MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

2006 ASSESSMENT REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

Montreal Protocol
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The text of this report is composed in Times New Roman.

Co-ordination: **Technology and Economic Assessment Panel**

Reproduction: UNEP Nairobi, Ozone Secretariat
Date: March 2007

Printed copies of this report are available from:

SMI Distribution Service Ltd., Stevenage, Hertfordshire, UK,
fax: + 44 1438 748844

This document is also available in portable document format from

http://www.unep.org/ozone

ISBN: 978-92-807-2823-1
Job No: OZO/0949/NA

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Acknowledgement

The Technology and Economic Assessment Panel, its Technical and Economic Options Committees and the Task Forces Co-chairs and members acknowledges with thanks the outstanding contributions from all of the individuals and organisations who provided support to the Panel and the Technical Options Committees. The opinions expressed are those of the Panel, the Committees and Task Forces and do not necessarily reflect the reviews of any sponsoring or supporting organisation.

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1 Executive Summary

Since the 2002 Assessment of the Technology and Economic Assessment Panel (TEAP), a large number of technical developments have taken place. The direction many of these developments have taken could not have been predicted in 2002. The Panel's Technical Options Committees, on Chemicals (CTOC), on Foams (FTOC), on Halons (HTOC), on Methyl Bromide (MBTOC), on Medical Uses (MTOC) and on Refrigeration and AC (RTOC) have each issued a 2006 Assessment Report that document these developments. The Executive Summaries of these reports form the body of the 2006 TEAP Assessment Report and their Abstract Executive Summaries, with the summaries of other chapters, form the Executive Summary of the 2006 TEAP Assessment Report."

During the year 2006, one Task Force under the TEAP has reported their findings, which were published in October 2006, shortly before the Meeting of the Parties in Delhi. In particular the findings of this Task Force on Emissions Discrepancies (TFED) are interlinked with the findings reported earlier in the IPCC TEAP Special Report and the Supplement to the Special Report by the TEAP and a Task Force in 2005. The summary of these findings was thought to be important enough to be part of the TEAP 2006 Assessment Report. The total issue of bank management, which has a direct link to emissions, is further addressed in a separate chapter in this report

The following structure has been adopted in each section of the Executive Summary that refers to the specific Technical Options Committee:

- *Current status; what has been achieved*
- *What is left to be achieved*
- *The way forward.*

This structure does not apply to the Executive Summary of the TFED Report, and the chapters containing the full Executive Summaries and other material. Before that the different executive summaries of each TOC are given in this TEAP 2006 Assessment Report, the Executive Summary presents a number of key messages in section 1.1.

1.1 Key Messages

The technical developments that have occurred between 2002 and 2006, and which are described in this 2006 TEAP Assessment Report, have served to increase the technical and economic feasibility of each of the following for both Article 5 and non-Article 5 countries:

a. accelerating the phase-out of consumption of most ODSs,
b. limiting the use or reducing the emissions in many applications, and
c. collecting and destroying unwanted ODS contained in foam and refrigeration and other equipment.

The key findings can be summarised as follows:

Chemicals (CTOC)

- Some carbon tetrachloride (CTC) and CFC feedstock and process agent uses exempted by the Protocol could be replaced by hydrochlorofluorocarbons (HCFCs) or by not-in-kind manufacturing processes using non-ozone depleting substances (non-ODS). Parties may wish to consider periodic assessment of available and emerging alternatives and substitutes for feedstock and process agent uses with a view to restricting exempted uses.
- Regulatory and technical changes may continue to impact earlier phase-out of ozone depleting solvent applications by introducing non-ODS or new cleaning processes for the applications where suitable alternatives are not available.
- The phase-out of ozone depleting solvents in Article 5 countries will require: (1) access to information and knowledge about the acceptable alternatives, (2) economic assistance, and (3) identification of small and medium users.

Foams (FTOC)

- As a result of further transition in developing countries, chlorofluorocarbon (CFC) consumption for foam is now down to less than 1% of its 1986 baseline level.
- Hydrocarbons are now the largest single class of blowing agents in use globally (36% of the total). Hydrofluorocarbons (HFCs) have been introduced into some foam sectors, but price and the application of responsible use criteria have limited uptake to less than 60,000 tonnes globally (16% of the total).
- HCFCs also continue to have a significant part of the market (22% of the total) --despite phase-out in many non-Article 5 countries-- primarily because of rapid growth in the use of insulating foams (particularly extruded polystyrene -- XPS) in some Article 5 countries to improve the energy performance of new buildings. Some estimates suggest that up to 50,000 tonnes per annum of additional consumption could emerge by 2015.

Halons (HTOC)

- The civil aviation sector continues to be dependent on halons, has not demonstrated further progress through the adoption of alternative technologies in new airframe designs. The sector lacks an agreed technical design strategy to implement alternative methods of fire suppression. The International Civil Aviation Organization (ICAO) may not take up these issues up at their 2007 Assembly as previously agreed.
- Adequate supplies of halons 1211, 1301 and 2402 are expected to be available on a global basis; however, they are projected to be unevenly distributed amongst the major regions of the world. These regional

imbalances are a growing concern and may need to be addressed by the Parties.

Medical Applications (MTOC)

- Global phase-out of CFCs in Metered-Dose Inhalers (MDIs) is achievable by 2010. However, considerable challenges remain in achieving transition to alternatives, particularly in Article 5 countries.
- A relatively large number of companies manufacturing CFC MDIs in Article 5 countries do not yet have the skills or knowledge to phase out CFC MDIs. It is critical that technical expertise and funds for technology transfer and equipment are available to ensure that patients in Article 5 countries receive essential inhaled treatment.
- Pharmaceutical-grade CFC production for MDIs may be economically impractical after 2009. If global transition in CFC MDI manufacture is not achieved by 2010, Parties may need to consider the necessity for a final campaign production of pharmaceutical-grade CFCs and the acquisition of remaining stockpile from non-Article 5 countries.

Methyl Bromide (MBTOC)

- Technical alternatives exist for almost all controlled uses of methyl bromide.
- Phase-out for the remaining methyl bromide uses will be greatly influenced by the registration and the regulatory controls on several key chemical alternatives (including 1,3-dichloropropene, chloropicrin, methyl iodide and sulfuryl fluoride) and by the incentives for non-chemical alternatives and Integrated Pest Management.
- Full implementation of barrier films in soil fumigation could significantly reduce methyl bromide dosage rates and emissions.
- Increased use of methyl bromide for Quarantine and Pre-shipment (QPS) is offsetting gains made by reductions in controlled uses for soils and other non QPS uses. QPS methyl bromide use is particularly increasing in response to the International Standard for Phytosanitary Measures (ISPM 15) encouraging methyl bromide use on wooden packaging material despite the availability of an authorised alternative to methyl bromide for this use.
- Parties contemplating controls on exempted methyl bromide use may wish to consider economic incentives that encourage minimal use, containment, recovery and recycling; as well as not-in-kind alternatives and substitutes for the products that are traded.

Refrigeration and Air Conditioning and Heat Pumps (RTOC)

- The long product life and low failure rate of the estimated 1,200 to 1,500 million domestic refrigerators currently in use result in refrigerant emissions from this bank being dominated by end-of-life disposal of these units. The management of this bank is expected to be a global agenda topic for at least another 20 years.

- In contrast with non-Article 5 countries, CFCs and HCFCs will continue to be the primary service refrigerants in most Article 5 countries because of long equipment life and the costs of field conversion to alternative refrigerants. Containment and conservation are therefore likely to need increasingly more attention with time.
- As is the case in many non-Article 5 countries, there is still a significant number of aged CFC chillers operated in Article 5 countries, which are characterised by a high energy consumption and high CFC leakages. Replacement is in many cases very cost effective; however, investment capital is often lacking. Replacement strategies combined with financial and other incentives could be the most urgent actions to be considered to substantially reduce both direct and indirect greenhouse gas emissions.
- Several low Global warming Potential (GWP) refrigerant candidates (one with an ozone depleting ingredient – CF_3I) are claimed to provide comparable energy efficiency to HFC-134a in vehicle air conditioning. Development of these low-GWP refrigerants may also have major future consequences for (new) refrigerant choices in other sectors and applications.

Cross-Sectoral Findings

The following are cross-sectoral findings:

- Technically and economically feasible substitutes are available for almost all applications of HCFCs, although transitional costs remain a barrier for smaller enterprises, particularly in developing countries.
- Accelerated phase-out of HCFCs could lead to incremental energy efficiency benefits if existing, less efficient, equipment is retired early.
- A considerable portion of the 3.5 million ODP-tonnes of ODS contained in banks is available for collection and destruction at costs that can be justified by benefits in reducing ODS and greenhouse gas emissions.
- Parties contemplating collection and destruction may wish to consider incentives for collection that avoid prolonged use of inefficient equipment, intentional venting or product dumping. In this context, the classification of ODS recovery and destruction activities as carbon offset projects could warrant further investigation.
- Since 2002, TEAP and its TOCs have undertaken extensive work to co-ordinate with the Intergovernmental Panel on Climate Change (IPCC) on climate protection and to refine and improve estimates of ODS banks and emissions. Parties may wish to consider whether additional co-ordination will provide useful policy-relevant technical information and, if so, how such co-ordination can be encouraged.

1.2 Chemicals TOC

What has been Achieved

Process Agents

CTOC has taken over the work of the Process Agents Task Forces, providing information to Parties on nominations of Process Agents. Taking into account Table A in decision XVII/7 and Table A bis in decision XVII/8, there are now 68 nominations to be assessed.

Feedstocks

Feedstock uses were summarised in the 2005 CTOC Progress Report. ODSs such as CTC and methyl chloroform are feedstocks for the production of CFCs and HCFCs, the latter continuing in use in Article 5 countries until 2040. Methyl bromide and halon 1301 can be used as feedstocks in manufacture of detergents and pharmaceuticals. Estimated ODS emissions from feedstocks were on the order of 3,500 metric tonnes or 1,619 ODP tonnes in 2002.

Laboratory and Analytical Uses

Advice has been provided on essential uses of CFC-113 and CTC. A review was carried out of potential laboratory and analytical uses of methyl bromide. Methyl bromide can be used in laboratories as a ‘methylating agent’. Alternatives to methyl bromide are generally available, but replacements in analytical applications can be more difficult to find.

Aerosol Products, Non-medical

Today more than 99.5% of non MDI aerosols use non-CFC formulations world-wide. The CFC consumption in this sector in 2003 and 2004 was around 2,000 tonnes in Article 5 countries and it is on the decline. There are no technical barriers to global transition to non-ODS alternatives, and many aerosol products have been replaced by not-in-kind substitutes such as mechanical pumps (finger or trigger pumps), sticks, roll-ons, brushes, etc as well as by non-ODSs.

Carbon Tetrachloride (CTC)

TEAP and CTOC provided a report on sources of CTC emissions and opportunities for reductions in 2006. Based on the calculation for the CTC demand 2002-2009, CTC emissions have been estimated. The discrepancy between emission data calculated from atmospheric concentrations and those derived from consideration of industrial activity is due possibly to under-estimation or under-reporting of the latter.

Solvents

Over 90 % of ODS solvent uses (based on the peak consumption of 1994-95) have been reduced by substitution to not-in-kind technologies and conservation. The remaining less than 10% of the ODS market is shared by several in-kind solvent alternatives.

Destruction and Other Issues

Under the decision XII/8, TEAP set up two separate task forces - Task Force on Collection, Recovery and Storage (TFCRS) and Task Force on Destruction Technologies (TFDT). Large amounts of: CFCs are contained in refrigeration equipment. CFC-11 remains in installed foams, and halons 1301 and 1211 in firefighting equipment. Some 16 of 45 ODS destruction technologies considered to meet the environmental and economic screening criteria adopted by the TFDT.

What is Left to be Achieved

Feedstocks

Halon 1301 is a very useful feedstock for preparation of bioactive compounds such as Fipronil, a broad-spectrum insecticide. A new development of non-ozone depleting trifluoromethylating agent will provide an option for resolution.

Laboratory and Analytical Uses

The reasons for slow progress in replacing ODS have been explored. It is estimated that laboratory uses of ODS could be reduced by 37% (over the 2003 figure) by 2008.

Solvents

The major challenges to total phase out are: providing access to information on already identified alternatives, overcoming economic considerations and identifying the small and medium users who, collectively, make up a major portion of the solvent market.

The Way Forward

Process Agents

The existing Process Agent nominations will be reviewed for the 19-MOP in 2007. Tighter collaboration between the Executive Committee (ExCom) and the TEAP will be important to clarify the real figures of process agent applications in Article 5 countries.

Feedstocks

TEAP and CTOC will continue to investigate on all feedstock uses, levels of emission and methods to limit emissions. The CTOC will keep monitoring feedstock uses of ODS that may not have been recognised formerly.

Laboratory and Analytical uses

Opportunities to reduce the use of ODS in preparative and analytical laboratories will arise as adoption of Green Chemistry practices. Meanwhile, the CTOC will maintain a watching brief on possible uses and report to Parties from time to time.

Aerosols, Non-medical

The completion of global CFC phase-out will occur in the near future as the reduction schedule mandated by the Montreal Protocol comes into force in Article 5 countries.

Carbon Tetrachloride (CTC)

Three potentially significant areas require further investigation to get better data for industrial emissions to enable resolution of the discrepancies with atmospheric measurements; the first area is to identify the production of CTC as a by-product and its subsequent use; the second area is to identify any other requirements for CTC and the third is the emission of CTC from sources such as landfills.

Solvents

Regulatory changes will continue to impact use of solvents. In some cases, this may require solvent and/or equipment change or a new cleaning process. The CTOC will investigate the Essential use Exemption of CFC-113 for aerospace applications by the Russian Federation for the years 2007 to 2010.

Destruction and Other Issues

One of the main synergies with the Basel, Rotterdam and Stockholm Conventions will be in the implementation of best practices in order to reduce and eliminate the use of certain chemicals and their waste, also reducing the pollution to the environment.

1.3 Flexible and Rigid Foams TOC

Current Status

In 2005, the consumption of CFCs in the foam sector dropped below 1% of the 1986 baseline consumption for the first time. This has been facilitated by the completion of virtually all projects in non-insulation applications and the near completion of those remaining in the insulation sector.

HCFC phase-out has now been achieved in a number of developed country regions. HCFC-141b continues to be used to a limited degree in Canada and Australia while more significant quantities of HCFC-142b and HCFC-22 continue to be used in North America, primarily to support the manufacture of extruded polystyrene (XPS) until 2010. In developing countries, HCFCs continue to be the dominant blowing agents in all insulation applications except for appliance foams, where the use of hydrocarbon blown foam continues to gain ground, particularly in the larger countries of Asia and Latin America. Of particular relevance at present, is the rapid growth of HCFC-142b and HCFC-22 consumption in China, driven by new XPS capacity. This is in turn driven by construction projects that are delivering in excess of 1 billion square metres of new floor area in buildings per year. The additional blowing agent demand from these sources against a 2001 baseline could amount to as much as 50,000 tonnes by 2015, having already added 20,000 tonnes so far.

The uptake of HFC technologies has been lower than expected in all regions and reached about 56,000 tonnes globally in 2005. This trend has been driven in part by the regulatory, economic and market pressures being exerted, particularly in Europe and Japan. However, innovative formulation methods have also contributed to the lower consumption figures. Limited HFC use is emerging in Latin America for appliances (mainly for export markets). Other minor uses include one component foams, integral skin foams and shoe sole applications.

Hydrocarbons are now well-established as the dominant blowing agent in most developed country regions. Other technologies are continuing to emerge, such as super-critical CO_2, which has now been commercially introduced for spray foam in Japan.

What is Left to be Achieved

There is expected to be little further challenge in phasing out the remaining use of CFCs in the foam sector, although some concern remains about the completeness of baseline reporting in some regions. Efforts to improve the UNEP reporting procedures, particularly with respect to end-use analysis, would greatly assist in ensuring transparency.

For HCFCs, there are a number of remaining challenges, two of which stand out. The first of these is the satisfactory phase-out of HCFC use in the North American XPS industry where the technical challenges differ considerably from those in Europe and Japan. The second challenge is to further assess and, if necessary, seek strategies to arrest the rapid growth in HCFC consumption in China and elsewhere. This will again involve close co-operation with the XPS industry. Adequate actions in this area could also have significant benefits for the climate.

In addition to these measures to address further consumption in the future, the foam sector affords the opportunity of managing blowing agents previous consumed, but still contained in the foams (the so-called banks). There are a number of opportunities available for doing this, some of which have already been implemented in various developed country regions (e.g. Europe and Japan). Recovery of blowing agents from appliances is generally easier than from building products, although recovery from some steel faced panels can be considered technically practical. If further measures are to be taken with appliances, the action needs to be fairly imminent, since many CFC-containing refrigerators are already reaching the end of their useful lives. This is also now true in developing countries where early retirement of inefficient refrigerators is seen as advantageous in limiting the need for additional power generation. For building insulation, the timescale is extended and most foams will not be entering the waste stream until 2015 or beyond. This leaves further time available for assessing and optimising end-of-life management techniques.

The Way Forward

The foam sector continues to provide a number of opportunities to avoid emissions of ozone depleting substances, both through on-going, and possibly additional, consumption measures and through end-of-life management strategies. However, the close interaction between ozone and climate issues in the foam sector, in terms of both the selection of CFC-alternatives and the on-going energy performance of insulation products makes the charting of the most appropriate environmental course a delicate operation. Appropriate end-of-life management strategies to minimise emissions from all foams could make this an easier task. Following this route would involve both the further characterisation of existing strategies (e.g. anaerobic degradation within landfills) as well as the potential exploration of innovative fiscal incentives to promote greater use of end-of-life management practices.

1.4 Halons TOC

Current Status

Only The Peoples Republic of China and the Republic of Korea continue to produce halons for fire protection purposes. Of more than 120 countries operating under Article 5, only 26 continue to import newly produced halons, primarily for the servicing of existing equipment. The use of halon 2402 as a process agent in the Russian chemical industry has substantially reduced the Russian inventory of halon 2402. Nevertheless, within Russia and the Ukraine there appears to be a sufficient quantity of halon 2402 for the servicing of existing applications.

The 2006 Assessment models estimate that the global bank of halon 1301 at the end of 2005 is 50,000 metric tonnes (MT), and the global bank of halon 1211 at the end of 2005 is 90,000 MT. Therefore, local and regional imbalances aside, the HTOC is of the opinion that adequate global stocks of halon 1211 and halon 1301 currently exist to meet the future service and replenishment needs of critical or essential halon 1211 and halon 1301 fire equipment until the end of their useful lives.

Halon use within the military sector is well managed, and many organisations have established dedicated halon storage and recycling facilities to support Critical Use equipment for as long as is necessary.

What is Left to be Achieved

There is growing concern from HTOC local and regional experts about the availability of halon 2402 to support the critical servicing needs of Russian produced aircraft, military vehicles, and naval vessels still in operation in countries outside of Russia and the Ukraine, particularly India.

In Article 5 countries, halon banking has been a mix of success and failure. In addition, the build up of stocks of contaminated or otherwise unwanted halons continues to be a problem in Article 5 countries, particularly in Africa and now also in China.

The civil aircraft sector continues to be dependent on halons, has not demonstrated further progress through the adoption of alternative technologies in new airframe designs, and lacks having an agreed technical design strategy to implement alternative methods of fire suppression.

The Way Forward

Within the civil aircraft sector, there is an immediate need to produce technical designs to conform with the minimum performance specifications that will in turn enable regulatory authorities to certify the systems to be fitted to new aircraft designs.

Well planned and managed halon banking schemes can play a significant role in ensuring the quality and availability of recycled halon in Article 5 countries, in managing the consumption down to zero, and in assisting with emission data by providing regional estimates that should be more accurate than global estimates.

While it appears that adequate supplies of halon 1211 and halon 1301 are expected to be available on a global basis, the majority of halon 1301 is projected to be in Japan, and the majority of halon 1211 is projected to be in China. As with halon 2402 in Russia and the Ukraine, these regional imbalances are a growing concern for the HTOC that may need to be addressed by the Parties.

1.5 Methyl Bromide TOC

Current Status

In 2005, global production for the MB uses controlled under the Protocol was about 18,140 metric tonnes, which represented 27% of the 1991 reported production data (66,430 tonnes) MB production in Article 5 countries for controlled uses peaked in 2000 at 2,397 tonnes, falling to 39% of the baseline, 538 metric tonnes, in 2005 (aggregate baseline for all Article 5 regions is 1,375 tonnes). Production for uncontrolled QPS uses was estimated to have increased from an average of about 10,000 tonnes used annually between 2000 to 2004 to 13,000 tonnes in 2005.

Global consumption of MB was reported to be about 64,420 metric tonnes in 1991 for controlled uses and remained above 60,000 tonnes until 1998. In 2000 it was estimated at 45,527 tonnes in 2000, and fell to about 26,336 tonnes in 2003. By 2003, MB consumption in non-Article 5 countries was reduced to about 14,520 tonnes, representing 26% of the baseline. The Meetings of the Parties approved 16,050 tonnes for Critical Uses in non-Article 5 Parties for 2005. Of this, less than 13,823 tonnes was authorised by national governments and reported consumption was 11,468 tonnes in 2005. This accounted for about 20% of the total non-Article 5 baseline.

Article 5 consumption for controlled uses peaked at more than 18,100 tonnes in 1998. Total Article 5 consumption was reduced to about 11,820 tonnes in 2003 (75% of the baseline) to 9,285 tonnes in 2005 (59% of the baseline). Presently, 87% of Article 5 consumption is estimated to be for soil fumigation and 13% for postharvest treatments.

The decline in total global consumption of MB is largely attributed to reductions in soils fumigation, although in Europe non-QPS postharvest uses have also been greatly reduced   Reductions in the soil sector have been achieved by the adoption of chemical fumigant alternatives, such as 1,3 – D/chloropicrin, combinations of chemical and non-chemical control methods and the adoption of practices that avoid the need for MB, e.g., substrate cultures, grafting or integrated pest management strategies. In areas where critical uses for soil fumigation are still being requested, the adoption of barrier films, reductions in dosage rate and use of mixtures of MB with chloropicrin have also led to major reductions in MB use. Formulation changes and new or improved application methods have increased the effectiveness of several alternatives.

The uptake of alternatives for post harvest uses has varied depending on the situation and commodity treated. Technically feasible alternatives are available for almost all structural treatments and fumigation of durable commodities, although a number of constraints to further adoption still remain, including economic considerations, treatment and market logistics and regulatory and registration requirements. In structural applications, heat and sulfuryl fluoride and heat, CO_2 and phosphine are in commercial use. Thorough application of IPM approaches is a pre-requisite for the effectiveness of any treatment, including efficient use of methyl bromide. IPM systems without fumigants are in use in many countries. For durable commodities, phosphine, heat and vacuum are the leading alternatives. For QPS treatments of commodities, there are various approved (situation-dependent) treatments including heat, cold, modified and controlled atmospheres, fumigants, water treatments under pressure, chemical dips and irradiation.

Significant effort has been undertaken by many Parties to transfer, register and implement alternatives and to optimise their use. Lack of registration is still a major constraint to the uptake of effective alternatives in some countries. In most instances the adoption rates for alternatives vary between 10 and 25% per year. This includes Article 5 countries that have adopted alternatives through investment projects. In some sectors however, some countries report slower adoption rates even though a number of technical alternatives have been proven world-wide and many countries have been able to transition successfully.

MB phase-out in Article 5 countries has been achieved mainly through MLF investment projects, which have shown that a similar range of alternatives to those in use in non-Article 5 countries can be successfully adopted. Costs and different resource availability can lead to preference for different alternatives in Article 5 compared to non-Article 5 countries.

The fact that MB can often not be replaced simply by one in-kind alternative has become clear through both demonstration and investment projects. MB users may need to change their approach to crop production and even make important changes in process management. Particular attention needs to be paid to appropriate, effective application methods and adaptation to specific local conditions. Strong emphasis on awareness raising activities, information transfer and training, is still most important.

What is Left to be Achieved

Trends in the adoption of alternatives for CUE uses in non-Article 5 has occurred at approximately 16 to 32% a year since the CUE process commenced in 2003. Of the remaining 11,545 tonnes of MB used for CUEs in 2005, MBTOC estimates that technical alternatives exist for all, but for about 1,136 tonnes of MB. Adoption of these alternatives is being affected by different regulatory constraints within countries.

Areas where technical alternatives are proving more difficult include some specific nursery situations where certification is required, ginseng replant and elimination of *Striga* and broomrape in some situations. In postharvest applications, MBTOC has not identified technically effective alternatives for only four uses: high moisture fresh dates, fresh market chestnuts, cheeses in cheese storages, and hams in ham storages. Additionally, it is uncertain whether there are technically effective alternatives that are sufficiently protective of immovable historical objects and museum components when infested with fungi.

Although QPS uses of methyl bromide are usually for commodities in trade, one Party has identified some of its methyl bromide uses in soils as being quarantine uses. For the 2002-4 period, a survey showed the major use categories for QPS treatments were soil (preplant 29%), grains (24%), wood, including sawn timber (16%), fresh fruit and vegetables (14%), wooden packing materials (6.4%), logs (4.0%) and dried foodstuffs (3.0%). The use of QPS methyl bromide for treatment of whole logs and timber appears underrepresented in these figures. Independent estimates of the volume of methyl bromide required to treat East Asian and Russian trade in logs suggest that QPS methyl bromide use for this use exceeds 4,000 tonnes.

The Way Forward

The main crops for which MB is still being used and for which further efforts to adopt and scale up alternatives in specific non-Article 5 and Article 5 countries include; cucurbits (melons and cucumbers), peppers, eggplants, tomatoes, perennial fruit and vine crops (particularly replant), strawberry fruit, and nurseries for the production of propagation material for forest plants, strawberry runners and flowers.

Increasing regulation of fumigants, including MB, is placing pressure on industries to either adopt new production systems, which avoid the need for MB, or to seek new alternatives that are more environmentally sustainable and safer. Continuation of registration of various fumigants, further investment into methods that avoid the need for MB and possible registration of key alternatives, such as methyl iodide, will greatly influence the ability to phase out the remaining uses of MB economically. An accurate assessment of the economic impact of the adoption of alternatives is not available   The existing literature on some alternatives and uses is narrow and to gain a better understanding more research would need to be done in all countries but especially in countries outside of the USA (particularly in Article 5 countries) and on a wider range of methyl bromide uses.

Studies in diverse regions, together with the large scale adoption of low permeability barrier films (LPBF) in Europe, have confirmed that such films allow for conventional MB dosage rates to be reduced and adoption of barrier films for all remaining critical uses will ensure that use/emissions of bromine can be further reduced. Equivalent effectiveness is achieved with 25 –50% less methyl bromide dosage applied under LPBF compared with normal polyethylene containment films.

For QPS treatments, MOP Decisions have urged Parties to minimise use and emissions of MB through containment and recovery and recycling methodologies, as well as to refrain from use of MB and to use non-ozone-depleting technologies wherever possible. Most commodity fumigation in non-Article 5 countries, especially for QPS applications, take place in well-sealed fumigation chambers with a high standard of gastightness. There are now several examples of recovery equipment in current commercial use. Further work and extension of recapture technology may be useful. There is potential for reduction of methyl bromide emissions from QPS uses of more than 90% of the quantity applied through adoption of recapture and efficient containment.

1.6 Medical TOC

Metered Dose Inhalers

Current Status

In 2005, approximately 4,650 tonnes of CFCs were used globally for the manufacture of metered dose inhalers (MDIs) for asthma and chronic obstructive pulmonary disease (COPD). This represents a 30 per cent reduction in CFC use since the last assessment.

It appears that MDIs are manufactured in at least 16 Article 5 countries. The amount of CFCs used in these countries in 2005 for the manufacture of MDIs is estimated at 1,875 ODP tonnes (equating to approximately 75 million MDIs). About 65 per cent of this consumption (1,283 ODP tonnes) is by nationally owned manufacturing companies.

Technically satisfactory alternatives to CFC MDIs are now available for short-acting beta-agonists and other therapeutic categories for the treatment of asthma and COPD. As anticipated, there have been no major problems with transition, including no major product issues.

What is Left to be Achieved?

Given the widespread availability of technically and economically feasible alternatives, MTOC believes that global phase-out of CFCs in MDIs is achievable by 2010. However considerable challenges will need to be addressed to achieve transition particularly in Article 5 countries. These challenges can be overcome through the transfer of technology, product launches of CFC-free alternatives and implementation of comprehensive transition strategies. There is an urgent need for all Article 5 countries that have not already done so to develop effective national transition strategies in accordance with Decision XII/2.

In some Article 5 countries there are a relatively large number of local companies producing CFC MDIs who have not yet gained access to the skills or knowledge to introduce suitable CFC-free alternatives. It is critical to ensure that appropriate technical expertise is identified, that funds for technology transfer and equipment acquisition are available, and that the management of the implementation is monitored.

