still need for awareness, outreach, and training to bring this large body of SMEs into the process. It is important they can become fully informed on low cost, proven alternative substances and technologies available for them to rapidly phaseout.

The number of Decisions taken by the Executive Committee of the Multilateral Fund also increased at each meeting aimed to facilitate ODS phaseout in Article 5(1) Parties. However, in several cases national experts working for/or co-operating with the Governments and/or Implementing Agencies were not aware of all the recently adopted Executive Committee Decisions and their implications in project preparation as well as project implementation.

Both Implementing Agencies and the National Ozone Units must continue to work to transfer updated technical and policy related information for those experts. It is also important to keep them informed on the technological developments as well as successes and failures of the technologies offered/ transferred to Article 5(1) Parties to avoid unwise choices and implementation delays.

Article 5(1) Parties not participating in the Executive Committee may wish to consider a way to improve understanding of the Executive Committee Decisions and especially on the implications of those Decisions to their Countries. UNEP Regional Network meetings may be a path to follow for the purpose of improving communication.

4.2.2 Challenges for Governments

4.2.2.1 Institutional Aspects

With the first freeze in 1999 and the reductions mandated for 2005, Governments are faced with great challenges and must be ready to act. Institutional strengthening support through the MLF made possible for Article 5(1) Party Government officials to improve their knowledge on the subject and is still helping them to manage the needs of the country to meet Montreal Protocol targets and obligations. Unfortunately, rapid turnover in Government personnel and particularly in the staff of Ozone Units has delayed the process in several cases. In several Article 5(1) Parties, global environmental issues such as ozone depletion are not treated as priority. Many National Ozone Unit officials successfully convinced their superiors in Government to look at the ozone depletion issue more closely and give it the necessary importance. Others faced newly assigned superiors managing the area without much information on the Montreal Protocol and the country's obligations towards it, causing delays in project implementation and in the overall phaseout progress.

In some countries, non-harmonised links with other Ministries' not directly involved with the ozone Program, and/or their lack of knowledge on the obligations with the Montreal Protocol, has also contributed to delays in obtaining required signatures on some project documents. The Implementing Agencies can not start their work until project documents are signed and cleared by the recipient Governments.

During project formulation and implementation, prompt reaction to requests to and from the Implementing Agencies and good co-operation between the Ozone Unit and the Implementing Agencies is also important to accelerating the implementation process.

Data reporting is another important aspect to be considered. Accurate data on the consumption by sector/sub-sector is not available in several Article 5(1) Parties. Many still rely on their country programs to give inputs to Implementing Agencies. This has occasionally resulted in country requests for assistance that do not reflect their real needs to meet obligations under the Montreal Protocol. UNEP is working with Article 5(1) Parties through the Network of Ozone Officers to improve the determination and communication of needs.

The weak capacity of governments to institute and/or enforce laws, regulations, and policies is a common problem in many Article 5(1) Parties. In areas where competent independent expertise is not available, serious conflicts of interests among ministries, and strong financial interests by long established industries that benefit by continuing ODS uses may cause resistance to phase out. Many kinds of support, including institutional strengthening, capacity building, information exchange and training provides tools, but ultimate responsibility lies with Governments to absorb and prudently use this support.

4.2.2.2 Regulatory Aspects

A major obstacle for several Article 5(1) Parties is the inadequacy of the regulatory structure to support the phaseout process. Decision IX/8 requires the Implementing Agencies to take steps to assist Parties in designing and implementing their national licensing system and instructs the Multilateral Fund to provide funds for this purpose. This should facilitate meeting the needs of Article 5(1) Parties in relation to this issue.

It is important to note that there were cases of Decisions taken by the Executive Committee of the MLF, as in cases of Recovery and Recycling projects, that conditioned the disbursement of funds upon having the supporting legislation in place.

The price of ODS are not competitive with substitutes in most Article 5(1) countries. Some countries even tax their imported substitutes, which further extends the price distortion. Therefore, enterprises which have MLF funded projects finalised may find themselves in a situation where high costs of non-ODS alternatives prohibit them to be competitive with enterprises which still have not converted to non-ODS. In addition, fiscal cultures that rely on collecting taxes are posing a problem that adds to project implementation delays and is a big challenge for some Governments, that must waive taxes for equipment procured under the MLF. The issue of local supply of reasonably priced substitutes is a challenge for the MLF and governments accustomed to levying high tariff on imported materials.

4.2.3 Technological Challenges

Uncertainties regarding availability and cost of technology have been mostly resolved. The Montreal Protocol brought high levels of technical innovation and business opportunities. Market strategies were designed to respond to increased consumer awareness in developed countries as well as in several developing countries. Environmentally friendly products and better public image by industry brought gains in competitive global and regional markets. Industry creativity, research efforts, and co-operation among industry sectors, and widespread adoption of new technologies were successful in lowering costs.

There are now alternatives to replace almost all ODS uses. Therefore, the greatest challenge that remains is the implementation of projects in developing countries. In general technology transfer has been very successful with mature, proven technology being transferred to Article 5(1) Parties. Still, even with these technologies, training remains an important part of the projects to assure that technologies are correctly adopted and adapted to local conditions. Sometimes, due to a global shortage of specialised experts capable to solve technical issues, delays occur which not always are well accepted or understood by the recipient enterprise or country. Governments may wish to consider improving efforts to identify local expertise. In addition, there have been cases where MLF projects based on emerging technologies have resulted in equipment orders that exceeded production capacity. Countries, which picked technologies supported by only one supplier, have experienced delays due to lack of industrial capacity.

It is possible to conclude that the Montreal Protocol has forced the replacement of several mature technologies by many new alternatives. In some cases, these new technologies were easy to identify and offered clear paybacks, as was generally the case in the aerosol sector. However, in other cases, replacements were not as evident, and a number of possible solutions are available and must be carefully evaluated in the context of each specific application.

4.2.4 Sector Specific Challenges in Article 5(1) Parties

4.2.4.1 Aerosols

For aerosol products, other than MDIs, there are no technical barriers to global transition to non-ODS alternatives. The phaseout of much of the remaining

CFCs in the aerosol sector is dependent upon the availability of hydrocarbon aerosol propellants (HAPs). Where HAP supplies were available at reasonable cost, much of the transition has already taken place. The remaining use of CFCs in most countries – especially Latin America and South East Asia Pacific – is concentrated in the industrial/technical aerosols and in non-MDI pharmaceutical products.

In several places (India, Indonesia) there are very small aerosol fillers, which may be in residential areas or in very congested industrial areas that cannot be converted to a flammable propellant because of their location. A test project is underway in India to evaluate hand-powered production filling equipment. Should this test prove positive, it would facilitate the conversion of very small aerosol industries.

The use of HAPs entails the risks associated with handling flammable materials. Therefore in the process of replacing CFCs every effort should be made to ensure that safety standards at the manufacturing plant and at the consumer level are maintained.

Continued supply of MDIs will depend either upon import of products or local production. Local production of CFC – free MDIs will require the transfer of new technologies and may require new licensing arrangements and transfer of intellectual property. The costs of such local production will involve capital costs and licensing arrangements.

Montreal Protocol Controls on CFCs make no allowance to permit exemptions for essential uses prior to the phaseout date of 2010. This will mean that MDI manufacturers in Article 5(1) Parties will be competing for CFC supply in their local markets with other users of CFCs. TEAP has suggested that Parties may wish to recommend that Article 5(1) Parties start work on preparing their national transition strategies for MDIs. Thus, in the near future, national Ozone Units will have to work closely with their Ministries of Health to develop Transition Strategies that are suited to the unique conditions of each country.

4.2.4.2 Foams

Although no major technical barriers have been identified for the phaseout of CFCs used in Article 5(1) Parties for foam products, several issues have been identified which may delay the successful replacement of CFCs:

- Uncertainty over long term solutions in developed countries
- Price of substitutes relative to CFCs;
- Availability of identified substitutes;

- Delay in transfer of new technologies; and
- Long term safe use of any relatively more hazardous substitute.

CFC-11 continues to be widely available and is generally much cheaper to use than the currently available alternatives. Another factor constraining a more rapid phaseout is that very few alternatives are manufactured in Article 5(1) Parties. The technical options for low CFC consumers in Article 5(1) Parties are also limited because funding cannot cover the capital costs of, for example, hydrocarbon or liquid injected CO_2. Given the advantage of using existing equipment with next generation HFCs, once the uncertainties in price and availability are clarified these substitutes may serve as a cost-effective replacement in Article 5(1) Parties in some applications.

Sound safety training and control is of the utmost importance in using flammable blowing agents. Consistent use of safe practices by Article 5(1) manufacturers during storage, production and transportation of products—especially foam sheet—manufactured with flammable blowing agents continues to be of some concern. Safety audits should be instituted as standard operating procedure when hydrocarbons are used. There is concern that foam manufacturers who are using substitutes that are relatively more toxic than CFCs, especially for flexible foam using methylene chloride, may not comply with recognised use and handling standards.

4.2.4.3 Halons

Reducing halon production in Article 5(1) countries represents the most effective option in significant ODS emission reduction for the sector. A promising start on the process of addressing this issue is represented by the funding, approved in November 1997, of a US$60M project in China to initiate their sector plan for halon phaseout. Continued monitoring will be required to ensure that this is progressed effectively.

There is a wide range of alternative options, which can be used, including both new gaseous replacements as well as existing technologies. Therefore, there is no technical justification for continuing halon production in Art 5 (1) countries. The “critical needs” of specific sectors, such as aviation, military, oil, and gas industry can be supported by adequate management of existing inventories utilising recovery and recycling systems (halon banking).

Awareness, training, national codes and standards, and governmental support are crucial to curbing demand for halons in Article 5(1) Parties. However, the necessary national fire protection standards and design codes do not always exist for the halon alternatives and systems in these countries. It appears urgent, that consistent regulations and standards are implemented. The local fire protection communities are in a unique position to educate the public and ensure compliance. Multilateral fund programmes have been initiated in Malaysia, Brazil, Venezuela, China, and India which are attempting to address these issues. It is critical that these programmes be followed through, both internally and by external authorities, and with adequate resources.

4.2.4.4 Methyl Bromide

Alternatives to MB in developing countries are similar to those in non-developing countries. However, their adoption is often constrained by poor economic conditions, lack of technical knowledge and under-developed infrastructure. These constraints can be overcome by actions such as early recognition of problems, a national-international focus on seeking solutions, and systems for providing technical and financial assistance.

Despite these constraints, some developing countries have decreased their consumption and even officially phased out MB while others have increased their consumption over the past 4 years. Those countries reducing MB usage have done so by developing or introducing alternatives sometimes at the request of companies purchasing agricultural products. In the cases of multinational farming companies active in developing countries, reduction of MB is dictated by the parent companies following the phase out schedule in developed countries.

Developing countries increasing their use of MB have done so probably due to several factors. These factors include no national strategy for phasing out MB ahead of the phaseout schedules specified by the Protocol; slow importation and/or adoption of alternative technologies since time is required to test their effectiveness under local conditions; effective in-country marketing of MB by manufacturers and suppliers; and concern regarding pest resistance to phosphine. Some countries are reported to be importing MB to add to stockpiles to hedge against price increases and potential shortages in supply.

In contrast to MB that had a broad spectrum of activity, alternatives are often crop and pest specific. Adapting alternatives to local conditions may involve significant effort in local applied research and field-testing, on-farm demonstrations, technology transfer and user education. Long term solutions include institutional capacity building, improved information exchange and ongoing training.

Developing countries are concerned that MB use may shift from developed to developing countries in the future as a result of earlier phase out in the developed country. It would therefore be prudent to monitor both the policies and practices that encourage or discourage the use of MB and its alternatives in order to avoid developing countries being left with outdated pest control technology.

In addition, developing countries are also concerned that developed countries may impose trade restrictions on products treated with MB. Such a situation may render the 10-year grace period, currently up to 2015, ineffective. This could be unfavourable to countries whose growers do not have access to viable alternatives.

Countries may wish to take advantage of lessons learned from demonstration projects being implemented under the Multilateral Fund, so that policy measures can be designed and implemented to promote development of alternatives and to encourage ongoing training in the adoption of those alternatives.

4.2.4.5 Refrigeration, Air Conditioning and Heat Pumps

The process of phase out of CFC has been initiated in most of the Article 5(1) Parties. CFCs phase out is a technically complex proposition in refrigeration and air-conditioning sector. Technologies for some of the sub-sectors of RAC have not yet been crystallised even in the Developed Countries. Moreover Article 5(1) Parties are not in position to go in for more than one change over. Thus these countries are taking longer period in change over from CFCs to non-ODS technologies.

Although a large number of conversion projects have been approved the Executive Committee of the Multilateral Fund, their implementation needs to be accelerated. This appears to be caused by two reasons, namely, uncertainty of technology and associated cost of conversion. Many projects require more funds than are considered eligible under Multilateral Fund rules and many enterprises are not in position to invest their own funds for this purpose. Many of these are very small enterprises (there are countries that have very low CFC consuming large number of SMEs).

Some of the countries are evaluating the available alternative technologies in their own climatic and social conditions so that the adopted technologies may be observed easily. In this situation phase out may take a slightly longer period.

In most of the Article 5(1) Parties except the end user of CFC based appliances the manufacturing of refrigeration and air-conditioning appliances/ equipment is still with CFCs. This is increasing the inventory of CFC based appliances. This will pose a great challenge to Article 5(1) Parties to meet the Montreal Protocol deadlines especially after 2005 because these appliances will have useful life and will require CFCs for servicing. The recovered and recycled CFCs may not be adequate to service these appliances. The trade-in-off the existing units may not be possible in these countries because of their economic conditions.

Servicing is very common in Article 5(1) Parties and in most of these countries servicing is done by unorganised sector. It is estimated in most of the Article 5(1) Parties approximately 60% of ODS of Refrigeration, Air Conditioning and Heat Pumps sector is used for servicing. The increased inventory of CFCs based appliances will be a challenge. An another important aspect for Developing Countries is training of service technicians and up-gradation of facilities to handle the new refrigerants like HFCs and hydrocarbons.

4.2.4.6 Solvents

The widespread use of OD solvents and the variety and complexity of their applications pose several unique challenges for Article 5(1) Parties. Some of these include:

- Providing awareness and training on the ODS problem and solvent sector alternatives
- Accurately identifying products containing ODS
- Identifying, reaching and educating the very large body of SME users
- Availability of substitutes at reasonable prices
- Rapid reduction of carbon tetrachloride use in open baths
- Availability of processing equipment with controlled emissions

In many Article 5(1) Parties, most large industries and in some countries strategies to phaseout the whole solvent sector have already been approved to receive technical and financial assistance from the Multilateral Fund. Many have phased-out ODSs or are in the final process of doing so. Since cost effectiveness of phasing out solvents is an issue many challenges remain to adequately address this sector using the MLF assistance.

Another challenge which has to be dealt with, is to identify the small users, since usually their ODS supplies are sub distributors, reluctant to provide information on their customers. In some countries, this problem was tackled by regulating production and distribution via quota, but this procedure is difficult to implement in others.

For the case of ODS, used as solvents, a frequent problem is that technologies applicable to large industries are capital intensive and are not suitable for SMEs because the equipment is designed for handling relatively large volumes of solvents, making them uneconomical for small volumes.

4.3 Challenges for CEIT

Countries with Economies in Transition (CEIT) are those countries which are in a transition from centrally planned systems to market-oriented systems. Many of them became independent states after the dissolution of the Soviet Union and Yugoslavia and by the splitting of Czechoslovakia. Therefore they face the problems associated with the emergence of their new political structures besides the problems that all these countries face as a consequence of their economic transition.

These countries are: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Romania, Russian Federation, Slovakia, Slovenia, Tajikistan, The former Yugoslav Republic of Macedonia, Turkmenistan, Ukraine, Uzbekistan, and Yugoslavia

When the Montreal Protocol was signed only 8 of the 27 CEITs were independent states. Three countries (Albania, Armenia, and Kyrgyzstan) are not yet Parties to the Montreal Protocol. Eight Parties, out of 27 CEIT, are classified as operating under Article 5 Paragraph 1 of the Protocol (Bosnia and Herzegovina, Croatia, Georgia, Moldova, Romania, Slovenia, Macedonia, and Yugoslavia). The challenges they face together with the other Article 5(1) Parties were dealt with in the previous section. Country Programmes for all Article 5(1) CEITs have been prepared and in several countries the implementation of Multilateral Fund supported projects are underway. It can be expected, that those countries will make the first phase-out step by 2000-2001.

4.4 Special Circumstances of Non-Article 5(1) CEITs

The TEAP 1994 Assessment Report pointed out that a number of CEIT would inevitably be in non-compliance by 1996 and/or later. A Task Force on CEIT aspects under the TEAP in its November 1995 and November 1996 reports highlighted that:

- There are substantial differences amongst individual CEITs. They include Central (and Eastern) European states with sufficient regulatory and economic infrastructures to meet the scheduled ODS consumption phase-out, non-Party CIS (Commonwealth of Independent States, successors to the former Soviet Union) that do not have adequate infrastructure to monitor and to regulate ODS consumption, and countries having per capita income levels and ODS consumption equal or even lower than some Article 5(1) Parties.
- A strong feeling against ratification of the London Amendment

exists in a number of CEITs (Baltic States and CIS). These Parties perceive the obligation to contribute financially to the Multilateral Fund as being imposed arbitrarily on them;

- One of the most difficult problems to be solved is and will be the phase-out of ODS production in the Russian Federation;
- No or little delay (not more than 1 year) is expected against the phase-out schedule in several (Central and Eastern European) non-Article 5(1) CEIT, whereas a delay of 3-5 years is inevitable in the Baltic States and CIS.

The Implementation Committee discussed cases of non-compliance of several CEIT since 1995 and the Parties took decisions at their 7th, 8th and 9th meetings. To avoid further delays in compliance, financial support by the GEF was envisaged, conditional to the commitment of the respective governments to phase out ODS in accordance with a realistic and approved Country Program and to the ratification of the London Amendment.

As of October 1998, the number of non-Article 5(1) Parties is 16. The observations made in 1995 related to the special circumstances of CEIT are basically still valid and one can add currently many other points. These are:

- Most CEIT lack the trade and industry associations that typically exist in other countries. The absence of trade and industry associations hampers the phase-out because there is no network of experts and because there is no venue for reaching consensus.
- Information exchange, training and raising of public awareness is necessary to be continued and/or improved. GEF supported projects might serve as proper channel for such activities.
- Governments continue in most CEIT to be challenged to improve inter-agency co-ordination, to introduce or strengthen substantially license and custom control system for ODS and generally to improve enforcement of existing new regulatory measures.

Amongst the non-Article 5 (1) Parties CEIT, 10 states (Baltic and CIS) are in non-compliance. Their delay against the phase-out schedule of the Protocol is around 4 to 5 years. Their actual consumption of Annex AI, AII, BII, and BIII compounds is decreasing. Among these countries in non-compliance GEF projects are being implemented in Belarus, the Russian Federation and Ukraine. For 7 other countries projects are in various stages of preparation, approval and endorsement and beginning of implementation.

In Central/Eastern European CEITs GEF supported projects being implemented from 1995 and on contributed very substantially to a timely

phase-out. In those countries no or rather limited delays occurred.
The consumption of controlled substances beyond their phase-out schedule set by the Protocol in non-Article 5(1) CEITs is decreasing year by year; its quantity in 1998 might be in the range of 10,000-12,000 tonnes. This indicates that although very substantial non-compliance has occurred and is yet occurring, it seems to be manageable and resolved by the year 2001. Several factors might however challenge the goal of full non-Article 5(1) CEIT compliance by that point of time. The most important ones are:

- To get those states which are not yet Parties to the Protocol involved in the process of the Protocol, including ratification of the Amendments (or of the London Amendment as a minimum);
- to agree on a Special Initiative for funding the phase-out of ODS production in the Russian Federation, and an early start of its implementation;
- that the latest extensive economic difficulties in the Russian Federation and in other CIS countries do not ruin the financial viability of recipient enterprises in these countries.

5 Executive Summaries of Technical Options Committee Reports

5.1 Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride

5.1.1 Aerosol products (other than Metered Dose Inhalers)

For aerosol products, other than metered dose inhalers (MDIs), there are no technical barriers to global transition to alternatives. The major issue remaining is the use of CFCs in Article 5(1) Parties and CEIT. Some significant reductions have been achieved in recent years, and further reductions can be expected in the near future. Conversions can be characterised as three types: (1) self-conversions, (2) conversions assisted by the Multilateral Fund (MLF) of the Montreal Protocol, and (3) conversions assisted by the Global Environment Facility (GEF). Self-conversions have occurred when good quality hydrocarbon propellant was available at reasonable cost. Where capital outlay is necessary assistance is generally required from the MLF or GEF. The former assists aerosol fillers in Article 5(1) Parties, while the latter may assist Parties that are not eligible for MLF financing.

The ATOC estimates that 1997 CFC consumption in the aerosol sector was less than 15,000 tonnes in Article 5(1) Parties and some CEIT, excluding MDI use. The ATOC estimate of regional break down of quantities for 1997 is as follows:

1997 CFC Consumption in non-MDI Aerosols (metric tonnes)

ASEAN and Indian Subcontinent Countries*	1,500
China	2,400
Indonesia	700
Latin America	600
Middle East, Africa	700
Russian Federation	7,800
Ukraine	800
Other CEIT and CIS**	200
Total	**14,700**

* South Asia: India, Pakistan, Sri Lanka, Bangladesh, Nepal, Bhutan
** CIS: Successor States of the former Soviet Union

Since the 1997 Report, significant reductions have occurred due to the diminishing use of CFCs in China, where only a few pharmaceutical and industrial/technical aerosols remain to be converted. A slight reduction in CFC use in aerosols in the Russian Federation was due to reductions in three of the eight domestic chemical enterprises. CFC usage in Ukraine has

reduced, as export of CFC-based products is no longer allowed.
Poor economic conditions in South East Asia were responsible for a significant decrease in all aerosol production, including aerosols with CFCs. Additional reductions will occur upon completion of ongoing phase-out projects in several countries such as Jordan, India, Indonesia, Malaysia, Thailand, Tunisia, and Vietnam.

The remaining use of CFCs in most countries – especially Latin America and South East Asia Pacific (SEAP) – is concentrated in the industrial/technical aerosols (principally electronics contact cleaners) and in non-MDI pharmaceutical products. In China, remaining consumption is mostly in non-MDI pharmaceuticals. It is necessary to address the needs of these two sub-sectors to achieve total phase-out in aerosols.

The specific problems of the industrial/technical aerosols and pharmaceutical products require technical assistance in reformulation. Contact cleaners can be reformulated by using different new products such as HFC-43-10mee, volatile silicones or hydrofluoro-ethers. In the case of pharmaceutical products, many topical sprays can use hydrocarbon aerosol propellants (HAPs) or DME, while HFC-134a is a more costly alternative.

Hydrocarbons are the preferred substitutes for CFCs used in aerosols. The phase-out of the remaining CFCs in the aerosol sector is dependent upon the availability of HAPs. Where HAPs supplies were available at reasonable cost, transition out of CFCs has already taken place. Lack of ready availability of HAPs or any good quality hydrocarbon propellant is the main factor impeding the elimination of CFCs in India and SEAP, and an important factor in the Russian Federation.

A HAPs plant may be a simple facility that consists of storage tanks for crude and purified propane and butane and several towers with molecular sieves. Alternatively, it could also be a much more complicated facility that uses the petrochemical process of hydrogenation to saturate undesired olefin molecules. The type of process required depends entirely upon the quality of feedstock available. Transport and safety equipment is also needed.

Construction of suitable HAPs plants under the MLF are contingent on a corresponding volume reduction in CFC production. Usually the HAPs supplier is neither a CFC manufacturer nor an aerosol producer. Furthermore, there is no link between aerosol product manufacturers and CFC producers. Neither the HAPs manufacturer nor the aerosol manufacturer is in a position to guarantee the reductions in CFC production that the MLF is requesting as a prerequisite to fund HAPs projects. Consequently although there are no technical barriers to transition, it is difficult to predict when total phase-out in the aerosol sector will occur.

The financial cost of retrofitting to handle flammable propellants is another factor constraining transition. This becomes especially important considering the proliferation of small and very small fillers that either continue to use CFCs, or that are using commercial LPG (fuel grade mixtures of butane and propane) in an unsafe manner. Haphazard conversions to hydrocarbons makes it obligatory for governments to develop suitable monitoring procedures to ensure safe practices including proper design, management and use of prescribed filling equipment, hydrocarbon storage and handling facilities. When considering the conversion of CFCs to hydrocarbons, the problems facing small aerosol fillers operating in congested areas in Article 5(1) Parties need to be resolved.

A test project is underway in India to evaluate hand-powered production filling equipment. Should this test prove positive, it will facilitate the conversion of very small aerosol industries, by providing an inexpensive and safe alternative that uses HAPs.

CFC use in aerosols is declining, but the pace is slow. However, it could be accelerated if the specific problems of (1) HAPs availability, (2) industrial/ technical aerosols, and non-MDI pharmaceutical products, and (3) conversion of small and very small CFC users, were resolved.

5.1.2 Metered dose inhalers

CFC-containing metered dose inhalers (MDIs) are reliable and effective therapy for respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD). MDIs generally use CFC-12 as a propellant and most use CFC-11 and CFC-114 either alone or in a mixture to suspend or dissolve medication. HFC-134a and HFC-227ea have been approved as propellants in MDIs.

The prevalence of asthma and COPD is increasing worldwide. There are estimated to be 300 million patients with asthma and COPD worldwide. Evidence now confirms that asthma prevalence is increasing as urbanisation of developing countries continues. Currently, approximately 500 million MDIs are used annually worldwide, using approximately 10,000 tonnes of CFC. Non-Article 5(1) Parties that requested essential use nominations for MDIs are reported to have used 7,893 tonnes of CFCs in 1996.

There is international consensus that primary treatment of these diseases should be by the inhaled route. Inhalation permits fast and efficient delivery of treatment to the airways, with minimal risk of adverse reactions. Therapy necessitates regular treatment, often with more than one drug. MDIs remain the dominant inhaled delivery system in most countries and for all categories of drugs.

Overall use of inhaled medication is increasing because of increased disease prevalence. World Health Organisation/US National Heart, Lung and Blood Institute (WHO/NHLBI-GINA) Guidelines in asthma management also encourage the inhaled route as the preferred method of administering medicine. The mainstay of therapy for asthma/COPD is likely to remain therapy administered by the inhaled route.

An MDI is a complex system designed to provide a fine mist of medicament for inhalation directly to the lungs for the treatment of respiratory diseases such as asthma and COPD. The active ingredient may be dissolved in the propellant but is more often presented as a suspension of particles, the majority of which are less than 5 micrometers in diameter. A surface-active agent may be included to ensure that the drug is well suspended and to help lubricate the metering valve. When a patient uses an MDI, the drug/propellant mixture in the metering chamber of the valve is expelled by the vapour pressure of the propellant through the exit orifice in the actuator. As droplets of drug in propellant leave the spray nozzle the propellant gases expand, with very rapid evaporation, resulting in a fine aerosol cloud of drug particles.

Currently available alternatives to CFC-based MDIs are primarily CFC-free MDIs, dry powder inhalers (DPIs) (single or multi-dose), nebulisers (hand held or stationary), orally administered drugs (tablets, capsules or oral liquids) and injectable drugs.

All the CFC-free MDIs under development contain the same components as the CFC products, but the very different physical properties of the HFC propellants have meant that significant changes have had to be made. CFC-free MDIs will contain the new propellants HFC-134a or HFC-227ea, and some products may contain both. The HFCs have very different properties to the CFCs, which have resulted in new formulations being developed. The CFC-free MDI may superficially look the same as the CFC MDI but will have a different taste and mouth feel that will be obvious to the user.

In the future alternatives are likely to include non-CFC MDIs, new DPIs, new nebulisers, novel non-inhaled treatments, and new propellant-free inhalation devices. Some of these are already in the market, and many others are in the late stage of development or under regulatory evaluation and will reach the market place in the next few years.

DPIs have been formulated successfully for most anti-asthma drugs. These inhalers are an immediately available alternative for a large proportion of patients, but they may not represent a satisfactory alternative to the pressurised MDIs for all patients or for all drugs.

Currently available DPIs are lightweight and portable like MDIs; they require less co-ordination to use than most MDIs; they have the potential to use pure drug without additives; they are difficult for patients with very low inspiratory flow – e.g. small children and the elderly; they may require special packaging for use in humid climates; some require special handling during use; the cost compared with MDIs varies between products and countries; patient acceptability is not uniform. In some countries, over 85 percent of inhalers used are DPIs.

There is an increasing use of the multi-dose dry powder inhaler and this is likely to accelerate as new multiple dose devices are produced, particularly as they may be more suitable for young children with sufficient inspiratory flow.

DPI usage globally as a percentage of all inhaled medication is estimated to be around 17 percent. This figure varies considerably from country to country, e.g. currently from 85 percent in Sweden to less than 2 percent in the USA and there are no DPIs yet available in Japan. It seems unlikely that the uptake of DPIs in most countries will be at the levels seen in Scandinavian countries.

Nebulisers are devices, which are filled with drug dissolved or suspended in aqueous solution, which is converted to inhalable droplets using compressed air or ultrasonic waves. Nebulisers are generally not considered to be alternatives to MDIs but are restricted mainly to the treatment of infants and severely ill patients where patient co-operation is minimal or to situations when larger doses of drug and/or prolonged administration times are desired.

Oral medications include tablets, capsules, and oral liquids and have been the standard form of therapy for most diseases for many years. For existing products such as steroids and bronchodilators, tablet therapies involve higher doses and greater risk of side effects.

Regulatory authorities in some countries have recently approved four novel oral compounds (leukotriene modifiers) for the treatment of asthma. These may be of value to a certain number of those with asthma, but it is unlikely that these will be a full substitute for the current inhaled preventive therapy.

Some drugs used for the treatment of asthma and COPD are also available in injection form. However, this is not practical for general use in ambulatory patients and is therefore reserved for the treatment of hospitalised patients.

A number of pharmaceutical companies have introduced or plan to introduce a number of CFC-free MDIs. The most recent details for each of the major manufacturers are listed below.

3M Pharmaceuticals has approvals for and is currently marketing salbutamol (a bronchodilator) HFC MDI in over 40 countries. In the USA, salbutamol HFC MDI has been licensed to Schering Plough. 3M's beclomethasone (an anti-inflammatory steroid) HFC MDI has been submitted for approval in several countries with the first introduction anticipated during the second half of 1998. Under a further licence agreement, Hoechst Marion Roussell and 3M Pharmaceuticals have entered into a strategic marketing alliance to co-promote some of 3M's HFC MDI products. Glaxo Wellcome has filed registration applications for both salbutamol HFC MDI and fluticasone propionate (an anti-inflammatory steroid) HFC MDI (125/250 mcg) in over 30 countries worldwide. Further product launches are anticipated in the coming year. Rhone-Poulenc Rorer has filed applications for triamcinolone (an anti-inflammatory steroid) HFC MDI in the USA and Canada. Filings for di-sodium cromoglycate (a non-steroidal anti-inflammatory) HFC MDI have been made in 21 European countries and in Japan. Boehringer Ingelheim's first submissions for reformulated products are scheduled during 1998. Ivax (Norton Healthcare) launched its first HFC MDI, beclomethasone dipropionate (an anti-inflammatory steroid) in Ireland in January 1998. The same product range is also approved in France and further international approvals are pending. Norton also expects to receive its first regulatory approvals for salbutamol (a bronchodilator) HFC MDI before the end of 1998.

In the ATOC 1997 Update Report, graphical representations were included for projected timetables for the launches of HFC MDI products in both the European Union and the USA. These were based on an industry survey of International Pharmaceutical Aerosol Consortium (IPAC) members. More recent company specific data are available that indicate that a number of companies are well advanced with their reformulation programs. However, it would appear that the projected IPAC "best case" scenario is now not possible due to technical and regulatory delays.

However, the schedule for the safe introduction of new propellants and reformulated products, which was suggested in the 1994 ATOC report and confirmed in the 1996 and 1997 reports, remains on target. It is likely that a wide range of reformulated products will be available in many developed nations and transition will be making good progress by the year 2000. Minimal need for CFCs for MDIs is envisaged by the year 2005 in non-Article 5(1) Parties. Remaining technical, patent, safety and regulatory issues for some commonly used drugs still make it difficult to predict the schedule for full phase-out with precision.

The ATOC does not believe that a rigid global transition strategy is appropriate in view of the widely differing circumstances of individual Parties. However, the Parties could consider the benefits of a "Global Transition Framework" which would underpin national strategies and ensure that they are complementary. Because the phase-out of CFC-containing MDIs in non-Article 5(1) Parties is anticipated in the next few years, the Parties may wish to recommend that Article 5(1) Parties and CEIT start work on preparing their national transition strategies.

The essential use assessment process has allowed a better understanding of CFC requirements for MDI manufacture. Overall greater than 90 percent of the CFCs required each year for MDIs are filled into the product used by patients. The manufacture and on-line testing of MDIs result in some CFC being released to the environment. Pharmaceutical companies have made substantial investments to minimise emissions.

An intensive study on the possibility of using recycled CFCs was carried out on behalf of IPAC in 1993. The study analysed materials recovered from refrigeration plants and concluded that both recovered and reclaimed CFCs are complex mixtures. To be used in MDIs recovered CFCs would have to meet the same rigorous specifications as applied to virgin materials (i.e. free of toxic impurities). Because of the very complex nature of the contaminants and their number, it is impractical to develop commercial facilities to purify used CFCs to pharmaceutical standards.