The Way Forward

After 2009, the economics of CFC production may make pharmaceutical-grade CFC production for MDIs impractical. If Article 5 countries face difficulties in achieving transition in their CFC MDI manufacturing plants by 2010, stockpiling may need to be considered to ensure a supply of pharmaceutical-grade CFCs for MDI manufacturing to meet patient needs beyond 2009. In these circumstances, it may be appropriate to arrange for a final campaign to produce pharmaceutical-grade CFCs before 2010, or to acquire pharmaceutical-grade CFCs through a transfer of existing stockpile in non-Article 5 countries.

Future CFC requirements are difficult to predict given the uncertainties of transition, particularly in Article 5 countries. However, the volume of CFCs required under the essential use process in non-Article 5 countries is reducing and will likely be less than 500 tonnes in 2008, which may be the last year a request will be made. CFC use in Article 5 countries for MDI manufacture is currently estimated at about 1,800 ODP tonnes per annum.

If quantities of pharmaceutical-grade CFCs are needed to allow the transition to occur globally and there is a need for a final campaign production in the later part of the decade or for the transfer of existing stockpile, then this will need careful consideration and management. Issues that will need to be considered include: timeframe for transition; estimation of CFC quantities; existing stockpile of suitable quality; logistics, commercial, and legal requirements for stockpile transfer; storage; and destruction.

Pharmaceutical Aerosol Products Other than MDIs

Current Status

Technically and economically feasible alternatives are available for all medical aerosol products. The manufacture of most CFC-containing medical aerosols in non-Article 5 countries ceased around 1996, or possibly shortly thereafter if stockpiled CFCs were utilised.

What is Left to be Achieved?

It is only in some Article 5 countries that CFCs are still used in medical aerosols. China alone uses up to about 500 tonnes per year for Chinese traditional medicines, topical sprays and nasal sprays.

The Way Forward

The world-wide phase-out of CFC-containing medical aerosols will occur as CFC production for developing countries is phased out under the Montreal Protocol schedule and as part of individual Article 5 country plans.

Sterilants

Current Status

The use of CFCs in sterilisation has been successfully phased out in non-Article 5 countries and in many Article 5 countries. In 2006, global CFC use for this application is likely to be minimal. Remaining world-wide use can be easily substituted, as there are a number of viable alternatives. In 2005 the estimated use of HCFC replacement mixtures was thought to be less than about 30 ODP tonnes world-wide.

What is Left to be Achieved?

Remaining small uses of CFCs and HCFCs in sterilisation will be replaced over time with suitable alternatives. EO/HCFC blends have a small ODP (0.03) and are not being used in countries that have not been major users of the EO/CFC blend. HCFC mixtures are now used mostly in the United States and in countries that allow venting of HCFCs to the atmosphere.

The Way Forward

EO/HFC blends are expected to replace the EO/HCFC mixtures, where they are used. Sterilisation is an important process in the provision of good quality health services. Therefore, any alternative to the use of ODS needs to be well proven and tested to avoid putting the health of patients unnecessarily at risk.

1.7 Refrigeration, AC and Heat Pumps TOC

Current Status

The required global phase-out of CFCs and later also HCFCs, coupled with steps to reduce global warming, continues to drive transitions away from ODS refrigerants. The technology options are universal, but regional choices are influenced by local laws, regulations, standards, and economics. The primary current solutions are summarised below by application.

Refrigerants: More than 20 new refrigerants were commercialised for use either in new equipment or as service refrigerants (to maintain or convert existing equipment) since publication of the 2002 RTOC report. Additional refrigerants still are being developed, and research continues to increase and improve the physical, safety, and environmental data.

Domestic refrigeration: More than 96% of new production uses non-ODS refrigerants, primarily HFC-134a and isobutane (HC-600a). CFC emissions from the 100,000 tonne bank are dominated by final disposal due to the intrinsic equipment durability.

Commercial refrigeration: Most stand-alone equipment uses HFCs, but hydrocarbon (HC) and carbon dioxide (R-744, CO_2) use is growing, especially in Europe and Japan. Use of HCFC-22 (USA and Article 5 countries) and R-404A (Europe) dominate in new supermarket systems. CO_2, HCs, and ammonia (R-717) are used in Northern European countries. The ODS refrigerant bank is 185,000 tonnes of CFCs and 240,000 tonnes of HCFC-22. Annual supermarket systems emission rates range from 15 to 30% of their charge.

Industrial refrigeration: Ammonia (R-717) and HCFC-22 are the most common refrigerants for new equipment; costs have driven HFC-use in small systems. CO_2 use is gaining in low-temperature, cascaded systems. The ODS refrigerant bank is 20,000 tonnes of CFCs and 130,000 tonnes of HCFC-22. Annual ODS emission rates are in the 10-25% range.

Transport refrigeration: New production has shifted to non-ODS options, such as HFC-134a, R-404A and R-507A, with recent increases also for R-410A. Nearly all CFC-containing systems will be retired by 2010. The ODS refrigerant bank is 4,300 tonnes of CFCs and 17,000 tonnes of HCFC-22 with estimated annual emission rates of 25%.

Air conditioners and heat pumps: HFC blends, primarily R-410A, but also R-407C, are the most common near-term substitutes for HCFC-22 in air-cooled systems. HCs are an option for low charge systems and limited consideration of CO_2 continues. The refrigerant bank is 887,000 tonnes of HCFC-22 with estimated annual emissions at a rate of 18%. HCFC-22 recovery and containment are necessary to ensure adequate refrigerant supply for service.

Water-heating heat pumps: This small but rapidly growing application area is driven by energy efficiency. HFCs, primarily HFC-134a and R-410A, are replacing HCFC-22. CO_2 systems have been introduced in Japan and Europe. The ODS refrigerant bank is very small as historical application was at a low level.

Chillers: HCFC-22 continues to be used in small chillers; the use of HFC-134a, R-407C, and R-410A is increasing here. HCFC-123 and HFC-134a are used in larger centrifugal chillers. Ammonia or HC use is limited. The ODS bank is 107,000 tonnes of CFCs and 112,000 tonnes of HCFCs with estimated annual emission rates of 15% and 10%, respectively.

Vehicle air conditioning: HFC-134a has been used almost exclusively since 1994 in new systems in non-Article 5 countries, and now also globally. Environmental pressure such as recently adopted EU MAC directive is driving possible future replacement of HFC-134a in vehicle air conditioning by low GWP alternatives. CO_2 and also HFC-152a are currently among important candidates. The ODS-refrigerant bank is estimated to be about 60,000 tonnes of CFC-12 with an estimated annual emission rate of 10%. Few ODS-containing systems will remain in service after 2012.

What is Left to be Achieved

CFCs and HCFCs still are common in installed equipment. The CFC bank is approximately 450,000 tonnes, 70% of which can be found in Article 5 countries. The annual global CFC demand of approximately 50,000 tonnes per year is decreasing slowly. HCFCs form the dominant refrigerant bank, estimated as more than 1,500,000 tonnes, representing 60% of the total amount of refrigerants in use. Two thirds of this bank can be found in non-Article 5 countries. Current service needs are estimated at 200,000 tonnes per year. Efficient refrigerant recovery at end-of-life and retrofit to non-ODS service refrigerants are essential to avoid HCFC shortages in Article 5 countries. The critical years could be 2009 and 2010 in Europe and later on in the USA and other countries.

The refrigerant demand for service needs can be minimised by preventive maintenance to improve containment and by reusing the recovered and recycled refrigerant. Retrofitting to non-ODS refrigerant is another option. Refrigerant recovery is required in the USA and EU upon equipment decommissioning or retirement; it is receiving increasing attention in other non-Article 5 countries. The countries with successful recovery and recycling have achieved that with technician training, certification programs, and comprehensive containment regulations.

The technological options for air conditioning and refrigeration are expected to be much the same in the next four years as they are today. In applications with high emission rates, such as commercial refrigeration, designs with lower emissions, and conversion to low-GWP refrigerants, such as CO_2, are expected.

The Way Forward

Research will continue to develop additional refrigerant options. Efforts also will increase and refine the physical, safety, and environmental data for refrigerants, to enable screening, to optimise equipment designs, and to determine application requirements. Changing refrigerant options and efficiency goals are likely to drive further innovations in air conditioning and refrigeration equipment. Technical solutions are being developed to lower refrigerant charges in equipment, thereby decreasing refrigerant emissions. Use of indirect systems (applying heat transfer fluids in secondary loops) is increasing to reduce charge sizes, to enable use of sealed systems, and to facilitate application of flammable ODS alternatives. Since the recently adopted EU F-Gas Regulation will ban HFC-134a and other refrigerants with GWPs exceeding 150 in new vehicle models by 2011, the industry will be forced to make a second refrigerant change in mobile air conditioning. Several candidates continue to be evaluated, including CO_2 and R-152a as well as new low-GWP refrigerants, some of which may have low ODPs. Development of these low-GWP refrigerants also may have future consequences for the refrigerant choices in other applications.

The use of HCs and CO_2 in stand-alone commercial refrigeration equipment is expected to grow, mainly in Europe. HFC blends are the most likely near-term refrigerants to replace HCFC-22 in several applications. The dominant HCFC-22 bank is expected to continue to grow for a number of years, and the HFC bank is expected to increase rapidly, at least during the next decade.

Contrary to non-Article 5 countries, the demand for service refrigerants in most Article 5 countries will consist of CFCs and HCFCs, a tendency driven by long equipment life and with the costs of field conversion to alternative refrigerants. One of the main concerns will be maintaining adequate supplies of HCFCs. Refrigerant conservation programs to be established for CFCs in Article 5 countries will mostly be government sponsored and regulatory in nature. As in many non-Article 5 countries, they may include restrictions on the sale, use, and end-of-life disposal requirements that mandate recovery and recycling of refrigerants. These programs will be expanded in countries without such requirements.

1.8 HCFCs – Future Scenarios

Comparisons for the period to 2015 between the production and consumption identified and predicted in the 2003 HCFC Task Force Report and parallel data emerging from more recent assessments (e.g. the 2006 TEAP Task Force on Emissions Discrepancies) show that, even in the space of three years, the most likely demand profile has changed significantly. The primary causes of this accelerated growth in demand for HCFCs are rooted in the overall economic growth statistics of a number of significant developing country regions such as China and India.

Sectors experiencing particular growth in demand are commercial refrigeration, stationary air conditioning and insulation foams. Some estimates for HCFC-22 are already suggesting that demand could reach 500-600k tonnes by 2010, which is already higher than earlier market predictions for 2015. Although much of the production capacity for HCFC-22 remains in the developed countries, there is a rapidly increasing base of production in developing countries as well. There is a risk that this may partially be fuelled by the availability of certified emission reduction credits (CERs) under the Clean Development Mechanism when action is taken to mitigate HFC-23 by-product emissions. The UNFCCC is working hard to close this potentially perverse incentive, but has some major challenges in defining 'new capacity' and also identifying that element of HCFC-22 demand which is going to non-emissive feedstock applications. TEAP has been requested by Parties at MOP-18 to assist in interpreting the respective impacts of this complex mix of drivers.

Meanwhile, growth in demand for other HCFCs (e.g. HCFC-141b and HCFC-142b) is more closely linked to non-refrigeration applications. Although HCFC-141b growth will continue to be driven by remaining replacement of CFC-11 and natural market growth in the closed-cell foam sector, there is concern that an additional and growing volume of the chemical is being consumed as a solvent or within other emissive applications. Further work is required to ascertain the precise end-use consumption patterns within these potentially emissive applications.

For HCFC-142b, the use pattern is closely linked to the foam sector, particularly the extruded polystyrene (XPS) application. The availability of relatively inexpensive extruding equipment in China and elsewhere and the low cost of polystyrene as a feedstock have both contributed to XPS being the insulation material of choice. With new building burgeoning in many developing country regions, the growth of HCFC-142b/22 use in the foam sector could add an additional 50,000 tonnes of annual consumption to these gaseous blowing agents by 2015.

1.9 Banks and Bank Management

In 2005, the IPCC/TEAP Special Report on Ozone and Climate (SROC) focused attention on the substantial remaining legacy of large historic use of ODSs in applications which were not significantly emissive in the short-term. The materials are stored up in what have become known as 'banks'. In 2002, these were estimated to exceed 3.5 million ODP tonnes and will still be at over 2 million ODP tonnes in 2015. This finding has had implications for the assessment of the future impact of historic ODS consumption and it was realised that the current depletion of the ozone layer, did not reflect the full impact of this historic consumption.

Since that realisation across the ozone community, there has been substantive and close co-operation between the Science Assessment Panel and the TEAP in order to make assessments of the impact of on-going releases of ODS into the atmosphere well into the future. The dynamics of such releases are complex because the nature and locations of the banks are, in many cases, diverse. Nevertheless, the Science Assessment Panel has been able to establish that the recovery of the ozone layer may be significantly affected by the on-going release of banked ODS.

On the more positive side, banks can offer opportunities for recovery of ODS which can not only limit further impacts on ozone recovery but can also have considerable climate benefits. Accordingly, the Parties have asked TEAP to focus a number of its recent activities in further quantifying the banks and, in particular documenting methods of emission reduction from them and the potential for recovery practices at end-of-life. Many of these methods and practices had already been adopted in some regions of the world as a general expression of good environmental practice. However, the significance of these measures is certainly now more prominent as a result of the SROC.

One of the on-going barriers to bank management is the economics of the selected measure, which can vary substantially by sector/application and by region. Although ODSs are not included in the basket of greenhouse gases under the Kyoto Protocol, there is currently a growing interest in using the voluntary carbon market as a possible vehicle for funding ODS recovery that would otherwise be classified as uneconomic. Although protocols still need to be written to ensure environmental probity, the voluntary market could establish a value for such projects on the basis of their demonstrable climate benefits rather than against a strict adherence to the Kyoto flexible mechanisms (e.g. the CDM).

1.10 Task Force on Emissions Discrepancies

The Task Force on Emissions Discrepancies compared the emissions determined from atmospheric measurements with the emissions calculated via bottom up methods for refrigeration, AC and foams. It presented concluding remarks as follows.

1.10.1 General Comments

This assessment of the available data on emissions derived from bottom-up models and atmospheric measurements has indicated better than expected correlation for most chemicals reviewed. However, the following specific observations should be highlighted:

- No single data source from UNEP, AFEAS or any of the bottom-up methods adopted can be considered as providing a uniquely accurate snapshot of the total situation. Accordingly, on-going development in the quality of each source will remain important.
- There is considerable variability in consumption and resulting emissions estimated year-to-year in the early phases of introduction of a new chemical while reporting practices become established
- There is particular sensitivity to the completeness and accuracy of the UNEP consumption dataset because differences between the dataset and bottom-up analysis are assumed to be representative of emissive applications.
- There is still work to be done with HCFC-142b in establishing its emission sources and particularly rates of loss from thermoplastic foams. This may include the continuing development of more versatile bottom-up models.

1.10.2 Conclusions Regarding CFC-11

The discrepancies between emissions derived from bottom-up methods and those derived from atmospheric measurements are largest for CFC-11. Whether this is a systematic discrepancy remains a matter for further study. However, the following observations have emerged from this study:

- There is no concrete evidence to suggest that CFC-11 emissions from closed cell foams are being under-estimated at present, although there is potential that first-year losses could have been higher than forecast in the earlier years of specific technologies.
- The currently estimated bank of CFC-11 in foams would not, in itself, be sufficient to make-up the cumulative difference between bottom-up and atmospherically derived estimates over the period of use in foams.
- The discrepancy between bottom-up and top-down emissions estimates for CFC-11 suggests the potential for additional emissive

uses for CFC-11 that are, as yet, unaccounted for within the UNEP dataset.

- The global atmospheric lifetime of CFC-11 and other gases have substantial uncertainties that directly affect emission estimates from the top-down approach. A lifetime of 65 (52-88) year would be required to minimise the discrepancy between CFC-11 emissions derived from top-down and bottom-up methodologies. Because this lifetime is larger than the best estimate, CFC-11 lifetime of 45 (35-57) year, which is derived from modelling and observation-based methods, it is unlikely that the entire emissions discrepancy results from an error in the CFC-11 lifetime.

1.10.3 Significance for Current Bank Sizes and Future Emissions Projections

One of the objectives of Decision XVII/19 was that further study of discrepancies between emissions derived from bottom-up and those derived from atmospheric measurements could allow for improved estimates of present-day bank magnitudes and, ultimately, future emissions of ozone depleting substances. As a result of the analysis conducted as part of this report the following conclusions can now be drawn:

- It remains true that atmospheric projections of future halocarbon emissions and atmospheric mixing ratios depend upon the size and character of present day banks and the rates of emissions from these banks as well as emissions resulting directly from future production and use.

- In comparison with the situation described in Annex 11B of the Special Report on Ozone and Climate, it has been possible to reconcile the various methods used to derive emissions from bottom-up modelling and from atmospheric measurement for most ODS. The only possible exception is CFC-11. This reconciliation has been partly due to a reassessment of the impact of atmospheric lifetimes and mixing ratios on the one hand and uncertainties in consumption patterns and emission functions on the other.

- This provides further evidence that there is no fundamental error in either approach but that appropriate caution is necessary in relying on either dataset independently of the other.

- In the case of CFC-11, it may be necessary to carry out further analysis of the use patterns represented in the UNEP consumption dataset before drawing further conclusions on the size of present-day banks and likely future emissions.

1.11 Low-ODP Substances

Original controls under the 1987 Montreal Protocol capped halon production and consumption and reduced CFC production and consumption by 50%. As the science became clear that more must be done, Parties added ODSs to lists of controlled substances and accelerated their phase-out. Today, only the lowest ODP substances are not controlled. Uncontrolled ODSs with significant market potential include n-propyl bromide (nPB) and trifluoromethyl iodide (CF_3I).

Since 1997, various Decisions (e.g. particularly IX/24, X/8, XIII/5, XIII/7) urged reporting any uncontrolled low-ODP substances, asked the Scientific Assessment Panel to assess the ODP of such substances and the possible effect on the ozone layer, asked the Technology and Economic Assessment Panel to evaluate the current and potential use of each substance, and urged Parties to discourage the development and promotion of such substances.

The April 1999 TEAP Progress Report predicted significant production of nPB and reiterated that nPB could be safely used only under limited circumstances where emission controls and worker exposure protection could minimise the effects of potential toxicity.

The May 2000 SAP report “Assessing the Impacts of Short-Lived Compounds on Stratospheric Ozone” reported that an uncontrolled substance containing chlorine or bromine would be harmful to the ozone layer only if the substance has 1) vapour pressure sufficient to generate a significant gas-phase concentration in the atmosphere, 2) low solubility in water, and 3) a lifetime in the lower atmosphere long enough for it or its halogen-containing degradation products to reach the stratosphere. The SAP explained that the amount of low-ODP emissions reaching the stratosphere was strongly dependent on the region and season of emission. Parties therefore encouraged TEAP to provide the SAP with emission estimates for nPB by latitude and season.

The 2001 TEAP “Task Force Report on the Geographical Market Potential and Estimated Emissions of n-Propyl Bromide” presented estimates of latitude-specific emissions and reported that nPB is aggressively marketed for applications traditionally using ozone-depleting and non-ozone-depleting substances.

Since 2003, TEAP/CTOC has reported the updates of nPB under Decision XIII/7 with general information on production, consumption and emissions, as well as toxicity data and regulatory actions in the 2005 and 2006 TEAP Progress Reports. No accurate production and emissions estimates are available because there is no yearly reporting by the Parties. The SAP 2006 Assessment Report includes the latest estimates of the latitude-specific ODPs.

The ODPs of nPB are 0.1 for tropical emissions and 0.02-0.03 for emissions restricted to northern mid-latitudes, unchanged from the previous assessment.

In 2006, Honeywell proposed a new refrigerant blend of tetrafluoropropylene with CF_3I as a minor ingredient, which is one possible option to satisfy the EC F-gas MAC Directive (2006/40) that requires a phase-out between 2011 and 2017 of HFC-134a use in air conditioning systems installed in new vehicles sold in the European Union.

The upper-limit ODPs for CF_3I are 0.018 for tropical emissions and 0.011 for mid-latitude emissions. The previous SAP report had an upper limit of 0.008. TEAP and its Refrigeration TOC have not yet estimated the possible future fleet of automobiles, the likely penetration of air conditioning systems, the portion of new vehicle air conditioners that may use the Honeywell ODS blend, the likely service practices, and the total possible emissions under the worst case scenario.

Parties may wish to re-consider the earlier proposal by the SAP and TEAP of phasing out all ODSs pending full assessment by the Assessment Panels. Production and consumption of specific chemicals proved to be harmless to the ozone layer could be permitted after the assessment through an adjustment of the Protocol. Industries proposing new potential ODS could support research to obtain information on the substances' actual ozone-depletion potential.

1.12 Military Progress

Military organisations have made significant progress in eliminating ODS use. The remaining uses are primarily halons and refrigerants. In non-Article 5(1) countries, these applications continue to be satisfied by recycling existing stocks of ODS. A small number of uses have been met through Essential Use Exemptions. Information about military ODS uses and alternatives is not as readily available as for the commercial sector. But many countries have provided information through a series of global military workshops and multilateral and bilateral military-to-military exchange projects.

The military has begun producing the first modern aircraft that do not use halon in engine nacelles. Five such military aircraft are currently in final development or production in the U.S. and U.K.

Dry bays are the interstitial spaces within aircraft structures adjacent to fuel tanks, that contain electrical cables, hydraulic lines or other equipment and which can be the source of fires or explosions. Inert gas generators are beginning to replace halon in new aircraft.

Two types of aircraft use halon during combat to inert the ullage space in their fuel tanks within wing structures. One of these, the F-16, is used by many countries. There are as yet no alternatives that can be retrofitted into these aircraft.

Halon 1211 is used by some countries in wheeled extinguishers placed adjacent to aircraft parking spaces for "first response." An aircraft can take off following a small pooled-fuel extinguished by halon, but not with other agents.

Because the choice of fire protection for ships and submarines is very platform-specific, a solution for one vessel or application is not necessarily a solution for all. As a result, halon usage across vessels is not consistent. Parties replace halon on warships as specific conditions and costs permit.

Some shipboard CFC refrigerant applications will remain for the foreseeable future due to a lack of economically viable retrofit options and high retrofit costs where alternatives are available. All CFC systems on EU ships and submarines will have been converted to HFC alternatives by the end of 2008 because of a legal mandate.

New technologies have only recently been introduced that can replace halon in ground combat vehicles. Crew protection systems activate very quickly and provide significantly improved crew survival rates. It is unlikely that existing vehicles can be modified, but alternatives should be designed into future vehicles.

Halon has been or is being removed through attrition from virtually all buildings. This removed halon has become the primary source of recycled halon for support of continuing uses in weapons platforms.

Canada, Germany, Norway, Sweden, the UK and the United States reported that they have virtually eliminated the use of ozone-depleting solvents in other military applications. Methyl chloroform available under an Essential Use exemption is used to manufacture solid rocket motors for propelling large payloads into space.

It is easier to design halon alternatives into new equipment than to modify existing equipment. Military systems tend to have very long lifetimes, lasting half a century or longer. They are highly integrated, highly constrained in terms of space and weight, and modification costs are generally very high.

Since its 1989 report, the Halon Technical Options Committee’s military experts have described halon uses in weapons systems that would persist beyond a phase-out date, and have predicted that new halon production would not likely be necessary provided that existing halon inventories were managed in a way that preserved them for ongoing military requirements.

These estimates and predictions appear to remain valid today. It appears likely that some ODS will continue to be necessary for legacy systems until mid-century, without additional technical breakthroughs.

There appears to be adequate supplies of halon 1301 to meet critical defence needs. Supplies of halon 1211 are less clearly in surplus with some indications of a shortage in some countries. There is growing concern about the availability of halon 2402 outside of Russia. In particular, India has reported a growing shortage that could be problematic. India also reported that halon 2402 systems are being routinely converted to halon 1301 to improve safety and help ensure future supplies.

Supplies of recycled or recyclable ODS are not always located in the areas where they are needed. Transnational shipment for reconditioning and re-use had become an occasional problem for military organisations. As global supplies decline, the need for flexibility in moving ODS to locations they are needed is becoming increasingly important.

Executive Summaries of all 2006 TOC Assessment Reports

2 Executive Summary of the 2006 Assessment Report of the Chemicals TOC

Introduction

This is a first assessment report of the Chemicals TOC (CTOC) since the reorganisation of the former ATOC (Aerosols, Sterilants, Miscellaneous Uses and CTC TOC) and STOC (Solvents, Coatings and Adhesives TOC) to the present CTOC in 2005. Its membership incorporates solvent, feedstock, and laboratory and analytical use experts mainly from the former STOC; and CTC, non-medical aerosol and miscellaneous uses experts from the former ATOC. In addition the experts on process agents and destruction technologies have been invited from the former task forces. Furthermore some new members have been recruited mainly from Article 5 countries to get balanced expertise.

The CTOC is responsible for annual progress updates on Solvents, non-Medical Aerosol and Miscellaneous Chemical Uses, and also for completing assessments requested by the Parties on Process Agents, Feedstocks, Laboratory and Analytical Uses, Carbon Tetrachloride (CTC), Destruction Technologies as well as new chemicals such as n-Propyl Bromide (n-PB).

The 2006 assessment report will describe the progress being made during these four years in phasing out ODSs in each sub-sector which is included in the CTOC activities.

2.1 Process Agents

The TEAP established Process Agents Task Forces (PATF) three times, first in 1997, in 2001 and in 2004, responding to the request of the Parties to review process agent uses applied by the Parties. In 2003, decision XV/7 provided a new list of 26 process agent applications to be reconsidered at the seventeenth Meeting of the Parties in 2005. With further 11 nominations for process agent uses from 8 Parties in 2004-2005, the 2004 PATF presented a report of its assessment to the Sixteenth Meeting of the Parties (2004). In 2006 the TEAP/CTOC considered two further applications for process agent designation, the one concerning the use of excess BCM in a reaction where a small part of this ODS was consumed as feedstock, and the other involving reduced energy consumption in the production of vinyl chloride monomer when small quantities of CTC were present in the reaction mixture. The 2006 TEAP Progress Report described the recommendation that both of these be considered process agent uses.

A guidance note with pro-forma has been prepared by the CTOC (Appendix 6-1 on page 102-105 in the 2005 TEAP Progress Report) to help Parties provide all necessary information when making nominations and submitting data for process agent applications to the Ozone Secretariat and the TEAP according to the decision XVII/6 paragraph(2) and paragraph (4).

Through intensive discussions on the findings of the PATF, three important decisions have been adopted on process agents at the seventeenth Meting of the Parties (2005). Decision XVII/7 listed a revised Table A with 39 entries, and decision XVII/8 presented an interim Table A-bis (29 new entries) subject to reconfirmation at the Nineteenth Meeting of the Parties in 2007.

Decision XVII/6 has called on Parties to submit necessary data of the process agent uses listed in decisions XVII/7 and XVII/8 before 31 December 2006 to the Secretariat and the TEAP. With these information, the TEAP/CTOC will investigate all the applications listed in decision XVII/7 and in decision XVII/8 and report to the 27th OEWG in 2007, and every other year thereafter and make recommendations to the Parties at the twentieth Meeting in 2008, and every other year thereafter, on process agent use exemptions; on insignificant emission associated with a use, and process agent uses that could be added to or deleted from table A of decision X/14 according to decision XVII/6 paragraph (7). Further, the TEAP/CTOC will review in 2008 and every other year thereafter, emissions of table B of decision X/14, taking into account and data reported by the Parties and will recommend any reductions to the make-up and maximum emission on the basis of that review.

It will be important to consider how to reduce the emissions of ODS from the process agent uses. Some of the more emissive uses of process agents have been modified, either by improving emission controls, by substituting a non-ozone depleting (or at least a less-ozone-depleting) substance for the original process agent, or by ceasing the process altogether. Further opportunities will exist for improving controls and for substituting by less harmful substances. For example, TEAP considers that in some instances HCFCs could offer the unique properties required in these chemical processes i.e. non flammable, good chemical and physical properties, excellent solvency, etc. in place of fully halogenated ODS, which have higher ODPs.

Also important is a tighter collaboration between the Executive Committee (ExCom) and the TEAP to clarify the real figures of process agent applications in Article 5 countries.

2.2 Feedstocks

Feedstock uses were summarised in the 2005 CTOC Progress Report in detail under Decision X/12. CTC, CFCs and HCFCs can be feedstocks either by being fed directly into the process as a raw material stream or they can be produced as an intermediate in the synthesis of another product.

Major feedstocks in chemical industries include HCFC-22, CFC-113 and HCFC-142b as raw materials for manufacturing a variety of fluorinated polymers and elastomers. Historically CTC was a major feedstock for CFC-11 and CFC-12, but as the phase-out of CFC production continues, volumes of CTC for this application will diminish. Instead some HCFCs and CFCs have been used as feedstocks for producing alternative CFCs like HFC-125. 1,1,1-Trichloroethane (TCA) is converted to HCFC-141b and HCFC-142b, which can continue until 2040 at high volume for emissive uses mainly in Article 5 countries. Methyl bromide and trifluoromethyl bromide can be used as feedstocks in manufacture of detergents and pharmaceuticals.

The ODS emissions from feedstock applications were estimated on the order of 3,500 metric tonnes or 1,619 ODP tonnes with an assumption of 0.5% emission based on the quantity of the feedstock used in the production according to the IPCC recommendation.