At present continued supply of newly produced material remains necessary since stockpiling can only be viewed as a short term measure to provide buffer stock of CFCs. Stockpiled CFCs cannot be seen as a complete replacement for the annual essential use allowance in non-Article 5(1) Parties.

Strategic CFC stockpiles of reasonable size are prudent to safeguard public health needs. Stockpile size will vary according to country and company specific situations. However, excessive stockpiles could be utilised to prolong CFC MDI manufacture against the spirit of the Montreal Protocol, and act as an impediment to the transition to CFC-free alternatives.

Strategic CFC stockpiles can safeguard manufacturing supplies against unforeseen production contingencies and other uncertainties. Pharmaceutical manufacturers advocate the maintenance of reserves of CFCs to protect against supply disruptions. Maintaining a strategic stockpile for a period of time, e.g. up to 12 months, is not unreasonable. However, these levels may be adjusted depending on special circumstances.

The ATOC has considered the implications of the transition for patient subgroups that may have compelling medical needs.

Some patients may have a personal preference for CFC MDIs. This matter is likely to be overcome by education and should not be the basis for a continuing essential use nomination. Many patients can convert to DPIs. DPIs are continuing to be introduced by a number of companies into many countries. There is good evidence that the previously noted trend of increased DPI usage continues but since overall inhaled therapy has increased further, they have not reduced the sales of MDIs.

A second subgroup which may have a compelling need for CFC products well into the phase-out is low income patients (whether in Article 5(1) or non-Article 5(1) Parties) who rely on less expensive generic or locally branded products for control of their diseases. This issue has less to do with HFC MDIs versus CFC MDIs than it does with branded versus generic product price differentials, since it does not appear that HFC MDIs will be more expensive than their branded CFC counterparts.

In Article 5(1) Parties, the first control measure on the total consumption of CFCs commences in the year beginning 1 July 1999. Controls on CFCs make no allowance to permit exemptions for essential uses prior to the phase-out date of 2010. This will mean that MDI manufacturers in Article 5(1) Parties will be competing for CFC supply in their local markets with other users of CFCs.

Parties may wish to consider the procedure by which non-Article 5(1) Parties that no longer need CFCs for their own use can continue to produce CFC MDIs for export for a limited period, as necessary. Some CFC supply will be needed by multinational companies in, for example, the EU to enable them to service the continuing need of some Article 5(1) Parties for CFC MDIs.

Communication with experts in a number of developing countries including India, Pakistan, China, and Brazil has revealed some similarities, but there are some country specific issues. In all of these countries, the limited available information suggests that the airway diseases of asthma and COPD are common and increasing in prevalence. Local manufacture by multinational firms and/or local firms is reported in these countries, with local products sometimes cheaper than those manufactured by multinational firms. In China sixteen million CFC MDIs were produced in 1996 and consumption of CFCs for use in MDIs totalled 400 tonnes. In India, 6 million MDI units are sold annually with an additional 3 million being exported by one Indian company to other Article 5(1) Parties. In each of these countries, there is reported to be poor awareness of CFC and transition issues in general, as well as a lack of health professional awareness. Also, since it is anticipated that in most Article 5(1) Parties and some CEIT there will be an increasing number of patients newly receiving MDI therapies, it would be preferable for them to start on CFC-free products.

Continued provision of MDIs in Article 5(1) Parties 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) Parties and will overlap with the importation and local production of CFC-free MDIs by multinational and national companies. Local production of CFC-free MDIs by a local producer, a multinational company, or by a local producer in collaboration with a multinational company will require the transfer of new technologies and may require new licensing arrangements and transfer of intellectual property. The costs of such local production of CFC-free inhalers will involve capital costs and licensing arrangements. Multinational companies operating in Article 5(1) Parties should be encouraged to make the technology transfer as soon as possible. One company is already committing resources to install manufacturing capacity in Latin America (Brazil) and Eastern Europe (Poland) to manufacture HFC MDIs. These plants will be operational in the next couple of years and will serve local and regional market needs.

In relation to Article 5(1) Parties, the ATOC suggests that Parties may wish to consider:

- the importance of maintaining adequate supplies of the necessary range of inhaled medications during transition in non-Article 5(1) Parties
- encouraging the introduction of CFC-free technologies into these countries
- encouraging these Parties to start work on preparing their national transition strategies.

To facilitate patient and physician utilisation of the reformulated products, global education and training are required. Options currently employed and planned include:

- *Professional associations* – through medical journals, medical symposia, reports and newsletters.
- *Treatment guidelines* issued by the country’s medical authority which document the advantages and drawbacks of different forms of therapy and recommend specific forms of care for specific patient groups.
- *Promotional material and media coverage* – Advertising and promotional material placed in medical journals and circulated to physicians by pharmaceutical companies.
- *Pharmaceutical industry* – Education of the medical profession, support of medical symposia, reprint of pertinent articles and reports and information sheets to patients are strategies to help to inform both professionals and the public of developments and alternatives.

- *Medical literature* – Articles appearing in the medical journals inform professionals of developments, and several have been published since 1994, many written by members of the ATOC, with further major editorials to be published in 1998.

- *Support groups* that provide information, seminars, and programs aimed at both the general community and through schools, sporting groups etc.

The amount of educational activity being undertaken varies from country to country and should involve increasing awareness of DPIs as well as the reformulated MDI products. As more alternatives become available it is essential that a more active patient strategy is developed. This will involve concerted effort by the industry, health professional associations and national health authorities working together with patient support associations (e.g. National Asthma Campaigns and Asthma Foundations). For Parties without patient support associations, the NHLBI/WHO Global Initiative (GINA) may be able to provide suitable literature for copying in the same way as they do with their current patient booklet, or add transition information to the GINA page on the Internet (http://www.ginasthma.com).

Professional bodies and patient associations are most likely to address this issue if governments take a lead in highlighting the importance of the subject. These educational activities are likely to require funding. Responsibility for and sources of adequate funding need to be identified if a successful transition is to occur.

Increasing numbers of medical symposia are scheduled for 1998/9, including the World Asthma Meeting in December 1998. This is supported by the major world respiratory organisations (European Respiratory Society, European Society for Asthma, Allergy and Immunology, American Thoracic Society, Asia-Pacific Society of Respirology, American Academy for Asthma, Allergy and Immunology, International Union Against Tuberculosis and Infectious Disease and GINA). This meeting will highlight issues surrounding the safe transition to non-CFC treatments. UNEP is a co-sponsor of the World Asthma Meeting.

5.1.3 Sterilants

By the beginning of 1997, CFC-12 use in non-Article 5(1) Parties for 12/88, a sterilant gas based on ethylene oxide (EO), had virtually disappeared, as final inventories were depleted. There remain no technical barriers to the phase-out of CFCs in sterilisation, but in some Article 5(1) Parties there are indications of increased use of CFC-12 as a sterilant gas diluent. Some manufacturers of surgical equipment may even be shipping products from non-Article 5(1) Parties to be sterilised in Article 5(1) Parties.

In non-Article 5(1) Parties, low temperature medical device sterilisation is being met by HCFC-diluent replacement sterilant gas and 8.5/91.5 EO/CO_2, both of which are non-flammable. Pure EO can also be used, but since it is a flammable/explosive gas precautionary measures are necessary to use it safely. In some European countries formaldehyde is also used. There are a variety of not-in-kind substitutes, but some of these substitutes may either have materials compatibility problems or may be less robust processes with serious quality implications. Not-in-kind substitutes include radiation (gamma and electron beam), plasma systems, and liquid chemical systems. In other instances medical devices compatible with the steam process have been developed.

Global consumption of CFC-12 in this sector is very difficult to estimate since it is basically located in Article 5(1) Parties; it is estimated to be less than 1,500 tonnes. Estimated use of substitute HCFC replacement is thought to be less than 3,000 tonnes (some 90 ODP tonnes). CEIT and Article 5(1) Parties could convert to EO/HCFC-124 sterilant gas rapidly with reasonable cost and no changes in operating procedures.

HCFCs remain important as transitional products for sterilisation technology. Quality health care is dependent upon sterility assurance of medical devices. A new non-HCFC/EO sterilant blend has been tried, but has not been successful due to low sterilisation efficacy, high pressure limitations, and high cost. This alternative was developed in reaction to the EU ban on HCFC emissive uses in new equipment.

5.1.4 Miscellaneous Uses

CFCs have a number of miscellaneous uses of which tobacco expansion is the most significant. It is difficult to estimate the 1998 worldwide use of CFC-11 to expand tobacco. Most countries have stopped or will shortly stop the use of CFCs to expand tobacco. After 1998, China may be the only remaining country to use significant quantities of CFCs for this purpose. In 1996, 4050 tonnes were used in China compared with 900 tonnes in 1992. Based on the recent and planned installation of alternative carbon dioxide technology in China, declining use in this country is expected.

The CFC-11 tobacco expansion process is a patented, physical process that uses CFC-11 to restore cured, aged tobacco to its original field volume. In this process tobacco is impregnated with CFC-11 in a stainless steel vessel maintained at 50 C (120°F) and pressurised at 20 to 75 psig. The tobacco is then contacted with hot air (up to 165 C, 330°F) which causes the tobacco to regain its original volume. The CFC-11 is vaporised and recovered by cooling and compressing, hence most of the CFC-11 is continually recovered and recycled.

Expanded tobacco is used in tobacco blends and cigarettes to improve the smoking characteristics of cigarettes and keep “tar” and nicotine levels within reduced ranges.

Carbon dioxide is an alternative expansion agent used in many countries. Others used less commonly are nitrogen, propane, and *iso*-pentane.

The principal difficulty for Article 5(1) Parties is the high capital cost of conversion to alternative technologies. Most are converting to carbon dioxide expansion technologies.

5.1.5 Laboratory and Analytical Uses

Typical 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. Other uses are for critical applications in research and development where substitutes are not readily available, or where standards set by agencies require specific use of the controlled substances.

Essential uses of 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 substances be collected, recycled, and/or destroyed. Other relevant decisions include Decision VII/11, Decision VIII/9(4), and Decision IX/17.

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

It has been estimated that the total global use of controlled substances for these applications in non-Article 5(1) Parties will not exceed a maximum of 500 metric tonnes. Use in CEIT is unlikely to be more than a few hundred metric tonnes. Additionally, up to 500 metric tonnes could be used in Article 5(1) Parties for an estimated global consumption of 1,500 tonnes of controlled substances for laboratory and analytical uses.

TEAP has learned that the following specific uses have identified alternatives and substitutes and therefore do not require the use of ODS:

- testing of oil, grease, and total petroleum hydrocarbons in surface and saline waters and industrial and domestic aqueous wastes including the testing of water which is separated from oil and discharged from offshore drilling and production platforms

- testing of tar in road paving materials by dissolving tar and separating it from aggregate

- forensic fingerprinting.

The Standard of Purity recommended by TEAP and decided by Parties was based on international and/or national standards such as the International Standards Organisation (ISO) or Japanese Industrial Standards (JIS). High purity ODS and mixtures containing ODS shall be supplied only in clearly marked containers that belong to one of the following: containers equipped with closures; high pressure cylinders smaller than three litres; and 10 millilitre or smaller glass ampoules.

5.1.6 Carbon Tetrachloride

CTC can be used:

- As a feedstock for the production of other chemicals. The 1997 Report of the Process Agents Task Force (PATF), offered the following definition of feedstock:

  "A controlled substance that undergoes transformation in a process in which it is converted from its original composition except for insignificant trace emissions as allowed by Decision IV/12."

- Used as a process agent. The 1997 Report of the PATF offered the following definition of process agent:

  "A controlled substance that because of its unique chemical and/or physical properties, facilitates an intended chemical reaction and/or inhibits an unintended chemical reaction.

  Note 1: Refrigerants, solvent & cleaning agents, sterilisation, aerosol propellants and fire-fighting, are not process agents according to this definition.

Note 2: Parties need not consider use of ODS for foam blowing, tobacco puffing, caffeine extraction, or fumigation because these uses are already covered in other Decisions and/or by Technical Options Committee

Reports."

- As a solvent. This includes simple solvent extraction such as caffeine extraction and palm oil extraction, and cleaning applications such as metal degreasing and textile spotting. Substitutes are commercially available and economic and, thus, these uses should be discontinued to protect the ozone layer as well as to safeguard the health and safety of people now using CTC.

- In miscellaneous applications such as fire extinguishers, as grain insecticide fumigant, and in an anti-helminthic agent (especially for the treatment of liver fluke in sheep). These uses also should be discontinued for the same reasons stated above.

- As a laboratory chemical.

Data on both CTC production and consumption have, in the past, been difficult to obtain. The new UNEP data reporting formats will enable the collection of much clearer data and a more detailed analysis of CTC applications. Indeed, total CTC production data including production for feedstock use is well known for 1996 and was reported to UNEP as 203,820 ODP tonnes.

ATOC has estimated atmospheric emissions of CTC to be 41,000 tonnes (-25 percent, +50 percent) for 1996. The primary source of atmospheric emissions of CTC are from the use as a feedstock to produce CFCs. This has been estimated to be between 27,500 and 29,100 tonnes for 1996 (67-71 percent of total emissions). The majority of the emissions from feedstock use originate from CFC production in Article 5(1) Parties and CEIT (25,700 to 27,300 tonnes, 64-67 percent of total emissions).

Whilst CTC atmospheric levels have reduced as a result of the phase-out of CFC consumption in the majority of non-Article 5(1) Parties, they will only fall significantly in the near future if the use of CFC and CTC in Article 5(1) Parties is phased out at a faster pace than required by the Montreal Protocol. Otherwise use of CFC and CTC will remain frozen until 1 January 2005 and CTC emissions will remain unchanged until that time.
There are a number of measures that could lead to reductions in CTC emissions to the environment:

- Closure of CFC manufacturing facilities in Article 5(1) Parties and CEIT with accelerated introduction of alternatives.

- Conversion of facilities using CTC as process agents in Article 5(1) Parties to alternatives.

- Use of improved emission control technology in CTC and CFC manufacturing facilities in Article 5(1) Parties and CEIT.

- Use of improved containment and emission control technology in Article 5(1) Parties and CEIT manufacturing facilities using CTC as process agents.

The ATOC wishes to point out that projects to phase out solvent uses of CTC are eligible for financing under the Multilateral Fund. The ATOC further believes that in some cases eligible solvent uses have been presented to the Multilateral Fund incorrectly as process agent uses and, as a result, have not been funded.

5.2 Economic Options Committee

5.2.1 Introduction

The main theme of the 1998 Assessment Report of the Economic Options Committee (EOC) is a description of the progress made towards full implementation of the Montreal Protocol control schedules. The analyses presented address economic aspects of the implementation process, including assessments of the key components of policy regimes. The assessment covers implementation in the Article 5(1) Parties, Countries with Economies in Transition (i.e., the CEITs), the use of cost-effectiveness criteria by the Multilateral Fund (MLF) and the Global Environmental Facility (GEF) and implementation by the Non-Article 5(1) Parties (excluding the CEITs). Updates on economic aspects of selected controlled substances, trade issues, and “lessons learned” from the Montreal Protocol experience are also presented with consideration of their transferability to other international environmental agreements.

5.2.2 Policy Regimes for ODS Phase-out

A range of policies can be used to promote national ODS phase-outs. Parties recognise the importance of designing and implementing policy regimes that provide comprehensive and coherent strategies and appropriate policy measures, including investment projects funded by the MLF or the GEF. Command-and-control policies, market-based instruments, and voluntary action programmes have important complementary roles in policy regimes. The policy challenge is to design and implement policy regimes that are appropriate to national institutional capacities, industrial structure and trade patterns with respect to ODS production and consumption. Furthermore, experience suggests that there is ample scope for more extensive use of market-based instruments to improve the cost-efficiency of implementation.

5.2.3 Implementation: Article 5(1) Parties

The issues facing Article 5(1) Parties include compliance, inter alia, with their first control target for Annex A, Group I chlorofluorocarbons (CFCs)[1]. Studies addressing this issue conclude that virtually all Article 5(1) Parties will comply with 1995-1997 "freeze level." To meet subsequent control measures for 2002 and beyond, the Article 5(1) Parties will need to improve compliance by the small and medium-sized enterprises (SMEs), including the informal sectors. The use of market-based instruments is likely to be more effective than command-and-control policies in raising compliance levels by the SMEs and the informal sector. The quality of data reporting and management has important implications for assessing compliance. Recent studies highlight the need to improve data quality and management. Case studies for China, India and several African countries highlights China's increasing use of market-based instruments in contrast to India's more extensive reliance on command-and-control measures. Egypt is progressing towards a complete ODS phase-out in 1998/99. Ghana had reduced ODS consumption by over 85 percent by 1997 and expects to achieve an accelerated ODS phase-out. Cameroon established its phase-out policy in 1994 and reports a decline in ODS use and some illegal imports. Kenya faces challenges in phasing out CFCs in refrigeration, customs enforcement to curb illegal imports and in stemming the increasing use of methyl bromide for soil fumigation in the production of cut flowers and strawberries.

5.2.4 Implementation: Countries with Economies in Transition (CEITs).

CEITs have experienced difficulties in complying with the control schedules and paying their assessed contributions to the Multilateral Fund. Overall, significant progress in reducing the ODS consumption has been achieved by the CEITs, but some of the Non-Article 5(1) CEITs, most significantly the Russian Federation, failed to comply with the January 1,1996 phase-out target for Annex A and Annex B substances. A formal extension for Russian compliance, although requested, was not granted, leaving Russia in breach of the Protocol. This matter has not been resolved. However, by encouraging the funding of Russian phase-out projects through the GEF and ad hoc donors, the Parties have kept open a channel for influencing and participating in the design, implementation and monitoring of Russian responses to its Protocol obligations. The problems that Russia faces in switching out of ODS consumption also apply to other CEITs. These are principally difficulties in obtaining funds for switching production to non-ODS substances at a time when industrial prospects are poor and capital is extremely scarce. At the same time, the option of closure is very unattractive when unemployment is

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[1] The July 1, 1999 freeze level or baseline will be determined by the 1995-97 average levels of production and consumption of Annex A, Group I controlled substances.

already very high. In the case of Bulgaria, an economic analysis of the costs and benefits of the closure option versus continued operation with and without GEF support was carried out in 1996. The results showed that the benefits of GEF supported ODS phase-outs outweighed the costs for all but one of the nine enterprises covered by the study. As a result of this and other analyses, the GEF provided US $11 million for enterprise restructuring in the ODS-using sector for those enterprises shown to have reasonable economic prospects.

5.2.5 The Use of Cost-Effectiveness Criteria by the MLF and GEF

Chapter 5 addresses the use of cost-effectiveness measures by the MLF and the GEF in pursuing consistency and cost-efficiency in the implementation of the Montreal Protocol. The role and application of cost-effectiveness thresholds continue to evolve as the Executive Committee takes decisions on new concepts of investment projects such as “umbrella projects”, “terminal umbrella projects” and “sector approach projects” (e.g., the Halon Sector Plan in China). Further developments are likely as the Executive Committee progresses in its work on the application of cost-effectiveness criteria to projects designed to phase out ODS production capacity in the Article 5(1) Parties.

5.2.6 Implementation: Non-Article 5(1) Parties

Non-Article 5(1) Parties, with the exception of some CEITs, are in full compliance with the control schedules of the Montreal Protocol. Full compliance by Non-Article 5(1) Parties has been assisted by the introduction of “essential use exemptions.” Several non-Article 5(1) Parties have either accelerated, or propose to accelerate, their ODS phase-outs. In response to concern over illegal trade, the Ninth Meeting of the Parties (Montreal, 1997) decided to require Parties to establish licensing systems to control the import and export of new, used, recycled and reclaimed controlled substances. With respect to contributions to the Multilateral Fund, the payment record has been satisfactory, although there are some notable exceptions. Over the period 1991-97 as a whole, 88 percent of the total assessed contributions have been received by the Trust Fund leaving some US $100 million outstanding, mainly by the CEITs. This is a very satisfactory payment record in comparison with other international environmental agreements. Bilateral projects provide donor countries with opportunities to reinforce their trade and diplomatic relations with certain Article 5(1) countries. They also provide first-hand experience for non-Article 5(1) Parties in designing and implementing investment projects. This enhances their respective capacities to facilitate the implementation of the Montreal Protocol. However, relatively few donor countries undertake bilateral projects and those that do typically use substantially less than the 20 percent of assessed contributions permitted by the Protocol.

5.2.7 Update on Economic Aspects of Selected Controlled Substances.

5.2.7.1 Methyl Bromide

The Ninth Meeting of the Parties (Montreal, 1997) amended the methyl bromide phase-out schedules for Article 5(1) and for Non-Article 5(1) Parties; established criteria and procedures for assessing “critical use” exemptions for methyl bromide; and reviewed national decisions to accelerate phase-out dates for methyl bromide. In contrast, the United States delayed its phase-out of methyl bromide January 1, 2005 to conform to the Montreal Protocol phase-out schedule. The Non-Article 5(1) Parties, in aggregate, are well within reach of the required 25 percent reduction in consumption by January 1, 1999. However, because most of the overall decline in methyl bromide consumption has occurred in the United States and several other non-Article 5(1) Parties have not yet achieved significant reductions, it is possible that some of these Parties will face difficult challenges in meeting the 25 percent reduction target. For the Article 5(1) Parties, their 20 percent reduction target for January 1, 2005 is unlikely to cause concern provided that technical innovation and investment projects progress as expected.

5.2.7.2 HFCs and HCFCs

There are trade-offs between the benefits of using HFCs and HCFCs for ozone protection and the environmental costs associated with their emissions. Economic analyses can go some way in providing appropriate frameworks for assessing these cost and benefits. However, not all costs and benefits can be quantified and economic analysis alone may not be sufficient to guide decisions on alternatives that might have widely different distributions of costs and benefits.

5.2.7.3 Halons

This update for halons is limited to recent experience in China with market-based instruments to improve economic efficiency in the implementation of the Halon Sector Plan. The main economic instruments are a tradable production quota system and a bidding system for MLF grants. The results of this initiative, as reported to the EOC indicate that (1) economic efficiency improved; (2) significant environmental benefits were achieved; and (3) the cost of the phase-out to the Multilateral Fund was reduced by about 27 percent compared with the estimated cost if the MLF’s normal project-by-project approach had been used. In general, China’s experience with the sector approach and the use of economic instruments to phase out ODS indicates that substantial gains in economic efficiency can be achieved. Based on this experience, China is moving quickly to apply this approach to other ODS sectors, e.g., for the CFC production sector plan, the solvent sector plan and the tobacco sector plan.

5.2.8 International Trade Issues

The Montreal Protocol prohibits trade in controlled substances with non-parties. The purpose was to put pressure on non-parties to accede to the Protocol. In the 1994 EOC Assessment Report the effectiveness of these provisions were assessed. The broad conclusion was that these trade restrictions had been effective in getting almost all States to become signatories of the Montreal Protocol. The updated analysis reported here provides additional evidence that the conclusion of the 1994 EOC Assessment Report on this matter remains broadly correct. The trade provisions of the Montreal Protocol have undoubtedly reduced international trade in controlled substances, as intended. At the regional level, there is quantitative evidence that trade flows in relevant product groups have been impacted by the Protocol. The reasons for these impacts are: (1) reduced demand for products containing ODS, (2) difficulty in switching production to non-ODS based output, and (3) differential phase-out schedules for Article 5(1) and Non-Article 5(1) Parties. These factors are re-emerging with respect to trade in more recently listed controlled substances such as HCFCs and methyl bromide. Unrestricted trade in second-hand ODS-using equipment can create problems. The attraction for Article 5(1) Parties is low initial cost, however the derived demand for ODS for recharge and the costs of disposal drive up long term costs, and can create additional ODS emissions. With these factors in mind, action to restrict the export of "second-hand" ODS-using equipment from the Non-Article 5(1) Parties to the Article 5(1) Parties is under consideration. Currently, a draft Decision has been submitted for deliberation by the 10th Meeting of the Parties (Cairo, November 1998). Actions to constrain illegal trade are in hand, especially with respect to (1) the decision of the Ninth Meeting of the Parties to require import and export licensing systems to be implemented by all Parties; (2) proposed additional controls on the use of controlled substances in some major countries; and (3) the reductions in the supply of illegal controlled substances due to the recent decision by ten donor countries to provide additional funding to phase out CFC production in the Russian Federation.

5.2.9 Transferability of "lessons learned" from the Montreal Protocol experience

"Lessons learned" and the possible transferability of these lessons to the design and implementation of other international environmental agreements are updated from the 1994 EOC Assessment Report. Important lessons include the following:

1. *The role of science* is fundamental in establishing the nature and cause of an environmental problem and the remedial action required. The credibility of the scientific evidence, the risks to the environmental media, human welfare and other life forms, and of the effectiveness of remedial action must be established and communicated to motivate the commitment of resources to manage the risks.

2. *The role of independent, objective technical experts* in assessing the technical and economic feasibility of alternatives to the use of substances that result in environmental degradation has proved valuable in the context of the Montreal Protocol, and may well be readily transferable to other international environmental agreements.
3. *The role of co-operation* in mobilising the human and material resources of government, industry, and scientific and technical communities and of the wider public is fundamental to society's efforts to identify and resolve environmental issues.
4. *The role of equity* in the remediation of environmental degradation and in providing the resources required for resolution is fundamental to securing effective remedial action.
5. *The economic costs* of phasing out controlled substances have been shown to be very much overstated during the initial stages of identifying an environmental problem and mobilising commitment to environmental remediation.
6. *Similarities* between the Montreal and Kyoto Protocols are found in that both address global atmospheric gases with inter-dependencies between the environmental effects of certain substances covered by the two Protocols; and also in the common roles played by science, technology, co-operation, and equity. *Differences* are found in the objective of phasing-out controlled substances under the Montreal Protocol whereas the Kyoto Protocol focus is on the control of emissions, not on phase-outs, of the listed greenhouse gases.
7. *Applying the "lessons learned"* from the Montreal Protocol experience is facilitated by the participation of many of the scientists, technical experts, government officials, industrial experts, NGOs and other concerned groups that have been involved in the Montreal Protocol experience in the design and implementation of the Kyoto Protocol.

5.3 Foams Technical Options Committee

Historically, the fully halogenated chlorofluorocarbons (CFCs) used by the foam plastics manufacturing industry have been varied. An assortment of CFCs, including CFC-11, CFC-12, CFC-113 and CFC-114, and methyl chloroform have been used in numerous foam plastic product applications. However, the effect of the phase-out process has been to create further diversification.

The following highlights the technically viable options available by each foam type to eliminate CFC use as of 1998. Updates on the progress of each product in reducing CFC consumption and a status report on transition out of CFCs across major geographical regions are included. Table 5.3-1 provides a summary of low- and zero-ODP CFC alternatives.

5.3.1 Technology Status

- Zero-ODP alternatives are the substitutes of choice in many applications including packaging, cushioning (flexible) and certain rigid thermal applications;

- No single solution has emerged from transition. Choices must be retained to allow optimal solutions for given applications, producer-specific and country-specific circumstances;

- Technically suitable liquid HFCs have been identified, however, commercialisation is not expected to begin until early 2002;

- As replacement technologies have matured there is a strong trend to optimise around blends of two or more blowing agents.

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 -152a;[1]

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

- polyolefin with hydrocarbons;

- polyurethane packaging with CO_2 (LCD) and CO_2 (water) ;

- 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, and HFC-134a;

- polyurethane rigid insulation foams where energy efficiency and fire safety requirements can be met with hydrocarbons, HFC-134a or CO_2 (water);

- polyurethane integral skin where skin quality requirements can be met with CO_2 (water), HFC-134a or hydrocarbons.

The development of liquid HFC replacements for HCFC-141b continues for thermal insulating polyurethane, polyisocyanurate and phenolic foams. Although not yet commercialised, both HFC-245fa and HFC-365mfc, liquid HFCs, are being actively developed as zero-ODP, near drop-in replacements for HCFC-141b. It is anticipated that both of these products will be commercially available around the beginning of 2002. HFC-245fa has been successfully evaluated in a wider variety of foam types and in larger scale trials than HFC-365mfc due to greater availability of samples. However, sufficient data is available on both to show that these molecules are technically suitable as replacements for HCFC-141b in all blowing agent applications where HCFC-141b is currently being used. No toxicity issues have been identified. Uncertainty, however, over cost, availability and the long term environmental management of greenhouse gases is slowing development. For polystyrene and polyolefin insulating foam, the most likely long-term candidates are CO_2 (LCD), HFC-152a, HFC-134a, or blends thereof.

Pentane-based technologies for rigid polyurethane foams continue to evolve. Technical properties including thermal insulation and lower density have been improved with the use of blends of cyclopentane with iso-pentane or with iso-butane. These gains, have also led to improved cost competitiveness for hydrocarbon blown products.

Whichever types of blowing agent are choosen, an increasing trend in the development of newer technologies is the use of optimised blends. These often combine new and existing materials and are typically low or, most commonly, zero ODP. Blends are preferred because they more closely match the performance of the original CFC technologies. This trend is seen in most sectors, and it appears that use of single blowing agent systems has ended in several foam applications.

5.3.2 Transition Status

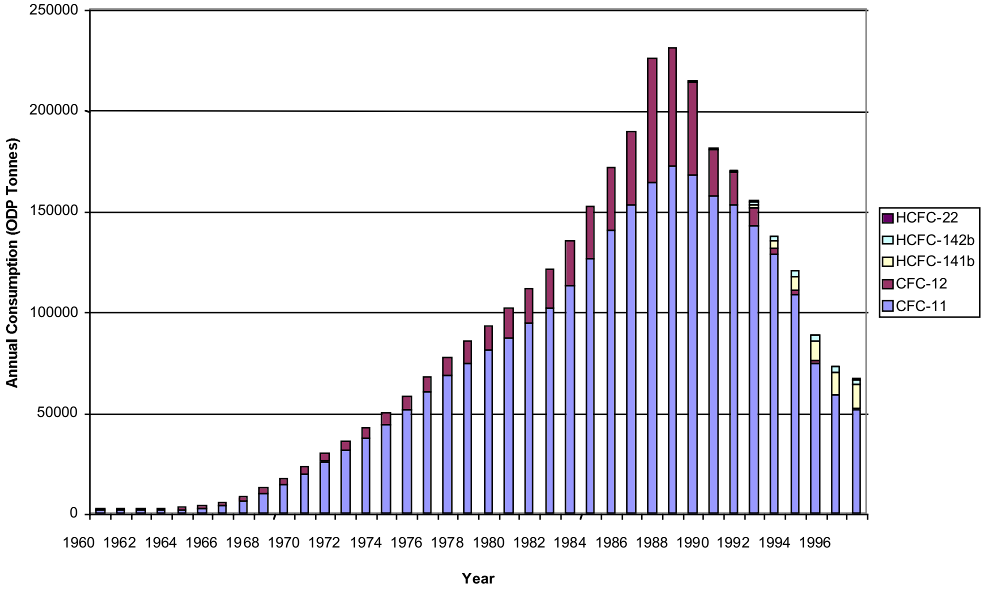
- Global use of ozone depleting substances in rigid foams has decreased by almost 75% since reaching a peak in 1989;
- 1997 HCFC use represents less than 20% of the total rigid foam sector use of ozone depleting substances, as measured in ODP tonnes;
- All CFC use in Non-Article 5(1) Countries (except for some CEIT) has been eliminated;
- In several markets and for certain applications HCFCs are necessary for rigid thermal insulating foams until zero-ODP solutions are available;
- In some Article 5(1) countries market expansion and related CFC use outpaces the phaseout results.

CFC use in non-Article 5(1) Countries was eliminated in 1996 except for some use in CEIT Countries. For Article 5(1) Countries CFC phaseout is technically feasible around the year 2001 provided Multilateral Fund projects are implemented without delay. However, the foam sector is growing very rapidly in a number of Article 5(1) countries. In addition to expanded CFC use among manufacturers who have not yet completed transition, some new operations are starting up with CFC technology. In some Article 5(1) countries this market growth and related CFC use outpaces the phase-out progress. It may be difficult in these countries to meet applicable phaseout deadlines.

In several markets and for certain applications HCFCs remain necessary for rigid thermal insulating foams until other long term zero-ODP solutions are commercially available. Given the availability of zero-ODP substitutes for other foam applications, it is unlikely that there will be expanding use of HCFCs in developing or developed countries beyond the insulation and some limited integral skin foam applications.

Figure 5.3-1 provides a summary of phase-out progress in rigid foams (including integral skin) as measured in ODP tonnes.

Figure 5.3-1 Phase-out of Ozone Depleting Substances in Rigid Foams



The long historic usage 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. This issue has been raised in previously by the Foams Technical Options Committee and will be addressed in more detail in future Foam Technical Options Committee reports.

5.3.3 Transition Barriers

- Some CFC and HCFC users are reluctant to finalize a transition strategy until there is greater certainty concerning HFC availability and suitability as long-term CFC replacements;

- Some alternatives are not always economically viable owing to high cost of capital investment and the sensitivity of unit foam costs to blowing agent costs;

- No technical transition barriers unique to Article 5(1) and CEIT Countries have been identified;

- Article 5(1) and CEIT transition may be delayed due to abundant supplies of low price CFCs, limited availability of alternatives, and on-going safety issues;

- The technical options for low volume CFC consumers in Article 5(1) and CEIT Countries are limited because funding cannot cover the capital costs of, for example, hydrocarbon or CO_2 (LCD) technology.