Recently the HTOC raised a question that there has been use of Halon 1301 as a feedstock and the CTOC found that Halon 1301 is a very useful feedstock for preparation of bioactive compounds such as Fipronil, a broad-spectrum insecticide. (TEAP 2006 Progress Report) The continued production of halon 1301 for feedstock use raises some serious issues that Parties may wish to consider and evaluate options to resolve.

A Party defines its own feedstock uses and exercises a range of stringency in reducing and eliminating unnecessary emissions of ODSs. TEAP and CTOC have become aware of a feedstock use that could jeopardise protection of the ozone layer and continue to investigate on all feedstock uses, levels of emission and methods to limit emissions. A watching brief will be maintained by the CTOC for feedstock uses of ODS that may not have been recognised formerly.

2.3 Laboratory and Analytical Uses

Under Decision IX/17 an Essential Use Exemption for laboratory and analytical uses of ODS was introduced. Decision X/19 extended this exemption until 31 December 2005. In 2003, the Fifteenth Meeting of the Parties, in Annex 1.B, approved the essential use of 1.025 metric tonnes CFC-113 and CTC for Poland in 2004.

Under Decision XVII/10, the Parties agreed to consider certain uses of methyl bromide as laboratory and analytical uses for the year 2006. In that same decision, Parties requested the TEAP to review those and other potential laboratory and analytical uses of methyl bromide, and, at the same time, to consider the criteria that had been previously adopted for laboratory and analytical uses of Annex A, B and C substances, in order to assess their relevance of those criteria to the laboratory and analytical uses of methyl bromide.

Methyl bromide is one of the most chemically reactive of the ozone depleting substances, and it finds use in laboratories as a ‘methylating agent’. Alternatives are available for many of these uses, and they often come into use when supplies of methyl bromide held in research laboratories are exhausted and difficulty is encountered in the purchase of quantities of 10-20 kg, as had been past practice.

Replacements for methyl bromide in analytical applications can be more difficult to find, but uses of this type are generally on a larger scale and there may be significant emissions. This is especially while methyl bromide uses continue to be permitted (CUN, QPS) and there are requirements for calibration or comparison with potential replacements.

The reports of laboratory uses of ODS received by the Ozone Secretariat in the period 2002-2005 are summarized in the table below. Small quantities (<0.005 MT) of CFC-12, CFC-124, BCM and HBFC-2281 are not included in the table.

Laboratory Uses of Quantities of Ozone Depleting Substances (MT) Reported to the Ozone Secretariat

Year	Parties Reporting	Category	CTC	CFC-11	CFC-113	Methyl chloroform (TCA)
2005	1	Production	47			
	6	Import/ consumption	0.78	0.02	1	
2004	4	Production	81.7		54.9	2.78
	6	Import/ consumption	5.09	<0.005	<0.005	1.81
2003	4	Production	69.2			2.80
	12	Import/ consumption	3.23	3.12	9.50	0.02
2002	3	Production	85			22
	13	Import/ consumption	16.52	<0.005	<0.005	9.11

Decision XV/8 asked TEAP to report annually on the development and availability of laboratory and analytical procedures that can be performed without using the controlled substances in Annexes A, B, and C (groups II and III). There has been only slow progress in replacing ozone depleting substances (ODS) that are used in laboratory and analytical procedures with substances that are less harmful to the ozone layer. In most cases this is due to the availability of ODS at favourable prices under the EUE and failure of alternative candidates to meet the demanding specifications that have brought about the use of ODS in the first place.

In 1996 the United States EPA compiled a list of institutions that develop laboratory standards, procedures, instructions and regulations that require the use of ODS, and also a list of those institutions that are investigating, researching or developing alternative procedures that do not require ODS. A section of the report listed 45 procedures that employed ODS (CTC, CFC-11, TCA, CFC-12, CFC-113, bromochloromethane, and HCFC-21), thus bringing to attention some opportunities for substitution.

A report commissioned by the EC and received in 2005 identified 125 laboratory procedures in which ODS were used – CFC-113>CTC>TCA, with smaller quantities of other CFCs and halons – mostly in extraction steps. The laboratory uses of ODS in 2003 totalled 9.933 ODS tonnes. It was estimated that this figure could be reduced by 37% by 2008 through the use of feasible non-ODS alternatives.

Opportunities to reduce the use (and therefore emissions) of ODS in preparative and analytical laboratories will arise as adoption of Green Chemistry practices – good laboratory practices and environmentally sound management of chemical reactions - spreads from the initial development in the USA and could eventually be enshrined in regulation.

While much as been discovered in the last few years, Parties need to be aware that there could be laboratory and analytical uses of ODS that have not yet come to attention. The surveys conducted by the United States and the European Union may be consulted to identify similar uses in other countries. Such uses may be discovered when orders are placed with suppliers of these chemicals, but volumes are usually small, and so some years may elapse before an on-going use comes to light. Members of the CTOC and other Technical Options Committees that report to the TEAP will maintain a watching brief on possible uses and report to Parties from time to time.

2.4 Aerosol Products, Non-medical

World-wide aerosol fillings have grown over the last years and were close to 11 billion cans in 2005, the largest number ever. Today more than 99.5% of non MDI aerosols use non-CFC formulations world-wide. There are no technical barriers to global transition to non-ODS alternatives in all these applications, which require either low flammability or specific pharmaceutical approval.

The latest CFC consumption in the aerosol sector reported by Parties in 2003 and 2004 was around 2,000 tonnes in Article 5 countries, down from the estimated use of 4,300 tonnes in 2001. Currently available alternatives for CFCs used in non-MDI aerosols as propellants include hydrocarbon aerosol propellants (HAPs), dimethyl ether (DME), HFCs (HFC-152a, HFC-134a and HFC-227ea), HCFCs (HCFC-22 and HCFC-142b) and compressed gases (CGs) such as compressed air , CO_2, N_2 and N_2O. HAPs and DME are both flammable and explosive and strict safety measures are required. HFCs are non-ODS but should be used only where they provide important safety, functional or health benefits for the users due to greenhouse gases.

There are many alternatives to replace ODS used as solvents or as active ingredients in non-MDI aerosols. These replacements can be hydrocarbons, high boiling HFCs like HFC-43-10mee, and HFC-245fa, high boiling HCFCs like HFC 141b, and other solvents like HFEs or even water. Many aerosol products have been replaced by such not-in-kind substitutes as mechanical pumps (finger or trigger pumps), sticks, roll-ons, brushes, etc.

In 2005 the residual CFC consumption was only due to the use in Article 5 countries. The main groups of non-MDI aerosol products still using ODS (CFC/HCFC) are:

- local anesthetics, vaginal foams, wound sprays, throat and nasal sprays, traditional Chinese medicines;
- Industrial/technical aerosols (dusters, electronics cleaners, freeze sprays, spinnerette sprays, anti-spatter sprays, tire inflators, fluorinated greases deposition etc.);
- Insecticides and disinfectants for aircrafts etc.

It is expected that the completion of global CFC phase-out in non-MDI aerosols will occur in the very short term as the reduction schedule mandated by the Montreal Protocol comes into force in Article 5 countries.

The residual ODS phase-out in the non-MDI aerosol sector will require:

- Efforts by national environmental facilities and governmental bodies, including national legislation and enforcement;
- Technical/financial assistance for reformulation;
- Educational assistance in alternatives choice and handling;
- Sufficient time for the conversion of medical aerosols that must be clinically tested and approved by national health and drug authorities.

2.5 Carbon Tetrachloride (CTC)

In accordance with decision XVI/14, TEAP and CTOC provided 'a report on sources of carbon tetrachloride emissions (CTC) and opportunities for reductions' in 2006.

The main sources of CTC emissions were initially its feedstock applications – conversion into fluorocarbons such as CFC-11 and CFC-12. CTC demand for the production of CFC-11 and CFC-12 exceeded 1 million tonnes in 1987. More recently, it has been used as feedstock for the production of a number of alternative CFCs like HFCs. By 2010, new HFCs can be estimated, using data in IPCC/TEAP 2005, to exert a demand of some 54 kilo-tonnes per annum of chemical intermediate CTC into HFC-245fa, HFC-236fa, and HFC-365mfc. In addition, there are a number of designated essential uses for CTC in pharmaceutical and agrochemical applications together with a large list of approved process agent uses for CTC.

The calculation for the CTC demand 2002-2009 was based on the CFC production for basic domestic needs for the period 2003-2009, an estimate of the "make-up" figure for process agent use contained in Decision X/14, and a forecast of the CTC use as a feedstock for HFCs through to 2015 on the future requirements of the foam insulation market (IPCC/TEAP Report, 2005). (cf. TEAP Progress Report 2006, p78-90)

Table 2.1 Estimated total CTC requirements for assumed demands (tonnes)

Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
CFC Feedstock	126,240	108,425	96,837	74,903	51,353	26,476	21,441	14,247	0
Emissive uses	36,426	33,784	30,700	32,958	34,636	36,414	38,299	40,297	41,920
Other Feedstock	3,295	23,649	32,412	38,231	42,342	44,399	46,422	48,376	50,285
TOTAL	**165,961**	**165,858**	**159,949**	**146,092**	**128,331**	**107,289**	**106,162**	**102,920**	**92,205**

The possible CTC emissions from these requirements were calculated between 13,728 and 21,960 metric tonnes in 2006 with reasonable assumptions.

According to the calculated emissions estimated from the historically observed CTC concentrations, annual CTC emissions peaked at approximately 130,000 tonnes in the mid-1980s, but then declined to about 80,000 tonnes by the late 1990s. Given the range of lifetimes considered for CTC, these figures could involve uncertainties of ±30%. Recent data from the IPCC/TEAP Report, 2005, estimate emissions in 2002 to be 64,000-76,000 kilo-tonnes.

There is an emerging conclusion that the discrepancy between emission data calculated from atmospheric concentrations and those derived from consideration of industrial activity is due to under-estimation or under-reporting of the latter.

The foregoing conclusion may need reconsideration if the behaviour of CTC in the atmosphere is reassessed by the Science Assessment Panel. As for additional formerly unrecognised sources, there is the possibility that CTC is emitted from landfills, which have come to attention recently as temporary sinks from which a number of chemicals substances can be released to the atmosphere. In the case of CTC, the substance might have entered the landfill as a component of wastes, or possibly been generated in the landfill by chemical or (more likely) microbiological action. No reports are available of such emissions but the attention being paid to landfills in recent times could provide confirmation or refutation of this hypothesis.

Three potentially significant areas require further investigation to get better data for industrial emissions in Article 5 and non-Article 5 countries to enable resolution of the discrepancies with atmospheric measurements; the first area is that of CTC production in order to identify, in particular, the production of CTC as a by-product and its subsequent use, re-cycling or destruction; the second area is to identify any other requirements for CTC and the third is the emission of CTC from sources such as landfills.

2.6 Solvents

Over 90 % of ODS solvent uses (based on the peak consumption of 1994-95) have been reduced by substitution to not-in-kind technologies and conservations and the remaining less than 10% of the ODS market is shared by several in-kind solvent alternatives.

Not-in-kind alternatives options include no-clean mainly in electronics and aerospace, aqueous systems in degreasing and precision cleaning, hydrocarbon in precision mechanics and oxygenated solvents in diverse cleaning applications. The primary in-kind substitutes for 1,1,1-trichloroethane (TCA) and CTC cover chrlorocarbon alternatives such as trichloroethylene, perchloroethylene and methylene chloride. Also, a brominated substance, n-propyl bromide, with similar solvent properties to those of the chlorinated solvents, has taken a significant market share in recent years for defluxing, general cleaning and adhesives applications in spite of its ozone depleting potential and toxicity. The in-kind substitutes for CFC-113 and CFC-11 are fluorinated alternatives such as hydrochlorofluorocarbons (HCFC-141b and HCFC-225ca/cb), perfluorocarbons (primarily C_6F_{14}), hydrofluorocarbons (HFC-43-10mee, HFC-365mfc and HFC-245fa, HFC-c447ef) and hydrofluoroethers (HFE-449s1, HFE-569sf2). HFCs are available in all regions but their uses have been primarily in non-Article 5 countries due to relatively high cost and importance of high tech industries. Their growth is expected to be minimal due to the increasing concern about their high GWP. In Article 5 countries, use of HCFC-141b is still increasing especially in China, India, and Brazil and its consumption exceeded 5,000t in 2002 (AFEAS, 2002). The HCFC total consumption phase-out for Article 5 countries is scheduled for 1 January 2040 with a freeze of consumption in 2015. But some countries are accelerating this for solvents (e.g., Malaysia, Thailand) – while applications that utilize HFC or HFE may be interchangeable transitions from HFCs and HFEs as to hinder conversions. Further barriers to transition occur where complex and crucial components are involved.

The challenges that are facing the world are phase out of ozone depleting substances in Article 5 countries. Preferable alternatives have been identified throughout the world and are generally readily available but the major drawbacks to the implementation are primarily access to information, and knowledge about what are the acceptable alternatives. A second major hurdle to be overcome is the economic considerations. However, the biggest problem is being able to identify the small and medium users who, collectively, make up a major portion of the solvent market.
Progress in achieving the phase-out in Article 5 countries has been good, given the widespread use of ozone-depleting solvents and the variety and complexity of their applications. Of the various uses, the large-scale electronics industry has progressed furthest towards a complete phase-out, although this is not the case with smaller units. Full phase-out for metal cleaning applications is hampered by the large number of small users, many of whom are undercapitalised. In precision cleaning applications, users have been aggressively implementing alternatives. Yet, in some cases, they are still searching for solutions for cleaning precision parts that are especially vulnerable to residues or reactions, or that have unusually stringent cleanliness criteria.

The regulatory changes continue to impact use of solvents as well as containment, emission, safety, health and recycling requirements. In some cases, they may require solvent and/or equipment change or a new cleaning process.

European Regulation Changes

It is important to note that HFC solvent uses have not been restricted in any way in Europe by the April 2006 Regulation on F-gases. By now the 1999 VOC Directive limiting emission of solvents in industrial uses including surface cleaning, has been fully implemented in EU 15. The new European chemical policy called REACH (Registration Evaluation and Authorisation of Chemicals) will come as a new regulation mid 2007. It could impact substances availability for certain uses (including solvents) in cases where low sales volumes cannot support the testing regime required by REACH or where the re-assessed properties of the substance militate against its use.

Japanese Regulation Changes

PRTR (Pollutant Release and Transfer Register) regulation came into effect in 2002. The law requires reporting of release and transfer of 354 substances including all ODSs and chlorinated solvents. The other new regulation which will have a major effect in controlling cleaning operation is the VOC (volatile organic compound) regulation. It came into effect from April 2006. The VOCs emitted in industrial cleaning in 2002 was 141,000 tons. Of those VOCs emitted, 66% was chlorinated solvents such as methylene chloride (34%), trichloroethylene (23%) and perchloroethylene (9%). In order to achieve reduction in emission, various combinations of cleaning equipments, operating manuals and peripherals to suit the processes are needed and efforts are made to develop such systems.

The selection of the alternative technologies to ODS solvents for Article 5 countries should be:

- "No-clean", keep-clean
- Aqueous/hydrocarbon-surfactant cleaning
- Organic solvent cleaning (with solvents less toxic than non-ozone-depleting halogenated solvents)
- Non-ozone-depleting halogenated solvents (HFC, HFEs, TCE, PCE)
- Organic solvent cleaning (with solvents more toxic than non-ozone-depleting halogenated solvents
- HCFC-225
- HCFC-141b
- PFCs

All applications to the Multilateral Fund that propose the use of aqueous or hydrocarbon surfactant cleaning should include funding for pollution prevention, recycling, waste water treatment, shower and eye-wash facilities and drying equipment, as appropriate. Applications that involve the use of organic and hydrogenated solvents should include containment equipment, adequate ventilation control, and/or low emission equipment. The guidelines for all processes should include requirements for personnel safety, for example, the use of eye guards and other personal protection equipment by workers who perform the cleaning operation and means for the measurement of operator exposure.

The CTOC will investigate the Essential use Exemption of CFC-113 for aerospace applications by the Russian Federation for the years 2007 to 2010.

2.7 Destruction and Other Issues

Under the decision XII/8, TEAP set up two separate task forces and reported to the Parties at MOP-14 in 2002 (Report of the TEAP April 2002 Volume 3; Report of the Task Force on Collection, Recovery and Storage (TFCRS) and Report of the Task Force on Destruction Technologies (TFDT). The TFCRS estimated the amounts of CFC contained in refrigeration equipment to be between 350,000 and 400,000 ODP-tonnes in 2002, 1.25 million ODP-tonnes of CFC-11 still remaining in installed foams in 2010 and Halon 1301 and halon 1211 installed in firefighting equipment to be 450,000 and 330,000 ODP-tonnes, respectively in 2002. The barriers to collection, recovery and storage are, for example, (1) lack of appropriate legislation and infrastructures, (2) financial resistance where manufacturer or owner has to pay, (3) ineffective collection of rigid construction foam within building structures, (4) restriction of trans-boundary movements of waste. The TFDT reviewed criteria for approval of the destruction facilities and assessed their environmental and economic performance. 16 ODS destruction technologies met the screening criteria among 45 considered.

In 2005, TEAP established the Task Force on Foam End-of-Life Issues, in response to decision XVII/10. The report in May 2005 was mainly focused on the description of the technical and economic aspects of blowing agent recovery and destruction from appliance and building insulation foams and proposed a new parameter, recovery & destruction efficiency (RDE) which would be valuable to accommodate the whole recovery and destruction chain, and concluded that currently practised recovery and destruction process have the potential to reach an RDE of greater than 85%-90% with a net cost of recovery of $25-40/kg. The existing banks of CFCs and HCFCs are estimated to be 1.5 million and 0.75 million tones, respectively.

Under the decision XVII/18 and decision 47/52 of the ExCom of MLF, foam, halon and refrigerant banks on the basis of recoverable ODS were discussed in order to assess the current and future requirements for the collection and disposition of non-reusable and unwanted ozone-depleting substances in Article 5 countries. In addition to non-reusable CFCs from refrigeration (3,500 metric tonnes), there is likely to be an excess of CTC production in the near future, and the excess will need to be destroyed. However, ODS recovery and destruction in these cases will not be achievable without any additional stimulation which may arise from other environmental agreement and economic imperatives.

Under the decision XVII/17(3), the CTOC reviewed possible synergies with other conventions, such as Basel, Rotterdam and Stockholm Conventions which are related to Montreal Protocol in several issues as environmentally sound management of ozone-depleting substances and their wastes. One of the main synergies between them will exist in the implementation of best practices in order to reduce and eliminate the use of certain chemicals and their waste, also reducing the pollution to the environment.

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

3.1 Introduction

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

The first technology transition in non-Article 5 countries took place in the early 1990s and led to the introduction of transitional substances such as HCFCs as well as the increasing use of hydrocarbons and other non-ODSs. A similar transition is now also reaching completion in Article 5 countries. Meanwhile, in non-Article 5 countries, attention has been firmly focused on a second technology transition out of HCFCs. This has resulted in further switches to both hydrocarbon and CO_2 technologies[1] and these technologies have gained market share in several sectors. Nonetheless, there are a number of sectors where safety and performance requirements have necessitated the use of HFC-based technologies – most notably in polyurethane spray foam and steel-faced panels. Secondary transition is still awaited in some key markets, such as the extruded polystyrene (XPS) market in North America and blowing agent selection for this sector is still not finalised.

As before, this report details, for each foam type, the technically viable options available to eliminate CFC the use of ODSs as of 2006. It concentrates primarily on the transition status by product group and region and on likely future scenarios. In this edition, the management of banks and emissions is promoted from an Appendix to a chapter in the core report, reflecting the subject's increasing importance to legislators. Coverage of technical options per se continues to be located for information purposes within the appendices only.

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

3.2 Transition Status

General

- In 2005 the consumption of CFCs dropped below 1% of total blowing agent usage for the first time.
- The very strong growth in the demand for insulation foams, particularly to support energy efficiency improvements in buildings and appliances continues to be a major factor in the demand for CFC alternatives.
- Controls on end-of-life emissions of fluorinated blowing agents are being applied within the appliance sector in several developed countries, while additional voluntary actions are being actively encouraged for blowing agent recovery in the building sector in Japan.
- In addition, consideration is being given to bank management projects in Latin America although foam recovery may be logistically difficult, particularly in remote regions.

Developing Countries

- Virtually all transition projects phasing out CFCs are materially complete in non-insulation areas and are nearing completion in insulation applications. However, many projects are still awaiting formal closure.
- HCFCs continue to be the dominant blowing agent in virtually all insulation applications with the exception of appliance insulation where the use of hydrocarbon-blown foam continues to gain ground, particularly in the larger countries of Asia and Latin America.
- Some use of HFC-blown foam is emerging in Latin America for appliances (mainly for export markets) as well as in OCF, integral skin polyurethane and shoe sole applications.
- Strong development of the insulation market in China, and to a lesser extent in MENA and Latin America, is driving the rapid introduction of XPS facilities using HCFC-based technologies. This sector alone has contributed a further 20,000 tonnes per annum of blowing agent consumption since previously assessed 2001.
- The rate of growth of consumption of HCFCs in foam applications indicates that there could be a significant shortfall in the period immediately after the introduction of the freeze in consumption in 2015, as foam producers seek alternative technologies to maintain growth.

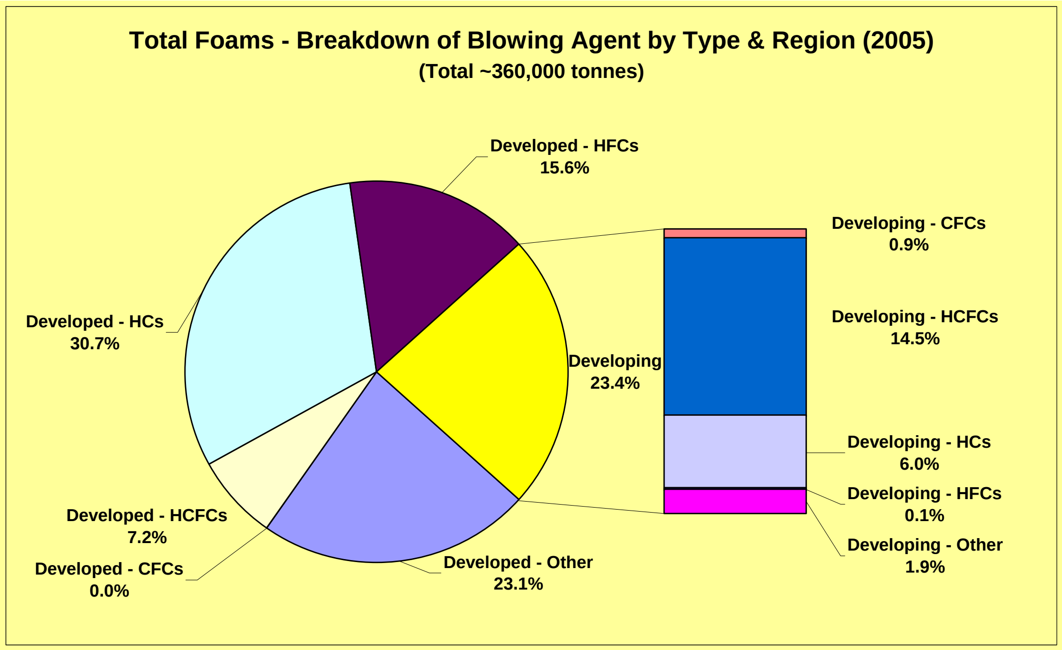
Developed Countries

- The use of HCFC-141b in insulation foams is now limited to relatively small amounts in Australia and Canada but significant usage of HCFC-

142b and HCFC-22 is likely to continue in both Canada and the USA until at least 2010.

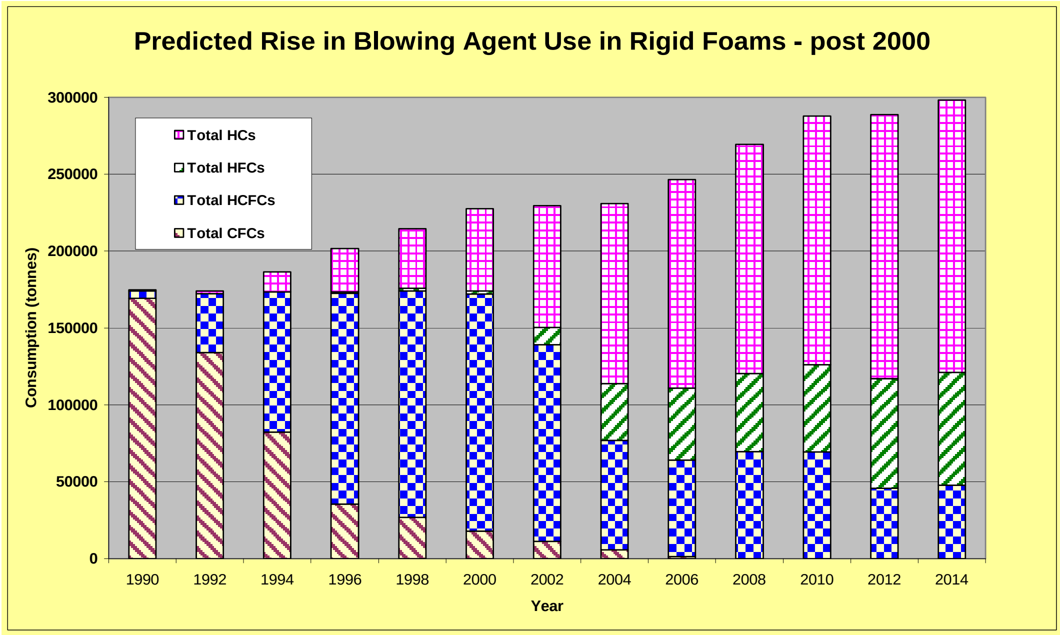
- In the European Union and Japan the actual uptake of HFCs following HCFC phase-out has been lower than previously predicted, partially because of increased use of other alternatives (e.g. hydrocarbons) driven by the regulatory and market pressures to limit HFC uptake and partially through more efficient formulation in recognition of the economic realities of HFC use.
- Super-critical CO_2 technologies have now been commercially introduced for spray foam in Japan.

The chart below illustrates the overall status of transition for Article 5 and non-Article 5 countries in the combined rigid & flexible foam sectors as at 2005.

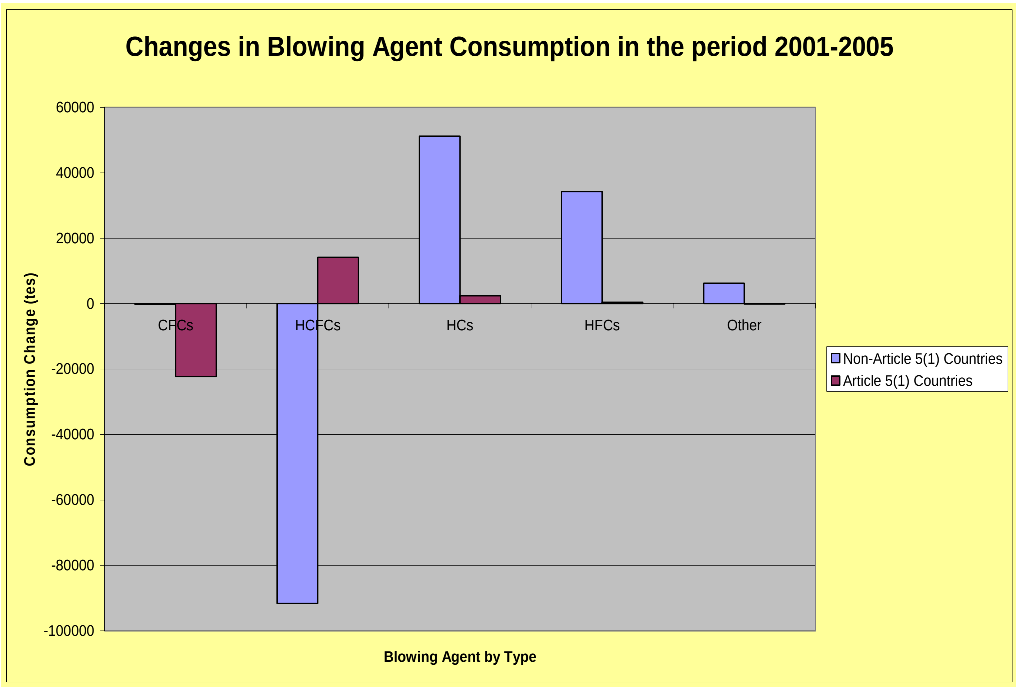


There has been a stabilisation or perhaps even a slight overall drop in the demand for blowing agents since 2001 which illustrates the ability of the industry to develop more efficient processes with more limited losses. However, as signalled in the IPCC/TEAP Special Report on Ozone and Climate (SROC-2005), the trend in blowing agent usage within rigid foams is expected to be upwards until 2015 driven largely by the requirement for better building insulation standards and product

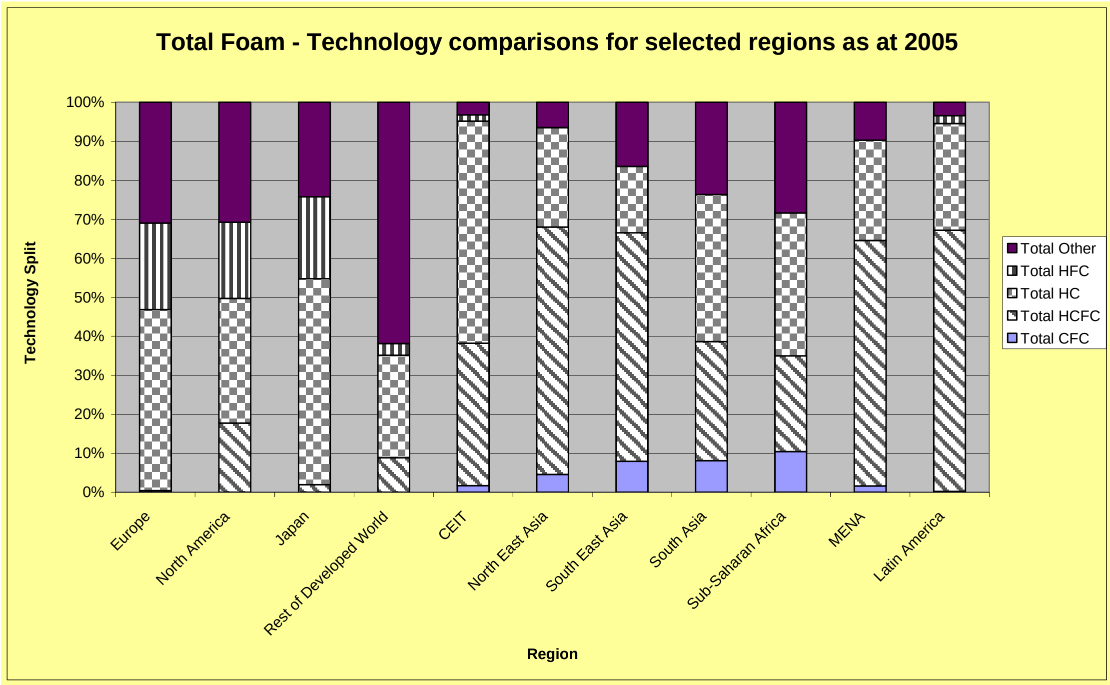
switches from less thermally efficient materials. The following graph shows the trend by blowing agent type:



The following graph illustrates the changes in blowing agent type by region since 2001…



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



The lack of major increase in hydrocarbon use in Article 5 countries since 2001 is illustrative of the fact that most of the larger projects suited to hydrocarbon had already been tackled in the pre-2001 period. Transitions from CFCs have therefore been primarily to HCFCs and there is little evidence yet of any transition away from HCFCs in developing countries. The only circumstances where this has seriously occurred is where products exported to non-Article 5 countries (e.g. appliances) have been required to be ODS-free.

Although many of the transitions have now already occurred, there are a number of steps remaining. These include:

- Transition out of HCFC-142b/22 in the North American XPS industry
- Transition of the remaining minor CFC use in Article 5 countries
- Avoidance of, or progressive transition from, HCFC technologies in Article 5 countries

In addition there are a number of actions which are being considered at regional level to minimise future emissions of ODSs. These include:

- Recovery of ODS blowing agents contained in domestic refrigerators and other appliances (see below under Banks and Emissions)
- Recovery of ODS blowing agents from building insulation where technically possible and economically viable (see below under Banks and Emissions)

- Further development of processes to reduce emissions of all types of blowing agent during foam manufacture and use

Whilst some transitions continue to take place and processes continue to be optimised, the technology choices are expected to vary with time and country status as shown in the following tables:

Table 3-1 Alternatives for Polyurethane Foams

Foam Type	CFC Alternatives		
	Currently in Use (2005/06)	Anticipated in 2010-2015 period	
		Developed Countries	Developing Countries
Polyurethane: Rigid			
Domestic Refrigerators and Freezers	HCFC-141b, HCFC 141b/22, HCFC-142b/22 blends, hydrocarbons, HFC-134a, HFC-245fa	HFC-245fa, HFC-134a, hydrocarbons	HCFC-141b, hydrocarbons
Other Appliances	HCFC-141b, HCFC-22, HCFC-22/HCFC-142b, HFC -245fa; HFC-365mfc	CO_2 (water), HFC-134a, hydrocarbons, HFC 245fa, HFC 365mfc/HFC 227ea	HCFC-141b, CO_2 (water), hydrocarbons
Reefers & Transport	HCFC-141b,HCFC-141b/-22, HCs, HFC-245fa	HFC-245fa, HFC-365mfc/227ea	HCFC-141b
Boardstock	HCFC-141b, HCFC-141b/-22, HCs	Hydrocarbons, HFC-245fa, HFC 365/HFC 227ea	N/A
Panels – Continuous	HCFC-141b, HCFC-22, HCFC-22/HCFC-142b, HCs, HFC-245fa, HFC-365mfc	HFC-134a, hydrocarbons , HFC 365mfc/HFC 227ea, HFC-245fa	HCFC 141b
Panels – Discontinuous	HCFC-141b, HCs, HFC-365mfc, HFC-245fa	HFC-134a, hydrocarbons, HFC 365mfc/HFC 227ea, HFC-245fa	HCFC 141b
Spray	HCFC-141b, HFC245fa, HFC-365mfc;	CO_2 (water), HFC 245fa, HFC 365mfc/HFC227ea	HCFC 141b
Blocks	HCFC-141b; HCs, HFC-365mfc	Hydrocarbons, HFC 365mfc /HFC 227ea, HFC-245fa	HCFC 141b
Pipe	HCFC-141b, HCs	CO_2 (water), cyclopentane	HCFC 141b
One Component Foam	HCFC-22, HFC134a, HFC-152a, propane, butane	HFC-134a or HFC-152a/ Dimethylether/propane/butane	HFC-134a or HFC-152a/ Dimethylether/propane/butane
Polyurethane: Flexible			
Slabstock and Boxfoam	HCFCs are not technically necessary for this end use	CO_2 (water, LCD), methylene chloride, variable pressure, LCD, special additives	CO_2 (water), methylene chloride, variable pressure, LCD, special additives
Moulded	HCFCs are not technically necessary for this end use	Extended range polyols, CO_2 (water, LCD, GCD)	CO_2 (water, LCD, GCD)
PU Integral Skin	HCFC-141b, HCFC-142b/-22	CO_2 (water), HFC-134a, -245fa, -365mfc/227ea, hydrocarbons	CO_2 (water), HFC-134a, hydrocarbons
PU Miscellaneous	HCFC-141b, HCFC-22/CO2	CO_2 (water)	CO_2 (water)

Table 3-2 – Alternatives for Other Foams

Foam Type	CFC Alternatives		
	Currently in Use (2005/2006)	Anticipated in 2010-2015 period	
		Developed Countries	Developing Countries
Phenolic	Hydrocarbons, 2-chloro-propane, HFC-365mfc/ 227ea	Hydrocarbons, 2-chloropropane, HFC-365mfc/227ea, HFC-245fa	HCFC-141b, hydrocarbons
Extruded Polystyrene			
Sheet	Primarily hydrocarbons, HCFCs are not technically required for this end use	CO_2 (LCD), hydrocarbons, inert gases, HFC-134a, -152a	Hydrocarbons, CO_2 (LCD)
Boardstock	CO_2 (LCD) or with HC blends, hydrocarbons (Japan only), HFC-134a, HFC-152a HCFC-22, HCFC-142b	CO_2 (LCD) or with HC blends, hydrocarbons (Japan only), HFC-134a, HFC-152a and HC blends	HCFC-142b, HCFC-22
Polyolefin	HCFC-22, HCFC-142b		

3.3 Likely Future Scenarios (including Barriers to Transition)

Likely future scenarios and issues affecting transition are reviewed in detail within Chapter 2 of the FTOC Report. They encompass factors in both Article 5 and non-Article 5 environments. There are several common elements and these often focus on SMEs. Key points to highlight at this stage are:

- The financial constraints of SMEs remain key factors in many transition strategies, both in developing and developed countries. This has a particular impact on on-going uptake of hydrocarbon technologies.
- Both product and process safety issues remain upper-most within some sectors (e.g. spray foam) that would otherwise consider hydrocarbons
- There remains concern among some Article 5 users about the possibility of a supply/ demand imbalance for HCFC-141b now that the phase-out in developed countries has taken place. This extends to the maintenance of adequate geographic supply chains.
- The future of HFC regulations in non-Article 5 countries continues to be an unknown. However, definition of longer-term use and emission

patterns is being established in many cases so that evidence-based decisions can be reached.

3.4 Banks and Emissions

The long historic use of CFCs in rigid foams, the long product lifetimes and the slow release rates of blowing agents continue to point to the existence of a significant bank of future CFC and HCFC emissions. These were well-documented in the foams chapter of the IPCC/TEAP Special Report (SROC) which was finally published in 2005. This report confirmed earlier estimates that suggested banks in excess of 1.8 million tonnes of CFCs and over 1.1 million tonnes of HCFCs. However, there has since been some debate about the precise size of these banks and particularly the reliability of the bottom-up emissions function approach in predicting overall emissions. A recent Task Force Report on Emission Discrepancies (TFED) has brought the subject into sharp relief and proposed three main explanations for possible discrepancies:

1. The under-estimation of use and emissions in the foam sector (affecting CFC-11, HCFC-141b and HCFC-142b projections in particular)

2. The under-reporting and misallocation of consumption of these chemicals resulting in the omission of consumption in emissive activities

3. The under-estimation of the lifetime of these chemicals in the atmosphere, resulting in an over-estimation of annual emissions by 'inverse modelling' from atmospheric concentrations

The conclusion of the TFED Report was that there was sufficient uncertainty in all of these areas to allow for the potential reconciliation of emissions estimated from bottom-up assessments and those derived by inverse modelling from atmospheric concentrations. Further work is required to evaluate the sources of uncertainty in more detail, and reduce them in some cases. This will involve further commitment from the foam sector in providing adequate information on consumption and use patterns, as well as improved information on emissions functions.

Meanwhile, in the light of this conclusion, the respective protocol communities are able to move forward with increased confidence when considering future projections of emissions from the foam sector and the value of bank management as an emissions reduction option. With respect to bank management itself, there is increasing interest in the potential for flexible mechanisms such as those found in the voluntary carbon market. Although these will trade fundamentally on the carbon value of ODS recovery, there are clearly mutually environmental benefits to be had under both protocols – particularly where recovery and destruction would otherwise be unaffordable.

4 Executive Summary of the 2006 Assessment Report of the Halons TOC

4.1 Introduction

The following sector summaries show the remarkable progress that has been made to reduce the need for halons, and highlights problem areas where attention needs to be focussed to ensure adequate stocks of halons are available to meet Parties' future needs.

4.2 Phase-out in Article 5 Countries

Only two Article 5 countries, The Peoples Republic of China (P.R. China) and The Republic of Korea (South Korea), continue to produce halons for fire protection purposes. The P.R. China stopped production of halon 1211 at the end of 2005 and its current production of halon 1301 is well below the limits agreed with the Executive Committee of the Multilateral Fund of the Montreal Protocol.

Only 26 of more than 120 countries operating under Article 5, paragraph 1, continue to import newly produced halons, primarily for the servicing of existing equipment. The demand for new halons has been reduced in developing countries through the availability of substitute fire extinguishing agents and alternatives, and only to a limited extent through halon recycling programs. Halon recycling remains a challenge as the commercial aspects of the trade in recycled halon are not fully understood and some operational and technical problems need to be resolved.

4.3 Phase-out in Countries that Use Halon 2402

During the period 2002-2003 when the average price of halon 2402 was low, its use as a process agent in the Russian chemical industry substantially reduced the Russian inventory of halon 2402. Nevertheless, within Russia and the Ukraine there appears to be a large installed capacity of halon 2402 and sufficient quantities are available on the market from storage and recovery/banking for the servicing of existing applications. There may also be a sufficient amount of recovered halon 2402 to support the current needs of other countries, however export of halon 2402 from Russia and the Ukraine is banned by national regulations. Owing to this, there is growing concern from HTOC local and regional experts about the availability of halon 2402 outside of the Russian Federation and the Ukraine to support the critical servicing needs of Russian produced aircraft, military vehicles, and naval vessels still in operation in some countries, particularly India.

There is little open literature information available on inventories and emissions of halon 2402. Parties may wish to request additional information be collected on existing inventories, historic and current emission factors, and projected needs to support critical or essential halon 2402 fire protection equipment through their end of useful lives.

4.4 Global Halon Banking

Halon banking can play a significant role in ensuring the quality and availability of recycled halon, in managing the consumption down to zero, and in assisting with emission data by providing regional estimates that should be more accurate than global estimates. In Article 5 countries, halon banking has been a mix of success and failure, with the establishment of halon recycling facilities and co-ordination between industry, government, and national militaries being challenges that some have found difficult to overcome.

4.5 Estimated Inventories of Halons

The HTOC has updated the inventory and emission models of halon 1211 and halon 1301 taking into account direct data on destruction, inventories and emissions, where available, and additional expert opinion on past practices.

For halon 1301, the 2006 Assessment indicates an even greater global inventory or bank of halon 1301 as compared with the 2002 assessment. The global bank of halon 1301at the end of 2005 is now estimated to be approximately 50,000 metric tonnes (MT) as compared with the 2002 assessment of 39,000 MT.

For the global halon 1211 bank, the 2006 Assessment provides as estimate of 90,000 MT at the end of 2005 as compared with 106,000 MT from the corrected 2002 assessment, as reported in the TEAP Supplement to the IPCC/TEAP Special Report on Fluorocarbons (TEAP, 2005), and 83,000 MT in the pre-corrected 2002 HTOC assessment report.

From the 2006 Assessment, the HTOC is of the opinion that adequate global stocks of halon 1211 and halon 1301 currently exist to meet the future service and replenishment needs of existing critical or essential halon 1211 and halon 1301 fire equipment until the end of their useful lives. While it appears that adequate supplies of halon 1211 and halon 1301 are expected to be available on a global basis, over 35% of the global supply of halon 1301 is projected to be in Japan, see Figure ES-1. Model projections for halon 1211 based on Article 7 reporting of production and consumption place over 60% of the halon 1211 in Article 5 countries, see Figure ES-2, with the clear majority being in handheld extinguishers and unused stocks in China. Similarly, expert opinion places the majority of halon 2402 in the Russian Federation and

Ukraine. These regional imbalances, where excess agent supply in some regions cannot be used to meet shortages in other regions because of obstacles presented by national or international regulations, either through complications or the outright prohibition of transfers, are a growing concern for the HTOC. Parties may wish to consider asking HTOC to investigate mechanisms to better predict and mitigate such imbalances in the future.

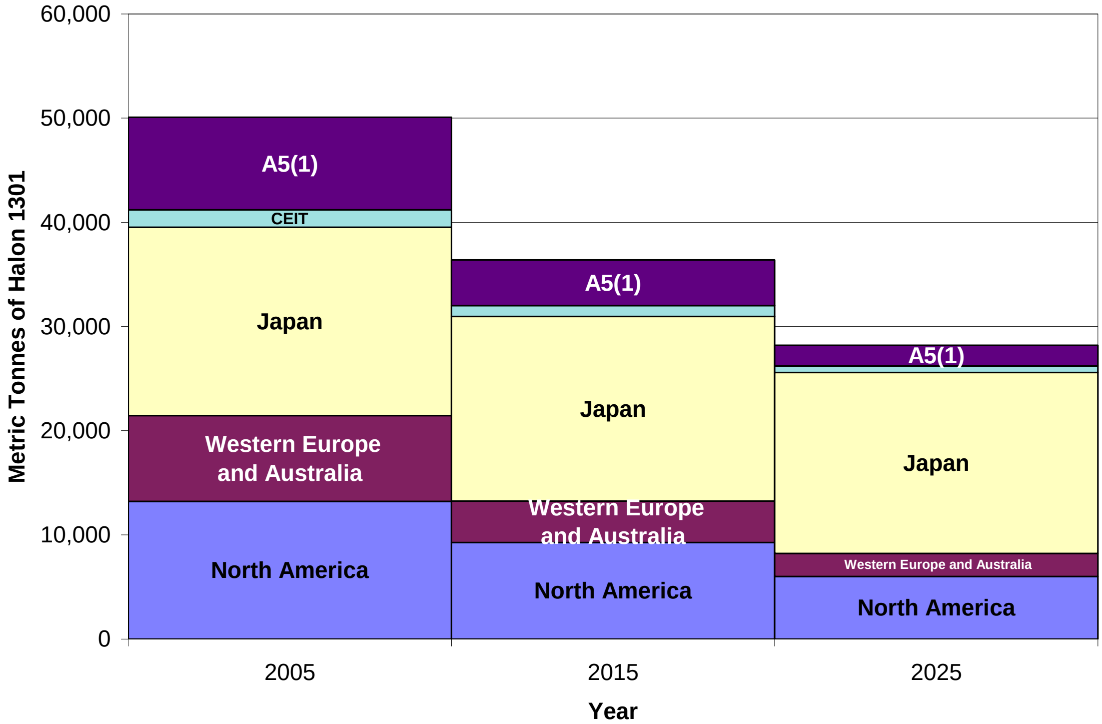


Figure 4-1 Breakout of Global Inventories (Bank) of Halon 1301 by HTOC Model Regions

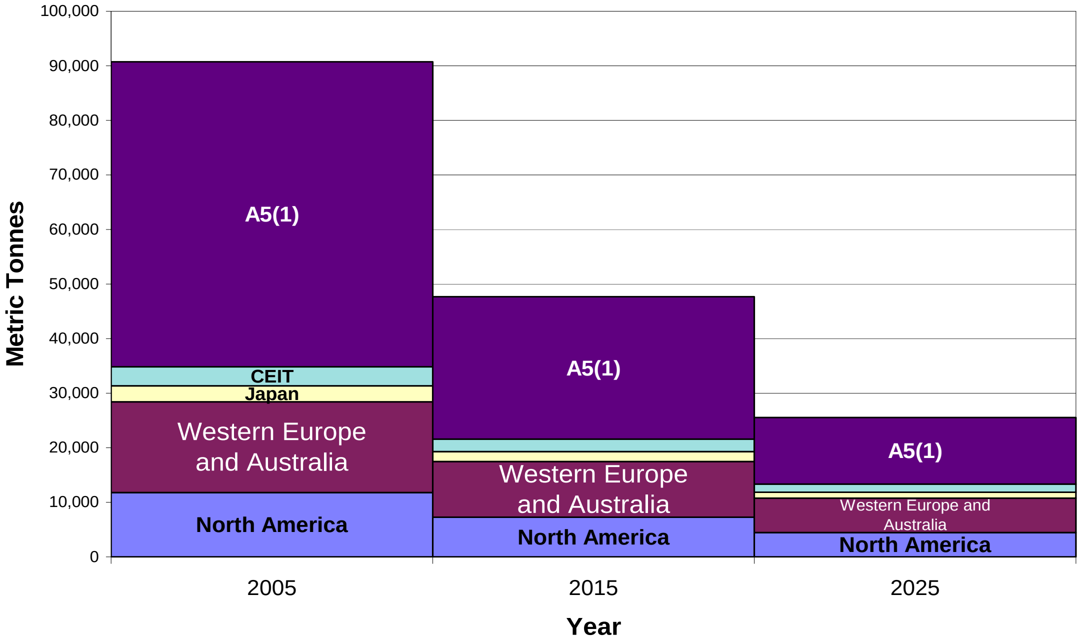


Figure 4-2 Breakout of Global Inventories (Bank) of Halon 1211 by HTOC Model Regions

4.6 Civil Aviation

The status of the transition away from halons in civil aviation reflects progress that has already been made in other sectors of use: minimising emissions of halons from testing and training practices, recycling and recovery of halons, testing of the available alternatives, and changing to alternative methods of fire suppression for ground based situations. However, unlike those other sectors, the civil aircraft sector continues to be dependent on halons, has not demonstrated further progress through the adoption of alternative technologies in new airframe designs, and lacks having an agreed technical design strategy to implement alternative methods of fire suppression. There is an immediate need to produce technical designs to conform with the minimum performance specifications that will in turn enable regulatory authorities to certify the systems to be fitted to new aircraft designs.

The civil aircraft business sector must demonstrate a focused leadership on this transition to deliver new technically certified systems that will meet the necessary regulatory processes and which can be consistently and broadly applied across the industry. Unless and until progress is made in this area, it will represent a significant barrier to the transition away from halons for new aircraft designs. Until supplies of recycled halons become unavailable, or until policy changes push a transition to the alternatives, the situation is unlikely to change in the near-to-mid term.

4.7 Merchant Shipping

Within the marine industry, it is important that stakeholders closely monitor the changes in availability of replenishment halon around the world. This is a dynamic situation and it will only be through pre-planning that owners and authorities are going to be prepared for a halon shortage. It is the recommendation of the HTOC that all Parties to the Montreal Protocol and all Members of the International Maritime Organization continually remind the marine industry of the importance of preparing for this inevitability.

4.8 Halon Usage and Replacement in Military Application

The military sector has shown leadership in the identification and implementation of halon alternatives, with considerable benefit transferring to the civilian and commercial sectors. Many equipment procurements are proceeding with alternative fire extinguishants and fire protection technologies. No new facilities or designs of equipment now require halons.

The conversion of existing equipment is more challenging, but programmes are underway or completed for many important applications. In other cases, especially for existing systems that protect normally occupied spaces in naval vessels, military vehicles, and military aircraft, very significant technical, economic and logistical barriers remain for retrofit. These halon systems may need to continue in service for the remainder of the operational life of the equipment, likely until the middle of the century in many cases. Halon use by the sector is well managed. Many organisations have established dedicated halon storage and recycling facilities to support Critical Use equipment for as long as is necessary.

4.9 Inertion/Explosion Suppression

Halons have been widely used to prevent explosions by suppressing deflagrations in their early stages of development. Explosion suppression and prevention (inertion) were challenging problems to overcome, but as with fire suppression, alternative agents or methods are now available for virtually all new applications. However, in some existing facilities in hostile climates, facilities were designed and constructed with halon 1301 fixed systems as an integral part of the safety system design as well as the physical layout of the facility. After extensive research, it has been determined that the replacement of such systems with currently available alternatives is not technically or economically feasible.

4.10 Destruction

Halons, more than some of the other ozone depleting substances (ODS), are readily accessible for collection, storage, and disposal. Options for disposal of surplus halons include destruction and transformation. One study sponsored by the Multilateral Fund Secretariat estimated that in 2010 no more than approximately 950 MT per year of contaminated halons would need to be disposed of in Article 5 countries. The actual amounts of the global halon inventory potentially available for destruction or transformation is highly uncertain due to business planning and economic considerations by users, local and regional imbalances of supply and demand, the availability of destruction or transformation technologies and facilities, inventory management approaches, and applicable disposal regulations.

Compliant ODS destruction technologies and facilities can be found in many countries, and some already have experience destroying some types of ODS. Owing to the relatively high market value and little outflow of halons into the waste stream, there is more limited experience in destroying halons. Continued research into transformation of halons – including feedstock uses - and the viability of producing useful products holds promise as a future option for halon disposal.

4.11 Other Issues

Although production of halon 1301 for fire protection uses has virtually ceased, France has continued to produce halon 1301 as a feedstock for production of an insecticide, and China has also begun to divert some production to feedstock use, and is likely to continue to do so. As the demand for bioactive compounds grows world-wide, it is conceivable that other manufacturing facilities may continue or restart production of halon 1301 to support feedstock needs. The continued routine, annual production of halon 1301 changes the economic considerations of the point at which halon is considered under Decision IV/25 to not be available in sufficient quantity and quality, and may provide an incentive for an essential use production exemption request.

The build up of stocks of contaminated or otherwise unwanted halons continues to be reported as a problem in Article 5 countries, particularly in Africa and also now in China. In many cases, this is becoming a storage and space issue as the halon needs to be stored in its pressure cylinder. Disposition options for contaminated halon include reclamation (assuming that one can sell it cost-effectively after reclamation), destruction, or venting. The first two options require monetary investment, which is generally not available in most circumstances. Unless there is a need for significant quantities of halon 1211 in the immediate future, the quantities stored and becoming available in China may also become unwanted with only destruction and, unfortunately, venting as disposition options.

5 Executive Summary of the 2006 Assessment Report of the Medical TOC

5.1 Metered Dose Inhalers

Global CFC Use for MDIs

In 2005, 2,754 tonnes of CFCs were used for the manufacture of metered dose inhalers (MDIs) for asthma and chronic obstructive pulmonary disease (COPD) in non-Article 5 countries under essential use exemptions. This represents a 70 per cent reduction in use compared to peak usage in 1997.

It appears that MDIs are manufactured in at least 16 Article 5 countries. The amount of CFCs used in these countries in 2005 for the manufacture of MDIs is estimated at 1,875 ODP tonnes (this equates to production of approximately 75 million MDIs). About 65 per cent of this consumption (1,283 ODP tonnes) is by nationally owned manufacturing companies.

Technically Satisfactory Alternatives are Available

Technically satisfactory alternatives to CFC MDIs are now available for short-acting beta-agonists and other therapeutic categories for the treatment of asthma and COPD. Whilst much effort has been focused on developing in-kind replacements for CFC MDIs (i.e. HFC MDIs) there are other methods of delivering drugs to the lung. Alternative methods to CFC MDIs for pulmonary drug delivery include: HFC MDIs; dry powder inhalers (DPIs), single or multi-dose; nebulisers; and soft-mist inhalers.

By the end 2005, around 40 per cent of the short acting beta-agonist salbutamol MDIs marketed around the world contained HFC as a propellant. Both propellants HFC-134a and -227ea are being widely used to formulate drugs in MDIs. There is widespread availability of salbutamol HFC MDIs, with almost 60 countries where there are at least two products approved. This is also true for a number of inhaled corticosteroids, including budesonide, beclomethasone and fluticasone propionate.

The introduction and acceptance of multi-dose powder inhalers has continued, along with single-dose DPIs (particularly in some Article 5 countries). Global use of DPIs has increased to over 30 per cent of total inhaler units (MDI+DPI). The use of DPIs in Europe is now comparable to HFC MDI usage.

By the end of 2005 all countries of the European Union had declared CFC MDIs for salbutamol non-essential. Salbutamol CFC MDIs may continue to be sold in the United States until the end of 2008, following which their sale will be illegal. Both the European Union and the United States are actively considering the phase-out of the remaining non-salbutamol CFC MDIs, which is likely in 2008/9.

As anticipated, there have been no major problems with transition, including no major product issues. The lack of problems may be attributed in part to the use of widespread education campaigns (primarily conducted by the pharmaceutical industry) to both healthcare professionals and patients.

It is likely that a number of CFC MDI products (usually older drug moieties or generic products) may never be reformulated due to technical challenges, economic considerations or changes in medical practice so suitable medical alternatives will need to be sought. For most of these, there is either suitable CFC-free alternatives in the same therapeutic category or other satisfactory alternative therapies. Increased regulatory involvement is likely to be needed as the transition reaches the phase where there will be a few CFC MDI products remaining.

Experience of Transition

The rate of transition from CFC MDIs to CFC-free products has varied from country to country. Even when new products have been introduced, the rate of their uptake has varied. This has occurred for a number of reasons including price considerations and the varied regulatory frameworks that cover product withdrawals in various countries.

It is very clear that the development of CFC-free products, their registration and launch into the market is only partially effective in achieving transition. Experience has indicated that transition can best be achieved by pharmaceutical companies ceasing CFC MDI manufacture and by regulatory policies that phase out corresponding CFC products on a drug-by-drug or category-by-category basis once alternatives are widely available.

However some pharmaceutical companies have not ceased supplying the CFC MDIs. There are also some companies, such as some generic pharmaceutical manufacturers, that have not developed CFC-free MDIs and they will continue to produce CFC MDIs for as long as they are allowed. It has proved necessary for national governments to implement regulatory policies to ensure that the transition is completed in a timely and safe manner, once sufficient, CFC-free alternatives are available.

There are continued concerns over the cost and/or availability of healthcare in all countries, particularly in Article 5 countries. The price of CFC alternatives could be a major barrier to transition if they are more expensive than comparable CFC products, unless governments and other payors agree to cover the higher cost of CFC-free alternatives.

Despite widespread educational initiatives, transition does not appear to be a high priority among most healthcare providers, many of whom have taken a passive approach to transition. Pharmaceutical companies' educational and marketing endeavours have been the main driving force in the uptake of alternatives.

Significant progress in Article 5 countries; considerable challenges remain

The CFC MDI transition in Article 5 countries has proved to be complicated, as it is influenced by medical, technical, economic and regulatory factors. Nonetheless, significant progress has already been made towards transition in Article 5 countries for certain key moieties. In many Article 5 countries, more than one CFC-free product is available. In over fifty Article 5 countries, at least two CFC-free salbutamol products have been approved.

Given the widespread availability of technically and economically feasible alternatives, MTOC believes that global phase-out of CFCs in MDIs is achievable by 2010. However considerable challenges will need to be addressed to achieve transition particularly in Article 5 countries. These challenges can be overcome through the transfer of technology, product launches of CFC-free alternatives and implementation of comprehensive transition strategies.