Technically viable zero-ODP alternatives have now been identified for all foam sector applications. However, some alternatives do not have the same quality of performance as CFC blown foam, and not all alternatives are commercially available.   Next generation liquid HFCs are expected to meet the technical performance needs of current HCFC-141b uses, however, these alternatives have not yet been commercialised. Liquid HFCs will be more expensive than currently used HCFCs, consequently, demand for full scale production is not expected until domestic phaseout schedules or HCFC use bans force transition. Uncertainty over the long-term implication of including HFCs in the basket of greenhouse gases to be addressed under the Kyoto Protocol has also further contributed to the reluctance of HCFC users to commit to transition.

Although no major technical barriers have been identified for the phaseout of CFCs used in Article 5(1) Countries for foam products, several issues have been identified which may delay the successful replacement of CFCs:

- price of substitutes relative to CFCs;
- availability of substitutes;
- delay in transfer of new technologies;
- long term safe use of any relatively more hazardous substitute, such as those that are flammable or have high vapour pressure.

CFC-11 continues to be widely available and is generally much cheaper to use than the currently available alternatives. Another factor constraining a more rapid phaseout is that very few alternatives are manufactured in Article 5(1) Countries. The technical options for low volume CFC consumers in Article 5(1) countries are also limited because funding cannot cover the capital costs of, for example, hydrocarbon or CO_2 (LCD). Given the advantage of using existing equipment with liquid HFCs, once the uncertainties in price and availability are clarified these substitutes may serve as a cost-effective replacement in Article 5(1) Countries in some applications. Consistent use of safe practices by manufacturers during storage, production and transportation of products—especially extruded polystyrene sheet—manufactured with flammable blowing agents continues to be of concern.

Table 5.3.1(a)
Technically Viable CFC Alternatives for the Foam Industry
Low ODP - Commercially Available Alternatives

Foam Type	**CFC Alternatives Low ODP Commercially Available**
Polyurethane: Rigid	
Domestic Refrigerators and Freezers	HCFC-141b, HCFC 142b/22 blends
Other Appliances	HCFC-141b, HCFC-22, HCFC-22/HCFC-142b
Boardstock/Flexible Faced Lamination	HCFC-141b, HCFC-141b/-22
Sandwich Panels	HCFC-141b, HCFC-22, HCFC-22/HCFC-142b
Spray	HCFC-141b, HCFC-22
Slabstock	HCFC-141b
Pipe	HCFC-141b
One Component	HCFC-22
Polyurethane Flexible:	
Slabstock and Boxfoam	HCFCs are not technically necessary for this end use
Moulded	HCFCs are not technically necessary for this end use
Integral Skin	HCFC-141b, HCFC-142b/-22
Miscellaneous	HCFC-141b, HCFC-22/CO_2(water)
Phenolic	HCFC-141b
Extruded Polystyrene:	
Sheet	HCFCs are not technically necessary for this end use
Boardstock	HCFC-22, HCFC-142b,
Polyolefin	HCFC-22, HCFC-142b

Table 5.3.1(b)
Technically Viable CFC Alternatives for the Foam Industry
Zero ODP - Commercially Available Alternatives

Foam Type	**CFC Alternatives Zero ODP Commercially Available**
Polyurethane: Rigid	
Domestic Refrigerators and Freezers	HFC-134a, hydrocarbons
Other Appliances	CO_2 (water), HFC-134a, hydrocarbons,
Boardstock/Flexible Faced Lamination	Hydrocarbons
Sandwich Panels	HFC-134a, hydrocarbons
Spray	CO_2 (water)
Slabstock	Hydrocarbons
Pipe	CO_2 (water), cyclopentane
One Component	HFC-134a or HFC-152a/Dimethyl ether/propane/butane
Polyurethane Flexible:	
Slabstock and Boxfoam	CO_2 (water), methylene chloride, acetone, AB Technology, pentane, CO_2 (LCD), extended-range polyols, additives, accelerated cooling, variable pressure
Moulded	Extended range polyols, CO_2 (water, LCD, GCD)
Integral Skin	CO_2 (water), HFC-134a, -152a hydrocarbons
Miscellaneous	CO_2 (water)
Phenolic	Hydrocarbons, 2-chloropropane
Extruded Polystyrene:	
Sheet	CO_2 (LCD), hydrocarbons, atmospheric gases, HFC-134a, -152a
Boardstock	HFC-134a, HFC-152a, CO_2 (LCD)
Polyolefin	Hydrocarbons, HFC-152a, CO_2 (LCD)

Table 5.3.1(c)
Technically Viable CFC Alternatives for the Foam Industry
Low ODP - Not Commercially Available Alternatives

Foam Type	**CFC Alternatives Zero ODP Not Commercially Available**
Polyurethane: Rigid	
Domestic Refrigerators and Freezers	HFC-245fa, -365mfc
Other Appliances	HFC-245fa, -365mfc
Boardstock/Flexible Faced Lamination	HFC-245fa, -365mfc
Sandwich Panels	HFC-245fa, -365mfc
Spray	HFC-245fa, -365mfc
Slabstock	HFC-245fa, -365mfc
Pipe	HFC-245fa, -365mfc
One Component	-
Polyurethane Flexible:	
Slabstock and Boxfoam	-
Moulded	-
Integral Skin	HFC-245fa, -365mfc
Miscellaneous	-
Phenolic	HFC-245fa, -365mfc
Extruded Polystyrene:	
Sheet	-
Boardstock	HFC-134
Polyolefin	-

5.4 Halons Technical Options Committee

5.4.1 Introduction, Background and Progress

Halons are halogenated hydrocarbons, first introduced into commercial use during the 1960s, which exhibit exceptional effectiveness in fire extinguishing and explosion prevention and suppression. They are clean, electrically non-conductive, and leave no residue. Halon 1301 has proven safe for human exposure at concentrations sufficient for fire extinguishing. This unrivalled combination of desirable properties led to the selection of these agents for many fire protection applications. Halon 1211, a vaporising liquid at room temperature, has been widely used in portable fire extinguishers, and to a lesser extent in fixed extinguishing systems for unoccupied areas. Halon 1301, a gas at room temperature, has seen widespread use in fixed systems throughout the industrial, commercial, marine, defence and aviation industries. Halon 2402, a low-boiling liquid, has primarily been used in the defence, industrial, marine, and aviation sectors in Russia and other countries of the former Soviet Union. Two other halons, 1011 and 1202, were much less widely used. Increases in atmospheric concentrations of halon 1202, recently reported in scientific journals, cannot be explained by use as a fire extinguishant. Halon 1202 was only used as a fire extinguishant on a few aircraft types that are longer produced. Parties may wish to examine the possibility that inadvertent production and release of halon 1202 during halon 1211 production in Article 5(1) countries is the source of these atmospheric concentrations.

Unfortunately, halons were later implicated in the catalytic depletion of the stratospheric ozone layer, and in consequence halons 1211, 1301 and 2402 are listed under Annex A Group II as Substances Controlled by the Montreal Protocol of 1987. As a result, extensive research and development was stimulated both into new liquid and gaseous halocarbon replacements for halons, and also into the use of existing and new alternative approaches including carbon dioxide and inert gases, water and water mists, powders and fine aerosols, foams, and pyrotechnic gas generators. The wide range of options that soon became available have now resulted in an almost complete cessation of halon use in non-Article 5(1) Parties and in many Article 5(1) Parties for new installations across a number of applications. These include industrial and commercial total flooding systems, electronics and computer facilities, ground vehicle engines and portable extinguishers. In some of these areas there has also been significant retrofitting of existing halon systems.

Well maintained halon systems are substantially non-emissive in normal circumstances. Emissions from testing and training, previously significant, fell substantially once the environmental consequences were understood, and at the same time recovery of agent during servicing and decommissioning of equipment became routine. In view of the existing installed base of halons, the low levels of losses now being achieved, and the availability of replacements and alternatives for many applications, it became apparent that future halon needs could probably be met by the use of existing material without the need for continued production, provided access to and international trade in recycled agent remained possible. Thus, with the support of the Halons Technical Options Committee, the cessation date for halon production in the non-Article 5(1) Parties was progressively brought forward under the London and Copenhagen Amendments to January 1994. The early phase-out of halon production was a notable success story - the first of the Ozone Depleting Substances (ODS) to be phased-out of production. For Article 5(1) Parties, a ten year grace period was agreed, relative to the London schedule, to give a production phase-out date of 2010.

There do, however, remain several applications for which no technically feasible substitute has yet been identified. For new installations in non-Article 5(1) Parties these are largely confined to halon 1301 used in aviation and some defence and oil and gas facilities. Particularly important and demanding requirements which have made the identification of replacements and alternatives exceptionally difficult in these “Critical Uses” include considerations such as fire suppression effectiveness at low temperatures; minimal toxic hazard to the health and safety of crews, maintenance staff and passengers; and the weight and space requirements of the agent and its associated hardware. In the case of already existing installations, more significant constraints may apply where the fundamental fire safety design is predicated on the unique properties of the halon system or where an expensive retrofit cannot be justified for an asset whose useful life expectancy has already become limited. In Article 5(1) Parties, further considerations may yet apply: for instance, no water supply may be available, or it may be unreliable or of insufficient quality; and the foreign exchange cost of imported fire extinguishants or equipment may be prohibitive compared with halon use.

As was envisioned when the date for cessation of production was brought forward, continuing needs, in particular those of the Critical Uses, are successfully being met by management of the existing halon inventory. In a very few instances, countries or individual users such as national defence ministries or major airlines have established halon repositories to support their anticipated future needs. However, the majority of the agent is actually being found from the continuing process of decommissioning existing installations. This in turn is being undertaken either as part of a halon replacement program or, much more commonly, when the protected asset has naturally reached the end of its useful life. This latter process may be facilitated by clearing houses which, in some countries, assist buyers and sellers of halon to establish contact, but which themselves hold no stocks.

The single exception to the ability to rely on halon banks relates to halon

2402. This agent was used almost exclusively by just a few Parties - principally Russia, but also other countries of the former Soviet Union, and some of the former Warsaw Pact nations - all of whom still face significant structural and economic problems. Significant progress has nevertheless been made by these Parties in limiting production of the other halons. However, in the case of halon 2402, there are no international stocks from which to draw; the installed base was relatively modest; it is often too recent to be giving rise as yet to any significant level of decommissioning; and its uses were largely limited to vital installations. As a result the resupply process described above has not arisen and is unlikely to be sustainable, at least in the short term. Approval of limited Essential Use production, at a level small compared with the previous rate, to allow the support of existing equipment was therefore recommended by the Halons Technical Options Committee and was subsequently approved by the Parties. This continues to be reviewed annually based on reported progress towards the complete phase out of production.

That it has not been found appropriate to support any other Essential Use application - from a substantial number which have been proposed - represents another significant success for the halon sector.

5.4.2 Outstanding Issues

Despite the successes achieved, concerns remain. These are set out below, and some of the strategy options by which they might be addressed are listed in Section 5.4.4.

5.4.2.1 Article 5(1) Production

Reducing halon production in Article 5(1) countries represents the most effective option to significantly reduce ODS emissions for the sector. While the developed countries accepted an accelerated phase-out date and ceased production of halons in 1994, the Article 5(1) Parties significantly increased production and were making as much halon 1211 by the end of 1997 as was produced world-wide just prior to 1994. A promising start on the process of addressing this issue is represented by the funding, approved in November 1997, of a (US)$60M halon sector project in China to initiate their country program. Continued monitoring will be required to ensure that this is progressed effectively.

As mentioned at the Ninth Meeting of the Parties, "There [is] … a need for vigilance to ensure that short term economic interests [do] … not now override the environmental concerns." Representatives from Article 5(1) countries noted that most of their halon consumption is not to maintain existing Critical Uses, but rather for newly installed non-Critical extinguishers or systems. This is because it is easier in the short term to continue with "business as usual", even though this is at the expense of users who will be left with protection systems requiring halon long after all production has ceased. These users will soon have a non-functional fire protection system or will need to reinvest in an alternative system, paying twice for protection in a short period. In contrast, discontinuing halon consumption has the added benefit of significant emission reductions. Additionally, there are a number of areas where adoption of appropriate strategies can yield incremental reductions in halon emissions. They are covered briefly as "controllable" halon emissions in this report and extensively in the HTOC Technical Notes[1].

Awareness by the fire protection community and users, training, national codes and standards, and governmental support are crucial to curbing demand for halons in Article 5(1) Parties. However, the necessary national fire protection standards and design codes do not always exist for the halon alternatives and systems in these countries. This leaves many users vulnerable to unfounded and exaggerated sales claims regarding fire suppression alternatives, resulting in inappropriate agents or systems being installed in many applications. To preclude this problem, consistent regulations and standards must be implemented. The local fire protection communities are in a unique position to educate the public and ensure compliance. Multilateral fund programmes have been initiated in Malaysia, Brazil, Venezuela, China, and India which are attempting to address these issues. It is critical that these programmes be followed through, both internally and by external authorities, and with adequate resources.

5.4.2.2 *Countries with Economies in Transition (CEITs)*

A second area of concern relates to the CEITs who have a number of particular difficulties that are greatly exacerbated both by the major economic problems, which these Parties continue to face, and by infrastructure limitations. For instance, little or no contribution to the implementation process from industry, trade associations or insurers, so that the entire responsibility rests with government bodies. A first grouping of CEITs is dominated by imported halon 1211 and 1301. These countries have largely introduced all control measures required by the Protocol, but their installed base is relatively small. Their installations tend to be quite recent and are largely limited to vital applications. This situation does not give rise as yet to any significant level of decommissioning from which continuing needs can be met. The modest installed base also means that establishment of recycling facilities and, if appropriate, repositories, even on a national basis, may not be economically viable, while the co-ordination necessary to build and operate regional facilities is difficult to achieve. A second group of CEITs, the Commonwealth of Independent States (CIS), whose key industrial facilities as well as military equipment originated in the former Soviet Union, are obtaining halon 2402 to support these installations from new Essential Use production by the Russian Federation. Establishment of a halon 2402 management program to eliminate the need for such production is a key aim.

5.4.3 Responsible Management

There remain continuing Critical Uses, almost all of which relate to halon 1301, whose needs must be met by recycling and reusing existing material. At present, the majority of the agent for this purpose is being found from the continuing process of decommissioning of existing installations, most commonly when the protected asset has naturally reached the end of its useful life; as the number of remaining halon installations dwindles - a process further accelerated by the increasing political encouragement to replace halon proactively in existing installations - this source of agent for reuse will diminish and eventually disappear. Not all long term Critical Users appear to be aware of this inevitable development, and some may therefore be inadequately prepared in terms of assessing their projected needs and making appropriate provision to ensure that they will be supported. Unless and until it is apparent that there is a clear surplus of agent for these needs, widespread destruction of halon 1301 cannot be recommended.

It continues to be essential to minimise emissions as far as possible in accordance with the implications of the Report on Scientific Assessment of Ozone Depletion, which identifies the benefits attainable “if halons presently contained in existing equipment were never released to the atmosphere”. This applies with equal force to existing installations (whether in Critical Uses or not), to the servicing and decommissioning processes, and to repositories. Also clear from the Scientific Assessment is that, while all emissions are undesirable, those which take place in the immediate future occur while the ozone layer is at its most depleted, and therefore most vulnerable, and thus have a greater impact than those which are delayed by some years or even decades. Actions which cause increased emissions in the short term where the alternative is safe retention of stored halons in installed systems, or which bring forward in time a potentially emissive transaction, should be carefully assessed with this in mind.

5.4.4 Strategy Options

5.4.4.1 Article 5(1) Production

In the case of portable fire extinguishers, there are three primary options for the replacement of general-purpose halon 1211 extinguishers. They are broken down by agent type as follows, and the probable percentage of halon 1211 replacement applications given for each:

1. ABC powder extinguishers, stored pressure type – 75 percent
2. CO_2 squeeze grip extinguishers – 20 percent
3. Halocarbon extinguishers – 5 percent

There is concern about good quality ABC powder production in Article 5(1) countries, and technology transfer may be required. Additionally, the manufacturing process for extinguisher containers and valves is moderately expensive. Projects for the conversion of manufacturing processes are being funded by the Multilateral Fund in some Article 5(1) countries.

In the case of total flooding fire suppression systems, the alternatives with the highest likelihood of longevity on the market are considered the preferred choice. There are environmental concerns such as ozone depletion, global warming, and atmospheric lifetime. Many options are currently available but high costs are a deterrent. Those that are considered to be accessible to Article 5(1) countries and have a strong likelihood of remaining so are as follows:

1. Inert Gas Systems
2. Halocarbon (HFC and HCFC) Systems
3. Water Mist Systems

However, there is still concern in Article 5(1) countries regarding the high cost and the necessary technology transfer on hydraulic and installation design for these extinguishant types. Until such time as these issues are resolved, existing systems should be serviced with recycled halon, and new alternative systems should be selected based on countries' plans and strategies.

Some Article 5(1) countries have stopped production of halon, and their projects for Multilateral Fund support are progressing. However, the current cost of alternative fire protection to these countries is very high. The most important concern at present is the need for new National Standards for alternatives, which will help in reducing these costs.

5.4.4.2 CEITs

Central and some Eastern European countries are in full compliance with the Protocol. However, problems remain to be solved, principally implementation of effective halon recovery and recycling systems. Establishment of a recycling station equipped with a halon reclamation unit in Hungary is a step towards effective recovery and recycling. In Poland, the Czech Republic and other countries there are no reclamation facilities, and so only a portion of the halon from decommissioned equipment (that which does not require removal of contaminants) is recycled. To organise a more effective recovery and recycling system while avoiding unnecessary emissions additional reclamation facilities are necessary, but current market conditions and funds will not support this. Funding assistance from international as well as national resources may be required. For instance, Poland's great size means that organising a recovery network is a major undertaking, and funds are being sought to initiate the process. For this and the remaining steps, it is expected that a substantial effort from many resources will be required. The unique circumstances of most CEITs, where there is no strong industrial body or trade organisation to be involved in the process, means that change is likely to require a strong lead from government organisations. In the present economic situation, taking into account community priorities, this may be difficult. Possibly a more efficient solution, but one very much more difficult to organise, is to establish recycling and destruction regionally, based on international co-ordination and financial support.

The Russian Federation continues to produce halon 2402, albeit at a rate of only about 6 percent of the peak: bringing this to an end and implementing a safe management and control system are the main issues at present. Accelerating procedures to enable execution of projects for recycling and the conversion of halon 2402 production to alternatives would facilitate the process. This should minimise halon 2402 dependency as well as support critical needs for halon 2402 in the Russian Federation and the other CIS countries. Critical needs for halons 1211 and 1301 are not currently a problem, as these halons are presently obtainable world wide, though there is no certainty that this availability will continue over the long term.

For CIS and Baltic countries, the important issue is the education of decision makers, technical authorities, and the fire protection community. This needs to include training, seminars, and the translation of technical materials (such as HTOC Reports and Technical Notes) into Russian, and their dissemination within those countries. Also required are estimates of national halon stocks and development of national strategies for halon phase out, including a halon management program and the subsequent steps related to decommissioning.

In the longer term, destruction of badly contaminated or excess halons will be required in most, if not all, CEITs. This represents a particular problem, as there are very limited facilities at present for destruction of hazardous chemical wastes. Early preparation for this future need should therefore be seriously considered. Well organised recovery and recycling schemes would be an important first step in preparing for this while avoiding unwanted emissions.

5.4.5 Responsible Management

The phase out of production of halon in non-Article 5(1) countries has resulted in recycled halon being the only available supply in the developed countries, and the primary supply of halon 1301 elsewhere. The key to ensuring an adequate halon supply for Critical uses, while at the same time minimising unnecessary emissions, is to develop programmes to encourage the wise management of this resource.

Repositories and clearing houses provide a sound pathway for halons to be directed to Critical Uses, and also allow for tracking of material if deemed necessary. They are also the key to responsible trade across international boundaries, and should be supported and encouraged by national governments. In addition, HTOC is of the opinion that a careful management program for the remaining inventory is also likely to result in a lower emission outcome. Wise management practices provide a basis through which to implement an environmentally sound disposition of excess stocks when alternatives for Critical Uses become available in future.

Establishing a list of Critical Use applications is not a recommended practice. It is crucial to maintain pressure on Critical Users to continue their search for replacements and alternatives. This is a prime reason for avoiding such a list, which introduces the possibility of complacency and a resultant reduction in the urgency of this activity. Continuing to apply the criteria set out in Decision IV/25, in the context of efforts by Critical Users to find alternatives, provides the necessary stimulus to maintain these efforts. Furthermore, it is no more possible to develop a list which is valid for all countries than it is for all time; technical as well as economic constraints will vary, and the final assessment will always be a matter for local experts. Many of the remaining applications are in highly regulated markets, and where substitutes are found, Parties can speed their implementation by removing impediments such as conflicting standards or regulatory barriers.

Another essential control mechanism in the plan to reduce halon emission levels is to ensure that mandatory use bans are not introduced abruptly. An appropriate timeframe for action, government investment, and infrastructure support are important considerations for the success of any regulatory initiative. Many users have invested heavily in halon fire protection systems. A marketable value for halons helps to offset the costs of replacement systems for applications where alternatives could be used and assists in mitigating the need for a future essential use nomination to meet the needs of applications where halon remains the only choice. Programmes that impose destruction costs on users or set unrealistic forced decommissioning targets are likely to result in surreptitious emissions - to the detriment of the environment. Thus the objective of any program must be carefully to balance supply and demand while ensuring that life safety is not compromised.

Finally, any management program must contain a key element of responsibility. The “Responsible User” concept and the possible introduction of an associated charter or voluntary industry Code of Practice would establish the practical measures to prevent unnecessary releases of halon to atmosphere.

5.5 Methyl Bromide Technical Options Committee

5.5.1 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 and come from 11 Article 5(1)[1] and 12 non-Article 5(1) countries. There are 39 members of MBTOC comprising 13 (33 percent) from Article 5(1) Parties and 26 from non-Article 5(1) Parties.

This MBTOC 1998 Assessment reports on MB usage; the quantities produced and consumed; existing and potential alternative treatments for its uses as a soil fumigant; as a fumigant of durable commodities and structures; and as a fumigant of perishable commodities. In addition, the report covers developing country perspectives, quarantine and pre-shipment issues, and methods for reducing MB emissions.

5.5.2 Mandate

Under Decision VII/34, taken at the seventh Meeting of the Parties to the Protocol in December 1995, the Parties requested the Assessment Panels including MBTOC undertake full Assessment[2] reports and submit them to the Secretariat for consideration by the Open-ended Working Group and by the eleventh Meeting of the Parties in 1999.

5.5.3 General Features of Methyl Bromide

MB is a fumigant that has been used commercially for more than 40 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 moderate amount is used for disinfestation of durable and perishable commodities, and a minor amount is used for disinfestation of buildings, ships, and aircraft.

[1] Article 5(1) refers to developing countries consuming less than 0.3 Kg ODS per capita; Non-Article 5(1) refers to industrialized or developed countries

[2] MBTOC. 1995. Report of the Methyl Bromide Technical Options Committee. Montreal Protocol on Substances that Deplete the Ozone Layer. *UNEP (Nairobi)*: 304 pp.

It has features which make it a versatile chemical with a wide range of applications. In particular, it 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.

Although MB is clearly a most useful pest management technique in specific instances, it was listed under the Montreal Protocol as an ozone depleting substance in 1992 which necessitates ultimately that its production must cease. There are also a number of concerns apart from ozone depletion which have 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.

5.5.4 Consumption

Under the Montreal Protocol, MB 'consumption' is defined as 'production plus imports minus exports, feedstock and quarantine/pre-shipment (QPS)' uses.

Of the 1996 global production of MB of 71,425 tonnes, approximately 2,759 tonnes (3.9 percent) was used as a feedstock for chemical synthesis, with the remaining 68,666 tonnes produced for fumigation. Based on official data, the 1996 global[3] consumption for fumigation (including that used for QPS) was estimated as 66,750 tonnes with approximately 75% of this being for soil treatment, 13% for fumigation of durable commodities, 3% for structures, and 9% for perishable commodities. QPS use is 15,000 tonnes equivalent to 22 percent of global fumigant use. Production for fumigation peaked in 1992 at 72,967 tonnes and has decreased by 5.9 percent in 1996 reflecting the freeze already implemented on 1 January 1995 by developed countries.

The Committee noted that some Article 5(1) Parties expect to increase their use of MB substantially, possibly due to an increase in the trade of commodities requiring MB fumigation. However, other Article 5(1) Parties expect to decrease their use, and have put into place strategies to curtail and eventually eliminate MB.

[3] Data quoted on MB consumption excludes feedstock in further quotes in this Executive Summary.

5.5.5 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 percent cut in production and consumption, based on 1991 levels, from 1 January 1999, a 50 percent cut from 1 January 2001, a 70 percent 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 percent 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 paragraph 5 for all Parties for the amounts of MB used for QPS purposes (refer Section 1.9). For those Parties wishing to consider the impact of the QPS exemption MBTOC has provided further information in a chapter in the report on QPS which may be of assistance.

In light of an Assessment to be provided by the Technology and Economic Assessment Panel in 2002 the Parties agreed in Decision IX/5 that, for Parties operating under Article 5(1), decisions would be taken in 2003 on further specific interim reductions on MB for the period 2005 and beyond.

5.5.6 Alternatives to Methyl Bromide

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 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[4]. Additionally, while local registration, environmental and social impact of an alternative were often discussed, these may be specific to the country or local region. Therefore, MBTOC did not consider it appropriate to omit alternatives on such grounds.

MBTOC could find no existing alternatives to MB for about 2500 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 95 percent of the current tonnage of MB excluding QPS. Significant effort must now be undertaken to transfer these alternatives to as many locations as possible and optimise the conditions under which they can be most effective.

Because of the controls that have been imposed on MB, both globally via the Montreal Protocol and via different national control schedules, a number of agricultural research institutions and private sector organisations are now engaged in work to develop and implement economically viable and environmentally sound alternatives to MB. It is likely that these efforts will result in a wider array of alternatives than are currently available.

5.5.6.1 Alternatives to Methyl Bromide for Soil Treatments

MB as a soil fumigant is the single largest use category accounting for about 75 percent of global use. It is used as a pre-plant soil fumigant in locations where a broad complex of soil-borne pests limit economic production of crops, and particularly in situations where the same crops are grown repeatedly on the same land. MB has been successfully used under a wide variety of cropping systems. The major current categories of use include vegetables, fruits, ornamentals, tobacco, and some nursery crops.

Since the 1995 Assessment, significant progress has been made in identifying alternatives to MB for soil fumigation. Approximately 70 percent of the references in this chapter in the 1998 Assessment have been published since 1994 which is indicative of the amount of research that has been undertaken in the past 4 years. There are a number of examples of alternatives in commercial use in developing and developed countries today. Factors affecting acceptance of alternatives include local availability, registration status, costs, labour inputs, and efficacy against target pests.

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[4] TEAP. 1996. Corrigendum to the TEAP March 1995 Report Concerning Methyl Bromide. Montreal Protocol on substances that deplete the ozone layer. *UNEP Technology and Economic Assessment Panel, June 1996*: Section 4.1, P118.

In spite of the widespread use of MB as a soil fumigant MBTOC did not identify a single crop that cannot be produced successfully without MB. However, increased investment in research and technology transfer will be necessary to fully implement alternative pest management systems worldwide.

Integrated pest management (IPM) strategies which combine various pest management methods (non-chemical and/or chemical) are the best alternative approach to the use of MB for soil fumigation. The following technologies are important components of IPM programmes:

- Cultural practices such as crop rotation, soil-less culture, organic amendments, biofumigation, planting time, water management and flooding, mulching, cover crops and sanitation;

- Biological control, plant growth promoting rhizobacteria, resistant plant varieties and grafting of annual and perennial crops;

- Physical methods such as soil solarisation and steam treatments; and

- Strategic applications of selective pesticides.

As with MB, alternative strategies both chemical and non-chemical, may have human health and environmental consequences which need to be taken into consideration. Some chemicals are effective when used individually against pests where MB was used. Complex pest problems may require the use of combinations of chemicals. Use of these chemicals can result in yields comparable to those obtained with MB.

The chemical alternatives which have recently proven effective for replacing MB in certain situations include, chloropicrin alone, combinations of 1,3-D with MITC generators (metam sodium and dazomet) and combinations of either 1,3-D or MITC generators with chloropicrin. With recently improved application technology, metam sodium and dazomet are used commercially in some countries and can result in yields comparable to those obtained with MB. Considerable success has been obtained with mixtures of 1,3-dichloropropene and chloropicrin in the crops for which most MB is used i.e. tomato, pepper, and strawberry production.

There are still chemicals which require research and development to determine their potential as alternatives to MB, e.g., inorganic azides, anhydrous ammonia and furfural.

Advances in research on combinations of fumigants with other chemicals, e.g. herbicides, and with non-chemical techniques, e.g. solarisation, improved the efficacy of the chemicals and provided the opportunity for lowering dosage rates and decreasing solarisation periods.

In spite of significant progress in the development of alternatives to MB in the last four years, MBTOC recognises that the complexity of soil pest problems and diversity of environments in agriculture require the continued development of non-chemical and chemical methods to broaden the ability to manage pest problems. For example, replant problems in areas with limited land availability and some certified pest-free propagation materials are difficult to solve without MB. These two cases are estimated to use less than 2500 tonnes per annum.

5.5.6.2 Alternatives to Methyl Bromide for Durable Commodities and Structures

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 and beverage crops; and non-foods such as wood products and tobacco. Wood products include: museum artefacts and other items of historical significance; unsawn timber, timber products and bamboo ware; and packaging materials and items of quarantine significance.

Structures include entire buildings and portions thereof which are being treated to control wood-destroying organisms and other pests in non-food facilities. Treatment of structures may also include food production and storage facilities for control of stored product insects and other pests. Transport vehicles, including ships, aircraft, freight containers and others may require treatment to control stored product insects, rodents and other pests.

Currently, MB is primarily used to disinfest grain stacked in bags; to disinfest food processing facilities such as mills; to treat durable commodities such as cocoa, grain, certain dried fruit and nuts at the time of export and post-entry; and a variety of quarantine applications, notably treatment of logs.

It is estimated that approximately 12 percent of the global consumption of MB is for the disinfestation of durable commodities and about 3 percent for structures. Some of the MB uses for durables, wood products, and structures fall within the QPS exemption.

There are a variety of existing alternatives to MB for disinfestation of durable commodities and structures. 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 risk, the speed of action required and the cost. There has been considerable research and implementation activity in this area.

About 40 percent of the references quoted for this sector in the 1998 Assessment Report have been added since 1994 indicating considerable research and implementation activity in this area in the past 4 years.

There are some current non-QPS uses of MB for which MBTOC did not identify any existing alternatives. For durables, these were: disinfestation of fresh chestnuts, disinfestation of fresh walnuts for immediate sale, elimination of seed-borne nematodes from alfalfa and some other seeds for planting, and control of organophosphate-resistant mites in traditional cheese stores. In the treatment of mills and food processing facilities where IPM systems have failed, it may be necessary to resort to occasional use of MB. Where hydrogen cyanide is not available as an alternative, for example, for disinfestation of aircraft, there are no proven alternatives to MB. The total of these uses is unlikely to exceed 50 tonnes per annum.

MBTOC also did not identify alternatives for a number of QPS uses for MB. In many cases, an integrated program combining several different measures can effectively replace a particular use of MB. Some IPM strategies require constant maintenance in order to succeed. Occasional full-site or curative treatments may be required to supplement IPM programmes. These may involve fumigation, possibly with MB, or other processes.

Phosphine is the only available in-kind alternative extensively used, principally for stored cereals and similar products. There are several other fumigants which may have limited potential as alternatives for MB. Treatment with controlled atmospheres based on carbon dioxide or nitrogen offers an alternative to fumigation for insect pest control, but not fungal pests.

Physical methods of insect control, including mechanical measures, cold, heat and irradiation treatments, offer further potential as non-chemical alternatives in individual circumstances. Cold treatments are now used as part of IPM systems for stored products and artefacts. Heat treatment technologies are now used and match the speed of treatment afforded by MB and other fast-acting fumigants. Heating can also synergise the effects of other treatments, for example fumigants, controlled atmospheres, and inert dusts.

Where registered for use, contact insecticides may provide persistent protection against reinfestation. In some situations, the use of dichlorvos (although non-persistent) offers a direct alternative to MB for disinfestation of bulk grain at point of export.

Biological agents and botanical compounds have limited application as part of IPM systems at this time. 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.

5.5.6.3 *Alternatives to Methyl Bromide for Perishable Commodities*

Perishable commodities include fresh fruit and vegetables, cut flowers, ornamental plants, fresh root crops and bulbs. About 9 percent of global MB consumption is used for disinfestation of perishable commodities, with about half used for disinfestation of fruit for quarantine purposes.

Although global consumption for disinfestation is relatively low in volume, this amount of MB is nevertheless very significant as, in the absence of site-specific alternatives, it allows import and export of high-value perishable commodities. MB used for quarantine treatments is currently exempt from control under the Montreal Protocol.

One of the major uses of MB in this category is to disinfest consignments intercepted on arrival with pests deemed unacceptable to the importing country. If one or more pests are detected, MB fumigation is by far the most predominant treatment to meet importing country phytosanitary requirements. Mandatory treatments in the exporting country may be required if pests are difficult to detect or if the pest is of extreme concern to the importing country.

These disinfestation treatments are crucial for minimising the risk of plant pests becoming established in new regions. Quarantine pests accidentally released into a country or region previously free of them can result in considerable cost to the importing country caused by suspension of exports, eradication measures and implementation of a disinfestation treatment for export commodities if eradication is not achievable. In addition, a minor quantity of MB is used to prevent the spread of exotic pests domestically.