There is an urgent need for all Article 5 countries that have not already done so to develop effective national transition strategies in accordance with Decision XII/2. MTOC strongly recommends that these activities be made a priority to ensure a smooth transition to CFC-free alternatives by about 2010. Countries will need to set an end-date for transition that accounts for the Montreal Protocol phase-out schedule.

Multi-national pharmaceutical producers provide the majority of MDIs in most Article 5 countries. In a few countries, local manufacture accounts for some MDIs, while the majority comes from multinational producers. In other countries (e.g. People's Republic of China, Cuba and India), local manufacture supplies the majority of MDIs to the market.

In countries that rely mainly on imports, the transition to CFC-free products will be driven mainly by marketing strategies of the multinational pharmaceutical companies. The national health and trade authorities will also drive transition. Transition strategies will be relatively simple, and be mainly concerned with regulatory approval of CFC-free alternatives and patient and physician education programmes. In most of these countries the affordability of alternative CFC-free products may be a factor in transition.

Countries that manufacture MDIs will each need to develop a detailed national transition strategy to phase out CFC MDIs. In some of these Article 5 countries there are a relatively large number of local companies producing

CFC MDIs who have not yet gained access to the skills or knowledge to introduce suitable CFC-free alternatives. It is critical to ensure that appropriate technical expertise is identified, that funds for technology transfer and equipment acquisition are available, and that the management of the implementation is monitored.

The cost of access to CFC-free MDI technology will depend on whether patents exist that cover the product being contemplated and whether these patents are enforceable in the Article 5 country. However, based on a preliminary evaluation by MTOC it does not appear that formulation patents will constitute a major barrier to the introduction of CFC-free MDIs in Article 5 countries.

A limited number of Article 5 countries may face specific problems. Firstly, they may not achieve the allowable levels of CFC consumption in 2007, and thus be in a potential non-compliance situation with their obligations under the Montreal Protocol. The MTOC is aware of at least two cases where such a potential non-compliance situation could arise once the major part of their CFC phase-out is completed. A recent report to the Executive Committee addressed the compliance issue (UNEP/OzL.Pro/ExCom/49/39).

Secondly, some countries may face difficulties in phasing out the consumption of CFCs for MDIs without incurring economic losses to local MDI manufacturers if they do not receive Multilateral Fund financing. Thirdly, without adequate planning for transition by national governments, patients may be deprived of inhaled therapy that is essential for health.

After 2009, the economics of CFC production may make pharmaceutical-grade CFC production for MDIs impractical. If Article 5 countries face difficulties in achieving transition in their CFC MDI manufacturing plants by 2010, stockpiling may need to be considered to ensure a supply of pharmaceutical-grade CFCs for MDI manufacturing to meet patient needs beyond 2009. In these circumstances, it may be appropriate to arrange for a final campaign to produce pharmaceutical-grade CFCs before 2010, or to acquire pharmaceutical-grade CFCs through a transfer of existing stockpile in non-Article 5 countries.

Future CFC Requirements for MDIs

Future CFC requirements are difficult to predict given the uncertainties of transition, particularly in Article 5 countries. However, the volume of CFCs required under the essential use process in non-Article 5 countries is reducing and will likely be less than 500 tonnes in 2008, which may be the last year a request will be made. CFC use in Article 5 countries for MDI manufacture is currently estimated at about 1,800 ODP tonnes per annum.

If quantities of pharmaceutical-grade CFCs are needed to allow the transition to occur globally and there is a need for a final campaign production in the later part of the decade or for the transfer of existing stockpile, then this will need careful consideration and management. Issues that will need to be considered include: timeframe for transition; estimation of CFC quantities; existing stockpile of suitable quality; logistics, commercial, and legal requirements for stockpile transfer; storage; and destruction.

The management of stockpiles at this final stage of the phase-out will be extremely important to avoid unnecessary production of CFCs. An efficient process is required to allow for transfers of CFC volumes between parties and / or companies in order to maximise the use of existing CFCs and minimise the need for future CFC license and production volumes.

5.2 Pharmaceutical Aerosol Products Other than MDIs

Technically and economically feasible alternatives are available for all medical aerosol products. The amount of CFCs used globally as propellants for pharmaceutical aerosol products (medical aerosols) other than MDIs has reduced substantially.

The manufacture of most CFC-containing medical aerosols in non-Article 5 countries ceased around 1996, or possibly shortly thereafter if stockpiled CFCs were utilised. It is only in some Article 5 countries that CFCs are still used in medical aerosols. China alone uses up to about 500 tonnes per year for Chinese traditional medicines, topical sprays and nasal sprays.

The world-wide phase-out of CFC-containing medical aerosols will occur as CFC production for developing countries is phased out under the Montreal Protocol schedule and as part of individual Article 5 country plans.

5.3 Sterilants

The use of ethylene oxide (EO)/CFC blends (12/88) for sterilisation has been successfully phased out in non-Article 5 countries and in many Article 5 countries. Although it is difficult to estimate, it is believed that the global total use of CFCs in 2001 for this application was less than 500 metric tonnes, and has continued to decrease. In 2006, global CFC use for this application is likely to be minimal. Remaining world-wide use can be easily substituted, as there are a number of viable alternatives.

EO/HCFC mixtures (10 percent by weight EO in a mix of HCFC-124 and HCFC-22) are virtual drop-in replacements for the 12/88 mixture and were introduced as transitional products for sterilisation in those countries that employed 12/88 extensively. HCFC mixtures are now used mostly in the United States and in countries that allow venting of HCFCs to the atmosphere. The European Union has legislation restricting the use of HCFCs in emissive applications such as sterilisation.

In 2005 the estimated use of HCFC replacement mixtures was thought to be less than 1,000 metric tonnes, which amounts to some 30 ODP tonnes world-wide. EO/HCFC use has been significantly reduced by using less mix per sterilise load and by hospital conversion to other technologies.

EO/HCFC blends have a small ODP (0.03) and should not be promoted in countries that have not been major users of the 12/88 EO/CFC blend. EO/HFC blends are expected to replace the EO/HCFC mixtures, where they are used.

Alternative technologies to which hospitals have converted include: use of more heat-sterilisable devices, more single-use devices, pure ethylene oxide sterilisers and other methods that will sterilise or disinfect some of the low temperature devices used in hospitals. These other low temperature processes include hydrogen peroxide gas plasma, steam-formaldehyde, ozone and liquid phase peracetic acid.

Sterilisation is an important process in the provision of good quality health services. It is also a process that requires strict application of the principles of quality management, reliability and long-term materials compatibility. Therefore, any alternative to the use of ozone-depleting substances needs to be well proven and tested to avoid putting the health of patients unnecessarily at risk.

6 Executive Summary of the 2006 Assessment Report of the Methyl Bromide TOC

6.1 The Methyl Bromide Technical Options Committee

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

MBTOC reports to the Technology and Economic Assessment Panel (TEAP), which advises the Parties on scientific, technical and economic matters related to the control of ozone depleting substances and their alternatives. MBTOC members have expertise in the uses of MB and its alternatives. At December 2006 MBTOC had 39 members; 14 (36%) from developing and 25 (64%) from developed countries and coming from 10 Article 5 and 12 non-Article 5 countries.

6.2 Mandate and Report Structure

Under Decision XV/53(2) taken at the Fifteenth Meeting of the Parties to the Protocol in 2003, the Parties requested the Assessment Panels to update their 2002 reports in 2006 and submit them to the Secretariat by 31 December 2006 for consideration by the Open-ended Working Group and by the Nineteenth Meeting of the Parties to the Montreal Protocol, in 2007.

This MBTOC 2006 Assessment reports on advances since 2002 in the technical and economic feasibility of alternatives to replace methyl bromide and, in particular, on commercial adoption of alternatives and potential alternative treatments to MB as a soil fumigant and as a fumigant of durable commodities and structures; and approved and potential alternatives for quarantine and pre-shipment (QPS) treatments, including treatments for perishables. It also shows trends in methyl bromide production and consumption in both Article 5 and non-Article 5 Parties, estimated levels of emissions of MB to the atmosphere, and strategies to reduce those emissions.

In addition, the report describes critical uses of MB that have been approved by the Parties for 2005 onwards and on economic issues influencing MB phase-out.

Information is provided on results of alternatives implemented in Article 5 countries through investment projects, sustainability of alternatives, constraints to adoption and other topics relating to MB phase-out in Article 5 countries.

6.3 General Features of Methyl Bromide

MB is a fumigant that has been used commercially for more than 60 years to control pests. Targets have included various fungi, bacteria, soil-borne viruses, insects, mites, nematodes and rodents. It also has sufficient toxicity to manage many weeds and seeds in soils. MB is used mostly for soil fumigation; a lesser amount is used for disinfestation of food processing buildings, durable commodities and other miscellaneous uses. MB also has well established uses for quarantine and pre-shipment treatment of a diverse range of pests and diseases on many commodities in trade, including timber, wooden packaging and some perishables (fruit and vegetables).

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

Methyl bromide was listed under the Montreal Protocol as a controlled ozone depleting substance in 1992. Control schedules leading to phase-out were agreed in 1995 and 1997. There are a number of concerns apart from ozone depletion that have also led countries to impose severe restrictions on MB 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.

6.4 Methyl Bromide Control Measures

The control measures, agreed by the Parties at their ninth Meeting in Montreal in September 1997, were for phase out by 1 January 2005 in non-Article 5 countries and for Parties operating under Article 5 of the Protocol (developing countries) a 20% cut in production and consumption, based on the average in 1995-98, from 1 January 2005 and phase out by 1 January 2015. The Protocol provides exemptions under Article 2H for the amounts of MB used for QPS purposes and for those uses deemed to meet the criteria for ‘critical uses’ for non-QPS purposes. The latter may be sought by the Parties after the scheduled phase-out date, either 2005 for non-Article 5 countries or 2015 for Article 5 countries

6.5 Production and Consumption Trends

Information relating to production and consumption of MB was compiled primarily from the database on ODS consumption and production of the Ozone Secretariat as available at the end of November 2006, including data from Accounting Framework Reports. Some countries have revised or corrected their historical consumption data at certain times, and in consequence official figures and baselines have changed. At the time of writing this report, almost all Parties had submitted data for 2005, and the database on MB consumption is much more complete than in the past. In the few cases where data gaps exist, data from the previous year were assumed to apply to MB production or consumption. All tonnages are given in metric tonnes in this report.

In 2005, global production for the MB uses controlled under the Protocol was about 18,140 metric tonnes, which represented 27% of the 1991 reported production data (66,430 tonnes). More than 90% of production occurs in non-Article 5 countries. MB production in Article 5 countries for controlled uses peaked in 2000 at 2,397 tonnes, falling to 39% of the baseline, 538 metric tonnes, in 2005 (aggregate baseline for all Article 5 regions is 1,375 tonnes, i.e. average of 1995-98 production). At least one Article 5 Party and two non-Article 5 Parties have recently ceased production.

Global consumption of MB for controlled uses was reported to be about 64,420 metric tonnes in 1991 and remained above 60,000 tonnes until 1998. Global consumption was estimated at 45,520 tonnes in 2000, falling to about 20,752 tonnes in 2005. The reduction in consumption of MB for soil fumigation has been the major contributor to the overall reduction in global consumption of MB because many non-Article 5 countries have achieved phase-out or substantial reductions in most sectors.

Historically in non-Article 5 regions about 91% of MB was used for pre-plant and about 9% for stored products and structures. The official aggregate baseline for non-Article 5 countries was about 56,083 tonnes in 1991. By 2003, this consumption had been reduced to about 14,504 tonnes, representing 26% of the baseline. The Meetings of the Parties approved CUEs totalling 16,050 tonnes for 2005, but at national level less than 13,808 tonnes was authorised. In 2005, MB consumption (production + imports) was reduced to about 11,468 tonnes in non-Article 5 Parties for critical use exemptions, accounting for about 20% of the total non-Article 5 baseline. The Meetings of the Parties have granted CUEs of 13,418 tonnes for 2006 and 9,161 tonnes for 2007, although lower quantities have been authorised at national level. The MOP has to date approved 5,884 tonnes in the first round for 2008 (about 3 additional Parties are expected to request CUEs in the second round for 2008).

The Article 5 consumption aggregate baseline is about 15,680 tonnes (average of 1995-98), with peak consumption of more than 18,100 tonnes in 1998. Recently, total Article 5 consumption was reduced from 75% of the baseline in 2003 to 67% of baseline in 2004 (about 10,520 tonnes) and 59% of the baseline in 2005 (about 9,285 tonnes). A MBTOC survey of ozone offices and national experts in 2006 provided information on the breakdown of MB uses in major MB-consuming countries. In 2005, an estimated 87% was used for soil and 13% for commodities/structures, not including QPS in Article 5 regions.

Consumption Trends at National Level

In 1991 the USA, European Community and Japan used more than 90% of the MB consumed in non-Article 5 countries. In 2005 the MB consumption (for CUEs) in these three Parties was 28%, 12% and 10% of their respective baselines In 2007 the approved or licensed consumption for CUEs was reduced to 17%, 3% and 10% of the respective baselines.

Most Article 5 parties achieved the national freeze level in 2002. Of 144 Article 5 (1) countries that are Parties to the Montreal Protocol, only 11 did not achieve compliance with the freeze target, and together needed to phase out a total of 440 tonnes. In 2005, 94% of Article 5 parties (136 out of 144) achieved the 20% reduction step by the required date; and in many cases they achieved this several years earlier than required by the Protocol. Only 8 Parties did not comply with the 20% reduction step in 2005; they needed to phase out a combined total of about 740 tonnes to get back into compliance. Over 80% of Article 5 parties (115 of 144 parties) reduced their national MB consumption to less than 50% of national baseline in 2005. 88% of Article 5 parties (127 parties) reported national MB consumption between zero and 16.6 tonnes (10 ODP-tonnes) in 2005. 67% of Article 5 parties (96 parties) reported zero MB consumption in 2005.

6.6 Alternatives to Methyl Bromide

Definition of an Alternative

Following the guidance provided in Annex 1 of the MOP-16 report, MBTOC defines ‘alternatives’ as any practices or treatments that can be used in place of methyl bromide. `Existing alternatives’ are those alternatives in present or past use in some regions. `Potential alternatives´ are those in the process of investigation or development.

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

Additionally, it was recognised that regulatory requirements, or other specific constraints may make an alternative unavailable in a specific country or region. When evaluating CUNs, MBTOC takes account of the specific circumstances. Decision IX/6 1(a)(ii) refers to alternatives that are 'acceptable from the standpoint of environment and health'. MBTOC has consistently interpreted this to mean alternatives that are registered or allowed by the relevant regulatory authorities in individual CUN regions.

Areas where MBTOC did not Identify Alternatives

MBTOC was able to identify alternatives for about 95% of controlled uses in 2005; situations where no alternatives have been identified amount to about 1,200 tonnes of MB. However these figures may be influenced by local regulatory restrictions on the alternatives for the remaining uses. Technically effective alternatives have not yet been identified by MBTOC for the following controlled uses of MB:

- For pre-plant uses: ginseng replant, elimination of broomrape and certain nursery plants and orchard replant situations in some situations

- For post-harvest: stabilisation of high-moisture fresh dates, fresh market chestnuts, cheese in storage, immovable museum artefacts (especially when attacked by fungi) and cured pork products in storage.

At this time, technically feasible alternatives have also been identified for many QPS applications, but there are many, diverse QPS uses where such alternatives are not at present available.

Further research or development, including refinement and extension of existing techniques is needed to address these areas.

Availability and Registration of Alternatives

MBTOC considers that technical alternatives exist for almost all remaining controlled uses of MB (including those seeking critical use exemptions). Regulatory or economic barriers exist that limit the implementation of several key alternatives and this is affecting the ability to completely phase out methyl bromide in several non-Article 5 countries.

Of the total of about 13,800 tonnes authorised or licensed for Critical Use Exemptions in 2005, MBTOC considers that technical alternatives are more difficult to adopt in certain pre-plant sectors (i.e. certain types of strawberry nurseries, some orchard replant industries and control of branched broomrape in certain locations) representing about 1136 tonnes of MB use. MBTOC recognises that economic constraints, regulatory issues and the period of time to uptake alternatives affect the rate of phase out for these remaining uses.

Impact of Registration on Availability of Alternatives

Significant effort has been undertaken by many Parties to transfer, register and implement alternatives and to optimise their use. While an alternative may be technically appropriate as an MB replacement for a given situation, it may not be available in practice. Lack of registration may still be a constraint in some countries, affecting the availability of certain types of alternatives. In many countries, any product or sometimes even a process, which claims to kill pests, must be registered. Overall, the registration and approval process is often costly and protracted, with the outcome uncertain from the point of view of the potential registrants. In addition, the market size for a particular MB application may be too small to justify the commercial risk and investment involved. Additional registration issues arise where treatments will be used on food commodities or where treatments used in food processing buildings might transfer residues to food because the residues must also be registered in importing countries. However, some countries have registered some alternatives in recent years and some large MB-volume consuming countries are in the process of registering additional alternatives and/or publishing maximum residue levels for the residues of some alternatives in foods.

It should be noted that chemical fumigant alternatives in general, like MB, have issues related to their long term suitability for use. In both the EC and US, MB and most other fumigants are involved in a rigorous review that could affect future regulations over their use. MBTOC has been informed that the US government has received a petition to stay (i.e. remove regulatory approval) the pesticide tolerances for sulfuryl fluoride (SF). Sulfuryl fluoride is a recently approved, methyl bromide alternative for several post-harvest applications. A stay or other action that removes the pesticide tolerance for SF would significantly increase pressure to revert to MB in structural and commodity fumigation.

Thus, consideration of the long-term sustainability of treatments adopted as alternatives to MB is most important; both chemical and non-chemical alternatives should be adopted for the short to medium term, developing sustainable IPM or non-chemical approaches for the longer term.

Critical Use Exemptions

Under Article 2H of the Montreal Protocol the production and consumption of methyl bromide was scheduled to be phased out in Parties not operating under Article 5 of the Protocol, by 1 January 2005, except for QPS and feedstock uses. However, the Parties agreed to a provision enabling further temporary exemptions for those uses of methyl bromide that qualify as ‘critical’. Decision IX/6 of the Protocol lays down the criteria that such uses need to meet in order to be granted an exemption. The procedures for applying for and evaluating CUEs are described in the Handbook of Critical Use Exemptions and in the TEAP Reports on Critical Use Nominations.

This Assessment Report analyses the sectors or categories still exempted as CUEs in non-Article 5 countries, constraints to adoption of alternatives in these categories and areas where future efforts might be concentrated in order to achieve total phase-out of MB.

6.7 Alternatives for Soil Treatments

The reduction in consumption of MB for soil fumigation has been the major contributor to the overall reduction in global consumption of MB with amounts used falling 85% from about 57,400 tonnes in 1992 to approximately 21,790 tonnes in 2005, 13,776 in non-Article 5 regions and about 8,014 in Article 5. Authorised or licensed soil uses in non-Article 5 countries fell to approximately 7,750 tonnes in 2007.

Since the 2002 MBTOC Report, clearer trends have developed in the adoption of alternatives to replace MB as a pre-plant soil fumigant. These include alternatives that either provide broad-spectrum control of pests, diseases and weeds (e.g. chemicals and their combinations, steam and solarisation) or cultural practices including the use of soilless substrates, resistant varieties and grafting which avoid the need for MB.

The main crops for which MB is still being used in some non-Article 5 countries are; cucurbits (melons and cucumbers), peppers, eggplants, tomatoes, perennial fruit and vine crops (particularly replant), strawberry fruit and nurseries for the production of propagation material for forests, and strawberries and ornamentals (cut flowers and bulbs). Remaining usage of MB in Article 5 countries follows very similar trends with some additional crops such as bananas, some brassicas and ginseng.

A recent review by MBTOC of over 160 international studies identified a large number of alternatives for strawberry fruit and tomato crops many of which are useful alternatives for other cropping systems.

Many sectors that were formerly heavily reliant on MB have adopted alternatives and as a result the use of MB has been substantially reduced or eliminated. The major adopted MB alternatives include:

- Fumigants and other chemical pesticides applied alone or as mixtures. 1,3-dichloropropene (1,3-D) and chloropicrin (Pic) (especially as 1,3-D/Pic formulations) are the most common fumigant alternatives adopted, followed by chloropicrin, metham sodium (MNa) and dazomet used alone. Combinations of 1,3-D, Pic, metham and dazomet, with or without Low Permeability Barrier Films (LPBF) or additional herbicides and fungicides, or other non-chemical alternatives have been shown to be as effective as MB in many research trials and in commercial practice. In some cases additional adaptation is needed to improve application methods at local level.

- Solarisation, alone or combined with biofumigation or low doses of fumigants, has gained wider adoption as a MB alternative in areas with sunny climates and where it suits the cropping season and the pest and disease complex.

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

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

- Grafting, resistant rootstocks and resistant varieties are commonly used practices to control soilborne diseases in vegetables, particularly tomatoes, cucurbits, peppers and eggplants. They are commonly adopted as part of an integrated pest control system, or combined with an alternative fumigant, and have led to the reduction or complete replacement of MB use.

Potential in-kind alternatives including methyl iodide, sodium azide and cyanogen (also sometimes referred to as ethane dinitrile or EDN), have demonstrated results as effective as MB in research trials in some cropping systems where MB is currently used. Methyl iodide is being used under permit in at least two countries and full registration is pending in these countries.

Formulation changes and more adequate application methods have improved the effectiveness of several alternatives (Pic 1,3-D/Pic, metham and others) and wider adoption has occurred where these improved methods are available. In many instances, the adoption of alternatives has involved a change in cropping practice, i.e. slightly longer plant back times and a greater awareness of soil conditions which improve the efficiency of alternatives; modification to application machinery, sometimes with economic implications. Some sectors that were formerly heavily reliant on methyl bromide have completely switched to chemical alternatives combined with improved crop rotation practices (e.g. tomato and pepper production).

The combination of chemical and non-chemical control methods has also been recognised as an effective strategy to overcome problems due to the narrow spectrum of activity of some single control methods. Soil solarisation and grafting vegetable crops onto resistant rootstocks for instance has proven to be a valuable non-chemical alternative. Similarly the efficacy of grafted plants can be greatly enhanced by combining it with biofumigation, green manures, and chemicals such as MITC generators, 1,3-D and non- fumigant nematicides. Combinations of fumigant alternatives (1,3-D/Pic, Mna /Pic) with LPBF or relevant herbicides have been shown to be effective for nutsedge (*Cyperus spp*.), which is the key target pest for several CUNs. In the more difficult nursery and replant industries where high levels of disease control are required to meet quality standards (e.g. certification requirements), several alternatives are also showing promise for control of pathogens.

MBTOC estimates that reductions from the 1991 consumption baseline by the end of 2006 in non-Article 5 Parties for soil fumigation will have resulted from the use of alternative fumigants and chemical treatments (60%); transitional strategies (about 15% of the reduction), and use of soilless systems (10%). Other measures, steaming and solarisation, account for less than 5% of the present reduction in use, though they are important as alternatives in some particular situations.

Projects in Article 5 countries have shown that a similar range of alternatives to those in non-Article 5 countries can be successfully adopted. Costs and different resource availability can lead to preference for different alternatives in Article 5 compared to non-Article 5 countries. There are a few specific MB uses in Article 5 countries where research is needed to identify or demonstrate suitable alternatives; these include post harvest stabilisation of high moisture dates.

Crop specific strategies implemented both in non-Article 5 and Article 5 regions are discussed in detail in the 2006 Assessment Report. These include alternatives used for the major crops using MB in specific climates, soil types and locations, as well as combinations of alternatives, application methods and others.

6.8 Aternatives for Treatment of Post-Harvest Uses: Food Processing Structures and Durable Commodities (non-QPS)

Food processing structures that currently use methyl bromide include flour mills, bakeries and other food production and storage facilities. These structures are fumigated to control stored product (food) pests. Additionally, historical or museum structures are fumigated to destroy wood boring pests and fungi. Previous structural uses for transport vehicles, where not a QPS application, have been virtually eliminated. These were routinely treated with

MB to control stored product or wood destroying insects, rodents and other pests.

Durables are commodities with low moisture content that, in the absence of pest attack, can be safely stored for long periods. The remaining durable commodities fumigated with MB in some non-QPS applications include milled rice, various dried fruits nuts, beans cocoa beans, rice fresh market chestnuts, dry cure ham and cheese in storage houses.

At this time, technically feasible alternatives have been tested and have shown efficacy for almost all durable and structural treatments currently treated with methyl bromide. MBTOC has not identified available and technically effective alternatives for high-moisture fresh dates, fresh market chestnuts against chestnut weevils, cheese in storage against cheese mites, immovable museum artefacts (especially when attacked by fungi), and cured pork products in storage.

There are, however, a number of constraints to the replacement of the remaining MB uses for durables and structures. These include cost differentials versus MB, treatment logistics (availability of appropriate chambers and other factors), market logistics (since phosphine, a principal alternative requires a longer treatment time), regulatory and registration requirements.

For 2005, MBTOC estimated that approximately 33% of the global fumigant usage of MB was for the disinfestation of durable commodities and about 3.9% was used for structures. These estimates included both non-QPS and QPS uses. The proportion of use on durables and structures has risen since 2002, with falling consumption for soils and rising use on wood and wooden packaging. Presently, based on CUEs granted by the Parties to the Montreal Protocol for use in 2007, approximately 2% of non-QPS MB is used in non-Article 5 countries for the control of pests in durable commodities (182.45 tonnes) and 6.2% in structures (573.61 tonnes). There has been considerable adoption of a wide variety of alternatives by durable commodities sector since 2002. The lower rate of adoption of alternatives for structural uses has been primarily as a result of issues with registration, logistics and efficacy, and cost concerns.

The main alternatives to the disinfestation of flour mills and food processing premises are sulfuryl fluoride (including combinations of SF and heat) and heat (as full site or spot heat treatments). Some pest control operators report that full control of structural pests in some food processing situations can be obtained without full site fumigation through a more vigorous application of IPM approaches. Other pest control operators report success using a combination of heat, phosphine and carbon dioxide. Phosphine fumigation of commodities has expanded.

Sulfuryl Fluoride

Sulfuryl fluoride is sufficiently registered in the US to allow virtually all mills and food processing facilities to test, adapt and consider adoption as an alternative to methyl bromide. Additionally, registration coverage for mills in Canada and for numerous milling and food processing applications in EC countries allows adoption on empty structures. The difficulty is that in some cases, emptying a mill to the extent required by regulators for SF fumigations is considered to be unworkable or impracticable with food production logistics. Some EC countries recently allowed the expansion of SF use through publication of maximum residue limits (MRLs) for fluorine residues in food. Although preparation for fumigation should include the emptying of mill equipment prior to fumigation, the publication of MRLs will decrease difficulty with the definition of 'empty' and will assist adoption of SF by those mills with attached silos. New research testing SF effectiveness for treatment of durable commodities that are currently subject of critical use nominations may further expand its use.

A registrant for SF is working to expand maximum residue levels (MRL) for fluorine and registration to expand the use of sulfuryl fluoride. The use of sulfuryl fluoride for mills and food processing facilities producing foods for export may be affected by upcoming decisions concerning the maximum residue levels for fluorine residues in the foods. More widespread adoption of fluorine MRLs in processed foods may increase adoption, but legal challenges to in the US intended to reduce fluorine levels in foods may reduce adoption.

In many cases, initial efficacy problems have been resolved through additional experience. In other situations, particularly larger mills with complex design and/or mills in cooler climates, a combination process of SF with heat has been used (temperature at or slightly above 26˚C). In this method, pest kill efficacy has been very high and fumigant costs have been minimised. This approach requires careful adaptation on an individual mill basis by knowledgeable and experienced fumigators.

Heat Treatments

Since 2002, considerable research and commercial phase-in trials of heat treatment in mills and other food processing have taken place. Some food processing facilities through diligent adaptation and investment have been able to achieve reliable pest control by using either full-site or spot heat treatments. Heat treatments must always be combined with IPM since sanitation is critical to the success of heat treatments. Several manufacturers of mobile heat treatment equipment have advanced with systems designed for flour mills and food processing facilities. New equipment has simplified heat treatments, made them more reliable and controllable. Depending on the circumstances, full-site heat treatment may be considerably more costly than fumigations with methyl bromide. However, some corporations prefer the convenience, greater relative safety (compared to fumigants) and environmental sensitivity of full site or spot heat treatments. Costs of heat treatment, length of time required, problems in reliability, especially in larger mills or large horizontal structures and concerns about heat equipment or temperature distribution damaging mill equipment or structure, are given as reasons that limit the use of heat as an MB alternative. To ensure success, heat treatments require as much planning, care in implementation and evaluation as do chemical fumigations.

Heat treatments for commodities are an active development area, and although there is considerable laboratory research data, more work is needed to know how to adapt research to actual treatments of commercial quantities of commodities.

Phosphine

The use of phosphine, which was already in widespread use before phase out, has increased in the treatment of dried commodities and in the treatment of warehouses holding non-food commodities (such as tobacco warehouses). Fast generating forms of phosphine (cylinderised gas, phosphine generators or faster acting formulations), spurred greater use of this fumigant since these forms were more easily controlled and since they reduced fumigation time. The use of these newly marketed forms of an older fumigant has been largely responsible for a considerable reduction in use of methyl bromide for commodities. Yet, in this commodity sector, MB continues to be requested when a fast treatment immediately before marketing is required.

Other Processes

Controlled atmosphere conditions are in commercial use for a wide variety of durable commodities and also for museum artefacts and building components where the conditions can be maintained sufficiently long. Many techniques have been developed to change and hold the atmosphere in numerous product adaptations. Grains and cereals are held in controlled atmospheres in silos, bubbles and bag stacks. Artefacts are treated in bubbles and chambers and under tarps. Commercial service providers use large, versatile chambers. Controlled atmosphere treatment usually requires more time than fumigation, but the lengthy hold times also deter re-infestation.

Vacuum, in flexible enclosures has been further commercialised since MBTOC’s last assessment with more testing and availability of the enclosures. Vacuum enclosure is a viable treatment for disinfesting those durable commodities that can withstand the physical pressures created by the vacuum system. The system can be applied to a wide range of situations from small on-farm stores to large storage premises.

Other Fumigants

Contact insecticides, in widespread use as grain protectants in some EU countries, are under regulatory pressure and may no longer be available for those uses in the near future. On the other hand, improvements in the techniques used for older volatile compounds may increase their effective use as part of IMP strategies.

Several other fumigants with apparent potential to replace MB in particular circumstances are at various stages of investigation, with registration being sought. Propylene oxide is registered to treat several dried food commodities in the US and new formulas have been released to improve its utility. The US nut processors have gained greater experience with propylene oxide since it was approved for control of bacterial contaminants and that experience may translate into expanded use in the dried fruit and nut category. Carbonyl sulphide and cyanogen are at advanced stages of investigation with registration being sought in Australia. Australia recently registered ethyl formate for dried commodities following research that showed good effectiveness in packaged food protection. It is now being tested for disinfestation of fresh chestnuts in France and Japan.

6.9 Alternatives to Methyl Bromide for Quarantine and Pre-Shipment Applications (Perishables, Durable Commodities and Structures)

For quarantine and pre-shipment purposes, MB fumigation is currently often a preferred treatment for certain types of perishable and durable commodities in trade world-wide, as it has a well-established, successful reputation amongst regulatory authorities. Commodities may carry pests and diseases that can be a threat to agriculture, health and the environment. Quarantine pests, detected in a country or region previously free of them, can result in considerable cost caused by restriction of exports, eradication measures and implementation of disinfestation treatments.

Quarantine pests of concern are numerous and include insects, mites, snails, nematodes, vertebrate pests and fungi. Although QPS uses are usually for commodities in trade, recently, some Parties have identified some methyl bromide soils uses as being quarantine uses.

Usually quarantine treatments are only approved on a pest and product specific basis, and following bilateral negotiations. This process helps ensure safety against the incursion of harmful pests, but also often requires years to complete. For this and other reasons, replacing methyl bromide quarantine treatments is expected to be a long term proposition. Many non-MB quarantine treatments are, however, published in quarantine regulations, but they are often not used.

Article 2H exempts MB used for QPS treatments from phase-out. The European Community is one of the few Parties that has placed conditions additional to those under the Protocol on MB consumed for QPS, including a cap on the amount that can be used and further reporting requirements. Japan has mandated application of coloured labels to the cylinders to differentiate MB used for QPS or non-QPS.

A survey of QPS use by Parties was carried out in 2004 by a consultant commissioned by the European Community, to provide a basis for response to Decision XI/13(4). Decision XVI/10(4) requested Parties that had not already submitted data to provide best available data on QPS uses and associated quantities. Data from these two sources was integrated to give an overview of QPS. Use of 6,893 tonnes was reported, being about 65% of reported annual QPS consumption (10,601 metric tonnes) in the 2002-2004 period.

Data was not received for 16 of the 70 Parties reporting non-zero consumption of QPS methyl bromide. Five of the 16 Parties with reported annual consumption for QPS purposes exceeding 100 metric tonnes annually did not report use or use details. In several cases, the quantity of methyl bromide reported as used for QPS purposes in a year differed substantially (> +/-30%) from consumption for that year reported to the Ozone Secretariat.

The seven categories with the highest QPS usage cover 96% of the total QPS methyl bromide reported with sufficient detail for analysis. The major use categories were soil (preplant 29%), grains (24%), wood, including sawn timber (16%), fresh fruit and vegetables (14%), wooden packing materials (6.4%), logs (4.0%) and dried foodstuffs (3.0%). The use of QPS methyl bromide for treatment of whole logs and timber appears underrepresented. Independent estimates of the volume of methyl bromide required to treat East Asian and Russian trade in logs suggest that QPS methyl bromide use for this use exceed 4,000 tonnes.

Reported production of methyl bromide for QPS purposes rose from 10,660 tonnes in 2004 to 13,815 tonnes in 2005, with the increase attributable largely to the widespread implementation of the ISPM-15 standard for treatment of wooden packaging materials.

Non-MB QPS Treatments

Quarantine treatments are designed, tested and negotiated bilaterally on an individual product and treatment basis. The treatments must both kill pests and maintain product quality, both difficult hurdles. The pest-kill requirement hurdle is set particularly high; generally it must be demonstrated that the treatment kills over 99% of the quarantine pests that might be present. Allowed treatments are found in the quarantine inspection manuals for the importing country, and these are usually available electronically.

For perishables, there are various approved treatments, depending on product and situation, including heat (as dry heat, steam, vapour heat or hot dipping), cold (sometimes combined with modified atmosphere), modified and controlled atmospheres, alternative fumigants, physical removal, chemical dips and irradiation.

ISPM-15 standard for wooden packaging material specifies a heat treatment as an alternative to methyl bromide. Some export timber is treated with alternative fumigants and processes to methyl bromide, including phosphine in transit.

Alternatives to methyl bromide for preshipment treatment of grains and similar commodities are the same as for these commodities in storage, but their use may be restricted by economic and logistic issues, notably the need for rapid treatment of large volumes of product under conditions at ports where storage and handling capacities may be very limited. Alternative fumigants are under development and registration, which may provide adequate speed of treatment. However, several countries specify use of methyl bromide as the only acceptable QPS treatment of imported grain from specified exporters.

Overall, there are technically effective and approved treatments available for more than half current QPS treatments by volume of methyl bromide consumed, but many individual QPS uses do not have proven, acceptable alternatives at this time.

There is scope for minimising emissions from those QPS uses of methyl bromide that lack alternatives through deployment of recapture technology.

6.10 Rate of Adoption of Alternatives

Generally, time is required to allow the relevant industry to transition to available effective alternatives once these are identified. Since the critical use process commenced in 2005, most industries show a reduction in nominated quantity requested from that of the preceding year, reflecting progressive adoption of alternatives; while others have the same or similar quantities of MB nominated. Some CUNs show comparatively slow rates of adoption.

When reviewing technical information on alternatives and their commercial adoption by Parties previously using MB in similar sectors to those where CUNs had been sought, it was found that in most instances the adoption rates varied between 10 and 25% per year. This includes Article 5 countries that have adopted alternatives through investment projects, where the rate of adoption is on average between 20 and 25% per year.

Difficulties for MBTOC occurred where in some sectors, even though a number of technical alternatives have been proven world-wide (e.g. tomatoes, some vegetables and strawberry fruit in particular) and many countries have been able to transition to alternatives, either voluntarily or by licensing, several countries have reported slow adoption rates for these sectors.

Analysis of the data indicates that by the end of 2006, 95% reduction of MB use or complete phase out of MB has occurred for tomato crops in Australia, Japan, New Zealand, Portugal, Spain, Greece, Belgium, and the UK; in strawberry fruit in Australia, Belgium, Greece, Japan, Portugal and Spain; and in peppers or eggplants in Australia, Greece, Israel, Japan, Malta, New Zealand, Spain and the UK. Reductions in the range of 35–42% have been made in the US and Israeli strawberry fruit and tomato industries and the US tomato industry since 1998. Israel has found transition more difficult in these sectors mainly because some formulations of alternatives are not registered and restrictions on the use of a key alternative, chloropicrin exist; also because of the occurrence of specific pests (*Verticillium dahliae* race 2, *Orobanche* spp.). Regulatory restrictions in the US have also limited uptake of a leading alternative, 1,3-D.

Many examples of successful phase-out or significant use reduction are available from Article 5 countries e.g. the tobacco sectors in Brazil and Argentina, the flower sector in Costa Rica, Uganda and Kenya, the vegetable and strawberry sectors in Lebanon, the horticulture sector in Morocco, Uruguay and Peru and others.

On the other hand, some countries have not been able to follow the adoption rates achieved in other countries, even if they were able to reduce MB in the years leading to phase-out. In some cases, technical trials have shown that Parties could achieve faster phase out than the Party had indicated was possible.

6.11 Progress in Phasing-out MB in Article 5 countries

Progress in phasing-out MB in Article 5 countries has been achieved mainly through MLF investment (or phase-out) projects. Alternatives chosen generally follow those identified as successful through demonstration projects carried out in the same country or in regions with similar circumstances. Projects in Article 5 countries have shown that a similar range of alternatives to those in non-Article 5 countries can be successfully adopted. Costs and different resource availability may lead to preference for different alternatives in Article 5 compared to non-Article 5 countries.

The projects showed that for all locations and all crops or situations tested, except stabilisation of high-moisture fresh dates, one or more of the alternatives proved comparable to MB in their effectiveness in the control of pests and diseases targeted in the projects in these Article 5 countries.

By December 2006 the Multilateral Fund (MLF) had approved a total of 324 MB projects in more than 72 countries. This included 43 demonstration projects for evaluating and customising alternatives, 79 MB investment projects for phasing-out MB and 202 other projects for information exchange, awareness raising, policy development and project preparation. Further MB phase-out activities have been funded directly by Article 5 countries and/or agricultural producers, bilateral assistance and the Global Environment Facility.

In the 72 countries implementing full phase-out projects, MB was scheduled to be reduced at an average annual rate of about 22.5% per year, in a total of 4.4 years on average (range 3-6 years). This includes countries that are small, medium and large MB consumers.

The fact that MB cannot generally be replaced by one in-kind alternative has become clear through both demonstration and investment projects. This implies that growers and other stakeholders need to change their approach to production and may even have to make important changes in process management. This relates mostly to IPM but also time management, as alternatives often require longer exposure times than MB. Reluctance to make management changes is often the major reason for resistance to adoption of alternatives, even over economic matters.

Results obtained from projects to date indicate that particular attention needs to be paid to appropriate, effective application methods. Adapting the alternatives to the specific cropping environment and local conditions is essential to success. Strong emphasis on awareness raising activities, information transfer and training, not only within one country and sector but also with other projects, regions and sectors still appears most important. Ways to promote such horizontal experience-sharing could include, for example, developing an electronic network, organising technical seminars, building a database with service and input suppliers all over the world and promoting field visits of technical teams and others.

More than 90% of all Article 5 countries complied with the freeze of 2002 and the 20% reduction of 2005. However, a small number of countries have experienced difficulties. A recent study conducted by the MLF found several common reasons to explain cases of non-compliance or significant delays, such as,

- Political and economic transformation processes;
- Recent ratification of the Montreal Protocol (after 2000) and/or its Amendments;
- Project implementation delays;
- Weaknesses of the National Ozone Unit (e.g. frequent staff changes; communication difficulties within the Environment Ministry and/or with other ministries);
- Low baseline due to exceptional circumstances (war, economic recession, insufficient data collection);
- Delayed approval and implementation of MB-related legislation;
- Reluctance of stakeholders to actively co-operate in the MB phase-out process or insufficient involvement of key sectors or stakeholders since the onset of the projects;
- Expansion of the main sector using MB after the baseline years.

Although a need to build up confidence on the use of certain alternatives or methods as well as further adjustment and trials were evident in some cases, lack of technically feasible alternatives was not found to be a cause of non-compliance. Some countries have opted for a revised schedule of MB reductions in projects that will be easier to achieve under their particular circumstances.

6.12 Economic Criteria

The purpose of the economics chapter is to survey the existing literature to provide an overview of economic information relating to alternatives as a guide to what is known about the economic impact of the MB phase-out. A review of the existing literature shows that there are three main economic criteria that have been used to determine economic outcomes from adoption of alternatives to MB. These include:

- Articles that report only the changed (increased) costs of using methyl bromide alternatives;
- Articles that use some form of partial budgeting technique to assess the impact of the use of methyl bromide alternatives on the revenues and costs of a particular application, i.e. on the net financial position of firms (mostly farmers in pre-harvest applications). In these cases the current use of methyl bromide (in terms of application methods and application rates, etc.) is used as the norm from which deviations are measured;

- Articles that report the impact of the use of methyl bromide alternatives on the sector (e.g. California strawberries, cut flowers in Spain) as a whole.

The variation in the means of assessing economics highlights the fact that little research has been done to increase understanding of the actual impacts of the methyl bromide phase-out. The existing literature is narrow in the sense that it relates primarily to the USA and a narrow range of methyl bromide uses. Economic data is available in some Article 5 countries that are implementing MLF projects but the MBTOC economic group did not assess these data.

TEAP/MBTOC have been asked to assess the economic feasibility of Critical Use Nominations. However, although Decision Ex. I/4 lays out the general scope of work for Parties and TEAP, guidance concerning economic feasibility benchmarks is lacking.

6.13 Emissions from Methyl Bromide Use and Their Reduction

Emissions from fumigation operations occur mainly through leakage and permeation during treatment (inadvertent emissions) and from venting at the end of a treatment (intentional emissions). Some additional emissions may occur after venting as a result of slow desorption of gas from treated materials (e.g. soils, commodities, materials in treated structures). A proportion of methyl bromide reacts to produce nonvolatile materials. This makes it inappropriate to equate consumption or usage directly with emissions.

Estimates of the proportion of MB used that is released into the atmosphere vary widely because of: differences in usage pattern; the condition and nature of the fumigated materials; the degree of gastightness; and local environmental conditions Under current usage patterns, the proportions of applied MB eventually emitted to the atmosphere are estimated by MBTOC to be 46 – 91%, 85 - 98%, 76 – 88% and 90 - 98% of applied dosage for soil, perishable commodities, durable commodities and structural treatments respectively. These figures, weighted for proportion of use and particular treatments, correspond to a range of 59 - 91% overall emission from agricultural and related uses, with a mean estimate of overall emissions of 75%, or 27,601 metric tonnes based on estimated use of 36,866 tonnes in 2005.

Emission volume release and release rate to the atmosphere during soil fumigation depend on a large number of key factors. Of these, the type of surface covering and condition; period of time that a surface covering is present; soil conditions during fumigation; MB injection depth and rate; and whether the soil is strip or broadacre fumigated are considered to have the greatest effect on emissions.

Studies under field conditions in diverse regions, together with the large scale adoption of Low Permeability Barrier Films (LPBF) in Europe, have confirmed that such films allow for conventional MB dosage rates to be reduced. Typically equivalent effectiveness is achieved with 25 –50% less methyl bromide dosage applied under LPBF compared with normal polyethylene containment films. There is a need for growers to obtain confidence in new sealing methods and new films when adopting such films for the first time.

The use of low permeability barrier films (VIF or equivalent) is compulsory in the European Union (EC Regulation 2037/2000). In other regions LPBF films are considered technically feasible for bed fumigation. However, in the State of California in the US a regulation currently prevents implementation of VIF with MB (California Code of Regulations Title 3 Section 6450(e)). This regulation resulted from concerns of possible worker exposure to MB when the film is removed or when seedlings are planted due to altered flux rates of MB.

For QPS treatments, Decisions VII/5(c) and XI/13(7) urge Parties to minimise use and emissions of methyl bromide through containment and recovery and recycling methodologies to the extent possible. There has been limited research into the development of recovery and recycling systems for MB. There are now several examples of recovery equipment in current commercial use. All these units use are based on absorption of used methyl bromide on activated carbon. Some are designed for recycling of the recaptured methyl bromide while others include a destruction step to eliminate the sorbed methyl bromide, thus minimising emissions. Adoption of these systems has been driven by considerations other than ozone layer protection, e.g. occupational safety issues or local air quality. The equipment is not is widespread use. In the absence of regulations requiring use of recapture equipment, companies reported they would not invest in the systems, because their competitors (who had not made the investment) would then have a cost advantage.

7 Executive Summary of the 2006 Assessment Report of the Refrigeration, AC and Heat Pumps TOC

7.1 Refrigerants

This chapter summarises data for refrigerants and specifically those addressed in subsequent sections of this assessment report. It discusses thermophysical (both thermodynamic and transport) properties as well as heat transfer, compatibility, and safety data.

The tabular data summaries are updated from prior assessments to reflect current data, from consensus assessments and published scientific and engineering literature where possible. The summaries address refrigerant designations, chemical formulae, normal boiling point (NBP), critical temperature (T_c), occupational exposure limits, lower flammability limit (LFL), safety classification, atmospheric lifetime (τ_{atm}), ozone depletion potential (ODP), global warming potential (GWP), and control status. The summary tables also add new blends introduced since the 2002 assessment report. The updated chapter adds guidance for ODPs and GWPs for regulatory reporting.

This chapter also provides similar information for heat transfer fluids (sometimes referred to as "secondary coolants" or "secondary refrigerants") for air-conditioning, heat pump, and refrigeration systems.

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

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

A major uncertainty for all of the refrigerants is the influence of lubricants on properties. The working fluid in most systems is actually a mixture of the refrigerant and the lubricant carried over from the compressor(s). Research on refrigerant-lubricant mixtures is continuing. The need for further studies is driven by introduction of new refrigerants, great variety of lubricants in use and being introduced, and by the often highly proprietary nature of the chemical structures of the lubricant and/or additives.

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

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

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

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

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

7.2 Domestic Refrigeration

Conversion of new production domestic refrigeration equipment from CFC-12 to non-ODS refrigerants has occurred well in advance of Montreal Protocol requirements. By the end of 2004, more than 96% of new production had converted to non-ODS refrigerants. 63% of these were converted to HFC-134a, 35% were to hydrocarbons (HC-600a or HC-600a/HC-290 blends) and 2% were to all other refrigerants. Original production conversion may be 100% complete by the time this report is published. Broad-based refrigerant alternatives continue to be HFC-134a or HC-600a with regional preference being influenced by multiple local and national codes, standards and regulations.

Conversion of domestic refrigeration field service refrigerant demand from CFC-12 to non-ODS refrigerants is significantly slower than new production conversion. By the end of 2004, only approximately 25% of field service refrigerant demand had converted to non-ODS refrigerants. The distribution of non-ODS service refrigerants is roughly comparable to the new equipment refrigerant selection. Approximately 75% of domestic refrigeration service refrigerant demand continues to be CFC-12. This sluggish conversion is a consequence of long equipment service life and technical difficulties with field-conversion of existing units to alternative refrigerants. Increased use of the binary and ternary blends of HFC, HCFC, PFC and hydrocarbon refrigerants specifically developed for the service industry is expected to somewhat accelerate conversion from CFC-12. These blends have current widespread use in Australasia and North America. The acceleration rate for their global use will be determined by the relative availability and economics of these blends versus CFC-12.

The long product life and low failure rate of the estimated 1200 to 1500 million currently installed domestic refrigerators result in refrigerant emissions from the domestic refrigeration bank being dominated by end-of-life final disposition of these units. This bank is estimated to contain 90,000 to 100,000 tonnes of CFC-12. The management of the potential emissions from this bank is expected to be a global agenda topic for at least another 20 years. Experience with various regulatory and market-driven refrigerant conservation initiatives is discussed in Chapter 11 of this report.

7.3 Commercial Refrigeration

Commercial refrigeration is part of the food chain. Two levels of temperature (medium temperature for preservation of fresh food and storage of beverages, and low temperature for frozen products) may imply the use of different refrigerants.

Commercial refrigeration has benefited from over 10 years of technical efforts, which have reduced refrigerant emissions, drastically lowered the refrigerant charge by developing indirect systems or other concepts, or replaced high-GWP refrigerants with lower GWP alternatives.

Commercial refrigeration is composed of three main categories of equipment: stand-alone equipment, condensing units, and centralised systems. The number of supermarkets world-wide is estimated at 477,000 in 2003 covering a wide span of sales areas varying from 500 m^2 to 20,000 m^2. The populations of vending machines, stand-alone equipment and condensing units are evaluated respectively at 18.5, 29, and 31 million units.

Stand-Alone Equipment

The majority of stand-alone equipment is based upon HFC technology. Some well-established beverage companies and ice-cream manufacturers have committed themselves in 2004 to eliminate the HFC use in their applications and so the use of HCs and CO_2 is growing in several applications. For existing systems, the conversion from CFC-12 to HFC-134a involves several steps, including the change of mineral oil to POE lubricant. These procedures are now well established but still significant training is necessary in many Article 5 countries to avoid unnecessary repair after retrofit.

Centralised Systems

The size of centralised systems can vary from refrigerating capacities of about 20 kW to more than 1 MW. The charge of refrigerant is related to the refrigerating capacity and store layout. In order to lower the refrigerant charge, a number of technical solutions have been developed including mainly indirect and distributed systems. An indirect system is composed of a refrigerating system installed only in the machinery room. In a centralised system, a heat transfer fluid (HTF) is cooled in the evaporator of a compact refrigerating system located in the machine room. It is then circulated to the display cases located in the sales area to extract heat from these display cases. The HTF is then returned to the machine room where it is re-cooled so the process can be repeated.

Depending on the country, HFCs, ammonia, HCs, and CO_2 are used as primary refrigerants in the refrigerating system entirely installed in the machinery room and/or outside. HFC-404A is the dominant choice in Europe, HCFC-22 is the most used refrigerant still in the US and in all developing countries. The uptake of R-404A and so called “intermediate” HFC blends has begun as of 2000 in the USA for the replacement of HCFC-22. In Europe there is now interest in the development of low GWP refrigerants and increased attention in containment. CFCs (CFC-12 and R-502) are mainly used in Article 5 countries and are needed for servicing of all commercial refrigerating systems. HCFCs are used both for new equipment and for servicing and in all countries except Europe for new equipment.

Refrigerant Banks

The bank of CFCs has reached about 185,000 tonnes from 1995 to 1999 with a slow decrease by then. The dominant bank as of 1999 is the HCFC-22 bank, which reached more than 240,000 tonnes in 2003. Its growth is expected to continue for a number of years. The HFC bank is increasing rapidly and has reached 50,000 tonnes in 2003.

The refrigerant emissions of CFCs, HCFCs, and HFCs are respectively of 44,000, 78,000, and 10,000 tonnes in 2003 /Clo06/. They are proportional to the size of their respective refrigerant banks.

7.4 Industrial Refrigeration

This chapter has been completely revised and updated from the previous 2002 RTOC report. Market and technology trends are updated and new developments covered. The market for industrial refrigeration covers food and drink processing and distribution, process industries such as pharmaceutical, chemical and petrochemical and some specialist plants in the building services market. It also includes heat pumps using the refrigeration cycle within these market segments. R-717 is widely used for industrial refrigeration in developed countries, but is less common in the developing world, particularly where there are concerns about plant integrity and maintenance capability.

The industrial refrigeration market in the developed countries is estimated to be growing at a rate of 4% per year, and there is also an increasing diversity of requirements in the food and drink market segment. Transition in these markets from CFCs and HCFCs has resulted in a significant investment in new equipment, principally R-717 plants. In some niche markets R-744 has been used in order to achieve specific benefits. It is particularly difficult to estimate the emissions of fluorocarbons owing to the wide variety of system types in this sector. Extrapolation from available information suggests world-wide annual leakage rates for 2006 of 18% of the charge for CFCs, 15% for HCFCs and 13% for HFCs.

7.5 Transport Refrigeration

Transport Refrigeration includes transport of chilled or frozen products by reefer ships, intermodal refrigerated containers, refrigerated railcars and road transport including trailers, diesel trucks and small trucks and vans. It also includes use of refrigeration and air conditioning on merchant ships above 300 gross tonnes.

According to a recent study, transport refrigeration still accounted for 0.8 % of all ODS emissions in 2002, while transport refrigeration equipment contained just 0.5 % of the world refrigerant bank. This indicates that leakage rates of transport refrigeration equipment are still higher than industry average. Since the working environment in all sub-sections of transport refrigeration is under rough conditions, emissions on average are higher than in other areas. To reduce leakages, better quality systems are now on the market, meaning higher costs to the user, but also better conditions for the goods transported.

Rough operating conditions bring about shorter life cycles so that the typical life span of many transport refrigeration systems is lower than for stationary refrigeration and air conditioning equipment. This is the reason that the transport refrigeration sector has already shifted more towards HFCs than other industry sectors.

All over the world, including Article 5 countries, new transport refrigeration systems are commissioned with HFC refrigerants, thus continuously decreasing the bank of ODS containing equipment in the transport refrigeration sector. HFC-134a and R-404A/R-507 have been implemented in many cases. Use of R-410A will advance further.

Since the 2002 Assessment, CFCs have not been used for new equipment in developed countries and a big proportion of CFC-containing equipment has disappeared. There are few remaining CFC-containing systems in the developed world today and they will not last longer than two to five years, thereby being replaced before 2010. Zero ODP will be reached within the next years in transport refrigeration equipment.

The prognosis of 2002, that vapour compression will remain the main cooling method in all the sections of world-wide transport, has proven true up to now. Several companies are working on non-HFC alternatives for applications within the transport sector, but there are still very few commercialised units running on absorption processes, air cycle, liquid air/nitrogen or carbon dioxide.

Efforts have to be increased in order to reduce leakage during lifetime and decommissioning. Very low values can be achieved with the right combination of good practice, legislation and incentives.

7.6 Air Conditioners and Heat Pumps

On a global basis, air-cooled air conditioners and heat pumps ranging in size from 2.0 kW to 420 kW comprise a vast majority of the air conditioning market (the majority are less than 35kW). Nearly all air-cooled air conditioners and heat pumps manufactured prior to 2000 used HCFC-22 as their working fluid. This installed base of units in 2004, represented a bank of approximately 887,000 metric-tonnes of HCFC-22 (see Table 7-1).

Air-cooled air conditioners and heat pumps generally fall into four distinct categories, based primarily on capacity or application: small self-contained air conditioners (window-mounted and through-the-wall air conditioners); non-ducted or duct-free split residential and commercial air conditioners; ducted, split residential air conditioners; and ducted commercial split and packaged air conditioners (commercial air cooled).

This assessment concludes that HFC blends are the most likely near-term refrigerants to replace HCFC-22 in air-cooled air-conditioning systems. Air-cooled air conditioning equipment using HFC refrigerants is already commercially available in most non-Article 5 regions of the world. Commercial availability of systems using HFC refrigerants is also occurring in some Article 5 countries. Hydrocarbon refrigerants may also be considered as replacements for HCFC-22 (with appropriate safety mitigation techniques) in some categories of products--particularly low charge level applications. In addition, there is a significant amount of research being conducted on R-744 (CO_2) systems to address efficiency and operating pressure issues. Commercialisations of R-744 air-cooled air conditioning systems will likely lag HC (hydrocarbon) and HFC technologies by many years.

The primary technical concerns of the Article 5 countries are: having adequate supplies of HCFCs to service equipment manufactured before the HCFC Phase-out dates mandated by the Montreal Protocol, and having the alternative refrigerants and technologies needed to transition products to non-ODP options.

As the state of development progresses, the alternative refrigerants and technologies available today in non-Article 5 countries could become readily available in most Article 5 countries. Since common manufacturing processes are increasingly being used throughout the world, one is rapidly approaching the situation where containment and conservation of refrigerants will become some of the key areas that will need to be addressed by Article 5 countries to ensure refrigerant supplies are available to service the installed base of HCFC-22 air conditioners. Since many of Article 5 countries will be importers and not manufacturers of air-conditioning equipment, the specific issues faced by these countries are mostly related to servicing, training of technicians, and regulation of refrigerants.

7.7 Water-Heating Heat Pumps[2]

Heat pumps are used to heat water for space heating (comfort) and for domestic hot water heating (DHW). Heat pumps have been developed for comfort heating only, domestic water heating only, and for combined service. Most of these heat pumps employ the vapour-compression cycle although absorption heat pumps also are available. Water-heating heat pump markets are significant in Europe, Japan, and China.

Recent Trends

Heating-only comfort heat pumps are manufactured in sizes ranging from 1 kW heating capacity for single-room units to 50-1000 kW for commercial/institutional/industrial applications. Most small to medium capacity heat pumps in buildings are standardised factory-made units. Air-source and ground-coupled heat pumps dominate the market. Larger heat pump installations usually are custom-made.

In countries with cold climates such as northern Europe, some heat pumps are used for heating only. In warmer climates, heat pumps serving hydronic systems with fan coils provide heat in winter and cooling in the summer. Systems are becoming available to provide both floor panel heating and fan coil heating or cooling.

European countries have been using domestic hot water heat pumps for years. The market for DHW heat pumps is growing rapidly in Japan where night-time electricity prices are low. The government in Japan now provides subsidies to introduce high-efficiency DHW heat pumps using R-744 (carbon dioxide) as the refrigerant. In 2006 over 300,000 R-744 heat pump water heaters are expected to be sold. The demand for DHW water heaters using HFC refrigerants, which do not benefit from the subsidy, also has increased as all-electric homes are becoming more common.