MBTOC identified at least thirteen different categories of alternative treatments e.g., heat, cold, irradiation, that are approved by regulatory agencies in one or more countries for disinfestation of perishable commodities, but only for very specific applications. 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 would they be easy to implement. To solve this problem, a range of alternatives are 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 in order to avoid congestion at air and sea ports.

In the future if MB for quarantine treatments is not permitted and if no alternative to MB are available to disinfest consignments intercepted with pests of quarantine concern, infested consignments may be prohibited until satisfactory "on-arrival" treatments are developed and approved, or the consignments may be reshipped or destroyed. Alternatively, import of consignments considered high risk for pest infestation may be prohibited until an alternative treatment has been implemented in the exporting country to reduce pest contamination to a level acceptable to the importing country.

Alternatives to MB for perishable commodities include those based on 1) Preharvest practices and inspection procedures; 2) Non chemical treatments; and 3) chemical treatments.

Those based on preharvest practices include a description of cultural techniques leading to pest reduction, agreement on pest-free zones, and inspection-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, surveillance for pests and diseases and careful documentation.

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 treatments is required to kill pests because they can be tolerant to treatments applied singularly. A greater understanding of the physiological changes occurring in both pests and commodities will be essential to expedite the development of disinfestation treatments based on these non-chemical alternatives.

Chemical fumigation treatments are feasible, but the number of chemicals is currently limited mainly because companies are reluctant to make submissions for registration due to the high costs of demonstrating compliance with health and safety standards. However, in some circumstances e.g., cut-flower exports, chemical dips can be a practical and efficacious method to control pests, particularly if occupational standards for their safe use and disposal are implemented and the treatment is approved by the importing country.

For each category of MB alternative, MBTOC noted country-specific regulatory agency approval for specific commodities or several commodities within a class (e.g. citrus): heat treatments for at least eleven commodities including citrus, mango, papaya, bell pepper, eggplant, pineapple, squash, tomato and zucchini; chemical treatments for citrus, vegetables, cut flowers and bulbs; cold treatments for apples, pears, citrus, grapes, kiwifruit, carambola and avocado; pest-free zones for apples, berryfruit, some vegetables, cucurbits, avocado and papaya; the systems approach for citrus, apples and melons; and irradiation for papaya, litchi and carambola. Currently, there are no approved alternatives for economically important exports such as apple, pear, and stonefruit hosts to codling moth; for berryfruit; for grapes infested with, for example mites, exported to some countries; and many root crops exported by countries if soil is present or pests of concern are detected on arrival.

MBTOC identified where alternative research was possible within each category. Commercialisation of any of these treatments as replacements for MB will depend on a number of factors that includes proven treatment efficacy, commodity tolerance, equipment design and commercial availability, cost competitiveness, regulatory approval, logistical capability, availability and agreement on the scientific research required for regulatory approval, and technology adoption. Given all of these considerations, the time from conception to implementation of a disinfestation treatment for perishable commodities can vary from 2 to 15 years.

5.5.7 Article 5(1) Parties perspective

Based on official data, MBTOC estimated Article 5(1) Parties consumed 15,350 - 17,500 tonnes of MB per annum, which is equivalent to 23-26 percent of global consumption. Article 5(1) countries use MB, mainly as a pre-plant soil fumigant, for producing certain high value exports such as tobacco, cut flowers, strawberries, bananas, melons; and tomatoes, peppers and some other vegetables. MB's other significant use in Article 5(1) countries is for disinfestation of durable commodities. About 70 percent of MB is used for pre-plant fumigation and about 20 percent for durable commodities. MB is not used in the production of staple foodstuffs.

The quantities of MB used in Article 5(1) countries vary widely. Some countries have officially phased out or greatly reduced their consumption over the past four years. Decrease in MB use may be due to the adoption of alternatives such as: 1) non-chemicals (crop rotation, soil amendments and compost, resistant varieties, grafting, cultural practices, soil-less culture, solarisation) and chemicals (metam sodium, dazomet, chloropicrin, and others) for soil borne pests; 2) phosphine (alone or in combination with carbon dioxide) for grain treatment; 3) heat treatments for perishable commodities; and 4) sulfuryl fluoride for structures and non-food commodities.

In contrast, some countries have substantially increased their usage and in some cases production, and may increase MB use still further unless alternatives are adopted. Increase in MB use may be due to a combination of factors including lack of national strategies for phasing out MB, the slow transfer of alternative technologies, marketing of MB by manufacturers and suppliers, and concern regarding pest resistance to phosphine. It is also possible that some countries are importing MB to stockpile as a hedge against price increases.

Article 5(1) Parties are concerned that MB use may shift from developed to developing countries in the future as a result of earlier phase out in the developed country. In view of the changing pattern of MB consumption in Article 5(1) countries, it would be prudent to monitor both the policies and practices that encourage or discourage the use of MB and its alternatives in order to avoid Article 5(1) Parties being left with outdated pest control technology.

Alternatives to MB in Article 5(1) countries are similar to those in non-Article 5(1) countries. At present, there is no single in-kind alternative for all uses of MB in Article 5(1) countries. The adaptation of alternatives is often constrained by socio-economic conditions, level of infrastructure and other conditions found in many of these countries. These constraints can be overcome by actions such as early recognition of problems, a national-international focus on seeking solutions, and mechanisms for providing technical and financial assistance.

There are a number of crop protection methods that can, together, address the pest problems for which MB is now used. Potential chemical alternatives to MB can be hazardous to humans and the environment and may require registration, regulation, and specific training to promote safe and effective use. It should be noted that MB is also hazardous to humans and the environment, requires skilled application and substantial precautions for safe and effective use. Lack of appropriate skills can be a constraint to use of both MB and alternatives in many Article 5(1) countries.

While it is possible to use alternative materials and methods to substitute for most MB uses, the conditions prevailing in Article 5(1) countries require that the alternatives to MB be appropriately adapted to specific climatic conditions, cropping techniques, resource availability and target pests. Some replacements to MB may involve significant effort in areas such as research and field testing to adapt alternatives to local conditions, on-farm demonstrations, technology transfer, user education, institutional capacity building, information exchange and training. UNEP-IE and other agencies continue to conduct workshops promoting alternatives to MB in Article 5(1) countries.

Concern has been expressed regarding future trade restrictions that may be imposed by importing entities upon Article 5(1) countries that use MB in the production or treatment of export commodities. Such a situation may render the 10-year grace period, currently up to 2015, ineffective. This could be unfavourable to Parties whose growers do not have access to viable alternatives. Furthermore, some Article 5(1) countries report slow progress on implementation of demonstration projects and other conditions necessary to provide growers with the proper pest control strategies to grow, store and export food without MB.

The Executive Committee of the Multilateral Fund under the Montreal Protocol has provided strategy and guidelines for MB projects which will be eligible for funding. A number of projects have already been approved. MBTOC noted that it would be helpful to monitor these projects as part of an overall effort to focus future strategies for the successful adoption of alternatives. Strategies include support for implementation of successful demonstration projects, review of lessons learned from these projects, and the need for policy measures and training.

5.5.8 Quarantine and Pre-shipment

Quarantine applications, as defined under Decision VII/5 of the Montreal Protocol, are treatments that aim "…*to prevent the introduction, establishment and/or spread of quarantine pests, or to ensure their official control, where official control is that performed by, or authorised by, a national plant, animal or environmental protection or health authority.*"

Pre-shipment applications, defined under the same Decision, are "…*those applied directly preceding and in relation to export to meet the phytosanitary or sanitary requirements of the importing country or existing phytosanitary or sanitary requirements of the exporting country.*"

The use of MB for quarantine and pre-shipment (QPS) is a remaining emissive use which is unregulated under the Montreal Protocol. Although there are some limited essential use exemptions agreed by the Parties for other ODS such as CFCs these only apply after phase-out. Under present controls QPS uses remain exempt from the freeze, reductions and phase-out schedules.

QPS use currently accounts for about 22 percent of worldwide MB consumption. Preliminary data from four countries indicate that MB used for QPS is increasing for both developing and developed countries.

MBTOC noted that there is some inconsistency in the interpretation of the terms 'quarantine' and 'pre-shipment'. For example, treatment of commodities with MB required contractually rather than officially does not qualify as QPS but some Parties appear to be incorrectly exempting this use. This inconsistency would result in an understatement of an individual country's calculated annual controlled consumption in a particular year.

MBTOC noted that there may be inconsistency in the interpretation of pre-shipment treatment defined as “directly preceding…export.” The interpretation may result in multiple applications when a single application of MB just prior to shipment would fully satisfy the sanitary or phytosanitary requirements of the importing or exporting country. In order to be clear for practical implementation of this measure, Parties may wish to define pre-shipment applications as those carried out within 14 days prior to shipment in addition to meeting the phytosanitary and sanitary requirements of the importing or exporting countries.

From current use worldwide, MBTOC provided examples it considered complied with the QPS definition and those which did not. MBTOC also designed a logic diagram to assist in differentiating between Q and PS uses.

Further data collection is required to assess the volume and uses of MB under QPS, the extent of the development of alternatives, the likely operation of exemptions in the future once MB is phased out, and the regulations governing the use of QPS treatments.

5.5.9 Emission reduction

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 patterns, the condition and nature of fumigated materials, the gas-tightness of enclosures, and local environmental conditions. Also, some MB may react during use, so it is incorrect to equate production with emissions as at least part of MB applied is converted in use to non-volatile materials.

Under current usage patterns, the proportions of applied MB eventually emitted to the atmosphere globally are estimated by MBTOC to be 32 - 87 percent, 85 - 95 percent, 69 – 79 percent and 90 - 95 percent of applied dosage for soil, perishable commodities, durable commodities and structural treatments respectively. These figures correspond to a range of 43 - 87 percent overall emission from agricultural and related uses, with a best estimate of overall emissions of 73 percent or 50,240 tonnes (based on 1996 production data).

Available containment techniques for decreasing MB leakage are in limited use worldwide. Lack of adoption is constrained particularly by lack of promotion of relevant technologies and by perceived or real increases in costs, regulatory and logistical problems. A high degree of containment is a prerequisite for efficient recovery of the used MB.

Better sealing of enclosures and the use of less permeable sheeting is an immediately applicable, technically proven means of reducing emissions from soil, durable commodity, and structural fumigations. These measures may permit reduced dosage levels while still achieving the required degree of pest control. Many facilities used for fumigating perishables, particularly for quarantine, already have a high standard of gas-tightness leading to very low leakage rates (often less than 2 percent of dosage).

There has been some limited further research into the development of recovery and recycling systems for MB. Most development work is directed at recovery from commodity fumigation which represents about 21 percent of global consumption. Some more recent research is aimed at Article 5(1) simple recycling technologies whereas most of the potential recovery and recycling systems previously considered were complex and too expensive to install compared with the cost of the fumigation facility itself. Some systems would also have had high running costs associated with energy requirements and many would have required a level of technical competence not normally found at fumigation facilities. Only a few special examples of recovery equipment are in current commercial use.

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, and because some of the recovery and recycling technologies under development are only suitable for "in-plant" recycling.

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 equipment efficiency, tolerable levels of emission, and other factors**.**

5.5.10 Technology Transfer

Most technical information generally transfers from developed to developing countries. However, developed countries can learn from Article 5(1) countries who, through management of pests and diseases in some cases without chemicals, have extensive experience on the use of IPM techniques for controlling pests in soil. Developed countries, on the other hand, have gained extensive experience in postharvest disinfestation for durable and commodity crops largely as a result of the drive to gain market access for agricultural commodities.

There are therefore benefits to be gained by both developed and developing countries in:

- Effective exchange of information;
- Selecting the appropriate technology for the climatic conditions, cropping techniques, resource availability and target pests;
- Adapting this technology to the local conditions;
- Obtaining sufficient funds to undertake research, technology transfer and demonstration of efficacy; and
- Training personnel to carry out new treatments.

Some replacements to MB may involve significant effort in areas such as: Accessing new information; research and field testing to adapt alternatives to local conditions; on-farm demonstrations; technology transfer; user education; institutional capacity strengthening; information exchange; and training. Additional investment in research and technology transfer is required to promote further implementation of alternatives to MB worldwide. Factors affecting their acceptance include local availability, registration status, costs, labour inputs, and efficacy against target pests. Developing and developed countries will continue to benefit from technical and financial assistance in introducing and/or adapting alternatives to MB.

5.5.11 The Future

Approximately 60 percent of this report is based on scientific literature and private sector expertise not cited in the 1994 Assessment (MBTOC 1995). This suggests that there has been considerable research effort and some adoption of alternatives in the past 4 years, particularly by scientists seeking to find alternatives to MB as a soil fumigant which accounts for more than three quarters of its use.

Increased investment in research and technology transfer will be necessary to fully implement alternative pest management systems for MB worldwide.

5.6 Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee

5.6.1 Introduction

This Refrigeration, AC and Heat Pumps Technical Options Committee report forms part of the regular assessments carried out pursuant to Article 6 of the Montreal Protocol, and is part of the 1998 assessment work of the Technology and Economic Assessment Panel requested by the Parties in Vienna in 1995 (in Decision VII/34). Nine chapters of the full report deal with application areas; one deals with refrigerant conservation; and one chapter gives historic data for fluorocarbon refrigerant production, consumption, and future estimates. The report also includes annexes with summaries of important properties for all known refrigerants. The 1998 Technical Options Committee included 48 representatives from African, Asian, European, Latin, and North American countries. Several drafts of the report were made and reviewed. Results were discussed in six TOC meetings held in Denmark (Aarhus), France (Paris) and the United States (Washington D.C.) in 1996 and 1997, and in India (New Delhi), Norway (Oslo), and Germany (Nürnberg) in 1998. The report has been peer reviewed by a number of refrigeration institutions and associations, as well as by NGOs.

The economic impact of refrigeration technology is far more significant than generally believed; 300 million tonnes of goods are refrigerated. While the yearly consumption of electricity in this sector may be huge, and where the investment in machinery and equipment may approach $100,000 million, the value of the products treated by refrigeration approximates four times this amount.

CFC production has been phased out in the non-Article 5(1) countries, and the CFC phase-out is underway in the Article 5(1) countries. In both the non-Article 5(1) and the Article 5(1) countries, HCFCs and HFCs have been the primary substitutes for CFCs. In many applications, although not in all, alternatives to HCFCs have become commercially available, mainly as blends of HFCs. As a result, HFCs have currently gained a large share of the replacement market. However, a rational approach to phase-out HCFC consumption as transitional chemicals could include a minimum time period to permit the industry to develop and commercialise alternatives. This has been applied to refrigerants, but only partly to the equipment that uses the HCFCs. This approach should provide for a rational phasing in of new equipment in order to avoid high obsolescence costs due to the need to continue servicing existing equipment.

In the short term, HCFCs are a valid global option for refrigeration and AC equipment. However, for the long term, there remain only five important different refrigerant options for the vapour compression cycle (in addition to various non vapour compression methods):

1. hydrofluorocarbons (HFCs, HFC-blends with 400 and 500 number designation);
2. ammonia (R-717);
3. hydrocarbons and blends (HCs, e.g. HC-290, HC-600, HC-600a etc.);
4. carbon dioxide (CO_2, R-744);
5. water (R-718)

None of the above mentioned refrigerants is perfect; all have advantages and disadvantages that should be considered by governments, equipment manufacturers and equipment users. For instance, HFCs have relatively high global warming potentials, ammonia is more toxic than the other options, and ammonia and hydrocarbons are flammable to certain extents. Appropriate equipment design, maintenance and use can address these concerns, though sometimes at the cost of greater capital investment or lower energy efficiency. Energy efficiency remains an important issue for all refrigeration technologies, and should be considered along with the factors enumerated above, since it is directly related to global warming.

Next to ozone depletion, global warming is the main issue governing the selection of refrigerant chemicals for the near- mid- and long-term. Although this issue is not covered by the Montreal Protocol, it nevertheless forms an important criterion in the ongoing “environmental acceptability” discussion. Interest in ammonia and the hydrocarbons is stimulated, at least in part, by the fact that the HFCs are greenhouse gases for which emissions may be controlled in future. However, safety aspects also imply stringent emission controls for ammonia and hydrocarbons. Similarly, energy efficiency research is partly spurred by the role of energy production in carbon dioxide emissions.

In all energy-related uses, the relationship between the CO2 produced in electricity generation (to operate the product) and the direct global warming of the substitute chemical has to be taken into account. The ‘Total Equivalent Warming Impact’ (TEWI) concept includes direct and indirect global warming effects. However, it is no criterion to decide upon certain options from an investment point of view since it does not take into account life cycle costs and related investment aspects. Options for energy efficient operation of equipment form an important issue in each of the chapters of this 1998 TOC Refrigeration Assessment report.

The five refrigerant options above are in different stages of development or commercialisation. HFCs are widely used in many sectors, ammonia and hydrocarbons enjoy growth in sectors where they can be easily accommodated, and CO_2 equipment is under development for certain applications, with the first demonstration components having reached the market. Equipment using water as the refrigerant has been developed and may see some increased use in limited applications. Several committees are working to develop standards to permit the use of new refrigerants. It is the intent of companies to reach world-wide acceptance of standards.

5.6.2 Global CFC and HCFC Production and Consumption Data-Estimates for the Near Future

CFC and HCFC production data have been accumulated through publications by manufacturing companies of the AFEAS group and from UNEP publications that report countries-provided annual data on production and consumption. CFC production in non-Article 5 (1) countries shows a decrease from 866 to 53 ODP-ktonnes in the years 1986 and 1996, respectively. By contrast, the countries China, India, and Korea increased their CFC production from 41 to 85 ODP-ktonnes between 1992 and 1996. However, the aggregated total production volume in Article 5(1) countries seems to have stabilised over the period 1994 - 1996.

CFC production in all Article 5(1) countries amounted to 109 ODP-ktonnes in 1996. The total global CFC production available for consumption in the Article 5(1) countries in 1996 was approximately 145-150 ODP-ktonnes. This includes quantities illegally imported to developed countries. CFC production in China, India and Korea was smaller than their consumption until 1995; this implies imports from non-Article 5(1) countries in the order of 0 - 14 ODP ktonnes during 1994 - 1996.

CFC consumption in non-Article 5(1) countries amounted to 8 ODP-ktonnes in 1996, compared to 788 ODP-ktonnes in 1986. Based on non-Article 5(1) country production of 53 ODP-ktonnes in 1996, one can conclude that the majority of 1996 exports to the Article 5(1) countries went to countries other than China, India and Korea (approximately 30-35 ODP-ktonnes).

If Article 5(1) countries were to continue producing on the order of 110 ODP-ktonnes annually, exports by non-Article 5(1) Parties could be rapidly reduced. This is because Article 5(1) consumption is expected to decrease due to project implementation and national measures being implemented by many Article 5(1) Parties.

HCFC production increased from 12,743 ODP tonnes in 1989 to 30,822 ODP tonnes in 1996 in countries that have manufacturing facilities belonging to the AFEAS group. The percentage of the HCFC production that took place in the non-Article 5(1) countries amounts to 91-95 percent of the aforementioned quantities. The increase between 1994 and 1995 was caused largely by an increase in the production of HCFC-141b; and the increase between 1995 and

1996 by an increase in HCFC-22 production. According to the 1996 manufacturers' data, the largest ODP consumption of HCFCs was not in refrigeration and air conditioning, but in the foams sector (HCFC-141b).

Forecasts for future HCFCs and HFC consumption have been derived by averaging forecast data submitted by developed country manufacturers, which yields a best estimate. HCFC global consumption is expected to decrease from 412 to 163 ktonnes between the years 1998 and 2015, respectively. There is a significant decrease in the HCFC consumption in the non-Article 5(1) countries after 2003 due to halting the production of most closed cell foams using HCFC-141b. It is estimated that the HCFC consumption in Article 5(1) countries in 1996 is larger than the capacity used for production, although the quantity is not substantial.

HFC-134a production has shown a continuous growth over the period 1990 - 1996, with a consumption of about 74 and 84 ktonnes in the years 1995 and 1996, respectively. This represents growth of 45 percent and 13 percent, respectively. The major contributor to this growth has been the refrigeration and A/C sector. The HFC-134a consumption forecast for all applications in the year 2015 equals 207 ktonnes, which is an increase of about 250 percent between 1997 and 2015; this figure includes 174 ktonnes for the use of HFC-134a in refrigeration and A/C. The same growth percentage also applies for the consumption of other HFCs in the 1997-2015 period (forecast consumption of 133 ktonnes in 2015). These growth estimates should be considered against a substantial decrease in HCFC consumption over the period 1997-2015. The HCFC consumption in the developed countries in 2015 is estimated to be only 15 percent of the consumption in 1997.

5.6.3 Domestic Refrigeration

All non-Article 5(1) country manufacturers have transitioned from CFC-12 to non-ODS refrigerants in new equipment. Transitions in the Article 5(1) countries are occurring faster than the Montreal Protocol requirements. Preferred alternatives were assessed for safety, environmental, functional and performance requirements. Broad-based OEM refrigerant alternatives have narrowed to HFC-134a and HC-600a. Both can provide safe, reliable and efficient domestic refrigerators and freezers. Multiple local and national codes, standards, and regulations govern the use of domestic refrigeration equipment. Analysis of regional requirements and consumer-selected product differences provides insight into refrigerant selections.

Field repair complexity is increased with the introduction of new refrigerants. Original equipment manufacturers should be consulted regarding proper repair procedures for their equipment. Equipment designed to use CFC-12 should be carefully assessed for safety prior to undertaking drop-in repair, particularly when using flammables. There is a significant difference in field repair rates between developed and developing countries, with estimates of approximately 2 percent and 10 percent, respectively. Differences result from use environment, extended life, uncertain power service, aggressive transport conditions and lack of service technician training. The premium value of capital goods relative to labour expense in many countries promotes component rebuilding by small, decentralised service shops. This has the strategic consequence of extending the use of obsolete materials and components.

Estimated refrigerant consumption for domestic refrigerators grew from about 15.5 ktonnes in 1992 to about 17.7 ktonnes in 1996. CFC-12 represented 99 percent of the 1992 demand versus 60 percent of the demand in 1996. CFC-12 continues to dominate the aftermarket service demand.
Energy efficiency of domestic refrigeration is a subject of increasing interest. Retirement and replacement of less efficient, older units and extended application of conventional state-of-the-art technology could result in large reductions in global energy consumption. Cumulative new unit energy use reductions up to 70 percent have occurred over the past twenty-five years.

5.6.4 Commercial Refrigeration

Commercial refrigeration includes a wide range of equipment. The refrigeration capacity of centralised systems in supermarkets varies typically from 20 kW to 1000 kW, but for stand-alone equipment the capacities concerned are in the same range as for domestic equipment. In the past five years, significant events introduced changes in commercial refrigeration techniques. In centralised systems, R-502 has been successfully replaced by HCFC-22 and HCFC-22 based blends (R-408A and R-402A/B). The use of these blends provide satisfactory performance and has permitted maintaining and, in some cases, improving energy efficiency of systems.

Stand-alone equipment, particularly small equipment, traditionally used CFC-12; most new equipment uses HFC-134a. Since German manufacturers started to use isobutane (HC-600a) for refrigerators and freezers, some manufacturers in Denmark, India, Sweden, and the UK have introduced small commercial equipment using various hydrocarbons. The expected more rapid HCFC phase-out in Europe has led to the choice of R-404A and R-507A in new systems, both in centralised systems (medium and low temperatures) and in stand-alone equipment for low temperature applications. For field-erected systems, due to detergent and hygroscopic characteristics of POE oils, new issues have to be handled by installers and contractors. Those include a lower level of evacuation before charging, better control of moisture content of oil and refrigerant, and better level of leak tightness.

Indirect systems using heat transfer fluids (also called «secondary refrigerants») have been installed in several European countries. These systems are intended to minimise refrigerant charge and consequently should decrease refrigerant emissions, at the expense of lower system efficiency. With proper choice of materials and added safety provisions the secondary use of loops also permits consideration of the use of ammonia or hydrocarbons, in systems located in machinery rooms. Medium temperature systems operating with heat transfer fluids are usually satisfactory but problems arise in low temperature applications. Due to pumping power of heat transfer fluid and to additional difference of temperature at the primary heat exchanger, the indirect systems structure implies higher energy consumption than achievable with direct systems. R&D projects have been developed to enhance the energy efficiency of the secondary circuit. Ice-slurry systems, CO_2 vapour-liquid loop, and CO_2 cascade systems complement traditional secondary loops using brines or anti-freeze solutions. Field tests are under way for some of those technical options.

Interesting developments are also appearing in single stage direct expansion systems aiming at minimising refrigerant charge. A new concept, developed in the US and in Europe, consists in installing compressors in the sales area within sound-proofing boxes, and the condensing heat is transferred out of the store by a water cooling circuit.

In some European countries certain industries are supplying units that either use ammonia or hydrocarbons. However, HFC blends as economically preferred refrigerants form the usual choice, due to safety considerations and initial costs. A number of units have been installed to evaluate the advantages and the drawbacks of indirect systems (using a secondary circuit with heat transfer fluids), and new concepts for direct expansion using water cooling, now in operation, are also being evaluated. Other developmental efforts are focused on improving energy efficiency, minimising charge size, and minimising refrigerant emissions. Due to the early CFC phase-out in some Article 5(1) countries and the level of refrigerant consumption (which can be up to 50 percent of the overall country consumption), the activity of repairing CFC-charged equipment may provide the opportunity to replace CFC-12 refrigerants with low- or non-ODP refrigerants.

5.6.5 Cold Storage

The consumption of chilled and frozen food world wide amounts to some 350 million tonnes per year, making cold storage and food processing one of the most important sectors of refrigeration. A variety of applications within the food and beverage industries are served by refrigerating systems ranging from some 50 kW refrigeration effect up to several MW of cooling.

No new refrigerant options have emerged since the last Montreal Protocol assessment. Ammonia has further strengthened its position as the leading refrigerant for cold storage and food processing in many European countries. There is a growing interest in other regions as well, largely driven by new "low charge" technology, which allows a very substantial reduction in refrigerant charge (up to 90 percent in some cases). Transfer of low charge technology, together with increased emphasis on teaching and training in ammonia refrigeration, are regarded as key elements in making ammonia a viable option to replace CFCs in Article 5(1) countries.

HCFC-22 is still the dominant refrigerant in countries with strict regulations concerning the use of ammonia, but a gradual replacement by non-regulated fluids is foreseen from 2000-2005 onwards. In Europe, HCFC consumption for new systems is already declining, as a result of the expected accelerated HCFC phase-out in Europe, and existing national regulations in several European countries. HCFCs represent a cornerstone in reducing the dependency on CFCs in Article 5(1) countries in the short term.

HFCs have relatively low critical temperatures, making cycle efficiencies deteriorate at high condensing temperatures. The performance of air cooled HFC systems in tropical climates, typical for many Article 5(1) countries, has to be adequately addressed. HFCs (mainly HFC-134a, R-404A and R-507A) have gained approximately 10 percent of the cold storage and food processing market in the industrialised world. HFC consumption in Article 5(1) countries is believed to be insignificant. A considerable growth is expected with the phasing out of HCFCs. It is anticipated that R-410A will account for an increasing proportion of the halocarbon market after the period 2003-05, and that it may become the leading industrial fluorocarbon refrigerant in the long term. Using R-410A, the system pressure will be 50 percent higher, therefore special efforts should be made to address the system tightness.

Hydrocarbon units are available and their market is growing in some European countries, although market shares are insignificant so far. Renewed CO_2 technology for low temperatures, e.g. its application in the lower stage of cascade systems and as a secondary refrigerant in indirect systems, has reached the stage of practical application.

Service refrigerants containing HCFCs and some HFCs, such as HFC-134a (for CFC-12) and the blends R-404A and R-507A (for R-502), have fulfilled their expectations as retrofit refrigerants. Due to lower costs and simpler retrofit procedures, the majority of retrofits have involved HCFCs. Hydrocarbons may be used with insignificant chemical implications, but flammability restricts their practical applicability. A minor number of conversions to ammonia have occurred in cold storage and food processing.

However, generally retrofit activity has been rather low, and three out of four CFC systems are believed to be still in operation. Refrigerants for service are supplied from recycled fluids and from stockpiled resources. A substantial increase in retrofit activity is inevitable in the near future as industry stocks of CFCs run low.

Compared to industrial refrigeration, cold storage and food processing is a more important sector in Article 5(1) countries; the refrigerants used include CFCs as well as the substitutes HCFC-22 and ammonia.

5.6.6 Industrial Refrigeration

Industrial refrigeration covers a wide range of uses and operating conditions within the chemical industry (including petrochemical and pharmaceutical), the oil and gas industry, the metallurgical industry, plastic moulding, and various other uses. System capacities span from some 20 kW up to several MW of cooling, and temperatures range from below –100 C (approximately –90 C in conventional systems) to above ambient temperature. Some small special purpose units, e.g. ultra low temperature freezers, may also be classified under this sector. Most industrial systems are custom made and erected on site; therefore, the refrigerant choice has to be evaluated on a case-by-case basis, whether for a new installation or the retrofit of an existing one.

R-508A and HC-170 have successfully superseded CFC-13 and R-503 in the bottom stage of cascade systems for the lowest temperatures. Near-azeotropic mixtures (e.g. HFC-32/HFC-125 and HFC-125/PFC-218/HC-290) are available for applications previously covered by R-13B1, although with somewhat lower specific capacities. These new fluids can also be applied in retrofits. From approximately -45 C and upwards, the picture is not very different from the one described for “Cold Storage and Food Processing.” Ammonia has gained major market shares in those countries where it already had a strong position, particularly in Europe. In other regions only a moderate increase in ammonia use has occurred.

Many countries have turned to HCFCs, primarily HCFC-22. However, the use of HCFCs is expected to decline after 2000, which has already happened in Europe. Most probably, HFCs will be the major successors, leading to a very substantial increase in HFC market shares from the current 10-20 percent. Industrial HFC use predominantly involves R-404A and R-507A. These blends have proved to be generally applicable, including in flooded systems commonly used in the industrial sector. In the future, R-410A may become an even more important industrial refrigerant, due to its higher volumetric capacity and a somewhat better cycle performance.

Low charge unit systems with hydrocarbons have achieved noticeable interest for industrial applications in some European countries. However, only a limited number of systems have been installed so far. Combined needs for cooling and heating, which are commonly found in many industries, can be efficiently met by CO_2 in a trans-critical cycle. A possible commercialisation, however, is still 5-10 years away.

HCFC-22 has apparently been preferred in the majority of retrofits. Other common options, which all have proved to be well-suited, include blends containing HCFCs, such as R-401A and R-409A which replace CFC-12 (only in direct expansion systems); the blends R-402A, R-403B and R-408A replace R-502 (in all types of systems). Conversions to HFCs have been successfully performed in a number of cases. The important fluids are HFC-134a (replacing CFC-12) and R-404A and R-507A (replacing R-502).

Hydrocarbons may easily replace CFCs from a technical point of view. However, in practice, most conversions are restricted to systems located in areas where relevant safety measures are already put in place. A limited number of industrial systems have been retrofitted to use ammonia.

5.6.7 Air Conditioning and Heat Pumps (Air Cooled Systems)

On a global basis, air-cooled air conditioners and heat pumps ranging in size from 2.0 kW to 420 kW comprise the vast majority of the air conditioning market. Nearly all of these units use HCFC-22 as the working fluid. An estimated 1700×10^6 kW of air conditioner and heat pump refrigeration capacity is installed world wide. Assuming an average charge of approximately 0.3 kg per kW of capacity, those 1700 million kW of installed capacity represent approximately 423 ktonnes of HCFC-22.

Significant progress has been made in developing HCFC-22 alternatives for this category of products since the last Montreal Protocol assessment. The results of current research programs and recent new product introductions indicate that the two HFC blends, R-410A and R-407C, are the leading candidates to replace HCFC-22 in these categories of products. Unitary equipment using both R-410A and R-407C is already commercially available in some regions of the world. Widespread commercial availability of systems using HFC refrigerants in the developed countries is very likely to occur between 1999 and 2005. At least one promising retrofit candidate is commercially available; the HFC-32/ 125/ 134a zeotropic blend, R-407C. It is likely that HFC-134a will be commercialised in larger capacity (>100 kW) unitary products. Hydrocarbons have seen limited commercialisation in portable air conditioners and de-humidifiers.

Hydrocarbon refrigerants may also be suitable replacements for HCFC-22 in some categories of products: air-to-water heat pumps and possibly very low charge level air-to-air systems. In addition, R-744 (CO_2) is the focus of significant research activities that could result in the commercialisation of trans-critical cycle products within the next 5-10 years. While alternative cycles are important and could have a long range penetration of this market, the impact of these technologies on the HCFC phase-out will be limited by high first costs, commercialisation timelines, and long market development intervals.

The estimated demand for HCFC-22 in the Article 5(1) countries is expected to increase nearly three-fold, i.e., to 52,000 tonnes by 2015. This represents nearly 62 percent of the 1996 world demand for HCFC-22 for this category of products. Article 5(1) countries will have a significant need for the transfer exchange of reclamation and retrofit technologies. Technologies, programmes and policies that can accelerate the transition of the Article 5(1) countries to non-ODP technologies could significantly reduce this demand.

5.6.8 Air Conditioning (Water Chillers)

The continuously growing number of water chillers for air conditioning, in service around the world, uses refrigerants including fluorocarbons (CFCs, HCFCs, HFCs), ammonia (NH_3) and hydrocarbons (HCs). The chillers employing fluorocarbons dominate the installed base and new production, due to relatively low initial costs. Because the HCFCs and HFCs are relatively similar to the CFCs physically and chemically, they can often replace the CFCs in new and existing chillers with less extensive modification of chillers and equipment rooms than are required for other replacement refrigerants. However, the ammonia and hydrocarbon chillers are enjoying some growth, particularly in Northern Europe. Interest in ammonia and the hydrocarbons is stimulated, at least in part by the fact that the HFCs are greenhouse gases for which emissions may be controlled in future under the Kyoto Protocol.

The largest chillers, those with the highest cooling capacity, employ centrifugal compressors, where the smaller chillers have traditionally employed reciprocating piston compressors. Today, these are being complemented, and in come cases replaced, by screw and scroll compressors.

CFCs were the dominant refrigerants for centrifugal chillers before 1993 when they started to be phased out of production in the non-Article 5(1) countries. Following CFC production phase-out in non-Article 5(1) countries at the end of 1995, replacement or retrofit of CFC chillers has been slower than was forecast in 1993, and the majority of the CFC chillers in service in 1993 are still operating on CFC refrigerants today. This creates a continuing need for CFCs for service of these chillers. This need can only be met from stockpiled or recovered refrigerants. The dominant refrigerants for new equipment today are HCFCs and HFCs. HCFC-22 was the traditional refrigerant in most positive displacement compressor chillers, complemented by ammonia in some applications.

Chillers are used less in Article 5(1) countries than in non-Article 5(1) countries, but the technologies tend to be the same, with the equipment often imported or produced locally in a joint venture with a non-Article 5(1) country chiller manufacturer. Thus, the latest technologies in equipment, refrigerants, and servicing equipment and practices are available to all countries.

Because chillers tend to be employed in large and sophisticated cooling systems, they require, and generally have more skilled maintenance staffs than is true for other types of cooling equipment. Thus, there is less difference seen in the service practices in developed and developing countries than may be the case for domestic refrigeration.

While consumption of CFCs is permitted in Article 5(1) countries until 2009, their use in new equipment is currently decreasing to permit these countries to benefit from the latest designs and technologies available in the world.
The principal changes since 1993-1995 are (i) the phase-out of CFCs (particularly CFC-11) in existing chillers has been significantly slower than forecast in 1994, (ii) the use of ammonia in new systems has grown more rapidly than anticipated in 1994, (iii) very low emission chillers are now being installed by all manufacturers, and (iv) hydrocarbon chillers have been introduced in several regional markets.

5.6.9 Transport Refrigeration

Transport refrigeration includes refrigeration in ships, railcars, containers, swap bodies and road transport equipment. It also includes refrigeration and air conditioning on merchant ships, and in buses and railcars. In all segments of transport refrigeration, emission rates can be significant due to the rough operating conditions, therefore containment and maintenance are very important together with system design improvement.

Most systems that used CFCs in 1994 have been retrofitted or scrapped, except for refrigerated containers and trucks due to the large existing CFC fleets. In ships, most systems use HCFC-22, though R-407C and R-404A are current options. For the future, R-410A is expected to become the dominant refrigerant in this sector.

About half of the 410,000 refrigerated containers still use CFC-12, and half of these will still be in use beyond the year 2003. HFC-134a predominates in new units. The number of refrigerated railcars and swap-bodies remains relatively small; furthermore, there are about 1,000,000 refrigerated road vehicles in use. Half of these still use the refrigerants CFC-12 or R-502. Current new equipment production applies uses HFC-134a, R-404A, or

HCFC-22, and some units with R-410A are already available. Research into hydrocarbon, solar and cryogenic systems is in progress.

Most systems on merchant ships use HCFC-22, and CFC, and this use has declined significantly since 1994. Fishing fleets and naval vessels form a significant part of this sector. The market penetration of bus and railcar air conditioning is increasing, and new equipment has changed from HCFC-22 to HFC-134a. Generally, this equipment is characterised by a significant leakage rate, although there seem to be huge regional differences, since bus air conditioning is often stated to have relatively low leakage rates.

Generally, HFCs are the preferred future refrigerant options, though there is limited development work on alternatives including hydrocarbons, ammonia, the air cycle, and CO_2. HCFC and HFC retrofit options exist for systems in use (only in some cases hydrocarbon options exist). Application of the HCFC retrofit options will be restricted by local legislation in some countries, especially in Europe. There is a need to concentrate on containment, training, and efficiency issues, and to accept the imminent non-availability of HCFCs in some countries.

5.6.10 Automotive Air Conditioning

By the end of 1994, all automobile manufacturers had converted mobile air conditioning systems to HFC-134a. Existing vehicles with CFC-12 are expected to have phased out due to “old age” by the year 2008. Overall, the change from CFC-12 to HFC-134a will not only eliminate all ozone layer impact but will also result in a 92 percent reduction in the “global warming impact” of mobile air conditioning. The major issue remaining is to encourage all countries, particularly the Article 5(1) countries, to phase out the use of CFC-12 in automotive air conditioning as soon as possible while, in the meantime, preventing unnecessary emissions to the atmosphere. Accordingly, automobile manufacturers and their international associations have provided information on available retrofit technology, recovery and recycling of refrigerant, service technician training, and current service and retrofit trends; this has already been used in several Article 5(1) Refrigerant Management Plans. The recommendations provided to Article 5(1) countries are based on the successes experienced in developed countries.

Manufacturers of HFC-134a systems are working to improve their designs to minimise refrigerant charge and refrigerant emissions, and to maximise total system energy efficiency. Hydrocarbons and carbon dioxide have been proposed as possible long-term replacements for HFC-134a and are being evaluated. Although concerns exist regarding the potential global warming impact of HFC-134a emissions from mobile A/C, new vehicles are expected to be equipped with HFC-134a until an alternative is developed and commercialised that offers comparable performance and reliability characteristics, and an economically viable global warming advantage.

5.6.11 Heating-only Heat Pumps

Heating-only heat pumps are used for space and water heating in residential, commercial/institutional, and industrial buildings. In industry heat pumps are used for heating of process streams, heat recovery and hot water/ steam production. They are often an integrated part of industrial processes, such as drying, evaporative concentration and distillation. Virtually all heating-only heat pumps are electric closed-cycle compression type systems.

The majority of heating-only heat pumps in buildings are located in the North of Western Europe. Though most heat pump installations in Japan, USA, and Canada are reversible air-conditioners, there is also a considerable number of heating only heat pumps in these countries. It is estimated that the total existing heating-only heat pump stock in the residential, commercial/ industrial and district heating sectors is roughly 1.7 million units, with a total heating capacity of about 13,300 MW. The corresponding figure for industrial heat pumps is 8,500 units, with a total heating capacity of 3,000 MW.

HCFCs are generally accepted as a part of the solution for a rapid CFC phase-out, especially for Article 5(1) countries, and HCFC-22 is the most important refrigerant in this category. Several European countries have regulations on HCFCs in order to phase them out more rapidly than agreed under the Montreal Protocol.

HFCs are at the moment the most important alternative refrigerant for heat pumps, both for new installations and for retrofits. Retrofits have occurred at a lower rate than expected. HFC-134a is applied for retrofitting of existing heat pumps using CFC-12 and for charging of new installations. HFC-134a heat pump technology is considered fully mature for new systems. The demand for HFC-134a as well as for other HFCs is expected to increase in the coming years. R-407C, R-410A and R-404A are currently the most promising HFC blend-alternatives to replace HCFC-22 in new equipment. Units with R-404A and R-407C are already on the market, and R-410A units are expected to enter the market shortly.

Ammonia has -in recent years- attained a small, but growing market share as refrigerant in medium and large capacity heat pump systems in Northern Europe. The phase-out of the CFC production and further technology development, may accelerate its market penetration in Europe, but also in Japan and in the United States.

Hydrocarbon blends, as well as pure hydrocarbons such as propane and propylene, are used in a certain number of residential heat pumps, mainly in Europe. Technology development and improved safety measures have reduced safety hazards and improved public acceptability. The number of hydrocarbon heat pumps is limited, but they are expected to play an increasingly important role in the next years in the small and medium capacity range.

Carbon dioxide is a promising long-term environmental friendly refrigerant for certain application areas, amongst which heating only heat pumps. The use of CO_2 is being evaluated and some components for CO_2 based systems are already commercialised. The most promising CO_2 heat pump applications are heat pump water heaters and heat pump dryers. Heat pump water heaters are expected to enter the market in the course of the next decade.

The refrigerant volume in use in this sector is estimated at 10,600 tonnes, with 45 percent being CFCs, 42 percent HCFCs, 11 percent HFCs, and 2 percent ammonia (base year 1998). Assessments indicate that the total annual refrigerant demand for heat pumps will be about 2,000 tonnes in the year 2005, of which 70-80 percent will be HFCs and the rest will consist of HCFCs, ammonia, and hydrocarbons. It can be assumed that, from scrapped and retrofitted heat pump equipment, 40 percent of the refrigerant inventory can be recovered. In this way, approximately 1,400 tonnes of CFCs and 1,800 tonnes of HCFCs can be made available for reuse between the year 1998 and 2005. This would still be only 50 percent of the expected demand for CFCs and HCFCs for servicing of existing heat pump installations during that same period.

5.6.12 Refrigerant Conservation

Until a few years ago, refrigerant conservation was considered to be important only for proper system function. Venting refrigerants during service and disposal was a common practice. The realisation that emissions of CFC and HCFC refrigerants led to stratospheric ozone depletion changed this, and refrigerant conservation is now a major consideration in refrigerating system design, installation, and service.

The benefits of refrigerant conservation include not only environmental protection and improved equipment efficiency and performance, but, in the case of refrigerants that are being phased out, the preservation of dwindling refrigerant stocks. Such stocks often provide the only source of refrigerant for servicing existing equipment. In the case of refrigerants that are substitutes for CFCs and HCFCs, conservation is critical to minimising any environmental (e.g., global warming) or safety (e.g., flammability) impacts that may be associated with the transition away from ozone-depleting substances.

Refrigerant conservation both saves money and is the most direct way to reduce emissions. Techniques to encourage conservation include information dissemination, financial incentives, and direct regulations. Without at least one of these measures in place, experience shows that refrigerant recovery will not take place.

Refrigerant conservation has several basic elements:

- properly design and install new equipment so as to minimise actual or potential leaks;
- leak-tighten existing systems so as to reduce emissions, both from systems that continue to use CFCs and from systems that are retrofitted;
- improve service practices, including recovery, permitting continued system operation with reduced need to add refrigerant;
- make sure that refrigerant is recovered at system disposal.

Good service practices, including regular leak detection and repair efforts and routine refrigerant recovery each time the system is opened, can significantly reduce refrigerant loss. Training of installers, operators, and service operators is required to accomplish both proper cooling system operation and refrigerant conservation.

Over the past three years, a number of technologies and practices for improving refrigerant conservation have been developed and implemented. In several countries, equipment is now being built to be more leak tight than it was five years ago, and leak detection and repair is being implemented regularly.

In the developed countries, the number of recovery equipment models has significantly increased over the last three years, and recovery techniques have reached maturity. Standards have been written in order to measure the performance of equipment, and methods have been developed to make recovery more efficient. Refrigerant removed from a refrigerating system may be returned to the same system after recycling. It may be required that refrigerant be reclaimed before it can be reused in another system to make sure that the contaminant level will not damage the equipment or degrade its performance. In all cases, refrigerant reuse requires taking measures to avoid mixing refrigerants.

Refrigerant that is too contaminated for reuse will ultimately have to be destroyed. At present, high temperature incineration is about the only practical method of destroying CFC and HCFC refrigerants, but other technologies may emerge in future.

In the Article 5(1) countries, an important priority is maintaining systems in proper operating condition, including tightening up systems by finding and repairing leaks, and to recovering refrigerant when opening the system. In order to be effective, conservation technologies must be matched by technician training and, in some cases, adaptation of technology. In addition, strong government incentives may be necessary to ensure that conservation occurs. Refrigerant conservation through recovery, recycling, reclamation and leak reduction are as important to achieving Article 5(1) controls as replacing CFCs in new and existing equipment. government incentives may be necessary to ensure that conservation occurs. Refrigerant conservation through recovery, recycling, reclamation and leak reduction are as important to achieving Article 5(1) controls as replacing CFCs in new and existing equipment.

5.7 Solvents, Adhesives and Coatings Technical Options Committee

5.7.1 Non-Article 5(1) Parties Progress

Industries in non-Article 5(1) countries have successfully complied with the production phase-out of ozone-depleting solvents that occurred nearly 2 years ago. A small quantity of ODS, which is authorised under post phase-out needs for Essential Use Exemptions, is still produced.

Over the past four years the number of Essential Use Exemption Nominations for ozone depleting (OD) solvents has decreased significantly and only a few of these requests have been granted. The users of ozone-depleting solvents have been quite successful in the phase-out but several industries still rely on them. Aqueous cleaning methods have been successful for many applications and indications are that a large percentage of users [about 50 - 60 percent] have made the transition to this alternative.

However, in several applications such as precision cleaning where factors such as high reliability, compatibility and short cycle time (e.g., fast, spot-free drying) are required, users are converting to alternative solvent processes. Many of these alternative solvents are more expensive on a per-kilogram basis and do not possess many of the desirable properties associated with the original ozone-depleting cleaning solvents.

The number of new ozone friendly solvents is quite small and the projection for continued research into new solvents is not high. Cost of research, time for governmental approval and user acceptance continue to be major concerns for developers. None the less several major chemical companies are still pursuing research with the expectation that users are tending towards solvents and not multi-step cleaning processes.

Continued dependency on stockpiled solvents and ongoing enthusiastic attendance at conferences and workshops provide evidence that interest in more economical and effective alternatives remain. One concern in particular is that in the near future, users who still rely on 1,1,1-Trichloroethane will soon begin to feel increasing pressure to find alternatives. This is because quantities of this solvent that have been stockpiled since the production ban at the end of 1995 are reaching the end of their shelf life.

An additional issue worth mentioning is the cost of solvent alternatives. Unlike the ozone-depleting solvents, the alternatives market is made up of many suppliers with numerous alternatives, many of which are variations or blends marketed under trade names of the same alternative. This dispersed nature of this market has made the economics of scale realised in the past, impossible today. Therefore, alternatives in general remain expensive relative to the OD solvents they replace, particularly for speciality uses.

The STOC continues to be aware of new solvents that have ODPs and incomplete toxicological assessment being offered in the market. The rush to promote these alternatives has been such that these properties are being overlooked and indeed minimised.

5.7.2 Article 5(1) Parties Progress

Although the phase-out effort is going well in non-Article 5(1) Parties, many unique challenges remain for Article 5(1) Parties. These Parties are allowed to produce ODS on per capita basis under the terms of the Montreal Protocol for their domestic use. Their large aggregate populations result in large allowances. Thus, one of the STOC's primary objectives is the rapid reduction in ODS demand by targeting SMEs and by eliminating carbon tetrachloride solvent use.

Another objective is to help provide awareness and training on both the ozone-depletion problem and solvent sector alternatives. These issues are addressed in following sections.

The solvent sector has proved the most difficult sector from which to receive project authorisation from the Multilateral Fund (MLF). Despite all of these obstacles, the Article 5(1) Parties have achieved satisfactory overall initial progress in the solvent sector, especially given the widespread use of ozone-depleting solvents and the variety and complexity of their applications. However, the freeze of ozone-depleting solvent production at mid-1999 levels and phase-down over the next ten years pose extremely difficult challenges to many Article 5 country users. The apparent ease with which the non-Article 5(1) Parties phased out will not be replicated in Article 5(1) Parties. The main challenges to the Article 5(1) Parties include the need to accurately identify products containing ODSs, the need to identify users. These are difficult because of complex distribution chains, and lack of communications and infrastructure for translating technical information and reaching many small and medium size enterprises. A further complication is the cost of the alternatives; capital costs of new cleaning and waste treatment equipment, and operating costs of alternative processes. While eligible for MLF funding, the procedures of the MLF, the implementing agencies and the governments to obtain such funding can be daunting for SME owners, some of whom may have literacy problems. In addition, many SMEs do not want to be identified, in an effort to avoid taxation or other government intervention.

A brief description of progress and challenges in each sub-sector is given below:

- **Electronics Cleaning:** Progress in the electronics industry has been good, amounting to a significant phase-out, in many cases due to local subsidiaries of multinationals being directed by their principals to change. “No-clean“ (low residue soldering) techniques have been extensively used in electronics applications. The process has been helped greatly by the many new factories and joint ventures started up in Article 5(1) Parties and relying for several tasks on “no-clean“ operations, so no phase-out was ever needed in these cases. The challenge to these new factories was finding local suppliers of the “no clean“ soldering materials required for success. Thus most of these factories must rely on imported soldering materials, since the MLF does not find that underwriting the costs of upgrading soldering materials is with their charter. Where a “no-clean“ process proves too difficult to use or is insufficiently reliable, then it will be necessary to clean. This requires higher capital investment, running costs, and training.

- **Metal Cleaning:** A speedy phase-out for the metal cleaning applications is hampered by the large number of small users, most of which are undercapitalised. Trichloroethylene, perchloroethylene, dichloromethane, and hydrocarbons (e.g. mineral spirits) do not deplete the ozone layer and offer low operative costs. The undercapitalised enterprises can use them as alternatives for speedy full phase-out for metal cleaning, provided proper workplace exposure, safety and waste solvent disposal measures are taken. A part of this sub-sector is involved with maintenance cleaning, which is not generally addressed by seminars or other outreach programmes. Much large scale metal cleaning has traditionally been done by aqueous or semi-aqueous processes, where the equipment and waste treatment requirements are easily justified by the volumes processed.

- **Precision Cleaning:** In precision cleaning applications, users have been aggressively implementing alternatives due to critical end-use requirements. Isopropyl alcohol is the preferred choice for many precision cleaning applications because of its good cleaning properties (although it does not have a high soil loading capability) and its low cost. Yet, in some cases, the users are still searching for solutions for precision cleaning of parts that are especially vulnerable to residues or reactions, or that have unusually stringent cleanliness, cycle time or compatibility criteria. In many of these cases an alternative solvent is the preferred choice. However, aqueous and semi-aqueous methods have also been shown to work successfully in many precision cleaning operations.

In the three applications cited above, standardised retrofits to replace ozone-depleting solvents in cleaning applications are not common. In all these sub-sectors, a thorough examination of the physical, chemical and other relevant properties of proposed alternative solvents should be carried out to decide the suitability of existing equipment.

5.7.3 Small and Medium Size Enterprises (SMEs)

One of the major problems yet to be resolved is the phase-out of controlled solvents in the small and medium size enterprises (SMEs) which, when taken collectively, consume the greatest volume of OD solvents. The SME problem, though common everywhere, assumes serious proportions in the Article 5(1) Parties. Countries like Malaysia, Thailand, Indonesia, and Mexico where almost all the SMEs are clustered in one region have successfully implemented a phase-out program mainly through the concept of umbrella projects. In countries like China and India, the SMEs are distributed over a wide range of regions where user identification itself is an immense task.

The task confronting China in terms of reaching the vast number of SMEs is especially instructive. In China solvents represent approximately 10 percent of the total ODS consumption but 50 percent of ODS users come from the solvents sector. These facts underscore the difficulty in identifying, reaching, and educating such a large body of Article 5(1) Party users in a time frame that is consistent with the agreed phase-down schedule.

A key issue identified in Article 5(1) Parties is the focus on cost per kilogram of cleaning agent, as opposed to cost per item cleaned. Cost per part cleaned is the only true measure of the economics of a cleaning process. Many of the effective ODS alternatives employed in non-Article 5(1) Parties have been rejected in Article 5(1) Parties on the basis of cost per kilogram. Thus, STOC is confronted with examples of Article 5 users who reject project funding via the Multilateral Fund (MLF) and instead plan to continue to use ODS as long as it is available.

This problem is compounded by the fact that some of the alternatives to ozone-depleting solvents at present need to be imported by the Article 5(1)

Parties because these are not produced indigenously. The substitutes must be made readily available at reasonable prices.

Newer solvents, some of which are less costly on a per kilogram basis, might seem attractive. However, until such new materials have undergone accepted rigorous, independent economic and scientific scrutiny regarding their environmental impact and health and safety issues, resulting in acceptance by appropriate government departments, it would be premature to propose their use. STOC will continue to monitor new products and provide recommendations regarding their applicability.

Concerted efforts are being made to reach the SMEs through seminars, conferences, and workshops. The obstacles to successful outreach programmes include the difficulty in identifying and contracting SMEs, and convincing them it is worthwhile to send take workers away from their jobs and pay their travel to attend.

Printed documentation in the users' languages of such activities needs to be readily available to supplement such programmes. Despite the challenges, these activities have created some awareness of the negative aspects of using ozone-depleting solvents. The number of SMEs in these countries using alternative non-ozone-depleting solvents is now increasing. In some cases the incentive to change has been economic, for example, "no-clean" techniques in the electronics industry. However, since the characteristics of the SME challenge tend to be unique by region and application, no universal or integrated solution can be easily devised. Moreover, the consumption of ozone-depleting solvents by SMEs is highly diversified in nature.

The cost per kilogram of OD solvents phased out in SMEs can be higher than other sectors, and this can present challenges to securing Project authorisations from the MLF when they rise above threshold values. These high costs are largely due to the capital and operating costs of most replacement processes.

Despite these difficulties, the phase-out rate of ozone-depleting solvents by the SMEs has been encouraging, especially in the Article 5(1) Parties. However, the magnitude of the global ODS phase-out task remains significant, and continued efforts are necessary to work with Article 5(1) Parties to achieve the upcoming control schedule.

In order to accelerate the pace of phase-out program, establishment of a demonstration centre strategically located within a country might be considered so that the SMEs can obtain first hand experience using alternatives. The personnel in such centres should be encouraged to publish the results of all their testing to benefit other users; thus phasing out many users based on the work with one user. This phase-out by industry segment approach can be very economical, both in terms of time and required funding. Suppliers are generally eager to donate reasonable quantities of cleaning agents for use in such centres, as well as assisting in seminars and teaching demonstrations. However, procurement of pilot scale machinery for major applications would need financial resources. A continuously updated database should be developed and maintained by the centre, with access provided to users, suppliers and industry trade associations, in an effort to encourage information dissemination. Implementing agencies, local and international corporations, and industrial associations may also provide support.

5.7.4. Carbon Tetrachloride use in Article 5(1) Parties

Since the last report the STOC has become aware of very significant use of carbon tetrachloride (CTC) in various cleaning processes in Article 5(1) countries. It is being used in simple open containers which presents not only a serious threat to the health of a large number of workers due to its proven toxic effects, but also to the ozone layer, because of the substances' very high ODP. Such cleaning operations are also coupled with significant spillage of CTC, where it enters the soil, even through cement or concrete, and often contaminates ground water, often a major source of potable water. There are a large number of small users in Article 5(1) countries using CTC under very emissive conditions and they have limited resources for change.

Some medium and large enterprises use CTC in inadequately sealed vapour degreasing machines, with equal risk to the environment and worker health and safety. It is the preferred solvent for metal cleaning, as it is the cheapest, it is easily obtainable in many countries and is a very efficient degreaser.

CTC is widely used in some countries for the dry cleaning of textiles. One STOC member recently witnessed the use of CTC in an old, leaky, rotary drum machine. The clothes removed from the machine were still quite damp with the solvent, but they were immediately passed to workers for pressing with both hand irons and rotary colander machines. The long-term health effects on these operators resulting from dermal absorption and inhalation are significant.

The committee consensus is that such cleaning with CTC in open baths must be avoided. This is especially applicable because non-ozone-depleting alternatives (notably, trichloroethylene and perchloroethylene) that would improve the effects of worker exposure are readily available and could be easily implemented provided suitable equipment is available. These solvents are not ideal, but they do offer an immediate solution to the problem. The users should have access to these processes at affordable prices. However, numerically, nearly all the users of CTC are SMEs (see the section on SMEs) and are difficult to identify. The long term solutions are dependent upon the actions devised by the national authorities and regulatory actions to prevent CTC usage under uncontrolled, emissive conditions.

5.7.5. 1998 Nomination for Essential Uses

Essential Use nominations are considered for exemptions on an annual basis. Exemptions granted for more than one year (if any) are still subject to annual review. The following provides a brief overview of the process and then describes recent STOC review of essential use applications. For complete details on the Essential Use Exemption process visit the TEAP web site at:

http://www.teap.org

An organisation in a non-Article 5(1) Party makes an application for an essential use exemption to the relevant government authorities. The government then reviews the application and decides whether to submit it for international review. Article 5(1) Parties may apply after the grace period.

- The STOC recommended to TEAP that the European Union request for use in coating cardiovascular surgical material be granted for 1999 and 2000. The amounts involved were small and the importance to health, were major considerations.

- STOC and TEAP were unable to recommend Poland's request for the use of an ODS for the maintenance of torpedoes on submarines. However, at the 17th OEWG meeting in Switzerland, Russia and Poland agreed to meet with the STOC experts and the OEWG agreed to recommend the essential use nomination to the Parties for decision at Cairo.

- The United States has been advised to reschedule the remaining authorised quantity of methyl chloroform (1,1,1-trichloroethane) for use in manufacturing solid rocket motors until such time that the allowance is depleted or until such time that safe alternatives are implemented for remaining essential use.

- Regarding Global Laboratory and Analytical Uses, the STOC and TEAP have presented two options for consideration by the Parties. First, is to discontinue the global exemption for laboratory and analytical uses after 1999, but request Parties to submit separate applications for individual uses through the annual essential use process. Second, is to permit continuing global exemption until 2001 but prohibit up to three additional specific uses with identified alternatives which are testing of oil, grease and total petroleum hydrocarbons in water; testing of tar in road paving and forensic fingerprinting.

5.7.6. Ozone Depleting Solvents Use Quantities

An attempt was made to obtain comparative data on the solvents use quantities for applications covered by STOC.

The data given below for Europe was provided by the DG.XI and gives figures for the year 1992 and 1996. The EC provided data on production sales and exports of ODS for Europe as a whole. The EC does not collect more detailed information (e.g., country by country or by type of solvent application). However, it is known that the bulk of the production and sales is to be found within a small number of the Member States, whereas others almost completely have stopped using all ODS for solvent purposes.

It should be noted that the figures reported relate to the placing on the European market sales of substances. They cannot be directly transposed to use figures because of changes in stock volumes etc.

Table 5.7.1:
EC-Production and sales of ODS in 1992 and 1996

	Year 1992			**Year 1996**		
Substance	**Production**	**Total sales**	**Sales as solvents**	**Production**	**Total sales**	**Sales as solvents**
1.1.1 CFC 113	39799	31732	30347	482	0	0
1,1,1-trichloroethane	182371	91050	not available	1722	1	0
Carbon tetrachloride	11418	6731	not available	421	0	0
HCFC 22	75989	41529	206	102000	51742	243
HCFC 123	38	54	44	240	154	78
HCFC 141b	4266	1929	104	34165	28571	6072*
HCFC 225	0	not available	not available	0	22**	not available

All figures in metric tonnes
*figure relate to 1995 sales but other information indicate a stabilisation at this level in 1996 (and 1997)
**figure relate to 1997 sales

The information on which this table is based gives the figures aggregated in three sectors; refrigeration, foams, solvents & other uses. Hence, the figures reported as solvent use may also comprise some other minor uses, however our estimate is that such uses are negligible.

Other data sources provide figures for the total production of global CFC and HCFC production and consumption. Reliable figures for specific solvent uses or for regions was not available at this time.

5.7.7. Military Progress

Military organisations in most non-Article 5(1) Parties have eliminated virtually all uses of ODS solvents. The majority of military solvent uses are identical to those found in the commercial sector, and implementation of ODS alternatives in both sectors is virtually complete.

Very few Parties operating under Article 5(1) have provided information to the TEAP regarding military ODS solvent uses and on their efforts to find alternatives. With the first control measure coming into force in 1999 for Article 5(1) Parties, it is important that military organisations in these countries identify their uses and begin planning their transition to alternatives. There is a wealth of experience in non-Article 5(1) Parties on specific military uses and alternatives which countries operating under Article 5(1) can call upon in order to simplify the transition. UNEP IE is producing a set of guidelines that capture the experiences from non-Article 5(1) Party military organisations and offer a framework for Article 5(1) militaries to begin implementing programs to manage their ODS uses.

5.7.8. Oxygen Systems

Oxygen systems include: life support systems such as diving, totally encapsulated suits, emergency breathing devices, fire & rescue backpacks, submarine, aircraft, manned spacecraft, and medical applications; propulsion systems such as liquid rocket motors; industrial systems such as chemical production, and other unique systems and customer products such as welding equipment.

Most oxygen systems have components and assemblies with similar functions such as tubing, gauges, regulators, valves, thermal compensators, and cylinders. A large variety of metallic and non-metallic parts are used to fabricate the system devices.

The use of oxygen involves a degree of risk because oxygen vigorously supports combustion when in contact with many substances. Thus, a high level of cleanliness is prerequisite for oxygen system components.

CFC-113 was the solvent of choice for many years in cleaning oxygen systems. This solvent displayed performance and safety characteristics that were uniquely suited for the cleaning of oxygen systems.

Progress has been made to introduce alternative cleaning methods without the use of CFC-113. For example US Navy and Lufthansa German Airlines have been using aqueous cleaning methods with no processing or operational problems. Some other organisations have started using HFE-7100, HCFC-225, HFC-43-10 and HFC-141b with certain limitations for components used in their oxygen systems. The acceptance of alternatives to CFC-113 by the industry has been slow because of stringent specification requirements on the degree of cleanliness and its verification. These requirements in many cases have been arbitrarily fixed.

5.7.9. Concerns of unannounced changes in speciality products

The Committee cautions that manufacturers may eliminate ODSs from products without notifying customers. There is the possibility that the manufacturer may not appreciate that their product is used in a particular application where the ODSs provided a necessary performance characteristic that is not duplicated by the reformulated product. Use of such reformulated materials and products under these circumstances could be costly or dangerous to life and health. The solution is for manufacturers of speciality products to better communicate to end-users, changes in product ingredients and to co-operate with end-users on performance testing of the new products.

5.7.10 HCFCs

HCFCs, although positioned as transition substances, are serving some limited and unique applications where other suitable alternatives have not been identified including:

- cleaning delicate materials such as cultural heritage and archival property
- cleaning assemblies or components with sensitive materials or particular soils
- cleaning certain oxygen systems
- cleaning where explosive or flammable conditions are possible
- as a carrier of oil in precision applications.

In countries where HCFCs are prohibited, enterprises may, in certain specific cases, select perfluorinated carbons (PFCs) as an adjunct to specialised cleaning systems. PFCs have extremely long atmospheric lifetimes and have potent global warming potentials (GWPs) and should therefore be avoided where possible.

The Committee does not recommend the use of HCFC-141b to replace 1,1,1-trichloroethane as a solvent. HCFC-141b has an ozone-depletion potential (ODP) comparable to 1,1,1-trichloroethane and is not technically suitable for many cleaning applications.

It is estimated that HCFC-141b and HCFC-225 together will not replace more than 1 percent of global CFC-113 uses unless HCFC-225 becomes a substitute for CFC-113 in dry cleaning, which could increase use to approximately 5 percent. In some countries with active HCFC sales efforts, approximately 5 percent of CFC-113 solvent use (excluding dry-cleaning which may increase use) may be replaced with HCFC-141b. It is estimated that HCFCs may replace 1-5 percent of 1986 CFC-113 and 1,1,1-trichloroethane use as transitional substances and where no alternatives or substitutes are currently available.

5.7.11 Brominated Solvents

Recently, two OD brominated solvents have been commercially introduced, chlorobromomethane (CBM) and n-propyl bromide (nPB). These two substances are also blended into solvent mixtures that are sold under many trade names. They are being marketed as substitutes for non-ozone depleting solvents (trichloroethylene and perchloroethylene) and ozone-depleting solvents (HCFCs, CFC-113 and 1,1,1-trichloroethane). These products have boiling points slightly less than and solvency nearly the same as 1,1,1-trichloroethane, which make them possible replacements. Less is known about materials compatibility and other important reliability factors. However, because of their ozone depleting potential and high probability of extensive use, STOC has recommended that the Parties of the Montreal Protocol consider the potential danger of these substances to the ozone layer. At the time of writing STOC is in the process of formulating options for further consideration by the Parties. The possibility of any future Protocol or national regulatory restrictions should always be considered when deciding on alternatives.

The UNEP Scientific Assessment Panel recently assigned chlorobromomethane (CBM) an ozone-depleting potential of 0.15, which is comparable to that of 1,1,1-trichloroethane. Additionally, CBM has significant toxicological concerns. The STOC does not recommend the use of CBM as a solvent alternative.

For nPB the UNEP Scientific Assessment Panel assigned an ozone-depleting potential value of 0.026. This ODP value puts nPB in the same range as HCFC-225. This would suggest that based on ODP it might be classified similarly. Testing to determine the long-term toxicological effects and safety of nPB is still in progress but preliminary results give cause for concern. Under certain test conditions, using standard flash point testing apparatus, pure nPB has demonstrated a flash point at -10°C. This corresponds with historical literature values that were not defined by the test method used. However, other ASTM test methods have resulted in no observed flash point. Solvent blends (solvents with inhibitors, stabilisers or other solvents) may have flash point characteristics different from that of the pure solvent, depending on the nature of the additives. The decision to use nPB should take into consideration ozone depleting potential as well as health and safety concerns. At the time of writing, the studies of health and safety aspects are still proceeding.

As nPB is ozone depleting, the Committee's position is that this solvent is not recommended as a substitute for other ozone-depleting solvents. This view is further substantiated by the fact that non-ozone-depleting solutions exist for all cleaning applications for which nPB is being promoted.