HCFC-22 still is used in heat pumps, but models are being introduced using HFC alternatives (HFC-134a, R-410A, R-407C, R-404A,) and hydrocarbons in smaller units in Europe. For larger water heaters for commercial use, R-410A is employed because larger R-744 compressors are not available. For comfort water-heating heat pumps with fan-coil units, water temperatures are in the range from 45^o to 55^o C. Hydronic circuits with radiators employ heat pumps delivering temperatures from 55^o to 75^o C. Water temperatures of 70^o to 80^o C are common for DHW heat pumps.

[2] These heat pumps also may be called “heat pump water heaters (HPWH)” in the literature

7.8 Chillers

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

Recent Trends

Air-cooled chillers represent about 75% of the annual unit production in the positive displacement category. Scroll compressors are increasingly used in chillers from 7 to 1600 kW. Screw compressors have displaced most reciprocating compressors in chillers up to 2275 kW capacity.

While HCFC-22 still is used in chillers with scroll, screw and reciprocating compressors, R-410A is used in many new chillers up to 350 kW capacity and HFC-134a is used in new chiller designs of larger capacities. R-407C has been employed as a replacement for HCFC-22 in positive displacement chillers but the trends favour R-410A and HFC-134a over the longer term.

For water-cooled chillers, screw chillers frequently are chosen as alternatives to centrifugal chillers in the range from 200 to 2275 kW, while centrifugal chillers are dominant above this range. Centrifugal chillers continue to be offered with HCFC-123 or HFC-134a refrigerants. The production of chillers using CFC-11 (and also CFC-12) essentially has stopped in developing nations. Conversion of existing CFC chillers to use non-CFC refrigerants nearly has ended because most good conversion candidates already have been converted. Existing chillers employing CFC refrigerants slowly are being replaced by new chillers using HCFC-123 or HFC-134a. Today’s new chillers use 20%-35% less electricity than the CFC chillers produced years ago, so the savings in energy costs often justify the replacement of aging CFC chillers.

Two trends continue in chiller development. The first is an effort to reduce refrigerant emissions through design changes and improved service practices. The second trend is to increase seasonal energy efficiency, represented by standard parameters such as IPLV (Integrated Part Load Value), reflecting concerns about indirect global warming effects and annual operating costs. A number of methods are used to achieve higher seasonal efficiencies. These include economisers, use of multiple compressors in a system, continuous unloading capabilities for screw compressors, enhanced electronic controls, and variable-speed compressor drives.

Absorption chillers are an alternative to chillers employing the vapour-compression cycle. The market for absorption chillers remains concentrated in the Asia-Pacific region, primarily in China, Japan, and Korea.

7.9 Vehicle Air Conditioning

Vehicles (cars, trucks, and buses) built before the mid-1990's used CFC-12 as the refrigerant. Since then, all new vehicles with A/C have been equipped with HFC-134a as the refrigerant in non-Article 5 countries; this process is now also virtually complete for new equipment in Article 5 countries. As a result, HFC-134a has now replaced CFC-12 as the globally accepted mobile A/C (MAC) refrigerant and the industry is busy expanding global production to meet the increasing demand. By 2008, almost all vehicles on the road are expected to be using HFC-134a and the transition from CFC-12 will be complete. Vehicles originally built with CFC-12 are expected to continue being serviced with CFC-12 until they are scrapped.

HFC-134a is considered a potent greenhouse gas and, due to concerns about its emission from MAC systems, the European Union has finalised legislation banning the use of HFC-134a in new-type vehicles from 2011 and all new vehicles from 2017. They have also limited replacement refrigerants to those with a maximum global warming potential (GWP) of 150. As a result, vehicle makers and suppliers are fully committed to developing a replacement.

Since 1998, the leading replacement candidate for HFC-134a has been carbon dioxide (R-744) for which many global vehicle manufacturers and suppliers have demonstrated prototype cars. The use of HFC-152a as a replacement was proposed in 2001 and has been publicly demonstrated in several prototype vehicles. Both refrigerants have a GWP below the 150 threshold and adoption of either would be of equivalent environmental benefit, next to other low-GWP substitutes that can be anticipated in the near future. The decision of which refrigerant to choose would have to be made based on other considerations than purely the GWP, such as energy usage, cost, heat pump capability, safety, and ease of servicing.

In early 2006, several chemical companies (others will likely follow) have each announced a new refrigerant blend to replace HFC-134a in Europe. One is an azeotropic blend of CF3I and 1,1,1,2-tetrafluoropropene. Two other formulations have not been publicly released. Since then, due to safety and cost issues of R-744 and R-152a, German carmakers have collectively asked for, and formally organised, a co-operative effort to assess the new candidates with a focus on selecting a replacement for HFC-134a during the second half of 2007. The SAE and Japanese Automobile Manufacturers Association are assisting this effort.

Given the large number of potential replacement options, and the promise of improved HFC-134a systems, it appears there will be at least two refrigerants in the global automotive marketplace in the near future, in addition to the residual use of CFC-12.

7.10 Refrigerant Conservation

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

1. proper design and installation of new refrigeration and air-conditioning equipment so as to minimise actual or potential leaks;
2. leak-tighten existing refrigeration and air-conditioning systems so as to reduce emissions;
3. improve service practices, including use of refrigerant recovery equipment and technician training; and
4. safe disposal techniques that provide for refrigerant recovery for systems at the point of final disposal.

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

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

Article 5 countries have the opportunity to leverage the knowledge gained from developed countries during their implementation of conservation programs. If a government plans to create a program to recover, recycle, and reclaim refrigerant or phase-out the use of CFCs, the government has to consider establishing economic assessments that make owners of systems take conservation efforts or enforce government requirements by means of financial or other penalties. Article 5 countries have also seen increases in the number of certified technicians and establishment of conservation programs. For example, Brazil is implementing several reclaim centres capable of handling recovered refrigerant. Several African countries have seen an increase in the use of portable recovery equipment in their efforts to reduce emissions of ozone-depleting refrigerants.

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

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

8 HCFCs

8.1 HCFC Task Force 2003 Results and Latest HCFC Consumption Data

In Decision XI/28, the 11th Meeting of the Parties to the Montreal Protocol in Beijing requested the Technology and Economic Assessment Panel to study the problems and options of Article 5 Parties in obtaining HCFCs in the light of the freeze on the production of HCFCs in non-Article 5 Parties in the year 2004. The TEAP established a Task Force to prepare the report on the availability of HCFCs to Article 5 countries, partly by assessing global supply and demand for the period to 2015.

In parallel, Parties to the UNFCCC and the Parties to the Montreal Protocol requested the IPCC and TEAP to work together in order to produce a Special Report on safeguarding the ozone layer and protecting the climate (SROC); this request was made both at the UNFCCC COP-8 in New Delhi and at MOP-14 in Rome in 2002. Although the subtitle of the report reads "issues related to HFCs and PFCs" the Special Report also addresses in depth the banks and emissions of CFCs and HCFCs using historic and future consumption estimates. This Special Report was published in 2005, and has been discussed several times by the Parties to the UNFCCC and the Parties to the Montreal Protocol, most recently in a workshop in Montreal, July 2006.

In 2005, in Decision XVII/19 taken at MOP-17, the Parties requested the Technology and Economic Assessment Panel, inter alia, to coordinate with the World Meteorological Organization and the Scientific Assessment Panel to clarify the source of the discrepancy between emissions determined from bottom-up methods and those derived from atmospheric measurement, with a view to: (a) identifying the use patterns for the total production forecast for the period 2002-2015 in both non-Article 5 Parties and Article 5 Parties; (b) making improved estimates of future emissions from banks including refrigeration, foams, and other sectors, given the accuracy of calculations of the size of banks and the emissions derived from them, as well as servicing practices, and issues relating to recovery and recycling end-of-life.

The TEAP therefore established a Task Force on Emissions Discrepancies (TFED), which published a report in October 2006, with an analysis of the discrepancies in emissions calculated from atmospheric concentrations and from bottom-up methods for refrigeration, foams and emissive uses. This report contained for the first time chemical specific data on the production and consumption of HCFCs as reported to UNEP under Article 7.

The more recent SROC and TFED data is used in this chapter to further analyse the production and production capacity forecasts originally set out in the 2003 HCFC Task Force report. At that time, the situation was viewed as follows:

"In response to on-going environmental concerns, non-Article 5 countries continue to reduce the consumption of HCFCs to comply with the Montreal Protocol control schedule and, in several cases, to make reductions that go beyond the Montreal Protocol requirements for compliance. National and regional bans on specific HCFC applications and the accelerated European HCFC phase-out, which also applies to the new EU member states as of 2004, are already drastically reducing global HCFC demand. This reduction in global demand will almost certainly lead to a decrease in global supply through the closure of some existing facilities and also raises the potential for restriction of imports of products made-with or containing HCFCs to the non-Article 5 countries."

The main uses for HCFCs were also summarised in the HCFC Task Force Report as shown in Table 8-1 below:

Table 8-1 HCFCs in Use Today and Typical Applications

Substance	**ODP**	**Significant use prior 1989**	**Replacement for / predominant use today**
HCFC-22	0.055	Refrigerant for room and packed air conditioners, small water chillers	Uses as prior to 1989, plus: replaces CFC mixture R502 in commercial refrigeration equipment (non-exclusive). Replaces CFC 12 in smaller chillers, commercial and some other applications (non-exclusive). Mixture component in some CFC-12 drop-in replaceme
HCFC-123	0.02	None	Replaces CFC-11 in centrifugal chillers and halon 1211 in portable fire extinguishers
HCFC-124	0.022	None	Mixture component in some CFC-12 drop-in replacements. Replaces CFC-114 in some heat pumps and special air conditioning equipment (non-exclusive). Also used in some sterilant mixtures
HCFC-141b	0.11	None	Replaces CFC-11 as blowing agent in rigid polyurethane foams and integral skin foams. Significant use in solvent applications.
HCFC-142b	0.065	None	Replaces CFC-12 as blowing agent in extruded polystyrene board and is a mixture component in some CFC-12 drop-in replacements
HCFC-225 ca/cb	0.025 / 0.033	None	Replaces CFC-113 and TCA as a solvent. Both isomers are used separately or as a blend

The report continued by stating that:

"Developing country usage patterns are expected to follow the technology trends in non-Article 5 countries, although the demand for insulation foams is likely to be less because of favourable climatic conditions and differing building practices in many Article 5 regions. Although the usage of HCFCs in non-Article 5 countries will continue to fall significantly over the next ten years, there are certain economies in Article 5 regions that will have substantial impacts on future consumption. These are particularly China, India, Brazil and other countries where population concentrations and economic growth rates are high and where living standards are expected to improve. Information has come to the Task Force indicating substantial growth rates for the commercial refrigeration sector in China and even the most pessimistic of these projections is likely to put a burden on the on-going supply chain for HCFC-22. Nonetheless, it is recognized that any such projections have inherent uncertainties in both economic and technical components, especially over a period of 12 years or more."

8.2 HCFC-22

For HCFC-22, the Task Force therefore adopted a "low demand" and a "high demand" scenario. The "low demand" scenario was based on a relatively conservative set of growth assumptions (~2%) which would serve to no more than double the Article 5 consumption in the period from 2000 to 2015. Meanwhile, the conditions applied for the "high demand" scenario were as follows:

- *If the average market growth for the period 1990-2000 was lower than +7% per year, the projected market growth rate was assumed equal to the average 1990-2000 value Under these circumstances, the period 2000-2015 is then characterised by a constant growth rate.*

- *If the average market growth rate for the period 1990-2000 was higher than +7% per year, the projected growth rate was assumed to decrease following an asymptotic curve, starting in 2000 with the value of the average growth during 1990-2000, and then decreasing to +7% in 2015 following an asymptote.*

In the 2003 assessment, the mean of these two demand profiles was used to determine the available capacity on an on-going basis through the period. However, the analysis was somewhat complicated by the demand for HCFCs as feedstocks and the fact that some plants (so-called "swing" plants) could be used for more than one chemical[3]. The assessment therefore had to be

[3] Within a limited ratio, the quantity of HCFC-22 produced can be rapidly adjusted between CFC and HCFC production. However, once CFC phase-out is completed, this flexibility will be lost. On the other hand, some CFC plants may remain operating as HCFC-22 plants to meet demand.

conducted on a chemical-by-chemical basis in order to derive the tables below.

The report noted the following characteristics about the HCFC-22 situation:

"HCFC-22 is produced by numerous companies in a number of countries and is currently used in air conditioning and refrigeration products world-wide and as a feedstock in the production of fluoropolymers ……… Total production of HCFC-22 will depend on a balance of declining consumption in non-Article 5 countries, increasing consumption in Article 5 countries and global increases in feedstock demand for fluoropolymers. There is also a potential for non-Article 5 countries to restrict exports of HCFCs. Such restrictions would further limit available capacity to meet the demand in Article 5 countries."

Table 8-2 HCFC-22 Demand and Production

HCFC-22	**Demand and Production (ktonnes) (year)**			
	2002	**2005**	**2010**	**2015**
Market Demand non-A5(1)	189	180	99	37
Market Demand A5(1)	104	132	212	305
Market Demand, total	293	312	311	342
Prod. Capacity: non-A5(1)	440	410	353	335
Prod. Capacity: A5(1)	166	181	205	230
Prod. Capacity: total	606	591	558	565
Feedstock Requirement	212	239	290	337
Available Market Capacity	394	352	268	228
Unused Capacity/ Insufficient production capacity (negative)	101	40	-43	-114
Capacity Utilisation	83%	93%	100%	100%

It can be seen that the existing capacity for HCFC-22 was expected to have been exhausted in the period shortly after 2005. Moving forward to the data accumulated for the TFED Report in 2006 (see Table 8-3), the total demand for HCFC-22 (excluding feedstock demand) in 2004 was 15% higher overall than that estimated for 2004 in the HCFC Task Force Report, with Article 5 demand being 67% higher than expected and non-Article 5 demand 19% lower.

This is given in the table below.

Table 8-3 Production-Consumption as Reported to UNEP (Article 7) for HCFC-22

PRODUCTION/year (ktonnes)	**2000**	**2001**	**2002**	**2003**	**2004**
Non- A5	225	202	183	164	142
A5	117	126	141	171	229
Total	342	328	324	335	371
CONSUMPTION (ktonnes)					
Non-A5	177	177	147	159	149
A5	155	151	151	161	204
Total	332	328	298	320	353

When comparing table 8-2 with table 8-3, the following additional points can be observed concerning the supply/demand balance. The available production capacity predicted for 2005 in 2003 was already too low for the production levels reported for 2004, and demand is estimated to be growing at such a rate that it will have exceeded 400 ktonnes per annum by the time that data is reported for 2005 and 2006., This growth is expected to continue to a much higher figure by 2010 (perhaps 500-600 ktonnes), even though the available production capacity, as forecast in the HCFC Task Force report, is expected to decrease from 352 to 268 ktonnes.

In 2003, The Task Force mentioned the following:

"The introduction of additional regulatory controls in non-Article 5 HCFC production after 2005 (over and above the required freeze) is likely to bring forward investment plans for further HCFC-22 capacity in Article 5 regions. This will give these investments more opportunity for commercial return. It is clear that Article 5 producers will not wish to invest if the climate at the time of investment is unfavourable. However, with the freeze on production in non-Article 5 countries in 2004 and additional unilateral controls in the European Union in 2008 and 2014, the market for HCFC-22 is expected to be tight from 2005 onwards, thereby encouraging further investment prior to 2010 in Article 5 countries."

In 2003, the following was also mentioned:

Article 5 producers would not invest if there were:

- *Poor prices in the HCFC-22 market place*
- *An uncertain regulatory future which could impinge on the life-expectancy of the investment*

- *Heightened environmental concerns over inadvertent production of HFC-23 and the need for emission abatement (HFC-23 is a potent greenhouse gas).*

However, the earlier the investment is called for, the less likely it is that these circumstances would exist in Article 5 countries. Ironically, therefore, the decision to limit export potential from non-Article 5 might inadvertently cause Article 5 investment in HCFC-22 to proliferate.

In summary, it is clear that increases in HCFC-22 demand in developing countries are now being met, at least partially, by capacity being installed in those same countries.

The above has also to be considered in the light of the CDM credits under discussion since 2004 (see below).

8.3 HFC-23

Although the impact of emissions of HCFCs and HFCs can be reduced by using lower GWP substitutes etc., the issue of credits under the CDM for the incineration of HFC-23 originating from the manufacture of HCFC-22 acts as an unfortunate counter-balance.

In essence, the giving of credits for the destruction of HFC-23 (at the value, which would apply to HFC-23 with its high global warming potential) creates a perverse incentive for further increasing the manufactured quantities of HCFC-22. This is because of the fact that the value of credits granted for the destruction of HFC-23 would largely offset the production costs for HCFC-22 (at the current level). This would in turn make it more difficult to accelerate the phase-out of HCFC-22 production for emissive uses.

Parties to the UNFCCC have discussed this issue for several years now. In the first instance, they have decided to discourage new (increased) production of HCFC-22 via "new HCFC-22 facilities" by proposing that they be ineligible for credits under the CDM because this could lead to higher global production of HCFC-22 and HFC-23 than would otherwise occur. However, to do this, the term "new HCFC-22 facilities" needed to be defined. The current definitions are found in Decision 8/CMP.1. Accordingly, for "new HCFC-22 facilities", Parties were encouraged to provide funding from sources other than the CDM for the destruction of HFC-23, in order to avoid providing such a perverse incentive.

Parties to the UNFCCC have always been aware that HCFC-22 used as a feedstock in the manufacture of other chemicals is not controlled under the Montreal Protocol. They also recognised that the existing and future demand for HCFC-22 as a feedstock (which would not be emitted) would be a continued source of HFC-23 emissions if action to mitigate HFC-23 releases was not taken in this area as well.

In May 2006 (SBSTA document FCCC/SBSTA/2006/L.15), the SBSTA reinforced the statement that the application of CDM credits should not lead to higher HCFC-22 production for emissive uses (and should therefore not be given) and asked Parties and others to submit relevant information. In November 2006, this statement was reiterated (SBSTA document FCCC/SBSTA/2006/L.23), but SBSTA noted that it could not conclude its consideration of the issue.

In summary, it seems unlikely that any credits will be given under the CDM to any new HCFC-22 facilities, although this is not currently a mandatory stipulation in any of the current texts. Indeed, there would still be a legitimate opportunity to include pre-existing plants or perhaps those only used for feedstock purposes in such projects. Failure to limit the provision of CERs under the CDM could otherwise lead to an unlimited increase of HCFC-22 production (whether or not there would be a demand).

In parallel, Parties to the Montreal Protocol are aware of the climate effects of increased HCFC-22 emissions and have requested the Technology and Economic Assessment Panel, in a Decision at MOP-18 (November 2006) in Delhi, to study the specific phenomenon and its impacts, as well as the HFC-23 crediting issue itself.

8.4 HCFC-141b

For HCFC-141b, it is also useful to compare the assessment in the 2003 TEAP HCFC Task Force report with more recent estimates. The table below shows the supply/demand analysis as prepared for the 2003 Report:

Table 8-4 HCFC-141b demand and production capacity

HCFC-141b	**Demand and Production (ktonnes) (year)**			
	2002	**2005**	**2010**	**2015**
Market Demand non-A5(1)	98	13	9	9
Market Demand A5(1)	20	24	34	43
Market Demand, total	118	37	43	52
Prod. Capacity: non-A5(1)	110	82-106	59-75	20-30
Prod. Capacity: A5(1)	20	23	29	35
Prod. Capacity: total	130	105-129	88-104	55-65
Feedstock Requirement	0	0	0	0
Available Market Capacity	130	105-129	88-104	55-65
Unused Capacity	12	68-92	45-61	3-13
Capacity Utilisation	91%	28-35%	41-49%	80-94%

The more recent estimates derived for the 2006 TFED Report, from data submitted under Article 7, are shown in Table 8-5 below:

Table 8-5 Production - Consumption as Reported to UNEP (Article 7) for HCFC-141b

PRODUCTION/year (ktonnes)	**2000**	**2001**	**2002**	**2003**	**2004**
Non- A5	128	118	124	55	35
A5	12	13	25	35	43
Total	140	131	149	90	78
CONSUMPTION (ktonnes)					
Non-A5	114	103	118	44	14
A5	38	34	43	56	70
Total	152	137	161	100	84

When comparing the table from the HCFC Task Force report with the table giving production and consumption figures for HCFC-141b for the period 2000-2004, the following can be observed:

- the available production capacity estimated back in 2003 for 2005 (105-129 ktonnes) remains large enough to cover the global demand, although global production reported to UNEP (Article 7) is estimated to exceed this capacity in some years.
- for the production reported for 2004, amounts produced in the non-Article 5 countries show a rapidly decreasing trend compared to earlier years in line with regulatory actions taken in Europe, United States and Japan. If the production capacity still available in the non-Article 5 countries were to remain unused, a much higher than anticipated growth in production capacity installed in the Article 5 countries would be required (perhaps 70-80 ktonnes larger than currently estimated).
- The fact that consumption has consistently exceeded production for the period since 2000 indicates that there may either be an under-declaration of production or, more likely, that some degree of stockpiling has occurred in earlier years in preparation for the phase-out period in non-Article 5 countries.
- For Article 5 countries, the demand given for the year 2005 (24 ktonnes annually) in the HCFC Task Force report may well be 45-50 ktonnes too low based on the 2004 data submitted under Article 7. However, this growth is only partially accounted for by the rigid foam sector, which has moved from 16,800 tonnes to 28,400 tonnes (69%) in the period from 2001 to 2005, almost entirely because of replacement of CFC-11. In fact the reliance on fluoro-chemicals in Article 5 regions has dropped from

72% to 60% for polyurethane foams based on further transitions to hydrocarbons. This may be an important trend for the future too, although overall market growth will almost certainly ensure that there is a steady increase in absolute to demand until 2015.

- Perhaps the biggest concern is that there is apparent growth appearing in non rigid-foam applications within Article 5 countries. This could be partly occurring in solvent applications, although use is also now being reported in refrigeration equipment flushing. Further work will be required to identify the on-going (and growing) uses.

8.5 HCFC-142b

For HCFC-142b, the situation is once again confused by the use of the chemical as a feedstock. Table 8-6 illustrates the situation:

Table 8-6 HCFC-142b Demand and Production Capacity

HCFC-142b	**Demand and Production (ktonnes) (year)**			
	2002	**2005**	**2010**	**2015**
Market Demand non-A5(1)	17	16	0	0
Market Demand A5(1)	0	0	0	0
Market Demand, total	17	16	0	0
Prod. Capacity: non-A5(1)	92	78-100	74-96	70-90
Prod. Capacity: A5(1)	5	5	5	5
Prod. Capacity: total	97	83-105	79-101	75-95
Feedstock Requirement	58	63	71	81
Available Market Capacity	39	20-42	8-30	(-6)-14
Unused Capacity	22	4-26	8-30	(-6)-14
Capacity Utilisation	77%	75-95%	70-90%	85-108%

Table 8-7 Production-Consumption as Reported to UNEP (Article 7) for HCFC-142b

PRODUCTION/year (ktonnes)	**2000**	**2001**	**2002**	**2003**	**2004**
Non- A5	40	33	25	27	34
A5	1	1	2	4	4
Total	41	34	27	31	38
CONSUMPTION (ktonnes)					
Non-A5	34	32	18	22	19
A5	2	2	2	6	6
Total	36	34	20	28	25

It can be seen from comparisons with Table 8-7 above that the estimates for demand in non-Article 5 countries are broadly re-confirmed by the data reported under Article 7 for the period between 2002 and 2004. This reflects the fact that the North American XPS industry is the only remaining user of any significance and that this product-group is well understood.

This is less the case for consumption in Article 5 countries, which is beginning to grow against a nil-forecast. The primary reason for this is the introduction of XPS facilities into China and other Article 5 country regions (e.g. the Middle East and Latin America). Recent reports suggest that consumption might have reached levels in excess of 10,000 tonnes in 2005 and could even reach 20,000-25,000 tonnes by 2015 based on announced foam capacity expansions. This would be of particular importance because of the relatively emissive production process and the high global warming potential of HCFC-142b (2270). These estimates are based on the assumption that XPS plants will divide 'loyalties' equally (50/50) between HCFC-142b and HCFC-22. Favouritism in either direction would result in higher and lower estimates respectively. Since HCFC-22 is the cheaper and more readily available blowing agent, it is possible that the ultimate balance will be in favour of HCFC-22 and that there could be another 40,000-50,000 tonnes of HCFC-22 foam consumption to add to the already burgeoning demand for HCFC-22 as a refrigerant. The counter-argument is that HCFC-142b provides a better foam performance and could become the norm where energy efficiency performance is paramount.

In summary, more results on:

1. historic production,
2. consumption data per country
3. how production matches consumption in certain Article 5 regions,

may become available once the surveys (conducted by UNDP as decided in 2005 by the Executive Committee of the Multilateral Fund) become available. This is expected to happen in the first half of 2007.

8.6 Drivers of Future Demand

Non-Article 5 Countries

Although the phase-out of HCFC use in one or two key markets (XPS) and countries (e.g. Canada and Australia) will not fully take place prior to 2010, the only drivers of relevance will be the underlying growth in the markets themselves. As transitions begin to accelerate, this steady growth will be more than offset as HCFC phase-out moves to its ultimate conclusion in non-Article 5 countries.

Article 5 Countries

In the Article 5 countries, however, drivers for future demand of (cheap) HCFC-22 (and further increases in capacity) are the increase in installed air conditioning and commercial refrigeration capacity on the one hand and the growth of XPS foam usage on the other. There will also be increasing demand for HCFC-141b based on increase use of insulation in buildings. However, this is expected to be offset to some extent by steady transitions to cheaper hydrocarbon technologies as economies of scale emerge and also by the on-going transition of appliance manufacturers to non-ODS substitutes by 2015.

8.7 Considerations on Costs for Replacements

In principle it is possible to consider future conversion projects from HCFC-22 to HFC based blends in the refrigeration sector. Again, economies of scale would be a factor here. Assuming that a factory would produce 1,000,000 A/C units per annum, the required investments would amount to about $2.5 million and additional operational costs for half a year would be around $8 million, bringing the total to 10.5 million. This implies a cost of 21 USD per kg, or about 420 USD per ODP kg.

8.8 Implications for the Montreal Protocol

The trends in growth of HCFC use in Article 5 countries are clearly upwards and well ahead of forecasts carried out as recently as 2003. There is a clear need to address the implications of these faster growth rates to the recovery of the ozone layer and to the effectiveness of the Montreal Protocol as currently structured. In two parallel Decisions at the Montreal Protocol Delhi meeting (MOP 18), TEAP was requested to evaluate the implications of a business-as-usual approach and compare this with potential mitigation measures that could be taken by the Parties to alleviate the worst excesses of this growth.

9 Banks and Bank Management

9.1 Introduction

Over the four years since the last TEAP Assessment Report, the significance of ozone depleting substances which are in banks [i.e. have been 'consumed' (sold for use) but not yet released] has further emerged. Banked ODSs can be found in products in use (typically foams, refrigeration equipment and fire fighting equipment) as well as in waste streams.

Banks pose a particular set of challenges for policy-makers in that they:

(1) Delay the impact of a significant proportion of the ODS consumption which has already occurred and may cause observers to under-estimate the overall environmental impact of previous societal choices.

(2) Make it more challenging to assess the rate of future emissions.

(3) Can cause releases to occur at times and in places where the ozone layer might be more vulnerable

On the more positive side, banks can provide some benefits in that they:

(1) Can slow the overall rate of release of ODS – a point which is important where the kinetics of ozone depletion controls the level of depletion in any given year

(2) Can offer opportunities for recovery of ODS, which can have both ozone and climate benefits because of the high global warming potentials of some ODSs.

However, predicting the overall impact of releases of ODS or actions to recover them from banks is often complex because, perversely, ozone itself is a greenhouse gas. Therefore, releasing an ozone depleting chemical can result in further ozone depletion which reduces (at least in the short-term) the overall global warming taking place in the environment. This has caused some to refer to concepts such as the 'net' global warming potential of certain ozone depleting substances. In some instances, compounds have even been classified as 'global coolers', where the climate impact of the ozone depletion caused, exceeds the direct global warming contribution. Halons are often cited as an example in this regard. However, members of the Science Assessment Panel have been quick to point out that the spatial distribution of releases are vitally important and that eventual ozone depletion at the poles does not directly offset the impact of global warming at mid-latitudes.

TEAP has contributed substantially to these discussions over the last four years with inputs such as:

- Task Force Reports on Destruction Technologies (2002 and 2005)
- Task Force Report on Collection, Recovery and Storage - TFCRS (2002)
- Task Force Report on Foam End-of-Life issues (2005)

However, without doubt, the most significant contribution to this agenda came from a co-operative effort with the Inter-Governmental Panel on Climate Change (IPCC), which looked at the interface between ozone depletion and climate change from both a scientific and a technological perspective. The resulting report has become known as the Special Report on Ozone and Climate (SROC) and much of the remainder of this chapter addresses issues which have emerged from that initiative.