5.7.12 Ready Reference List

It has become apparent over recent months that many persons in both non-Article 5(1) and Article 5(1) Parties are having difficulty in identifying products consisting of or containing ozone depleting solvents. As opposed to other ozone depleting substances such as refrigerating gases, halons, aerosols propellants, the ozone depleting solvents are shipped and labelled in identical ways as hundreds of solvents that are not ozone depleting. The STOC has produced a brochure intended to help users, agents, ozone officers, customs officers and others identify which solvent containing products are ozone depleting and therefore, fall under the regulations of the Montreal Protocol. This brochure can be accessed at our web site at the following URL:

http://www.protonique.com/unepstoc/stocfile/stocrr.htm

5.7.13 Sector Progress

5.7.13.1 Electronics Cleaning

The electronics sub-sector was one of the largest consumers and emitters of OD solvents, but fortunately there are a wide range of substitutes available. The two main uses of OD solvents are for defluxing soldered assemblies and developing dry film photoresists.

The wide choice of substitute processes can be an embarrassment, because any error may be costly. Experience has shown that production engineers make mistakes. If, for example, a "no-clean" process proves too difficult to use or is insufficiently reliable, then it will be necessary to clean. This requires more capital investment, higher running costs, and training. On the other hand, if a company cleans unnecessarily, it may lose competitiveness. The best choice, in any set of circumstances, must be made first time. This requires much skill and experience on the part of the decider.

Where possible, "no-clean" soldering offers the best economical and environmental choice. However, the process is the most difficult to master and may require higher quality components than other methods. In Article 5(1) countries, the skills to keep a "no-clean" process functioning successfully, with uniformly satisfactory results, may be difficult to find and it may take months to acquire.

Where cleaning is necessary, water-soluble chemistry is most common, except in Japan. The cost is usually slightly less than that of CFC-113 defluxing, but can occasionally be higher. It offers the widest operating windows and the best soldering quality. The residues are easy to remove with water, and adequate equipment is readily available. In most cases, no cleaning chemicals are required. Wastewater treatment is usually simple. However, the process is not a forgiving process and a deviation from the norm may lead to unacceptable results. A rigid statistical process control is essential.

Saponifier defluxing has one advantage compared to water-soluble processes: it may be possible to use the same flux and solder paste as for CFC-113 cleaning. It also has some disadvantages, because saponifiers are alkaline. They may attack some components and materials, require wastewater treatment, and may have higher operating costs. However, it is successfully used in many countries.

Hydrocarbon-surfactant (HCS), sometimes incorrectly known as „semi-aqueous," cleaning has not fulfilled its initial promises. Consisting of solvent defluxing, it is followed by a water wash and rinse to remove the dirty solvent. It is expensive in terms of capital equipment, running costs, and wastewater treatment. It is still popular in Japan but has lost much ground in many other countries.

Straight hydrocarbon defluxing is rarely used, except for a few niche applications. Flammability is a major concern and requires tight process control for safety. Consistent defluxing quality may reveal itself as barely sufficient.

Halocarbons are sometimes used for niche applications where water cleaning, in any form, is unsuitable. These may include HCFC-225, HFC, or HFE blends. Equipment to minimise emissions is expensive, but essential, because of economic, environmental, health and safety concerns.

For printed circuit fabrication, the main use is 1,1,1-trichloroethane for developing dry film resists. Aqueous systems have been available for over 25 years in non-Article 5(1) Parties. The same may be used in Article 5(1) countries, although the operating window is narrower, requiring a small investment in improved operator training. For very fine line work, wet film resists, developed either in a non-OD solvent or in an aqueous solution, may provide another answer.

Drying printed circuits after an aqueous operation occasionally used a CFC-113 system. Hydrocarbon displacement or absorption systems have both been used for this, but with flammability issues. Another, more expensive, possibility is to use a non-OD halocarbon system. The use of this is likely to diminish, as new water-based copper protection chemistry becomes more widespread.

Phasing out OD solvents used for electronics in Article 5(1) Parties can be rapidly done, as in non-Article 5(1) Parties. Nevertheless, some users may find it difficult to use „no-clean“ and may prefer aqueous methods, where there is a good supply of suitable water. Where water is scarce or expensive, recycling may become economical where this would not be the case elsewhere. Regulations governing wastewater vary widely from country to country, but must be respected.

The major problem for which a universal solution is still evasive is that of Small and Medium Enterprises (SMEs) in Article 5(1) Parties. In many cases these may require less than $50,000 for equipment, but they are numerous and difficult to identify. Sub-sectorial umbrella projects may offer a partial solution but are difficult to implement as the needs of individual SMEs vary widely. In some situations, SMEs are widely distributed across large geographic regions, posing significant logistics challenges.

5.7.13.2 Precision Cleaning

The STOC has been reviewing the technical feasibility of the phase out of ozone depleting substances since the signing of the Montreal Protocol. The committee has been successful in making many technical recommendations for elimination of ODSs in research development and manufacturing.

There has been considerable success in applying alternatives for precision cleaning, the result of a great deal of focused research by several large chemical companies and equipment manufacturers. HCFCs, HFCs, and HFEs have been shown to be useful for a number of precision cleaning applications. While HCFC 225 has a measurable ODP, it has proven to be useful in some critical cleaning applications as an alternative to high ODP substances. HCFC-225 is recognised by the committee as useful in precision cleaning, recognising that HCFCs are only transitional, and will be phased out.

The HFEs and HFCs have also demonstrated usefulness as alternatives to ODS in precision cleaning. They have no ODP and are preferred for this reason. However, consideration should be given to their global warming potential (GWP) and impact on climate change.

Because of its complexity, precision cleaning has presented several challenges. Some within the sector believe that that the requirements for precision cleaning can be achieved without the use of solvents. Aqueous and semi-aqueous cleaning have been proven successful in several applications. However, the disadvantages of these include multi-step processes and longer process time.

Retrenchment to the traditional solvents, such as acetone, isopropyl alcohol, and hydrocarbons has occurred for some applications. The disadvantages of these solvents include; flammability risks; and operator discomfort due to odour and possible dehydration effects of alcohol and vapours. Despite these drawbacks, these solvents have been used for many years and there is a lot of experience in managing their use in the workplace.

Methods such as ultra-violet / ozone and super critical fluids have also been successfully used for a number of precision cleaning applications. However, the high skill level required for their proper use, and high initial cost of equipment act as barriers to more widespread adoption. Likewise, the high cost of the new non-ODP solvents remain barriers to more widespread transition. While technically feasible, cost continues to be a barrier. If costs come down as the market for these processes expands, the transition should become easier.

Brominated solvents, such as n-propyl bromide, have been suggested recently, and are being aggressively marketed, as alternatives for precision cleaning. There are concerns over ODP a lack of toxicological assessment data.

It is the opinion of the committee that research has produced numerous alternatives that fulfil the critical performance requirements previously delivered by ODSs, thus virtually eliminating the need for ODSs in precision cleaning applications.

5.7.13.3 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, or packaging. Parts may be cleaned multiple times during the manufacturing process.

The control approaches available for metal cleaning operations include solvent conservation and recovery practices and the use of alternative cleaning processes. The alternatives can be organised into the following major categories; alternative solvents and their blends, aqueous cleaners, hydrocarbon/ surfactant cleaners, and other miscellaneous alternatives. Alternatives to CFC-113 and 1,1,1-trichloroethane must be selected and optimised or each application given the varying substrate materials, soils, cleanliness requirements, parts and equipment compatibility, process specifications, and end uses encountered in metal cleaning. Economic, safety and environmental factors must also be taken into consideration.

The committee has recently found that there is significant use of carbon tetrachloride in various cleaning processes in Article 5(1) Parties. These uses have been identified primarily where a low cost, non-flammable, and simple cleaning process are 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.

Cost of alternatives can be divided into two groups, one time and recurring. The evaluation of environmental, health, and safety impacts of an alternative prior to its use would be considered a one time cost. Disposal of hazardous waste generated by an alternative is a recurring cost.

The Committee consensus is that most CFC-113 and 1,1,1-trichloroethane used in metal cleaning applications can be replaced by existing alternatives in accordance with the Montreal Protocol. However, it should be noted that there is continued dependency on stockpiled solvents, ongoing enthusiastic attendance at conferences and workshops, and illegal imports into countries that have phased out production. This provides evidence that interest in more economical and effective alternatives remains.

Companies in Article 5(1) countries should be able to closely follow the same scenario as the companies in the non-Article 5(1) countries, with some possible lag time for smaller domestic industries. Each Article 5(1) Party will have somewhat different scenarios depending upon their unique industry basis.

5.7.13.4. Dry Cleaning

Major reductions in CFC-113 and 1,1,1-trichloroethane usage in dry cleaning has resulted from the replacement of cleaning machines designed for use with these solvents. Machines using perchloroethylene or hydrocarbon solvents are the logical choices for replacement depending on the required solvency power.

1,1,1-trichloroethane use in dry cleaning has all but ceased. Tail end uses of CFC-113 will continue until private stockpiles are exhausted. Purchase of new supplies of CFC-113 is increasingly unviable and is only continuing short-term whilst small businesses decide on reinvestment in new equipment or closure.

Recycling and recovery technology is already at an advanced stage however, optimum solvent efficiency from dry cleaning machines can be achieved by improved operator practices and better engineering maintenance and controls. The solvent reduction benefits from centralised facilities may be more fully realised with perchloroethylene or the other alternatives described as companies replace machines using CFC-113 and 1,1,1-trichloroethane.

The committee consensus is that CFC-113 or 1,1,1-trichloroethane is no longer necessary for dry cleaning in non-Article 5(1) countries. CFC-113 and

1,1,1-trichloroethane use can be eliminated through the use of currently available alternative solvents, such as perchloroethylene and hydrocarbon. Most Article 5 countries never used CFC-113 or 1,1,1-trichloroethane. For cost reasons, perchloroethylene has always been the preferred alternative. Improvements in equipment tightness and labour training are still needed. Whilst work continues to modify international care labelling agreements, the STOC advises clothing manufacturers to ensure that fabrics, trimmings, and interlinings are suitable for dry cleaning in perchloroethylene.

5.7.13.5 Adhesives

The use of 1,1,1-Trichloroethane as a solvent based adhesives has almost been completely eliminated in the non-Article 5(1) Parties. In Article 5(1) Parties it is still being used but with declining rate. Many alternative technologies are now commercially available depending upon the end uses. The costs and the environmental impact of the alternative technologies are in most cases counter effective. Water based adhesives though environmentally friendly, require significant conversion costs. However, hot melt adhesives may be more expensive per unit of weight, but in many applications their use leads to reduced overall costs. The radiation-cured adhesives may be the most advantageous due to low energy costs and reduced emission of waste effluents and polluting gases and liquids. Though there is limited data on the worldwide market for alternative adhesives, information available on the United States, European Union and Japanese markets indicate that in almost all adhesive applications there is a suitable alternative.

5.7.13.6 Aerosols Solvent Products

1,1,1-Trichloroethane functions as either an active ingredient (e.g., degreaser or cleaner) or as a solvent of other active substances in aerosol product formulations. Though many of the aerosol applications traditionally used 1,1,1-trichloroethane as their solvent, there are a small number of products that made use of CFC-113 as well. Most aerosol products currently employing CFC-113 and 1,1,1-trichloroethane can be reformulated with alternative compounds. Except for water, some HCFCs, and non-ozone-depleting chlorinated solvents (e.g., trichloroethylene, perchloroethylene, methylene chloride), all of the substitute solvents currently available are more flammable than 1,1,1-trichloroethane. The flammability is also a function of the propellant; propane and butane being flammable, whereas carbon dioxide, nitrous oxide or the traditional CFC-11/CFC-12 mixture are non flammable.

Alternative solvents currently exist for virtually all aerosol solvent applications of CFC-113 and 1,1,1-trichloroethane. However, while some of these alternatives are functional, they are considered to be less than optimal for a variety of reasons. For example, in applications where a strong solvent is required, but the use of a flammable solvent would pose serious safety risks (e.g., cleaning live electrical circuits), substitutes may include only HFCs, HCFCs, and chlorinated solvents. While these solvents would be functional, HCFCs contribute to ozone-depletion, and chlorinated solvents are toxic and may pose health risks to workers and users of a product.

5.7.13.7 Other Solvent Uses of CFC-113, 1,1,1-Trichloroethane, and Carbon Tetrachloride

Some amount, in most cases relatively small quantities, of CFC-113, 1,1,1-trichloroethane, and carbon tetrachloride are employed in a number of industry and laboratory applications. The application areas include drying of components, film cleaning, fabric protection, manufacture of solid rocket motors, oxygen systems cleaning, laboratory testing and analyses, process solvents, semiconductor manufacturing, and others.

The Committee consensus is that nearly all of the CFC-113, 1,1,1-trichloroethane, and carbon tetrachloride used for these applications can be replaced by alternatives, in accordance with the Montreal Protocol.

In the applications of laboratory analyses and in the manufacture of large scale solid rocket motors, the Parties have granted an exemption for continued use of specified ozone-depleting solvents. The exemptions are subject to review and alternatives are being investigated.

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B.2 1998 Membership of the Technology and Economic Assessment Panel and its Technical Options Committees

B.2.1 1998 Technology and Economic Assessment Panel (TEAP)

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Suely Carvalho	Montreal Protocol Unit - UNDP-NY	Brazil
Lambert Kuijpers	Technical University Eindhoven	Netherlands

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Paul Ashford (Acting)	Caleb Management Services	UK
Thomas Batchelor	Department of Primary Industry, Water & Environment	Australia
Walter Brunner	Envico	Switzerland
Jorge Corona	CANACINTRA (National Chamber of Industry)	Mexico
Barbara Kucnerowicz-Polak	State Fire Service	Poland
Mohinder Malik	Lufthansa German Airlines	Germany
David Okioga	Ministry of Environmental Conservation	Kenya
Jose Pons Pons	Spray Quimica	Venezuela
Sally Rand	Environmental Protection Agency	USA
Rodrigo Rodriguez-Kabana	Auburn University	USA
Lalitha Singh	Independent Expert	India
Gary Taylor	Taylor/Wagner	Canada
Helen Tope	Environment Protection Authority, Victoria	Australia
Robert van Slooten	Consultant	UK
Ashley Woodcock	University Hospital of South Manchester	UK
Shiqiu Zhang	Peking University	China

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Helen Tope	Environment Protection Authority, Victoria	Australia
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Francis M. Cuss	Schering Plough Research Institute	USA
Chandra Effendy	p.t. Candi Swadaya Sentosa	Indonesia
Carmen Flasch	Boehringer Ingelheim Pharma KG	Germany
Charles Hancock	Charles O. Hancock Associates	USA
Eamonn Hoxey	Medical Devices Agency	UK
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P. Kumarasamy	Aerosol Manufacturing Sdn Bhd	Malaysia
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Daisaku Sato	Ministry of Health and Welfare	Japan
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Ian Tansey	3M Health Care	UK
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B.2.6 TEAP Methyl Bromide Technical Options Committee

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Bob Taylor	Natural Resources Institute	UK
Bill Thomas	Environmental Protection Agency	USA
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B.3 Technology and Economic Assessment Panel Co-Chairs, Senior Expert Members and Members background information

TEAP has interpreted the Terms-of-Reference (TOR) regarding Code-of-Conduct to require disclosure statements by TEAP members. These are presented in full in annual TEAP Reports. Disclosure for members of TOC and others subsidiary bodies and compliance with the Code-of-Conduct are reviewed each year by TEAP and reported to Parties. The TOC Co-Chairs are currently requesting disclosure statements for 1998-99.

Since 1988 many Parties have made substantial in-kind and financial contributions to the operation of TEAP and its TOCs, Working Groups and Task Forces. The principal financial contributors include Australia, Canada, Germany, Japan, Netherlands, Sweden, Switzerland, United Kingdom, and the United States. In a typical year TEAP requires US$100,000-150,000 in administrative and management wages, communication, word processing, printing, and mailing costs. TOCs typically spend US$35,000-100,000 depending on whether the time of chairs is an in-kind contribution or a sponsored contribution.

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B.4 History of TEAP Organisation and Biographical Information of Current Members

In the 1970's and 1980's a large number of studies on the science of ozone depletion and its environmental effects were published. Little effort was expended to develop alternative technologies as there was a lack of concensus that there was a direct link between CFCs and ozone depletion. Interest in developing alternatives increased radically after the Montreal Protocol was signed

In 1988, Dr. Mostafa Tolba, G. Victor Buxton and Dr. Stephen O. Andersen organised a Technical Conference in the Hague to demonstrate the importance of industry participation in assessments of the feasibility of going farther and faster in protecting the ozone layer. The separate Scientific, Environmental Effects, Technical, and Economic Assessments were formally initiated at the First Meeting of the Parties to the Montreal Protocol in May 1989 in Helsinki Finland.

In 1989, one hundred and ten experts from 22 countries (Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Egypt, France, Germany, India, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, Union of Soviet Socialist Republics, United Kingdom, United States, and Venezuela) formed the first UNEP Technology Assessment with five Technical Options Committees.

B.4.1 Annual progress

1989
Technology Assessment Panel (TAP)
Aerosols, Sterilants and Miscellaneous Uses Technical Options Committee
Halons Fire Extinguishing Agents TOC
Refrigeration, Air Conditioning and Heat Pumps TOC
Electronics, Degreasing and Dry Cleaning Solvents TOC
Flexible and Rigid Foams TOC

In 1990 the Parties combined the Technology Assessment Panel and Economic Assessment Panels into the Technology and Economic Assessment Panel (TEAP).

1991
Technology and Economic Assessment Panel (TEAP)
Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride TOC
Halons TOC
Refrigeration, Air Conditioning and Heat Pumps TOC

Solvents, Coatings, and Adhesives TOC
Flexible and Rigid Foams TOC
Economic Options Committee

1992
Interim Methyl Bromide Science
Technology, and Economics Assessment Panel
1993
Technology and Economic Assessment Panel (TEAP)
Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride TOC
Halons TOC
Refrigeration, Air Conditioning and Heat Pumps TOC
Solvents, Coatings, and Adhesives TOC
Flexible and Rigid Foams TOC
Methyl Bromide TOC
Destruction Working Group

1995
Technology and Economic Assessment Panel (TEAP)
Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride TOC
Halons TOC
Refrigeration, Air Conditioning and Heat Pumps TOC
Solvents, Coatings, and Adhesives TOC
Flexible and Rigid Foams TOC
Methyl Bromide TOC
Laboratory and Analytical Uses Working Group
Process Agents Working Group
Countries with Economies in Transition (CEIT) Working Group

1996
Technology and Economic Assessment Panel (TEAP)
Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride TOC
Halons TOC
Refrigeration, Air Conditioning and Heat Pumps TOC
Solvents, Coatings, and Adhesives TOC
Flexible and Rigid Foams TOC
Methyl Bromide TOC
Countries with Economies in Transition (CEIT) Task Force
Process Agent Task Force

1997
Technology and Economic Assessment Panel (TEAP)
Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride TOC
Halons TOC
Refrigeration, Air Conditioning and Heat Pumps TOC

Sub-committee on Flammable Refrigerants
Solvents, Coatings, and Adhesives TOC
Flexible and Rigid Foams TOC
Methyl Bromide TOC
Essential Uses Handbook Working Group
Process Agent Task Force

Current
Currently the TEAP has 23 members from 16 countries—Australia, Brazil, Canada, China, Germany, Hungary, India, Japan, Kenya, Netherlands, Mauritius, Mexico, Poland, Switzerland, UK, USA, and Venezuela. The TEAP operates on the basis of consensus and its 50 published reports represent a balanced view. TEAP Reports are respected by the Parties because they are objective and explain difficult technical issues in a manner useful to policy makers.

B.4.2 TEAP Membership

TEAP membership includes the Co-chairs of the TEAP, the Co-chairs of the 6 Technical Options Committees, the Co-chairs of the Economic Options Committee and Senior Technical Advisors. The TEAP strives to maintain technical excellence and geographic balance and is assisted in this regard by receipt of key nominations from National Governments. It is a condition of TEAP membership that all members act independently and are not subject to direction from their sponsoring organisations.

The 7 Technical Options Committees are Aerosol Products, Economics, Foams, Halons, Solvents, Refrigeration, and Methyl Bromide. Over 600 experts from 45 countries have served on TOCs since 1988. TOC members have primarily been from industry and the expertise and leadership they have provided has verified the initial supposition that involvement and co-operation of industry would contribute to the objectives of the Montreal Protocol.

The TEAP recommends TOC chairs to the Parties and may temporarily appoint acting chairs. In all cases the Parties decide the final selection of TOC chairs. TOC members are selected on the basis of their ability to contribute to the work of the TOC, with special emphasis on their technical expertise. Every effort is made to ensure geographic balance.

In order to answer specific technical questions raised in Decisions of the Parties that are beyond the purview of the standing Technical Options Committees, the TEAP sometimes creates Task Forces or Working Groups with a limited and specific mandate. These temporary subsidiary bodies support TEAP in providing the best possible response to Parties.

The TEAP was established to meet the needs of Parties for objective and unbiased consensus findings. The TEAP presents policy relevant technical information in answer to questions to the TEAP contained in Decisions of the Parties. TOC reports are reviewed by the TEAP to ensure that a relevant response has been generated and to ensure that consensus has been achieved by the TOC in formulating their response. The TEAP relies upon the technical expertise of the TOCs and does not filter or otherwise modify a technically accurate response that represents the consensus view of the TOC. The TEAP may summarise the policy relevant findings of the TOC.

The balance of interests that is an integral part of the structure of the TEAP and TOCs fosters unbiased technical honesty and has garnered the respect of Parties and industry. Political independence has also provided confidence in the findings of the TEAP. The avoidance of outside influence has also encouraged the recruitment of members with outstanding technical qualifications.

The inclusion of a high proportion of TOC members from industry has had several advantages. It has provided wide credibility for TEAP and TOC findings and it has encouraged cross-discipline technical breakthroughs. The TOCs have also provided an important forum for achieving consensus on technically viable solutions and this in turn promoted rapid commercialisation. Consensus on viable options by both industry and governments helped transform markets and lessened dependence on ozone depleting substances at a much more rapid pace than had been thought possible when the process began. Governments were able to prepare detailed plans for market transformation based on confidence in the technical basis for controls and compliance. Governments were provided with competent technical advice to ensure that public safety was not compromised by the transition.

B.4.2.1 TEAP Biographies

Several members of the TEAP were asked to provide short resumes to illustrate how the TEAP has achieved a diversity of technical capability, a balance of interests and global representation.

Professor Radhey S. Agarwal is the Dean of Industrial Research and Development and a professor of Mechanical Engineering at Indian Institute of Technology, Delhi, India. He has held several academic and administrative positions including Chairman of Mechanical Engineering Department at the same institute. He has also been consultant to various Indian industries and visiting faculty in international universities.

He studied Mechanical Engineering as an undergraduate and received Master of Technology degree in Thermal Engineering in 1969 and Ph.D. degree in the area of Thermodynamics of Zeotropic CFC Mixtures and their Applications in Refrigeration in 1975 from Indian Institute of Technology, Delhi.

Professor Agarwal has guided 12 Ph.D.'s and 40 Master's theses on various topics related to Refrigeration and Air-conditioning, Energy efficient Technologies, Non conventional sources of energy, Thermal System Simulation and Optimisation, and non-ODS technologies for Refrigeration and Air Conditioning. He has published over 70 research papers in International journals and conferences on various topics mentioned above. He has edited conference proceedings of Indian Society of Mechanical Engineers, National Society of Refrigeration and Air-conditioning and International Institute of Refrigeration. He is Vice President of IIR commission B-2, Vice President of Indian Society of Mechanical Engineers, Member ISHRAE. He is also chairman of IIR sub-commission on Global Warming.

At the start of international effort for CFC phase-out to protect ozone layer, he started research and development work in the field of non CFC refrigerants, and led India in education and dissemination of the information on ozone friendly technologies to the policy makers in Indian government and industry. He became a member to the task force formed by Ministry of Industry, Government of India to asses the ODS consumption in the refrigeration and Air-conditioning subsector in 1988. He was an active member of the team responsible for the development of India country program under Montreal Protocol for ODS phase out. Later starting in 1993, he became a member of Technical and Finance Committee of MoEF, government of India responsible for policy formulation and reviewing of ODS phase-out projects under Montreal Protocol. Currently he is the technical advisor for reviewing and updating of continuing India Country Program for ODS phase-out. Presently, He is also chairman of Bureau of Indian Standards on Refrigeration committee responsible for updating standards and making policies for energy and Eco-levelling of refrigeration appliances and machinery.

He was opted for Technology and Economic Assessment Panel in 1988 as a member of technical options committee on Refrigeration, Air-conditioning, and Heat Pumps. He has actively participated in 1991, 1995 and the current 1998 assessments. He was the lead Co-author of domestic Refrigeration section in 1995 assessment. He was elected as Co-chair for TOC on Refrigeration, Air Conditioning, and Heat Pumps in 1996 and also as a member of TEAP. He was a member of OORG sub committee for commercial Refrigeration. He has also made substantial contribution to the development of use of flammable Refrigerants. He also developed a manual for safe use of Hydrocarbon Refrigerants in domestic and standalone commercial Refrigeration appliances. He produced a paper for UNEP-IE in cyclopentane as foam blowing agent for polyurethane insulating foams. He along with Martien Janssen of Re/gent conducted a study on the potential for Hydrocarbon Replacements in domestic and small commercial Refrigeration systems. He has also carried out energy efficiency studies on domestic Refrigerators using Hydrocarbon Refrigerants under Ecofrig project.

Prof. Agarwal has organised workshops and educated Indian industry on alternative technologies and safe conversion of domestic and commercial refrigeration appliances to use of hydrocarbon and HFC refrigerants. He organised 1998 IIR conference on Emerging Trends in Refrigeration and Air-conditioning in Delhi, India. He has also participated in workshops and conferences in Argentina, Canada, Denmark, Germany, Japan, Norway, and USA. In recognition of his Ozone layer protection efforts Prof. Agarwal has received 1998 US EPA Stratospheric Ozone Protection Award.

Dr. Stephen O. Andersen was promoted in 1997 from his position as Deputy Director of the U.S. Environmental Protection Agency (EPA) Stratospheric Protection Division to his current position as Director of Strategic Climate Projects in the U.S. EPA Atmospheric Pollution Prevention Division.

He studied business administration and economics as an undergraduate and received his Ph.D. in Agricultural and Natural Resources Economics from the University of California, Berkeley.

Prior to joining EPA he worked for environmental and consumer non-governmental organisations (NGOs) including Sierra Club Research, the Environmental Law Institute, and the Consumer Energy Council. He was also a professor of economics and environmental studies at College of the Atlantic and the University of Hawaii.

Dr. Andersen studied stratospheric ozone depletion and climate change in the early 1970s as a member of the Climatic Impact Assessment Project that investigated the consequences of super-sonic transit. In 1986 he was hired by EPA's stratospheric ozone protection office. His EPA responsibilities included analysis of regulatory impact, cost, and trade, technology co-operation, and sector projects in halons, foams, mobile air conditioning, and military uses.

Dr. Andersen pioneered EPA's voluntary approaches to ozone layer protection including the phase-out of CFC in the manufacture of food packaging, the recycling of CFC from vehicle air conditioning, the halt to testing and training with halon, and the accelerated CFC solvent phase-out in electronics manufacturing. In 1986 Dr. Andersen brought Soviet authorities together with NASA scientists and EPA senior managers to gain acceptance for U.S. ozone monitoring satellite be carried to space on a Soviet rocket in order to overcome loss of access to space resulting from the Challenger accident. He helped organise military support for ozone layer protection including projects to change military specifications requiring use of ODSs and three international conferences on the importance of the military to ozone layer protection. In 1992 he helped the North Atlantic Treaty Organisation (NATO) take the unprecedented step of writing directly to UNEP supporting the proposed accelerated phase-out of ozone-depleting substances. NATO also endorsed technology co-operation, exchange of information regarding halon banks and the harmonisation of standards to allow production and maintenance of military equipment without the use of chemicals that deplete the ozone layer.

Dr. Andersen also helped organise global technology co-operation including the early phase-out of CFCs in refrigerator manufacturing in Thailand and the corporate pledge to help Vietnam avoid increased dependence on ODSs. He served on the team that commercialised "no-clean" soldering and the team that is phasing out ODSs from solid rocket motors. Dr. Andersen helped organised the Halon Alternatives Research Corporation and the International Co-operative for Ozone Layer Protection.

Stephen Andersen Co-Chaired the 1989 Economic Assessment Panel, the 1989-1997 Solvents Coatings and Adhesives Technical Options Committee, the 1992 Methyl Bromide Assessment and since 1989 has Co-Chaired the Technology and Economic Assessment Panel (TEAP). He chaired the 1992 OEWG Contact Group on designing the Essential Use Exemption and he was a member of the 1995 Laboratory and Analytical Uses Working Group and the 1996 Process Agents Task Force.

Dr. Andersen has organised technology co-operation including the Egypt and Mexico country studies, the Thailand Leadership Initiative, and The Vietnam Pledge. He has participated in workshops and conferences in Australia, Brazil, Canada, China, Hungary, India, Indonesia, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Philippines, Saudi Arabia, Singapore, Switzerland, Taiwan, Thailand, Turkey, United Arab Emeritus, United Kingdom, United States, and Vietnam. Dr. Andersen has received the 990 EPA Gold Medal, and the 1995 EPA Fitzhugh Green Award, the 1996 Sao Paulo Brazil State Ozone Award, the 1995 UNEP Global Award, the 1998 EPA Stratospheric Ozone Protection Award, and the 1998 Nikkan Kogyo Shimbun Stratospheric Protection Award. In 1998 he was elected to the United Nations Environment Programme (UNEP) Global 500 Roll of Honour.

Paul Ashford graduated from the University of Bristol (UK) in 1979 with an honours degree in Chemistry. He immediately joined the phenolic resins business of BP Chemicals where he spent 15 years in a variety of technical and commercial roles. These included process and product development, technical service, technology licensing, business development, and finally business management. Paul was particularly involved in the development and licensing of BP's patented technology on low thermal conductivity phenolic foams, which was subsequently exploited on a global basis.

As the manager responsible for technology licensing and business development at the time of the emergence of the CFC issue, Paul took personal responsibility for the management of the issue, including the technological changes required to phase out CFCs. Paul also became involved in the external communication of these changes; firstly with the UK Government and subsequently with the European Commission and UNEP. He was a founder member of the Foams Technical Options Committee and has taken responsibility for the phenolic foam chapter in all three TOC Reports.

In 1994, Paul left BP Chemicals to set up his own consultancy, Caleb Management Services, with the particular aim of assisting understanding and co-operation between industry, regulators and other interest groups. In this context he has worked for private companies, trade associations, government departments and other international agencies. The latter has included substantial work for UNEP IE where Paul was responsible for the preparation of a series of foam case studies (1995), an update of the foam abstracts database (also 1995) and, most significantly, the Foam Technology Sourcebook in 1996. Indeed, the success of the Foam Sourcebook has led to Caleb's subsequent involvement in the restructuring of the Refrigeration and Air Conditioning Sourcebook along similar lines.

Paul continues to take a wider interest in the dynamics of the chemical sector and is well respected for his work in foam raw materials (e.g. phenol, polyols, isocyanates etc) as well as blowing agents. Accordingly, Caleb was recently engaged to carry out a study for the Multilateral Fund Secretariat on the chemical prices affecting MLF projects. In addition, the company has been involved in the quantification of global foam markets and, in particular the existing and projected use and emission of ozone depleting blowing agents.

From a wider environmental perspective, Paul has been particularly active in the promotion of environmental awareness amongst the SME community in the UK and chaired his local environmental business club for two years. He is a registered environmental auditor and is actively involved with the mechanistic elements of environmental management systems.

Paul has recently become extremely active in the area of energy efficiency in buildings. He has been involved in the assessment of the potential carbon dioxide savings achievable in the European building stock and, considering his background, is understandably interested in the potential of thermal insulation materials in this respect. He is currently providing advice to both industry groups and the European Commission in this area.

Dr. Tom Batchelor is currently Acting Director (Industry Development) for the Department of Primary Industry, Water and Environment in Tasmania, Australia. Industry Development specialises in technology transfer for farmers in the fruit, vegetable, extensive agriculture, beef, wool, and dairy industries.

Dr. Batchelor received his B.Sc. and M.Sc. (First Class Honours) degrees from the University of Auckland, New Zealand. He was awarded a Ph.D. in Entomology from the University of California (Davis) in 1989.

Dr. Bachelor worked as a scientist for the Department of Scientific and Industrial Research (most recently called HortResearch) where he was founder member of a team developing post-harvest disinfestation treatments to overcome quarantine restrictions for New Zealand perishable exports. His team successfully developed quarantine treatments based on methyl bromide fumigation that overcame stringent Japanese quarantine requirements and achieved the first exports of cherries and apples from the Southern Hemisphere to Japan. The team subsequently focused on non-chemical disinfestation based on heat, cold, irradiation, and controlled atmosphere treatments to control a range of temperate quarantine pests. Projects were implemented in New Zealand and in developing countries in the Pacific.

He joined the ENZA (New Zealand International) in 1993 as Market Access Manager to improve exports of apples and pears through ‘greener’ pest control in the orchards and post-harvest treatments. He is a technical expert for the New Zealand Ministry of Agriculture and has accompanied the team on numerous visits to Japan and the United States to negotiate improved access conditions for fresh fruit and vegetables.

Dr. Batchelor was a founding member of the United Nations Environment Programme (UNEP) Methyl Bromide Technical Options Committee (MBTOC). He is currently chair of the Perishables (Quarantine) subcommittee and lead co-chair of UNEP-MBTOC. He became a member of TEAP in 1998. He formed Touchdown International as a scientific consultancy service in 1998.

Dr. Batchelor has participated in workshops and conferences in Australia, Chile, Canada, France, Kenya, South Africa, Morocco, the Netherlands, New Zealand, and the United States.

Dr. Walter Brunner is an environmental consultant. He is president of envico AG in Zurich, Switzerland. He studied microbiology at the Federal Institute of Technology in Zurich and got his Ph.D. for work on microbial degradation of chlorinated solvents. He spent several years doing research on microbial degradation of xenobiotics in soils before moving into the field of environmental consulting.

His involvement with halons started in 1988, when he while working for the Swiss Fire Prevention Society (BVD) organised the first international conference on Halons and the Environment. He served on the Halons Technical Options Committee (HTOC) since its inception in 1989, becoming a co-chair of the committee in 1996.

Dr. Brunner serves as national halon expert to the Swiss Government, helping develop Switzerland's halon usage reduction policy. He is in charge of the Swiss national halon register and the Swiss halon bank. He continues to advise the Swiss fire protection community on questions regarding halon management and the phase-out of halon use.

He has worked for UNEP IE, developing their halon banking information brochure for Art. 5(1) Parties. He also served as a consultant to the Austrian government during halon negotiations at the European Union.

Dr. Brunner has given presentations on halon management and halon banking in Australia, China, Malaysia, Poland, and the UK.

He is a recipient of the US EPA Stratospheric Ozone Award and the US EPA Best of the Best Stratospheric Ozone Award.

Dr. Suely Carvalho is deputy chief of the Montreal Protocol Unit at the United Nations Development Programme in New York. She co-ordinates also Art5 (1) countries activities approved under the Multilateral Fund for Latin America countries.

She graduated in Physics in Sao Paulo, Brazil, and received her Ph.D. degree from Purdue University in 1979. She was a research associate for one year at the National Superconducting Cyclotron Laboratory at Michigan State University, in East Lansing, Michigan.

Back in Brazil she worked for the National Nuclear Energy Commission co-ordinating several projects related to environmental impact of Nuclear Fuel Cycle activities, mainly uranium mining and milling. As a full time professor at the Institute of Physics of the University of Sao Paulo she worked in co-operation with several national and international institutions including NOAA and NASA doing measurements of air pollutants in remote areas in the Amazon and Antarctica, to contribute to global climate change studies.

Dr. Carvalho was an invited adviser to the Brazilian delegations of several Meetings of the Parties to the Montreal Protocol. She was instrumental in launching the first industry advisory body to the Government of Brazil on ozone related issues; served as an important advisor to industry associations; provided important information on the impacts of the Montreal Protocol, and advised government and industry on new technologies and transition strategies.

She was director of technology transfer at the environmental protection agency of Sao Paulo, called CETESB, under the Secretary of Environment. She pioneered the first program to implement the Montreal Protocol as well the first climate program to reduce emissions of greenhouse gases at the state level in Brazil, in co-operation with the federal government. She organised several workshops and awareness campaigns at various levels in the public and private sectors. During her time at CETESB she organised the celebration of the International Ozone Day with the presence of Dr. Mario Molina, Dr. Stephen Andersen, and Brazilian authorities. During the ceremony, the decree ending procurement of new ODS equipment by all state government institutions was launched.

She co-chairs the UNEP Technology and Economic Assessment Panel since 1993 and is a member of the Economics Options Committee. She was a member of the Task Force for the Replenishment of the Multilateral Fund in 1996 and participated in conferences and workshops in Argentina, Brazil, Panama, Mexico, USA and the EU to discuss technology transfer to developing countries.

She was awarded the 1996 EPA Stratospheric Ozone Protection Award, the 1997 EPA Best of the Best in the Protection of the Ozone Layer Award and the 1997 UNEP Global Award in recognition of her contribution to the protection of the ozone layer.

Jorge Corona heads the Foreign Affairs section of the Environmental Commission of the National Chamber of Industries of Mexico (CANACINTRA) in Mexico. He is a graduate of the Universidad Nacional Autonoma de Mexico, School of Chemistry.

Mr. Corona has worked for the Royal Dutch/Shell Group at their headquarters in The Hague, Industrias Polifil (a synthetic fibre manufacturer in Mexico), and as the operations director of San Rafael (Mexico’s largest paper mill). In 1982, Mr. Corona started his own company, Astral Internacional, (later known as Quimica Blakor) and served as its’ General Director until 1997.

Mr. Corona has served in a variety of professional associations and positions. He has been Vice-chair of the synthetic fibre section of the National Association of Chemical Industry (ANIQ); President of the Industry

Association of the State of Tlaxcala, Mexico; President of the Mexican Aerosols Institute (IMAAC); Chair of aerosols section of the National Chamber of Industries (CANACINTRA); and Director of Ecology of CANACINTRA.

Since 1989, Mr. Corona has been instrumental in organising a wide range of activities designed to assist developing countries efforts to phase out ODS. He has participated in the International Conferences on Ozone Protection Technologies and Earth Technology Forums in Washington DC; co-ordinated workshops in Mexico City in co-operation with US EPA, CANACINTRA and SEDUE (Mexican Environment Secretariat); and organised a workshop for disseminating ODS free technologies, in the "maquiladora" (in-bond) electronics industry in Tijuana, Baja California, Mexico. He organised the Programme for Technology Transfer in Electronics Industry with US EPA, UNEP and Nortel, CANACINTRA and the Mexican Electronics Manufacturers Association. He secured voluntary agreements between industry sectors and the Mexican Government to phase-out ODS in aerosols, solvents, refrigeration, plastic foams, halons, and CFC manufacturers. He also participated in technology transfer workshops organised by US EPA and the World Bank; helped develop the Mexico Country Programme; and worked with the Swedish Environmental Agency to develop Kenya's Country Programme. He was the driving force and architect behind the Mexican government initiative to accelerate the phase-out of ODS ahead of Montreal Protocol schedule, which served to inspire a number of other Article 5(1) Parties to accelerate their phase-out as well. Mexico's program calls for a 2000 phase-out, rather than the 2010 allowed under the Protocol.

Mr. Corona has participated in technology transfer workshops on ODS alternatives, management policies, and recycling technologies in preparation of implementation projects in Tijuana B.C. Mexico, Thailand, Japan, Indonesia, Ecuador, Kenya, Switzerland, Liechtenstein, Germany, Sweden, UK, Venezuela, Holland, and Italy. He prepared Country Programmes for Colombia, Costa Rica, Bolivia, Paraguay, Nicaragua, and El Salvador.

Mr. Corona has supported projects involving technology transfer, policies, management, and project implementation in solvents, foams, aerosols, refrigeration, and methyl bromide. He is Co-Chair of the Solvents, Coatings and Adhesives Technical Options Committee; member of the Methyl Bromide Technical Options Committee; and a member of the Technical and Economics Assessment Panel. His awards include the Mario Molina Award granted by the Mexican Chemistry Society (SQM), the 1991 EPA Stratospheric Protection Award, and the EPA "Best of the Best" Stratospheric Ozone Protection Award.

László Dobó is consultant to the Hungarian Ministry for Environment since 1992 on issues related to the Montreal Protocol.

He was born in 1929 in Budapest, Hungary and graduated as Chemical Engineer at the Technical University of Budapest in 1951.

Mr. Dobó was first employed by an industrial research institute in laboratory to pilot-plant scale research on catalytic conversion of hydrocarbons to produce high-grade motor gasoline. This was followed by process engineering, project engineering and project management assignments at the leading national engineering company for the first commercial platinum-catalyst naphtha-reforming unit in Hungary, and subsequently project management for a complete green-field oil refinery. As a project manager he was first confronted with environmental problems.

He served from 1972 to 1984 in various assignments to the Ministry for Industry, the emphasis in his work being shifted gradually from project developments for the chemical industry to environmental issues of the Hungarian industry. From 1984 to 1990 Mr. Dobó was general manager of a chemical engineering company, when he retired. He served simultaneously as an advisor to the Ministry of Industry on environmental issues.

Mr. Dobó was in 1984 elected as Vice-Chairman of the Executive Committee of the Geneva Convention on Long-range Transboundary Air Pollution and has chaired in 1985-1986 the group drafting the Protocol on NO_x reduction.

He participated in 1989 in London at the worldwide conference “Saving the Ozone Layer” hosted by the UK Government. Mr. Dobó attended since 1992 the Meetings of the Open-ended Working Group and those of the Parties to the Montreal Protocol as a member of the Hungarian delegation. In 1993-1994 he as initiated and has managed the elaboration of the Country Programme for Phasing-out ODS in Hungary. In 1994 Mr. Dobó was nominated by the Hungarian Ministry for Environment as a Senior Advisor to the TEAP and his nomination has been confirmed by the Parties.

In 1995-1996 Mr. Dobó Co-chaired the TEAP Task Force on Aspects of Countries with Economies in Transition (CEITs). He participated in those meetings/workshops, which were organised by UNEP and UNEP IE to support CEITs in their efforts to accede to the Montreal Protocol and/or to comply with (Minsk 1994, Riga 1994 and 1996, Tashkent 1997). Mr. Dobó also participated in the elaboration of the Country Programme for Macedonia (1996) and has managed/elaborated it for Bosnia and Herzegovina (1997-98).

Mr. Dobó is a recipient of the 1997 US EPA Stratospheric Protection Award.

Yuichi Fujimoto graduated from the University of Tokyo in Electrical Engineering in 1956. He has worked as an electrical engineer for heavy manufacturing including rolling mills and other equipment. In 1988 he became Director of the Japan Electrical Manufacturers' Association (JEMA) where he organised Japanese industry to protect the ozone layer and became a key co-operator with the Ministry of International Trade and Industry (MITI), the Environment Agency, and the Ministry of Foreign Affairs. As the director of JEMA**,** Mr. Fujimoto led Japanese efforts to phase out CFCs in electronics manufacturing. In 1996 he moved to the Japan Industrial Conference for Ozone Layer Protection (JICOP) as an advisor.

He helped motivate Japanese companies to advocate early phase-out of ozone-depleting substances including the pledges of accelerated phase-out by Asahi Glass, Hitachi, Honda, Matsushita Electric, Mazda, Minebea, Mitsubishi Electric, Nissan, Sanyo, Seiko Epson, Toshiba, and Toyota. He was a chief organiser of the international "Pathfinder" leadership conferences in Woodshole Massachusetts (1990), Yauntville California (1992), Osaka Japan (1994), Nara Japan (1996), and Tokyo Japan (1997). In 1997 he persuaded MITI and the Electronics Industry Association of Japan to form a voluntary partnership to reduce PFC emissions.

Mr. Fujimoto also helped organise Japan's extensive technology-sharing program focused in Southeast Asia, including conferences in China, Indonesia, Korea, Malaysia, Philippines, Singapore, Thailand, and Vietnam. He was critical in organising global technology co-operation including the early phase-out of CFCs in refrigerator manufacturing in Thailand and the corporate pledge to help Vietnam avoid increased dependence on ODSs.

Mr. Fujimoto is a senior advisor to the UNEP Technology and Economics Assessment Panel and is a key member of the UNEP Solvents, Coatings, and Adhesives Technical Options Committee.

Mr. Fujimoto earned the 1993 EPA Stratospheric Protection Award and the 1997 Best-of-the-Best Stratospheric Protection Award. His leadership helped JEMA earn the 1991EPA Stratospheric Protection Award and the 1997 UNEP Global Award.

Dr. Barbara Kucnerowicz-Polak is Adviser to the Head of Polish Fire Service, with responsibility for international co-operation on chemical safety, including implementation of the recent European Union directives and OECD recommendations regarding chemical safety programs.

She graduated as a Master of Science in Engineering with speciality in chemistry from the Technical University of Warsaw, took numerous postgraduate courses related to chemical safety in industry, and completed a PhD in combustion chemistry.

Dr. Polak has extensive experience in combustion science and fire protection research, has published approximately 70 papers national and international professional journals, and holds 6 patents. She has held positions as university professor in Poland, Canada, and India.

Dr. Polak has organised awareness, education, and training programs on halon issues for government and business leaders, and technical staff within the fire protection community. She has also organised international workshops on issues related to phasing out halon production for CEITs. Dr. Polak became a member of the HTOC in 1993, and has served as its co-chair and as a TEAP member since 1996. To maximise accessibility of important HTOC and TEAP information she translated HTOC and TEAP documents into Russian.

Dr. Polak developed Poland's national strategy for phasing out halon, including a set of guidelines that provide step by step technical approaches to implementing Montreal Protocol decisions for the fire protection community. She took responsibility for widespread national distribution of the guidelines, advised regulatory authorities on approvals for alternative technologies and equipment, and was instrumental to the successful introduction of environmentally preferable alternatives to halons into the Polish market.

She is a recipient of the UNEP Stratospheric Ozone Award, and the US EPA Stratospheric Ozone Protection Award.

Dr. Lambert Kuijpers is currently an independent consultant with a part time assignment on the faculty of Technology Management, Department of Technology for Sustainable Development, Technical University Eindhoven. At the Technical University Eindhoven, Dr. Kuijpers is involved in the development of environmental projects for several developing countries.

After college graduation, Dr. Kuijpers was involved in nuclear fusion research at the KFA institute in Jülich, Germany. He received a Ph.D. degree from the Technical University in Eindhoven. Prior to joining Philips Research Laboratories in the Netherlands, Dr. Kuijpers carried out a number of post-doctoral studies at several European research institutes until 1978.

At Philips, he was involved in thermodynamic research for refrigeration, air conditioning, and heat pumps. The group he managed concentrated on the introduction of new refrigerants, new compressor concepts, and control strategies for small refrigeration equipment, the main target being energy efficiency increase. Before the Montreal Protocol was signed, Dr. Kuijpers started the effort under the umbrella of the International Institute of Refrigeration that made an inventory of measures that refrigeration companies could take to cope with the CFC reduction schedule proposed in the original 1987 Montreal Protocol. The results of this study were reported at several conferences in 1988. He left the Philips Company late 1992.

Dr. Kuijpers has been intensely involved in activities under the Montreal Protocol Assessments. Since 1988 is has been Co-chair of the Refrigeration, Air Conditioning, and Heat Pumps TOC and since 1992 he has been Co-chair of the TEAP. He also co-chaired the 1993 Inadvertent Losses Working Group, the 1995 and 1996 Task Force on Aspects of Countries with Economies in Transition (CEITs), the 1997 Task Force on Flammable Refrigerants, the 1997 Task Force on Replenishment of the Multilateral Fund, and the 1999 Task Force on Replenishment of the Multilateral Fund. Since 1992, Dr. Kuijpers is a member of the Ozone Operations Resource Group of the World Bank, and he is a reviewer of many refrigeration investment project proposals. Since the early 1990's, Dr. Kuijpers is also an advisor to UNEP IE in Paris, particularly in relation to their OzonAction Program.

In undertaking CEIT investigation, Dr. Kuijpers designed all aspects of the work including data collection and reporting. He also participated in many meetings of the Implementation Committee under the Montreal Protocol. He participated in the Conferences of the Parties to the United Nations Framework Convention on Climate Change (FCCC) in 1995-1997 and in many UNFCCC subsidiary body meetings held in Bonn, Germany.

Dr. Kuijpers has published numerous articles on refrigeration topics in the 1980's. He attended many conferences and meetings on refrigeration in the 1980's and 1990's. He has also published many articles on environmental issues including Montreal Protocol developments, particularly in relation to refrigeration, on energy efficiency and the "Total Equivalent Warming Impact" and on the parallels between the implementation of the Montreal and the Kyoto Protocol.

Within the framework of the Montreal Protocol, Dr. Kuijpers participated in a large amount of workshops and seminars in several developing and CEIT countries including Belarus, Egypt, Kenya, Latvia, Lebanon, Malaysia, Mauritius, Russia, Thailand, Uganda, and Venezuela. He earned the 1993 EPA Stratospheric Ozone Protection Award, the 1997 UNEP Ozone Award, and the 1987 U.S. EPA "Best of the Best" Award. Dr. Kuijpers is a member of ASHRAE, the British Institute of Refrigeration, the German Refrigeration Society DKV, and the Dutch Association for Refrigeration.

Dr. Mohinder Malik is manager of Materials and Process Technology Department at Lufthansa German Airlines in Hamburg, Germany.

He studied Metallurgical Engineering at the University of London and graduated with an Honours Degree in 1962. During his studies in London, he worked with British Oxygen Co. Ltd. in the field of joining technology. Since 1962, he has been with Lufthansa German Airlines and worked in broad field of materials and processes involved in aircraft maintenance and overhaul.

As Chairman of the European Airlines Committee for Materials Technology (EACMT) environmental protection aspects were introduced in the work plan of the Committee in 1980. A working group was formed in 1985 to look into the possibility of eliminating all halogenated hydrocarbons including CFCs and methyl chloroform in aircraft maintenance and overhaul. He co-ordinated a concerted action initiated at Lufthansa in 1986 in order to eliminate the use of halogenated hydrocarbons and stepwise substitute materials and processing techniques were introduced. This led to elimination of all controlled materials under Montreal Protocol in aircraft maintenance work already in 1994.

Through channels of EACMT information on Lufthansa's experience with alternative technologies was passed on to other airlines, and aircraft and engine manufacturers. This accelerated the phase-out of ozone-depleting solvents in this sector.

In 1994 Dr. Malik hosted a large group of representatives from the US EPA and TOC members to witness ODS-free maintenance and overhaul of aircraft, engines and electronic components and assemblies.

In 1995 a team of engineers from USAF and Lufthansa jointly compiled four case studies on processing of aircraft oxygen systems after scrutinising all details of the operation at Lufthansa.

Since 1992 Dr. Malik is Co-ordinator of the EU Commission research and development program - (COST-501) – "High Efficiency Low Emission Technology for Gas Turbines" and has continuously passed on the experience gained in utilisation of ODS-free technologies in this sector.

Since mid-1996 Dr. Malik has served as Co-Chair of Solvents, Coatings and Adhesives Technical Options Committee. During this period among others he has helped to organise workshop/seminars in Asian and Arab regions.

Recently as Chairman of the International Institute of Welding's "Select Committee on Thermal Spraying and Coatings Technology" he persuaded the Governing Council to incorporate ozone layer protection and climate change issues in all activities of the IIW.

Dr. Malik earned the 1995 US EPA Stratospheric Protection Award and the 1997 Best-of-the-Best Stratospheric Protection Award.

E. Thomas Morehouse Jr. is Adjunct Research Staff, Institute for Defense Analyses. From 1978-1994 he was employed by the United States Air Force.

He received his Bachelor of Science degree in Electrical Engineering from Union College New York and his Master of Science degree in Mechanical Engineering from Boston University Massachusetts.

As an active duty military officer, he held a variety of positions in facilities, energy, and environmental engineering and management at all levels of command including major command, Service headquarters staff, and the office of the Secretary of Defense. From 1986 through 1989, managed the Air Force research and development program on alternatives to the use of halons for military applications. From 1989 through 1991 was responsible for the development and implementation of Air Force ODS budget and policy, and from 1991 through 1993 on pollution prevention budget and policy, which included ODS. From 1993 through 1994, he was the military assistant to the Deputy Under Secretary of Defense (Environmental Security) and assisted in the establishment of programs covering the breadth of military environmental programs. From 1994 to present, he has been on the research staff of the Institute for Defense Analyses, an independent non profit organisation dedicated to providing independent and objective studies and analyses to the Secretary of Defense on matters of national security. He has published studies on a wide range of environmental issues affecting the military.

From 1989 through 1996, he co-chaired the Halon Technical Options Committee. He is an original members of the Technology and Economics Assessment Panel and is currently a senior expert member for military issues.

Mr. Morehouse has been participated in international policy and technology co-operation projects involving plans, policies, strategies and technologies for military management of ODS in China, Germany, Indonesia, South Korea, Malaysia, Mexico, India, Poland, and Singapore. He was a key organiser of the First, Second the Third International Workshops on the Role of the Military in the Montreal Protocol (1991, 1994, 1997 respectively), and the First International Workshop on the Role of the Military in Climate Protection (1997). Additional work in this areas includes the Asia Pacific-Indian Ocean Defense Environmental Workshop, the Western Hemisphere Defense Environmental Conference, and a number of other multilateral conferences, workshops and military to military information exchange. He is a recipient of the 1992 EPA Stratospheric Protection Award, and the 1997 “Best of the Best” Stratospheric Protection Award.

Dr. David Okioga graduated from Makerere University College for East Africa in March 1968. After graduation, he worked as a plant pathologist at the Tropical Pesticides Research Institute under the East African Community. Dr. Okioga received his Masters degree, doctorate, and a Diploma from Imperial College (DIC) from the University of London.

Prior to joining the Ministry of Environmental Conservation at the Co-ordinator of the National Ozone Unit, Dr. Okioga worked as the Director, Plant Quarantine Station of the Kenya Agriculture Research Institute. He served as a committee member of the FAO Consultative Group on Harmonisation of the Plant Quarantine Principles under the Plant Protection Convention. He was also an Expert Committee Member of the Inter-African Phytosanitary Council of the Organisation of the African Unity.

He has participated in a member of the Methyl Bromide Technical Options Committee since its inception. Since 1994 he has been the subcommittee chair for the Developing Countries on MBTOC.

Dr. Okioga was the first to propose that UNEP-IE establish Regional Ozone Officers Networking activities to collate regional planning strategies. This led to the establishment of the UNEP-Regional Ozone Officers Networking commonly referred to as ODSONET (Ozone Depleting Substances Officers Network).

Dr. Okioga is the Co-chair of MBTOC and the focal point for the joint Kenyan Government and UNDP project on Institutional Strengthening for Phasing Out Ozone Depleting Substances in Kenya under the Montreal Protocol. The project is funded by the Multilateral Fund of the Montreal Protocol on Substances that Deplete the Ozone Layer.

Based in Nairobi, Dr. Okioga is responsible for co-ordinating, processing and monitoring, on behalf of the government of Kenya, the Kenya country program implemented by the United Nations specialised agencies or through bilateral assistance to Kenya under the provisions of the Montreal Protocol. UNDP makes in-kind contribution of wages and miscellaneous expenses. Funding for travel and communication costs related to MBTOC are provided by the UNEP ozone secretariat.

Dr. Okioga has participated in international conferences on the protection of the ozone layer in Australia, Burkina Faso, Chile, Egypt, Ethiopia, Italy, Malawi, Mauritius, Morocco, Mozambique, the Netherlands, Nigeria, and South Africa.

Jose Pons is President Spray Quimica C A. He received a BS in Chemical Engineering from Universidad Simon Believer, and an MBA from Santa Clara University.

From 1976 - 1978, he worked as a process engineer in PEQUIVEN, then from 1978 - 1981 in research & development for Spray Quimica 1978 - 1981. In 1981, he became General Manager of Spray Quimica, and president in 1991.

Mr. Pons has been a member of the Aerosols Technical Options Committee since 1989 and a member of the TEAP since 1991.

He has presented at conferences on aerosols and atmospheric pollution in Caracas for FONDOIN, in Mexico City for the Instituto Mexicano del Aerosol, and on Metered Dose Inhalers in San Francisco for the American Lung Association.

Mr. Pons received the EPA Stratospheric Protection Award in 1995, and the EPA "Best of the Best" Stratospheric Protection Award in 1997.

Sally Rand is currently Director of PFC/HFC Voluntary Programmes in the U.S. Environmental Protection Agency (EPA) Atmospheric Pollution Prevention Division. Previously, Ms. Rand worked for six years in EPA's Stratospheric Protection Division and served as Team Leader and Foam Sector Manager in the Significant New Alternatives Policy (SNAP) Programme.

Ms. Rand has a BSc. and Diploma in Economics, and earned a MSc. in Environmental Health at the Harvard School of Public Health. Prior to joining EPA, she worked at the Environmental Law Institute, a non-profit environmental policy research centre.

Since beginning work on ozone layer protection in 1992, she participated in the development and implementation of the only regulatory program, which evaluated the potential environmental, health and safety risks of CFC replacements. She worked closely with the U.S. foam industry to evaluate technical progress in completing the transition, including participation as an ex-officio member of the American Home Appliance Association Insulation Technical Assessment Committee. In addition to U.S. domestic programmes, Ms. Rand participated in technology co-operation forums sponsored by UNEP IE on small and medium enterprises, and safety, and helped organise a 1998 workshop on CFC replacement technologies for the India foam industry.

Ms. Rand joined the Flexible and Rigid Foam Technical Options Committee in 1993 and became Co-chair in 1995. She has served as a member of the Technology and Economic Assessment Panel since 1995, and was a member of the 1996 TEAP Process Agent Task Force.

Rodrigo Rodriguez-Kábana is an emeritus professor of nematology at Auburn University, Alabama, USA.

Sateeaved Seebaluck is the Principal Assistant Secretary – Ministry of Environment Human Resource Development and Employment of Mauritius. He graduated with a BA (Honours) in Economics, and a Diploma in Public Administration and Management.

He has 22 years of experience in Public Service at Senior Management levels, 9 of which have been in the Ministry of Finance co-ordinating investment projects, and 12 years in the Ministry of Environment at policy making level. Mr. Seebaluck has been involved principally in international and global environment issues. He has contributed to the UNEP Governing Council, African Ministers Conference on Environment, GEF issues, Sustainable Development of Small Island States, Commission for Sustainable Development issues, Convention on Biological Diversity, UN Framework Convention on Climate Change and its Kyoto Protocol and the Montreal Protocol on Substances that Deplete the Ozone Layer.

As Head of the Ozone Unit in Mauritius, he participates in most of the ozone meetings, specially the Meetings of the Parties and the Open Ended Working Group. He headed the Mauritian delegation at the Diplomatic Conference, which adopted the Montreal Protocol in 1987. Mr. Seebaluck has been and is still actively involved at all levels of negotiations under the Protocol. He championed the cause of the low volume consuming countries to ensure that they were brought in the mainstream. He has held various positions in the Montreal Protocol process, as hereunder. Most remarkably, he has been Co-Chairman of the Open-ended Working Group of the Parties to the Montreal Protocol in 1996 and he presided over the negotiations for the replenishment of the Multilateral Fund for 1997-1999. These negotiations concluded with Article 2 countries accepting to contribute US$540 million to the Fund. Mr. Seebaluck won the UNEP International Ozone Award for outstanding contribution to save the ozone layer in 1997.

1993	Member of Executive Committee of the Multilateral Fund
1994	Vice President of Bureau of MOP
1995	Chaired Contact Group of the Parties on the Terms on Reference for the Review of the Financial Mechanism
1996	Member of Steering Panel on the Review of the Financial Mechanism

1995 Participated in informal consultations convened by ExCom Chairman in Cairns, Australia on Article 5(1) issues. Moderated workshop on Low Volume Consuming Countries issues.

1995 Adviser to TEAP on review of Phase-out Schedule for Article 5(1) countries.

1995 Member of Contact Group on recommendations contained in the Report on the Review of the Financial Mechanism

1996 Co-Chair of Open Ended Working Group of the Parties to the Montreal Protocol.

1997 Appointed Senior Expert Member TEAP

1998 Winner UNEP International Ozone Award for outstanding contribution for the protection of the ozone layer

1999 Co-Chair Task Force on Replenishment of the Multilateral Fund for 2000-2002

Lalitha Singh has until recently been Advisor in the Ministry of Chemicals and Fertilisers, Government of India, and is currently independent expert working on sustainable development and environmental issues with Chemical industry.

She has a Masters Degree in Chemistry and wide experience in industrial chemistry, technology transfer, and technology forecasting and planning.

Before she joined the Ministry, she worked in the Indian Institute of Petroleum where she pioneered many demand forecasting and end-use analysis studies that were instrumental to launching the Five Year Plans on Hydrocarbon and Petrochemical Industry in India. Simultaneously, she initiated and participated in Technology Absorption and Development Plans in these sectors.

Her responsibilities in the Ministry included policy development and promotion of chemical and petrochemical industry growth, keeping in view the international technology developments. Promotion of project development and screening them for approvals, monitoring were also part of the overall activities. Her continuous interaction with the Indian Chemicals industry, international technical community, and research institutions contributed to major inputs into the policy planning and establishment of industry in line with global developments. During this development process, she focused on sustainable development and safety and environmental issues. She has been part of the process of dialogue with Chemicals industry in establishing air and water pollution standards in India.

She has been chairperson and member of many committees on research programs, technology development, and Scientific Advisory Committees for the hydrocarbon and petrochemical sectors. She has been a member of delegations of Government of India on bilateral co-operation in petrochemical sector to countries in Southeast Asia and the Middle East.

She has carried out studies for UNIDO, UNCTAD, and UNEP on technology transfer, safety issues in petrochemical industry, and ozone-related areas. She has been a member of the Intergovernmental Consultation Groups organised by UNIDO.

She has been involved in Montreal Protocol-related activities at the national level, even before the preparation of the country program, as a member of working groups initiated by the government and industry. She has been a member of the committee for screening of projects to be submitted to Multilateral Fund. She is an expert member of the committee to review and update the India Country Programme.

She has been co-chair of Technical Options Committee of Rigid and Flexible Foams and member of Technology and Economic Assessment Panel from 1996.

She has been chairperson of panel on chemical industry – 2020 for a study done for the Technology Assessment Forecasting Council of India (TIFAC) in 1997.

Attended large number of seminars and workshops, often chaired sessions on petrochemical industry, Montreal Protocol awareness, sectoral ODS phase-out. Ms. Singh published many reports and papers on environment, safety, and ODS phase-out issues in the Hydrocarbon, Chemical, and Petrochemical sectors.

Gary Taylor is a fire protection consultant. He is a principal of Taylor/ Wagner Inc. of Toronto, Canada.

Mr. Taylor has wide experience in the use of halons in fire protection, based on numerous fire protection design projects that utilised halons and his tenure as Chair of the National Fire Protection Association Technical Committee on Halogenated Extinguishing Agent Systems.

He has served as Co-chair of the Halons Technical Options Committee (HTOC) since its inception in 1989. The goal of the Halons Technical Options Committee is to support a safe transition to alternatives to the use of halons. Protection of life and property is an important aspect of the work of the fire protection professionals that serve as members of the HTOC and a safe transition is a very important issue to the fire protection community.

Mr. Taylor has met with the fire protection communities in China, the United Arab Emirates, India, Venezuela, Brazil, the United States, Canada, Australia, United Kingdom, Switzerland, Mexico, and Finland to explain the halon issue and report on the technical options available to fire protection professionals. He has also met with environmental groups and policy makers in many of these same countries and others to discuss the options available to encourage and support a safe transition.

During this same period of time Mr. Taylor continued his work and involvement in his chosen profession. He has been involved in the design of fire protection measures for aircraft hangar projects around the world, has served as a member of the Canadian Commission on Building and Fire Codes and serves as Chair of the Standards Council of the National Fire Protection Association.

Mr. Taylor acted as a consultant to FONDOIN of Venezuela in the design and implementation of a national halon strategy that made it possible for Venezuela to phase-out all halon imports on the same schedule as the non-Article 5(1) countries.

Utilising his experience in helping technical people to reach a consensus view and provide understandable explanations of complex technical issues, Mr. Taylor served as co-chair of the Process Agents Task Force during 1996-97.

Mr. Taylor is a recipient of the UNEP Stratospheric Ozone Award, the US EPA Stratospheric Ozone Award, and the US EPA Best of the Best Stratospheric Ozone Award.

Dr. Helen Tope graduated as Bachelor of Science (Honours) in Chemistry from Monash University, Australia in 1984. She completed a Ph.D. in synthetic organic chemistry in 1992 studying synthetic approaches to novel organic semiconductors.

Dr. Tope has worked for the Environment Protection Authority Victoria, Australia, since 1991. During this time, she has been involved in the development of policy for ozone layer protection, management of chemicals and hazardous industrial wastes, the development of air emissions inventories for the cities of Brisbane and Auckland, and as part of EPA's emergency response to environmentally hazardous incidents.

She is Co-Chair of the UNEP Aerosols, Sterilants, Miscellaneous Uses, and

Carbon Tetrachloride Technical Options Committee and a member of the UNEP Technology and Economics Assessment Panel. She has participated in seminars, colloquia, and conferences for ozone layer protection and on behalf of the Aerosols Technical Options Committee in Australia, Canada, Kenya, and the United States.

Dr. Van Slooten is an independent economic consultant with a special interest in global environmental issues. He serves as a member of the UNEP Technology and Assessment Panel in his capacity as a Co-Chair of the Economic Options Committee with financial support provided under contract by the Department of the Environment of the United Kingdom. He also undertakes special assignments on economic and trade aspects of the implementation of the Montreal Protocol.

Dr. Van Slooten received his Bachelor of Arts Degree from Colgate University in Hamilton, New York (1962) and his Ph.D. in Quantitative Economics from Iowa State University in Ames, Iowa (1968). During 1965-68, he served as an Economic Research Associate with the Iowa-Peru Project in Lima, Peru under with the U.S. Agency for International Development. He served as a Lecturer in Economics at the University of Wales (1968-70) and Bristol University (1970-72) in the UK before joining the Government Economic Service in London in 1992. He served for 25 years as an economic adviser to various Whitehall Departments and as Head of the Central Economic Service in the Department of Finance in Northern Ireland. He has been working on economics aspects of stratospheric ozone-depletion and climate change since 1989. He has been Chair or Co-Chair of the Economic Options Committee of the UNEP Technology and Economic Assessment Panel since 1991.

Dr. Van Slooten has been closely associated with the UNEP IE OzonAction Programme since 1991. He has advised on the rationale and operation of training projects and regional networks; served as a member of the OzonAction Programme's Informal Advisory Group since 1991, and moderated the "OzonAction Roundtable" discussions at the annual Earth Technologies Conferences in Washington, DC since 1991. He served as Co-Chair of the TEAP Task Force on the 1996-99 Replenishment of the Multilateral Fund and is currently Co-Chair of the TEAP Task Force on the 2000-02 Replenishment of the Multilateral Fund. He has participated in most Open-Ended Working Groups and Meetings of the Parties since 1991, and prepared documents and presentations on economic aspects of "basic domestic needs" of the Article 5(1) Parties, methyl bromide alternatives, the 1996-99 Replenishment and the trade measures of the Montreal Protocol.

Dr. Ashley Woodcock is a Consultant Respiratory Physician at the North West Lung Centre, Wythenshawe Hospital, Manchester, UK. Dr. Woodcock is a full-time practising physician and Professor of Respiratory Medicine at the University of Manchester.

Shiqiu Zhang is an associate professor at the Centre for Environmental Sciences, Peking University of China. She has served as Co-chair of Economic Options Committee and TEAP member since 1997.

She received her B.A degree in Economics, and M. S. degree in Environmental Sciences from Peking University of China. She was an associate of Leadership for Environment and Development (LEAD, sponsored by Rockefeller Foundation) during 1993-1995, a visiting scholar at the Project for Global Change of University of Michigan during 1991-1993.

She started her ozone-related activities since 1993, starting on technology transfer issue.

1995-1997 she and her group based in Peking University conducted the study on Sector Plan for Halon Phase-out in China, under the organisation of State Environmental Protection Agency (SEPA) and World Bank. As a key member, she was responsible for organising overall technical related activities of this project. She proposed and helped Chinese government designing the Tradable Production Quota System for Halon and Bidding System for Allocating the Multilateral Fund, which was being implemented. She is also working for extending these approaches and policies to other ODSs and other sectors.

Since 1997, she has been technically responsible for organising the Updating China's Country Program, worked with her group in Peking University, under the organisation of SEPA of China and UNDP. She has also been responsible for policy analysis in support of the development of Sector Plan for CFCs Production Phase-out, Sector Plan for Solvent Phase-out, Sector Plan for ODS Phase-out at Tobacco Sector in China.

As a policy consultant for Ozone Layer Protection for the Chinese government, she has been working on a wide range of policy issues, including a tradable quota system, a bidding system for selling back the quota, taxation issues, import and export control.

She has been working closely with World Bank, UNDP, UNEP, UNIDO and other organisations, and has participated conferences and workshops in China, Korea, Thailand, USA, Canada, Costa Rica, and Singapore.

She won the China Youth Environmental Scientist Award and 100 Best Youth Scientist in China in 1998 for her efforts and achievements on environmental economics and environmental policy.

C Timeline of Ozone layer related events

1840 *Atmospheric and Environmental Science*

- C.F. Schoenbein discovers and names “ozone.”

1920 *Atmospheric and Environmental Science*

- G.M.B. Dobson invents an instrument to monitor total atmospheric ozone.

1928 *Atmospheric and Environmental Science*

- G. Findlay discovers that ultraviolet (UV) radiation causes skin cancer.

Technology and Corporate Actions

- Thomas Midgley invents chlorofluorocarbons (CFCs).

1935 *Atmospheric and Environmental Science*

- R. Latarjet estimates the relationship between the thickness of the ozone layer and the intensity of the ultraviolet radiation.

1957 *Atmospheric and Environmental Science*

- The International Geophysical Year encouraged scientific co-operation and integrated earth monitoring stations.

1970 *Atmospheric and Environmental Science*

- Harold Johnston and Paul Crutzen hypothesise that nitrogen oxide emissions from super-sonic transport will deplete the ozone layer.

1971 *Atmospheric and Environmental Science*

- Damaging effects of UV-B radiation on plants reported and quantified.
- James Lovelock measured CFCs in the atmosphere.

1972 *UNEP and Montreal Protocol Actions*

- Stockholm Conference on the Human Environment proposes creation of UNEP and Nairobi selected as its headquarters. The UN General Assembly founds UNEP "with a mission to provide leadership and encourage partnerships in caring for the environment by inspiring, informing and enabling nations and people to improve their quality of life without compromising that of future generations." UNEP integrates environmental efforts by intergovernmental, non-governmental, national and regional bodies.

1974 *National Actions*

- U.S. Climatic Impact Assessment Project (CIAP) concludes that expansion of super-sonic transport (SST) would be environmentally and economically unacceptable.

Atmospheric and Environmental Science

- Ralph Cicerone and Richard Stolarski conclude that chlorine can deplete ozone.
- Mario Molina and Sherwood Rowland hypothesise that CFCs will release chlorine in the stratosphere and deplete the ozone layer.

1975 *National Actions*

- The CFC/ozone depletion issue is discussed at the North Atlantic Treaty Organisation (NATO).

Technology and Corporate Actions

- The S.C. Johnson company announces phase-out of CFCs as aerosol product propellants.

1976 *UNEP and Montreal Protocol Actions*

- UNEP Governing Council calls for a meeting to co-ordinate activities on protecting the ozone layer.

Atmospheric and Environmental Science

- The U.S. National Academy of Science concludes that CFCs affect the ozone layer and that some regulation is almost certain to be necessary.

1977 *UNEP and Montreal Protocol Actions*

- UNEP Governing Council establishes the Co-ordinating Committee on the Ozone Layer (CCOL) to undertake annual science review.

National Actions

- The United States hosts the first intergovernmental conference on CFCs.

Technology and Corporate Actions

- Hydrofluorocarbon (HFC) 134a developed as a zero-ODP refrigerant with refrigerant properties comparable to CFC-12.

- Vehicle manufacturers reduce the quantity of CFC used in air conditioners.

1978 *National Actions*

- The United States bans most CFC cosmetic products; Canada, Norway, and Sweden soon enact similar controls.

- The Federal Republic of Germany hosts the second intergovernmental conference on CFCs.

1979 *Atmospheric and Environmental Science*

- Second major U.S. National Academy of Sciences Report.

1980 *UNEP and Montreal Protocol Actions*

- UNEP Governing Council calls for reduction in CFC use and production capacity.

National Actions

- European Community reduces CFC aerosol use by 30% and enacts production capacity cap.

- The U.S. issues an "Advance Notice of Proposed Rulemaking" outlining a production capacity cap to limit total CFC uses.

1981 *UNEP and Montreal Protocol Actions*

- UNEP Governing Council establishes a Working Group to elaborate a convention for protection of the ozone layer.

1982 *UNEP and Montreal Protocol Actions*

- UNEP Ad Hoc Working Group of Legal and Technical Experts for the Preparation of a Global Framework Convention for the Protection of the Ozone Layer meets in Stockholm.

Atmospheric and Environmental Science

- Third major U.S. National Academy of Sciences Report.

Technology and Corporate Actions

- The International Institute of Refrigeration (IIR) Congress in Paris focuses on ozone depletion and global warming.

1983 *National Actions*

- The Natural Resources Defense Council, a non-governmental organisation (NGO) sues U.S. EPA for failure to protect the ozone layer as required by the Clean Air Act.

1984 *Atmospheric and Environmental Science*

- Fourth major U.S. National Academy of Sciences report.

1985 *UNEP and Montreal Protocol Actions*

- The Vienna Convention for the Protection of the Ozone Layer is signed and a Protocol is scheduled for 1987.

Atmospheric and Environmental Science

- British scientists publish report on Antarctic "ozone hole."

Technology and Corporate Actions

- The DuPont company acknowledges increasing evidence that CFCs deplete the ozone layer.

1986 *UNEP and Montreal Protocol Actions*

- The UNEP Economics Workshop on CFC Controls is held in Rome Italy.

- UNEP Conference on impacts of ozone depletion on health and environment held in Washington, DC.

- The UNEP Co-ordinating Committee on the Ozone Layer meets in Nairobi on atmospheric science and in Holland to update environmental effects science.

- The UNEP Workshop on Demand and Technical Controls and General Control Strategies is held in Leesburg, Virginia.

- The UNEP Co-ordinating Committee on the Ozone Layer meets in the Netherlands on effects of ozone depletion.

National Actions

- USSR and US agree to expand research into stratospheric ozone depletion under environmental bilateral agreement.

1986 *Atmospheric and Environmental Science*

- NASA ozone assessment published.
- The International Conference on Environmental Effects of Ozone Modifications & Climate Change is held Washington DC.
- WMO/UNEP Atmospheric Ozone Assessment (1985) published.

Technology and Corporate Actions

- The DuPont Company and the Alliance for Responsible CFC Policy change their original positions and recommend a global approach to stratospheric ozone layer protection.

1987 *UNEP and Montreal Protocol Actions*

- The Montreal Protocol on Substances that Deplete the Ozone Layer is signed by 24 Nations and the European Economic Community on 16 September 1987: Belgium, Canada, Denmark, Egypt, Finland, France, Germany, Ghana, Italy, Japan, Kenya, Mexico, Netherlands, New Zealand, Norway, Panama, Portugal, Senegal, Sweden, Switzerland, Togo, United Kingdom, United States of America, and Venezuela.

National Actions

- Venice economic summit declaration lists stratospheric ozone depletion as first environmental priority.

Atmospheric and Environmental Science

- Meeting on atmospheric modelling held in Wurzburg, Germany.
- Aircraft monitoring campaign detects the “smoking gun” proving CFCs deplete stratospheric ozone.

Technology and Corporate Actions

- A panel of experts from Germany, Japan, United Kingdom, and the United States conclude that the absence of a market - rather than technical or environmental issues–is the principal barrier to commercialisation of CFC substitutes. HCFC-225 is identified as a replacement for CFC-113.

1988 *UNEP and Montreal Protocol Actions*

- The Scientific, Environmental, Technology, and Economics Assessment processes are informally initiated at a UNEP conference in The Hague Netherlands.

- Vienna Convention enters into force.

National Actions

- The first International Conference on Alternatives to CFCs and Halons is held in Washington, DC.

- Brazil bans use of CFCs as aerosol propellant in all household and cosmetic products

Atmospheric and Environmental Science

- Ozone Trends Panel concludes CFCs cause global ozone depletion and the Antarctic ozone hole.

Technology and Corporate Actions

- AT&T and Petroferm announce a semi-aqueous solvent that cleans electronics as well as CFC-113.

- U.S. industry and environmental NGOs announce the world's first voluntary national CFC phaseout in food packaging.

- Nortel and Seiko Epson announce corporate goals of a complete CFC-113 phaseout on accelerated schedules.

- DuPont announces plan to halt CFC production.

- The First International Halon Conference is held in Lugano Switzerland.

- The U.S. Air Force restricts new applications of halons.

- The Institute of Interconnecting and Packaging Electronic Circuits announces a plan to benchmark CFC, test alternatives, and modify military specifications to protect the ozone layer.

1989 *UNEP and Montreal Protocol Actions*

- The Montreal Protocol enters into force.

- The First Meeting of the Parties to the Montreal Protocol is held 2-5 May in Helsinki Finland and officially establishes the Assessment Panels with Terms-of-Reference (TOR) according to Article (6) of the Montreal Protocol. Dr. Stephen O. Andersen, John Hoffman, and George Strongylis Co-Chaired the Economic Panel (EP). Dr. Jan van der Leun and Dr. Manfred Tevini Co-Chaired the Environmental Effects Panel (EEP). Dr. Daniel L. Albritton and Dr. Robert T. Watson Co-Chaired the Scientific Assessment Panel (SAP). Dr. Stephen O. Andersen and G. Victor Buxton Co-Chaired the Technology Review Panel (TRP).

- The Technology Review Panel with five Technical Options Committees is formed with one hundred and ten experts from 22 countries. The Economic Assessment Panel is formed with 25 experts from 12 countries. The Science Assessment and the Environmental Effects Panels are formed.

- Assessment Reports of the Scientific Assessment Panel, the Environmental Effects Panel, the Technology Review Panel (TRP), and the Economic Panel, are published. The TRP includes separate reports from Aerosols, Foams, Halons, Refrigeration, and Solvents Technical Options Committees (TOCs). A Synthesis Report integrates the findings of the four Panels.

National Actions

- Prime Minister Margaret Thatcher and the U.K. host the Conference on Saving the Ozone Layer to encourage corporate and government leadership in protecting the ozone layer.

- The Australian Governments with the leadership of the Association of Fluorocarbon Consumers and Manufacturers of Australia (AFCAM) decides that halon production and import would be phased out by 31 December 1995.

Atmospheric and Environmental Science

- Aircraft campaign reveals that the chemical composition of the Arctic is perturbed and is primed for ozone depletion.

Technology and Corporate Actions

- The Mobile Air Conditioning Society (MACS), U.S. EPA, and international motor vehicle manufacturers develop a CFC recycling standard that is accepted worldwide under factory warranties. The Society of Automotive Engineers (SAE) establishes complementary recovery/ recycle equipment standards and technician service procedures stopping venting during service.

- Nissan commits to phase out CFCs in vehicle manufacturing.

- Woolworths Australia sets a goal of halting the use of CFC refrigerants.

- The Industry Cooperative for Ozone Layer Protection (ICOLP) and the Halon Alternatives Research Corporation (HARC) are founded.

- The American Electronics Industry Association adopts industry-wide goals to reduce CFC and methyl chloroform emissions.

- The "International Conference on Military Applications and Alternatives to Halons" hosted at Tyndall Air Force Base Florida.

1990 *UNEP and Montreal Protocol Actions*

- The Second Meeting of the Parties to the Montreal Protocol is held 27-29 June in London England and amends the Protocol to create a Financial Mechanism including a Multilateral Fund. UNDP, UNEP, and the World Bank are designated as implementing Agencies. The Interim Multilateral Fund is set at US$160-240 million for the first three years to finance the incremental costs of substitution in Article 5(1) countries and the clearinghouse function. Parties combined the Technology Review Panel and Economic Panel to form the Technology and Economic Assessment Panel (TEAP) and appointed Stephen Lee-Bapty to replace G. Victor Buxton as Co-Chair of the TEAP.

- The Interim Multilateral Fund is established in Montreal Canada and the first Meeting of the Executive Committee is held.

1991 *Awards and Honours*

- The first annual U.S. EPA Stratospheric Ozone Protection Awards are presented to 3 companies, 5 associations, 1 laboratory, and 16 individuals from Canada and the United States.

National Actions

- The governments of Egypt and Mexico with co-operation of the U.S. EPA and national industry publish "Case Study of the Cost to Egypt of Protecting the Ozone Layer" and the "Case Study of the Cost to Mexico of Protecting the Ozone Layer," establishing a quantitative basis for financing of the Interim Multilateral Fund.

- The Mexican government signs voluntary agreements with industrial associations to phase out CFCs and halons earlier than required by the Montreal Protocol.

Technology and Corporate Actions

- The National Fire Protection Association (NFPA) clarifies that halon discharge testing and training with halon was never required and issues technical standards incorporating specific tests of satisfactory system performance without halon discharge. In anticipation of halon alternatives, a new NFPA committee is established to prepare necessary technical standards.

- Digital Equipment Corporation (DEC) donates patented technology in support of CFC phase-out.

1991 *UNEP and Montreal Protocol Actions*

- The Second Meeting of the Parties to the Vienna Convention is held 17-19 June in Nairobi Kenya.

- The Third Meeting of the Parties to the Montreal Protocol is held 19-21 June in Nairobi Kenya.

- Reports of the Scientific Assessment Panel (SAP), the Environmental Effects Panel (EEP), the Technology and the Economic Assessment Panel (TEAP) published. The TEAP includes separate reports from Aerosols, Foams, Halons, Refrigeration, and Solvents Technical Options

Committees (TOCs) and the Economic Options Committee (EOC).). A Synthesis Report integrates the findings of the four Panels.

- UNEP establishes the OzonAction Programme under the Multilateral Fund at its Industry and Environment centre in Paris to assist Article 5(1) Parties as a clearinghouse and for capacity building. OzonAction publishes its first newsletter and holds its first Regional Workshops in Thailand, Egypt, and Venezuela.

Awards and Honours

- The 1991 U.S. EPA Stratospheric Protection Awards are presented to 6 companies, 4 associations, and 12 individuals from Canada, Ireland, Japan, Mexico, Sweden, United Kingdom, and the United States.

National Actions

- Camara Nacional de la Industria de la Transformacion, Nortel/Northern Telecom, ICOLP/ICEL and the EPA form a partnership to phase out CFC solvents in Mexico by 2000

- "The First International Conference on the Role of the Military in Protecting the Ozone Layer" sponsored by North Atlantic Treaty Organisation (NATO) is held in Williamsburg Virginia (USA).

- The Royal Norwegian Navy Material Command announces the first military acceptance of alternatives for halons used on combat vessels.

- The U.S. Department of Defense (DoD) recommends that CFC solvents be phased out.

- Finland provides financing to UNEP to assist non-Party developing countries.

- China ratifies the Montreal Protocol.

Atmospheric and Environmental Science

- The Scientific Assessment concludes much larger ozone depletion than predicted by models.

1991 *Technology and Corporate Actions*

- Daikin, DuPont, ICI, and Showa Denko are first to commercialise HFC-134a. Asahi Glass builds the first HCFC-225 production plant.

- Nortel becomes the first multinational telecommunications company to eliminate CFC-113 from its global manufacturing operations.

- Nissan and then Mercedes-Benz become world's first automobile manufacturers to introduce CFC-free air conditioning (HFC-134a).

- The U.S.-Japan-Russia Environmental Executive Leadership Workshop, Woods Hole Massachusetts promotes technology co-operation.

- SAE publishes standards for recovery/recycling equipment and technician service procedures for HFC-134a.

1992 *UNEP and Montreal Protocol Actions*

- The Fourth Meeting of the Parties to the Montreal Protocol is held 23-25 November in Copenhagen Denmark, with Amendments and Adjustments requiring developed countries to phase out halon by 1994; to phase out CFCs, 1,1,1-trichloroethane (methyl chloroform), and carbon tetrachloride by 1996; and to freeze methyl bromide production and consumption. Parties also make permanent the Multilateral Fund and the Financial Mechanism. Parties appoint Dr. Lambert Kuijpers to replace Stephen Lee-Bapty as Co-Chair of the TEAP and appoint new Co-Chairs Dr. Pieter Aucamp to the SAP, Andre P.R. Cvijak to the TEAP, and Professor Xiaoyan Tang to the EAP.

- Reports of the Interim Report on the Scientific, Technology, and Economic Assessment of Methyl Bromide and the Ad-Hoc Technical Advisory Committee on ODS Destruction Technologies are published.

- UN Conference on Environment and Development (Earth Summit) held in Rio de Janeiro opening Framework Convention on Climate Change for signature.

- London Amendment enters into force.

Awards and Honours

- The 1992 U.S. EPA Stratospheric Protection Awards are presented to 15 companies, 6 associations, and 12 individuals from Australia, Belgium, Brazil, Germany, Japan, Mexico, Norway, Sweden, United Kingdom, and the United States.

National Actions

- By 1 January the Netherlands completes phase-out of methyl bromide soil treatments.
- The North Atlantic Treaty Organization (NATO) supports accelerated phaseout.
- The U.S military orders rapid elimination of ODSs from all weapons acquisition and ODS banks for mission-critical uses.
- Switzerland prohibits CFC and HCFC, 1,1,1-trichloroethane and carbon tetrachloride solvents and new halon installations.
- The European Community (EC) announces plans to phaseout of CFCs and CTC by 1995.
- Mexico commits itself to an accelerated phaseout with target year 2000.
- UNEP conducts four regional workshops with participants from 90 developing countries.
- Sweden provides financing to UNEP IE OzonAction Programme to establish the first Regional Network of ODS Officers in the South East Asia & the Pacific Region.
- India ratifies the Montreal Protocol.

Technology and Corporate Actions

- Seiko Epson is the first multinational manufacturer of precision instruments to eliminate CFC-113.
- General Dynamics is first to eliminate virtually all ODS solvents from aircraft manufacture and Lufthansa is first to halt the use of most ODS solvents in aircraft maintenance.

- The Coca-Cola Company halts the purchase of CFC refrigerated equipment, rapidly motivating manufacturers in developed and developing countries to meet global demands.

- Japanese refrigerator companies in Thailand announce plans to phase out CFCs in 1997.

- US-Japan Environmental Executive Leadership Workshop is held in Yountville, California to promote technology co-operation for ozone layer protection.

- MacDonalds halts purchase of CFC containing polystyrene for food packaging in Brazil, pushing phase out of this sub sector in the country

- Dow Chemical shuts down methyl chloroform production plant in Brazil

1993 *UNEP and Montreal Protocol Actions*

- Interim Fund transitions to Multilateral Fund.

- The Third Meeting of the Parties to the Vienna Convention is held 22 November in Bangkok Thailand.

- The Fifth Meeting of the Parties to the Montreal Protocol is held 17-19 November in Bangkok Thailand, replenishing the Fund with US$ 455 million. Parties appoint Dr. Suely Carvalho to replace Andre P.R. Cvijak as Co-Chair of the TEAP.

- Reports of the TEAP and the Halon Technical Options Committee are published focusing on nominations for essential use of halons and halon bank management.

- UNEP initiates the International Halon Bank Management Information Clearinghouse.

Awards and Honours

- The 1993 U.S. EPA Stratospheric Protection Awards are presented to 36 companies, 5 associations, and 38 individuals from Australia, Chile, Egypt, Germany, Japan, Netherlands, Singapore, Sweden, Thailand, United Kingdom, and the United States.

National Actions

- Australia establishes the first national halon bank.
- Uruguay launches “ozone friendly” product labelling.
- 17 countries sign a Declaration to phase out methyl bromide consumption.
- The USA plans to phase out methyl bromide by 2001, Denmark issues a draft regulation proposing to phase out by 1998, and Sweden completes phase-out of methyl bromide soil treatments.

Technology and Corporate Actions

- Cadbury, Sainsbury, and Woolworth’s Australia complete CFC phaseout.
- Matsushita is the first multinational company to manufacture kitchen appliances and entertainment equipment without CFCs.
- Minebea, the company previously consuming the largest quantities of ODS in Thailand, completely phases out.
- U.S. Air Force halts purchase of newly produced halon and prohibits the purchase of commercial vehicles and equipment requiring CFCs.
- CSIRO Australia announces carbonyl sulphide as a replacement for commodity fumigation with methyl bromide.
- Hortico Zimbabwe introduces alternatives to methyl bromide for strawberry production.
- All major German refrigerator manufacturers choose refrigerant isobutane and most choose cyclopentane as the candidate blowing agent for polyurethane insulating foam.
- SAE publishes procedures for converting CFC-12 vehicle air conditioners to HFC-134a.

1994 *UNEP and Montreal Protocol Actions*

- January 1, 1994 halon production halted in developed countries.
- UN Convention on Climate Change enters into force.

- The Sixth Meeting of the Parties to the Montreal Protocol is held 6-7 October in Nairobi Kenya.

- Assessment Reports of the (SAP), the Environmental Effects Panel (EEP), the Technology and the Economic Assessment Panel (TEAP) are published.

- The United Nations General Assembly designates September 16 as the "International Day for the Preservation of the Ozone Layer."

- UNEP IE OzonAction and the Ozone Secretariat hold the first Workshop for Countries with Economies in Transition (CEIT) in Minsk, Belarus.

Awards and Honours

- The 1994 U.S. EPA Stratospheric Protection Awards are presented to 21 companies, 2 associations, and 27 individuals from Denmark, Germany, Japan, Malta, Poland, Sweden, Switzerland, Thailand, United Kingdom, United States and Venezuela.

National Actions

- "The Second International Conference on the Role of the Military in Protecting the Ozone Layer," is held in Brussels.

- The State Fire Service of Poland organises the "International Conference on Problems Related to Halons Phaseout" for fire authorities in Poland and the other countries with economies in transition (CEIT). Halon alternatives and halon banking options are identified that allow Poland to withdraw its pending halon essential use nomination.

- Venezuela implements a halon management program and eliminates the need for further halon imports.

- Indonesia, Denmark, and Sweden issue regulations to phase out methyl bromide by 1998.

- Malaysia prohibits the use of CFCs as aerosol propellant.

Technology and Corporate Actions

- Virtually every new automobile air conditioning system worldwide uses HFC-134a.

1995 *UNEP and Montreal Protocol Actions*

- The 10th Anniversary of the Vienna convention is celebrated.

- The Seventh Meeting of the Parties to the Montreal Protocol is held 5-7 December in Vienna Austria, deciding a methyl bromide reduction and 2010 phase out schedule for developed countries and a freeze in developing countries.

- Assessment Reports of the SAP, the EEP, and the TEAP are published. The TEAP includes separate reports from Aerosols, Economics, Foams, Halons, Methyl Bromide, Refrigeration, and Solvents Technical Options Committees (TOCs) and an update of ODS Destruction Technology.). A Synthesis Report integrates the findings of the four Panels.

- Additional publications include supplementary analysis of HCFC and Methyl Bromide Emissions, the Report of the TEAP Working Group on Laboratory and Analytical Uses, the Report of the TEAP Working Group on Process Agents, and the Report of the TEAP Working Group on Countries with Economies in Transition (CEIT).

Awards and Honours

- Paul Crutzen, Mario Molina, and Sherwood Rowland receive the Nobel Prize in Chemistry for their groundbreaking work on stratospheric ozone depletion.

- The first UNEP Global Ozone Protection Award is presented Daniel L. Albritton, Stephen O. Andersen, Rumen D. Bojkov, Eileen Claussen, Paul Crutzen, Joe Farman, Tang Meng Leng, Juan Antonio Mateos, Mario Molina, Sherwood Rowland, Patrick Szell, Gary Taylor, Manfred Tevini, Jan C. Van der Leun, Robert Watson and John Whitelaw; the Alternative Fluorocarbons Environmental Acceptability Study and Programme for Alternative Fluorocarbon Toxicity Testing (AFEAS & PAFT), Friends of the Earth Canada, and the Japan Electrical Manufacturers' Association.

- The U.S. EPA 1995 Stratospheric Protection Awards are presented to 24 companies, 6 associations, and 31 individuals from Australia, Canada, France, Hong Kong, India, Japan, Netherlands, Norway, Singapore, Switzerland, Taiwan, United States, and Venezuela.

1995 *National Actions*

- CFC production for all but export and essential uses is halted in the European Union.
- 21 countries sign a Declaration to limit use of methyl bromide to strictly necessary applications and to phase out as soon as possible.
- Austria finalises regulations to phase out use of methyl bromide for storage facilities by 1998.
- Australian farming sectors agree to methyl bromide reduction targets and finance alternatives trials with a voluntary levy on sales.
- European tobacco companies inform suppliers in Zimbabwe and Asia that they will no longer accept tobacco treated with methyl bromide.

Technology and Corporate Actions

- More than forty multinational companies from seven countries pledge to help the Government of Vietnam protect the ozone layer by investing only in modern, environmentally acceptable technology in their Vietnam projects
- 3M markets the world's first CFC-free metered-dose inhaler (MDI).
- Japanese companies in Thailand phase out CFCs for household refrigerators—the first sectoral phaseout in an Article 5(1) country. Thailand prohibits manufacturing and importing of CFC refrigerators—the first trade barrier enacted by a developing country to protect the global environment.

1996 *UNEP and Montreal Protocol Actions*

- By January CFC, carbon tetrachloride, and 1,1,1-trichloroethane production halted in developed countries (with exceptions for exports to Article 5(1) Parties and for essential, process agent and feedstock use).
- The Eighth Meeting of the Parties to the Montreal Protocol is held in San Jose Costa Rica and decides a US$ 465 million replenishment of the Fund.
- Assessment reports of the TEAP and its Task Force on Countries with Economies in Transition (CEIT) are published.

Awards and Honours

- Paul Crutzen elected to the United Nations Environment Programme (UNEP) Global 500 Roll of Honour.

- The 1996 “Mario Molina” Award and honorary mentions, an initiative of the Secretary of Environment of Sao Paulo, Brazil are presented to Dr. Mario Molina, two individuals and eleven enterprises, for their leadership towards protection of the ozone layer.

- The 1996 U.S. EPA Stratospheric Protection Awards are presented to 18 companies, 7 associations, and 23 individuals from Australia, Brazil, Canada, France, India, Japan, Malaysia, Malta, New Zealand, Sweden, United Kingdom, and the United States.

National Actions

- By 1 January Denmark phases out use of methyl bromide on tomatoes.

- Colombia bans methyl bromide with limited exemption for quarantine treatments.

- Ghana reduces CFC use by 85% mainly through training in refrigeration servicing.

- Australia introduces substantial fees for methyl bromide.

- The Danish Environmental Protection Agency and UNEP IE issue a joint study of Strategic Options for Accelerated ODS Phase-out in CEIT.

- Government of the State of Sao Paulo, Brazil bans purchase of non-essential equipment that uses ODS by state agencies.

Atmospheric and Environmental Science

- A decrease is measured in growth rate of atmospheric concentrations of CFC-11, CFC-12, and methyl chloroform.

Technology and Corporate Actions

- The World Semiconductor Council pledges voluntary reductions in emissions of PFCs.

1997 *UNEP and Montreal Protocol Actions*

- The Ninth Meeting of the Parties to the Montreal Protocol is held in Montreal Canada with a gala 10th Anniversary celebration. The Parties decide to phase-out methyl bromide in Article 5(1) and non-Article 5(1) countries and create a licensing system for ODS trade. Parties appoint Professor Gerard Megie Co-Chair of the SAP.

- Assessment Reports of the TEAP are published including a Handbook on Essential Use Nominations.

Awards and Honours

- The 1997 UNEP Global Ozone Protection Award is presented to James G. Anderson, Ralph J. Cicerone, Susan Solomon, Richard S. Stolarski, Christos Zeferos, Robert C. Worrest, Edward C. DeFabo, H. Jonathan Banks, Suely Machado Carvalho, Lambert Kuijpers, Barbara Kucnerowicz-Polak, John Carstensen, Ilkka Ristimaki, Sateeaved Seebaluck, Willem Kakebeeke, Paul S. Horwitz, Richard E. Benedick, Elizabeth Cook, Melanie Miller, Greenpeace International, CFC Alliance, the Department of Environment Malaysia, and NORTEL/Northern Telecom.

- Jan van der Leun, Co-Chair of the UNEP Environmental Effects Panel, is elected to the United Nations Environment Programme (UNEP) Global 500 Roll of Honour.

- UNEP IE OzonAction Programme presents 12 National Ozone Unit Awards for leadership and policy innovation and phase-out results.

- The U.S. EPA presents “Best-of-the-Best” Awards to honour the most extraordinary technical and leadership contributions over the first decade of the Montreal Protocol. The 71 Best-of-the-Best Champions are from Australia, Brazil, Canada, Germany, Japan, Malaysia, Mexico, the Netherlands, Switzerland, Thailand, United Kingdom, United States, and Venezuela. 25 of the 36 individual winners served on the TEAP and two on the SAP.

- The 1997 U.S. EPA Stratospheric Protection Awards are presented to 15 companies and 31 individuals from Australia, Canada, China, Dominican Republic Hungary, India, Japan, Malaysia, Malta, Netherlands, Philippines, Poland, Spain, Thailand, United Kingdom, and the United States.

National Actions

- Guyana hosts workshop for business and media to promote their national phaseout program.
- Hungary launches its Halon Recycling Station.

Technology and Corporate Actions

- Flower farms in Kenya and Israel join the Floriculture Environment Project initiated by Dutch flower auction houses to qualify for higher prices for crops grown without methyl bromide.
- The UK Co-Op Food Company bans the use of methyl bromide as a soil fumigant on its own farms and encourages suppliers to its retail supermarkets to phase-out methyl bromide.
- The “Fourth International Workshop on the Role of the Military in Protecting the Ozone Layer” and the “First International Workshop on the Military Role in Climate Protection” are held concurrently in Washington, DC.
- At the invitation of UNEP IE OzonAction Programme, 23 multinational corporations voluntarily pledge to support the 1999 freeze goals, including a commitment not to transfer new CFC-using technology to CEIT and Article 5(1) countries.
- Automotive industry in Brazil stops using CFCs in all new models.

1998 *UNEP and Montreal Protocol Actions*

- The Tenth Meeting of the Parties to the Montreal Protocol is held November 23-24 in Cairo, Egypt. The Tenth meeting requests the Assessment Panels to study the effect of the Kyoto Protocol on the implementation of the Montreal Protocol and also asks for a study of the impact of new, uncontrolled, ODSs that are now being marketed.
- By fall 1998 the Multilateral Fund has financed over US$ 850 million for the phaseout of more than 140,000 ODP tonnes of ODS.
- Assessment reports of the SAP, EEP, and TEAP are published including separate reports from the Technical Options Committees. A Synthesis Report integrates the findings of the four Panels.

Awards and Honours

- UNEP presents Mostafa Tolba with a Global Award for Ozone Layer Protection.

- Stephen O. Andersen, Co-Chair of the UNEP Technology and Economic Assessment Panel, is elected to the United Nations Environment Programme (UNEP) Global 500 Roll of Honour.

- The 1998 U.S. EPA Stratospheric Protection Awards are presented to 11 companies and military organisations, 2 associations, and 19 individuals from Australia, France, Hungary, India, Japan, Netherlands, Poland, Singapore, Switzerland, United Kingdom and the United States.

National Actions

- Denmark phases out all uses of methyl bromide, including quarantine treatments. Sweden completes methyl bromide phase-out except for wood exported to Australia.

- Vietnam plans to phase out methyl bromide by 2006, nine years faster than the Protocol schedule.

- Philippines prohibits halon imports.

- Government of Brazil bans purchase of new products containing ODS for non-essential uses by all federal agencies.

Technology and Corporate Actions

- DuPont announces shut-down of CFC production in South America by the end of 1999. Theonly remaining production facility in Brazil is included in the shut-down program.