9.2 Further Estimates of Bank Sizes

Although previous efforts had been made to assess the size of banks (most notably by AFEAS), the complexity of actual usage patterns in the primary sectors of refrigeration and foam made these estimates very difficult to compile at an aggregated level. The SROC (originally commissioned in 2002), therefore provided a focal point for a more systematic assessment of consumption, emissions and, by deduction, banks. Much of this work was specially commissioned for the Report but was properly published in peer reviewed journals[4] prior to inclusion. Indeed, the demand for such information spawned a number of supporting study activities into areas such as the release rates (characterised through emission factors) of various product types.

The outcome of these activities was a series of estimates of current bank sizes and a business-as-usual projection of how they might look in 2015. A conscious decision was taken not to estimate bank development beyond 2015, because on-going consumption of ODS and ODS substitutes was viewed as very difficult to assess beyond that year. Nevertheless, authors were very conscious that the environmental impacts of previous accrued banks could extend well beyond 2015, particularly in long-life products such as foams.

Because the SROC was initiated under the UNFCCC framework, its primary focus was on the global warming impacts of ODS substitutes. However, it had become fairly obvious in the early stages that the impacts of the ODSs themselves were equally important, if not more so. However, under this framework, such a judgement could only be made based on the climate

[4] e.g. **Ashford, Clodic, Kuijpers and McCulloch**; Emission Profiles from the Foam and Refrigeration Sectors – Comparison with Atmospheric Concentrations, International Journal of Refrigeration, 2004

impact of releases from banks rather than any direct ozone depleting contribution. As a consequence of this constraint, Parties to the Montreal Protocol subsequently requested TEAP to produce a Supplementary Report, which expressed the same findings in terms of their ozone significance. The following graphs are extracts from that Report which was presented to MOP-17 in Dakar in December 2005:

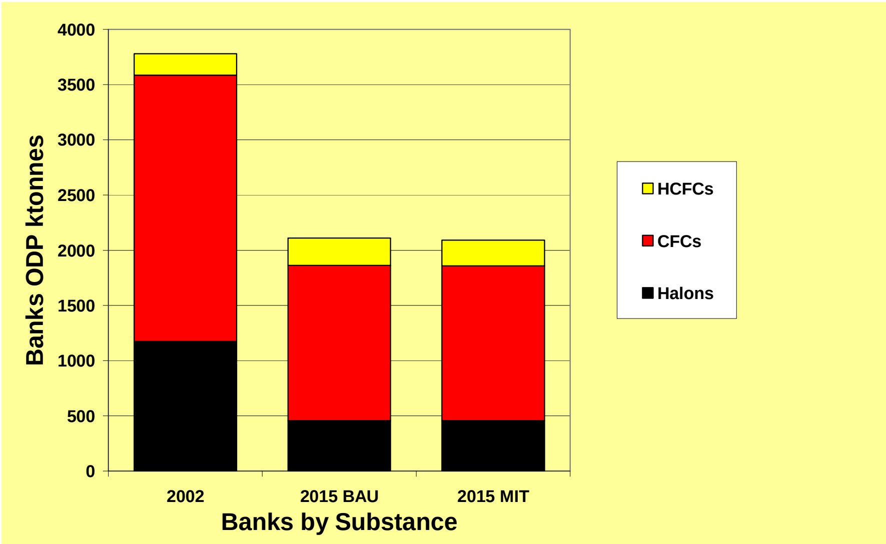


Figure 9-1 Bank estimates for 2002, 2015 Business-as-usual and 2015 Mitigation Scenarios

Figure 9-1 clearly illustrates that banks in 2002 were in excess of 3.5 million ODP tonnes and were expected to reduce to around 2 million ODP tonnes by 2015 because of releases to the atmosphere in the interim. It was also concluded that actions to mitigate releases would not generally involve earlier intrusion into the banks, which, where reachable, were generally stable within products in active use.

The location of the banks was revealed by a parallel assessment of the sectors in question and Figure 9-2 illustrates that the bulk of the banks in 2002 existed in foams and will continue to do so in 2015 and beyond:

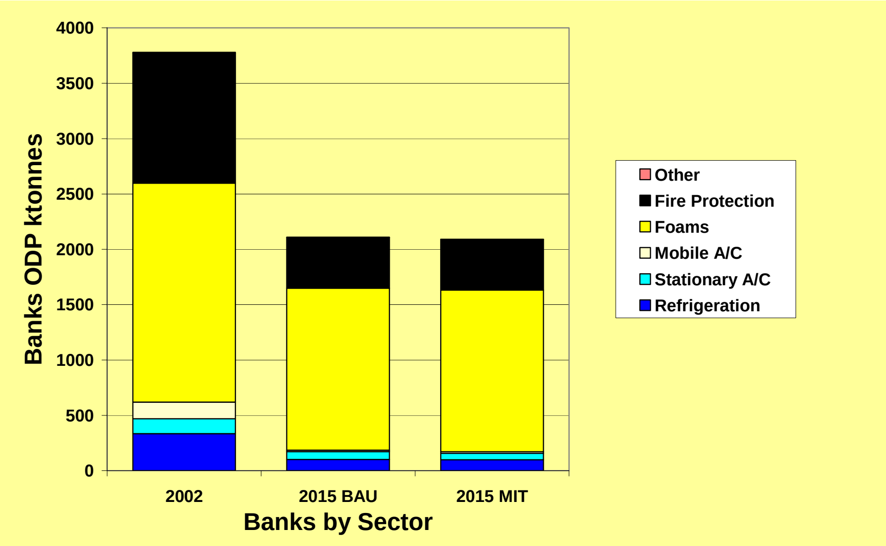


Figure 9-2 Bank estimates per sector (above)

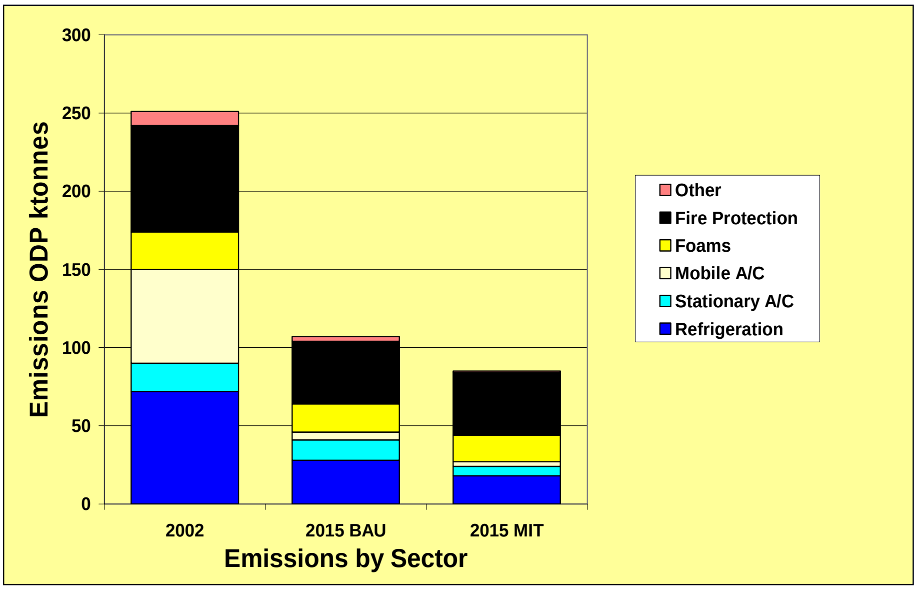


Figure 9-3 Trends in Emissions from Banks and the Impact of Mitigation Measures for ODS (below)

For ODSs being released (i.e. annual emissions), it was clear that mitigation measures could play a substantial role in reducing their impact, as shown in Figure 9-3 above.

In this assessment, it was found that annual emissions of ODSs in 2015 could be reduced by approximately 20% through a series of mitigation measures, mostly in the refrigeration and air conditioning area. This is not to underplay the opportunities in the foam sector, but most of these could only be realised after 2015. Perhaps the most important single aspect to emerge from the analysis was the high percentage of annual emissions arising from the refrigeration and air conditioning sector in 2002 and thereafter. This is consistent with the change in banks identified in Figure 9-2 and provides confirmation that emission mitigation efforts should be focused on the refrigeration and air conditioning sector in the period prior to 2015 for best effect.

9.3 Additional Efforts on Discrepancies between Bottom-Up and Atmospherically Derived

One aspect that emerged during the preparation of the SROC was the need to reconcile emissions estimates from the bottom-up assessments with inversely modelled annual emissions derived from atmospheric concentrations. In general, it had been observed that the bottom-up estimates were consistently lower than those derived from atmospheric measurements. There were a number of potential explanations for this:

(1) The SROC was focused on those applications of ODS being substituted by other substances controlled under the Kyoto Protocol (notably HFCs) and therefore not all previous/current ODS uses were included;

(2) Not all consumption had been accounted for within the sectors covered by the bottom-up models;

(3) Emission factors were under-estimated in some key application areas.

Although there was opportunity to give a limited assessment of the discrepancies between bottom-up and top-down assessments in the SROC, it was not possible in the time available to assess the uncertainties to any significant degree. This fact led to a subsequent Decision at MOP-17 (Decision XVII/19) to carry out a further assessment of the source of these discrepancies. This assessment had the privilege of access to UNEP data (reported under Article 7) on a chemical-specific basis and this enabled a better assessment of production and consumption patterns. However, since the Article 7 data had no end-use analysis, there was still a significant need to reconcile the consumption assessments with sector-specific data. The Task Force on Emissions Discrepancies reported to MOP-18 on the outcomes of this work and concluded that discrepancies were less pronounced than had been identified in the SROC. The reasons for the closer agreement were as follows:

- More complete consumption datasets arising from the Article 7 submissions.
- Proper consideration of the impact in uncertainties of the lifetime of chemicals on the emissions estimates derived from atmospheric measurements.

Nonetheless, despite this closer agreement, some discrepancies still remain. However, in virtually all cases, these can be accounted for by a combination of the following on-going uncertainties:

- Reporting gaps and lack of use-pattern definition in UNEP consumption data
- Emission factors used in bottom-up methods and particularly their variation over time with technology and market development
- Removal rates of each chemical – linked to uncertainties in atmospheric lifetime determination

9.4 Needs for Improved Reporting

There is clear evidence that, as the use of HCFCs grows further in Article 5 countries, the efficacy of AFEAS end-use analysis will further decrease. Individual sector databases will also have their limitations because of difficulties in obtaining activity data using bottom-up methods in developing countries. Therefore, it will become increasingly important for future reporting processes to provide some end-use specificity within the reporting framework if the level of confidence in the estimation of banks and emissions is to be maintained, or even improved.

9.5 Spread of Emission Reduction Measures

*- **Better servicing practices (refrigerants and halons)***

An additional distinction for some applications (e.g. refrigeration and fire protection) is that equipment is serviced and replenished during its life-time. This creates a further consumption and emission pattern through the life of the equipment, which, in many cases, can be more significant than the initial charges when the equipment was manufactured. The emissions of the major banked chemicals in fire protection, refrigeration and air conditioning equipment therefore occur primarily during the use phase, a fact that is reflected in the more dynamic nature of the banks contained in such equipment. In the refrigeration and air conditioning sector, several potential measures will be introduced progressively in the period to 2015 and will have an impact on ODS emission patterns, even after phasing out the use of ODSs in new equipment. These measures relate to specific servicing practices, such as recharging to offset earlier leakage, particularly in Article 5 countries, where ODS (CFC) based equipment is still abundant. Nonetheless, the main mitigation strategies likely to have effect on ODS emissions in the mid-term (e.g., as of 2008) are those associated with end-of-life measures in refrigeration and (mobile and stationary) air conditioning. Accordingly, recovery and possible destruction may have a significant impact on the level of emissions released from the banks.

The activities leading to further emissions of fluorocarbons are expected to expand significantly between now and 2015. These activities (such as increases in requirements for refrigeration, air conditioning) will involve a number of technologies, including CFCs and HCFCs. In non-Article 5 countries, the consumption and emissions of CFCs and HCFCs will decline as obsolete equipment is retired. In Article 5 countries, ozone-depleting substances (particularly HCFCs) may be used for several decades and significant growth is expected.

Improved servicing practices in refrigeration can result in reductions of emissions of up to 25% against a business-as-usual scenario, dependent on the specific sector and the region for non-Article 5 countries. These percentages are lower in Article 5 countries and are often zero to maximum 15-25% for some sectors. There is a potential to decrease the amounts used for servicing (i.e. that refrigerant used to replace what has already been emitted) by 20-50% dependent on the specific sector and the region. Figure 9-3 has already illustrated this potential. A large reduction in emissions (40%) is assumed to take place between 2002 and 2015 in the refrigeration sector. This will also include the impact of certain recovery measures at end-of-life.

Emissions from HCFCs in Europe will decrease further in the next decade due to the fact that the manufacture of new equipment containing ODS has been phased out in Europe since 2001-2003. This will, in turn, lead to a decreasing bank and resulting decreases in servicing amounts. However, it should be mentioned that the trends in HCFC emissions for servicing in Article 5 countries will be in the opposite direction, mainly due to a rapidly increasing bank.

Most halon 1211 is widely dispersed in building and residential portable fire extinguishers averaging only a few kg each. Other halon 1211 has been centralised in military, aviation and large fire brigades. Collection of the widely dispersed portable extinguishers may prove to be unproductive or uneconomic in some countries. National programs that require halon owners to donate substances and to pay for destruction have resulted in recovery of only a small portion of estimated banks, with unreported quantities likely emitted or lost to avoid the expense. On the other hand, national programs offering a bounty for recovered halon and financing of destruction have demonstrated higher recovery rates.

Available halon 1301 should be banked and managed for critical uses, but halon 1211 may be available for destruction. The costs for destruction of halon 1211 would be less per ODP tonne than destruction of CFCs. At the sectoral level, collection and destruction of the halon 1301 bank is counterproductive because available supply is necessary for critical uses.

- Mandated and voluntary end-of-life management in appliances (Europe, Japan etc.)

As of 1 January 2002, it became mandatory to recover and/or destroy blowing agents contained in foams within domestic refrigerators within the EU in addition to the former requirements for refrigerant recovery. Some EU Member States have struggled with implementing the foam requirement since, but there is now little argument that it is technically feasible and environmentally beneficial to do so. In the UK, where some stockpiling of refrigerators had to take place prior to the installation of appropriate blowing agent recovery equipment, the process has been relatively smooth since. However, capacity for handling of refrigerators currently exceeds the supply through the waste stream and prices are therefore artificially low. The enlargement of the EU, first to 25 Member States and now, most recently, to 27 Member States, has broadened the impact of the EC Regulation 2037/2000 significantly.

In Japan, the initial recovery of foams and refrigerants at end-of-life was driven by wider ‘producer responsibility’ recycling laws which did not mandate recovery of blowing agents from foams. Nevertheless, this was commonly practised and has now been enshrined in law as a mandatory requirement.

The Foams End-of-Life Task Force Report deals with the relevant processes and technologies used regionally, and highlights the use of lower-cost manual methods for removing foams from refrigerators where there are no legislative drivers (e.g. the USA and some developing countries). These have generally been demonstrated to be environmentally sound when practised by responsible contractors despite the lack of automation. Such technologies have proved particularly valuable for voluntary programmes where the throughput can vary considerably depending on the incentives offered. These programmes are often sponsored by utilities companies, either as part of their contribution to existing energy efficiency targets or as a way of putting off the need to invest in new electricity generation capacity. As voluntary programmes grow in stature they are likely to merge into networks with sufficient critical mass to justify the more automated processes currently used in Europe and Japan.

Meanwhile, research has continued into establishing the baseline for emissions from appliances that are currently landfilled – with or without shredding. There continues to be growing evidence to support the potential for anaerobic degradation of CFCs in landfills, with the latest work in Denmark showing that this can occur in real-life landfills. However, there is still uncertainty about the release profiles from foams during the land-filling process, particularly during the period of initial compaction. Accordingly, a comprehensive mass balance for this waste stream is far from complete.

9.6 The Challenge of Buildings

- Chillers and A/C

Relatively, the largest potential reduction in emissions is in the stationary air conditioning sector with more than 50% reduction in the MIT versus the BAU scenario, followed by refrigeration with a reduction of about 40% in 2015. Stationary air conditioning is the largest consumer of HCFCs among all the sectors (even in chillers HCFC-22 and HCFC-123 are the most frequently applied refrigerants). In terms of share within the MIT scenario, the largest absolute reductions are also observed in the stationary air conditioning sector (67% of the total). This is mainly due to a conversion from HCFCs to non-ODP refrigerants, better servicing practices, low charge designs for new equipment, and en-of-life recovery that is assumed to increase.

Emissions from HCFCs in Europe will also decrease further in the next decade owing to the fact that new equipment manufacturing has been phased out in Europe since 2001-2003, leading to a decrease in the bank size and resulting decreases in servicing amounts. However, it should be mentioned that the trends in HCFC emissions for servicing in Article 5 countries (particularly from stationary A/C) will be in the opposite direction, mainly due to a rapidly increasing bank. Servicing with ODP refrigerants in the EU will also be impacted by the recently adopted F-gas regulation for maintenance and better practices, which will have its impact on all sectors (where also end-of-life recovery is an important issue).

Chiller replacement in all countries, especially non-Article 5 countries, is proceeding. In the USA, there are still about 30,000 CFC based centrifugal chillers in operation (mainly CFC-11), compared to more than 60,000 centrifugal chillers on HCFC-123 and HFC-134a. The CFC chillers manufactured before 1993-1994 cannot be retrofitted cost effectively and replacement is the only viable option. Such replacement needs urgent consideration not only from the point of view of ODP emissions but also from an energy consumption point of view. In Article 5 countries, the potential for the replacement of old centrifugal chillers is large. These aging chillers are still operated on CFCs and show relatively large leakages between 30 and 40% (see TEAP Report of the Chiller Task Force, 2004). Inventories of the order of 400-500 kg per chiller are involved and the total amount of CFC chillers in Article 5 countries is estimated at more than 15,000 units (which implies an emission of about 2000 tonnes per year). These emissions can only be mitigated by a replacement program, which emphasises the incentive to replace in order to substantially decrease energy consumption. Some demonstration (revolving fund) projects started years ago which showed reasonably good results when the projects were assessed afterwards. New demonstration projects for the replacement of chillers have been approved by the Multilateral Fund ExCom in 2005, at a value of about US$ 15 million. However, it should be realised that a complete replacement of all CFC-based chillers in the Article 5 countries will cost considerable time and will be very much dependent on whether or not refrigerant management plans are operative in a country.

- Foams

In Japan, the Japanese Technical Centre for Construction Materials (JTCCM) has recently completed a five year study on the quantification of blowing agent banks within buildings and the potential for recovering these banks. While it is clear that large quantities of ODS blowing agent are potentially available for recovery (approximately 80,000 tonnes in total for Japan alone), the project has confirmed that not all such foams are technically recoverable. This is largely as a consequence of the methods of building construction involved and the foam application methods used. In many other cases, foams may be technically recoverable but the economics can be prohibitive (sometimes up to 100 times more expensive than refrigerant recovery). With this in mind, the Japanese Government has elected to actively promote the voluntary recovery of ODS at end-of-life within the framework of the Construction Material Recycling Law, rather than to introduce a mandatory requirement.

Member States within the European Union have been considering similar agendas. There are very few, if any, construction applications which fit the current provisions of Article 16 of EC 2037/2000 in terms of practicability – containing, as it does, an economic component as well as technical component within its definition. Steel-faced foam panels (sandwich panels), which are a particularly popular means of construction for warehousing and industrial buildings in Europe, are one technology area where the technical capability for recovery is now beyond doubt. Trials carried out during 2005 in an existing refrigerator recycling plant have shown that blowing agent recovery rates are in line with those achieved for refrigerators and that there are no fundamental practical problems. However, the costs of such measures remain challenging.

9.7 List of Practical Measures Derived from the Montreal Workshop

For a Workshop organised by UNEP’s Ozone Secretariat in Montreal, in conjunction with the 2006 OEWG-26, Parties were invited to submit a list of measures that were viewed as ‘practical’ in nature. After appropriate collation of these proposals by the TEAP facilitators, the full list of measures was discussed and ultimately approved at the Workshop. These included a series of measures related to the management of banks:

- Leakage reduction measures during operation and servicing;
- Recovery of ODS from domestic refrigerators, drink dispensers etc. at end-of-life;
- Reduction of charge requirements by greater adoption of indirect systems etc.;
- Management of steel-faced panels at end-of-life where practicable.

In a further Decision taken at MOP-18 in Delhi, TEAP has been asked to further assess this list of practical measures with the aim of providing some indication of priority in terms of urgency and impact. This will be the subject of a further Task Force Report during 2007.

9.8 The Way Forward

The progress made in understanding the size, nature and dynamics of ODS banks during this Assessment Period has been significant, based broadly around the initiative established under the UNFCCC and supported by the IPCC and TEAP to develop the SROC.

It is self-evident that the environmental benefits of ODS bank management extend well beyond ozone itself and there are clear opportunities to contribute to the mitigation of climate change in parallel. However, the value of these dual benefits needs to be recognised and quantified if the necessary actions are to be justified, particularly where the economics of bank management are unfavourable from an 'ozone-only' perspective. Although it seems unlikely in the short-term that an international agreement can be struck to address this interface between the Montreal and Kyoto mechanisms, there is now growing interest from the voluntary carbon market in including ODS recovery projects within the portfolio of environmentally justifiable options for investment. While protocols still need to be written and validated to support such an approach, the benefits to bank management are obvious. Effectively, the 'voluntary recovery' measures envisaged by the Japanese Government, amongst others, could be

facilitated by such a funding mechanism, even if the value of credits were to be considerably lower than carbon traded on the formalised trading floors of the Clean Development Mechanism or the EU Emissions Trading Scheme. In some cases, the credits might not even need an externalised financial value if they were considered as part of a wider carbon management programme.

Such approaches could go a long way towards maximising the recovery rates from buildings, in particular, without the difficulties of legislating for the non-uniform circumstances which buildings so often engender. Parameters already developed under the Montreal Protocol, such as the Recovery and

Destruction Efficiency (RDE), could be used to evaluate avoided emissions in a robust fashion.

Parties may wish to consider whether approaches of this nature would be consistent with the objectives of the Protocol and, if so, how the Protocol might be used to assist the broadening acceptance of such voluntary frameworks.

10 Update on Low-ODP Substances

10.1 A Brief History of Concern by Parties in Low-ODP Substances[5]

In 1987 when the Montreal Protocol was signed, Parties chose to control only halons and CFCs by a freeze and a 50% reduction respectively. As years passed, the Scientific Assessment Panel increasingly warned that the ozone layer could be protected only with full global compliance and with an accelerated and complete phase-out of all ODS. The Environmental Assessment Panel predicted grave consequences by delaying such action and the Technology and Economic Assessment Panel (TEAP) confirmed that fast action was technically feasible and often more economical than a slow pace.

In 1990, Parties adjusted the Protocol to phase out CFCs and Halons by the year 2000 and amended the Protocol at the London MOP to add additional fully-halogenated CFCs, carbon tetrachloride and 1,1,1-trichloroethane (methyl chloroform) to the list of controlled substances with phase out by the year 2000. The HCFCs were recognised as transitional substances on which Parties must report annually.

In 1992, Parties adjusted the Protocol at the Copenhagen MOP to advance the dates of phase out of the controlled ODS and amended the Protocol to add: HCFCs as transitional substances, hydrobromofluorocarbons and methyl bromide to the list of controlled substances with specific dates of phase out.

In 1997, the Ozone Secretariat reported that two new ozone-depleting substances not controlled by the Montreal Protocol--bromochloromethane and normal-propyl bromide (nPB) --had entered the market and referred the issue to the Scientific Assessment Panel. The US EPA had notified the Secretariat that they proposed banning bromochloromethane as a substitute for CFC solvents. The Scientific Assessment Panel confirmed the ODP of bromochloromethane as between 0.11 and 0.13 and advised that new scientific investigations would be required to estimate the ODP of n-propyl bromide (nPB) because the atmospheric residence time was only about ten days (later revised upwards).

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[5] Summarized primarily from "Protecting the Ozone Layer: The United Nations History," by Stephen O. Andersen and K. Madhava Sarma, Earthscan Publications, London, 2002 by permission of the authors and also from TEAP, CTOC, STOC, and SAP reports, which are available from the Ozone Secretariat.

The 1997 Meeting of the Parties in Vienna expressed, through Decision IX/24, concern at the emergence of new and uncontrolled ODS and urged the Parties to report on any such substances and the Scientific Assessment Panel to assess the ODP of such substances and the possible effect on the ozone layer. It also requested the Technology and Economic Assessment Panel to report on any new substance estimated to have a significant ozone-depleting potential, including an evaluation of the current and potential use of each substance. The Parties were also urged to discourage the development and promotion of such substances.

In 1998, the tenth MOP in Cairo, in Decision X/8 further decided that the Parties should discourage bromochloromethane and that the Parties would take action under the Protocol against new ODS that posed a significant threat to the Ozone Layer. It requested the Scientific and Technology and Economic Assessment Panels to assess whether substances with very short atmospheric lifetimes, such as nPB, were a threat to the ozone layer. In the same year, the Solvent, Coatings, and Adhesives Technical Options Committee came to the conclusion that nPB could be safely used only under limited circumstances where emission controls and worker exposure mitigation could minimise the effects of potential toxicity and ozone depletion.

In April 1999, the TEAP Progress Report predicted significant production of nPB and recommended: "… that the Parties consider appropriate action to prevent or limit further depletion of the ozone layer due to this substance."

At the Eleventh MOP in Beijing in 1999, the Parties amended the Protocol to add bromochloromethane to the list of ODS and mandated its phase out by 2002. Decision XI/19 asked TEAP and the Scientific Assessment Panel (SAP) to develop criteria to assess the potential effect on the ozone layer of new chemical substances.

In May 2000, the SAP published its report: "Assessing the Impacts of Short-Lived Compounds on Stratospheric Ozone" (UNEP 2000a and 2000b) which emphasised the need for geographic estimates of nPB emissions in order to estimate the risk to the ozone layer. That year, the SAP reported at the Open-Ended Working Group in Geneva that an uncontrolled substance containing chlorine or bromine would be harmful to the ozone layer only if the substance has 1) vapour pressure sufficient to generate a significant gas-phase concentration in the atmosphere, 2) low solubility in water, and 3) a lifetime in the lower atmosphere long enough for it or its halogen-containing degradation products to reach the stratosphere. The SAP explained that because the transport to the stratosphere mainly occurred through the tropical tropopause, a short-lived species might undergo significant loss through various removal processes before reaching the tropics. The amount reaching the stratosphere was strongly dependent on the region and season of emission.

Parties therefore encouraged TEAP to provide the SAP with emission estimates for nPB by latitude and season.

In March 2001, (Decision 33/46) the Multilateral Fund approved a grant (subsequently fixed at $2M) for China to produce and use nPB as a solvent, conditional on not being able to export. Subsequently, the MLF in Decision 40/46 in July 2003 requested the Government of China to return the funding of US $2 million reallocated pursuant to Decision 33/46 for uses as originally approved in the solvent sector plan.

In April 2005, MLF Executive Committee made Decision 45/47[6]:
(a) To approve US $5,680,000, plus support costs of US $426,000 for UNDP, for the 2005 tranche of the solvent sector plan for China;
(b) To approve an amendment to the 2005 annual implementation programme to reallocate US $2 million in savings from previous tranches of the solvent sector plan to purchase and install equipment for the purification of n-propyl bromide (nPB), subject to the following conditions:

(i) HEP-2 (an nPB solvent blend) produced by China would not be made available for export;

(ii) An annual production quota would be imposed on HEP-2 to meet the requirement for solvent use only;

(iii) China would ensure that HEP-2 was only supplied to enterprises involved in the China solvent sector plan;

(iv) The Import and Export Office of China would monitor and ensure that no HEP-2 was exported by China; and

(v) The implementing agency of the China solvent sector plan, UNDP, would include in its annual audit verification plan that no HEP-2 was exported.

HEP-2 nPB solvent blend is widely used in China but, to the best of the knowledge of TEAP, has never been exported. Only unblended nPB, in a more or less pure form, has been exported. Foreign nPB vendors do their own blending and stabilising of solvents containing nPB. Thus, Decision 45/47 did not prevent nPB from being exported, only HEP-2.

Later in 2001, TEAP published the findings of the nPB Task Force: "Report on the Geographical Market Potential and Estimated Emissions of n-Propyl Bromide." The location of emissions of nPB depends on the latitude of the manufacturing plants and service facilities where it is used because nPB, as a

[6] UNEP/OzL.Pro/ExCom/45/55, Decision 45/47, para. 153.

solvent, is used only for manufacturing and service and is not contained in ODS products,. There is little seasonal variation in manufacturing and emissions because the products produced with nPB are sold throughout the year.

The TEAP Task Force found that nPB is aggressively marketed for applications traditionally using ozone-depleting and non-ozone-depleting substances, that users of nPB may not fully appreciate the importance of worker safety and ozone layer protection through limiting emissions, and that Parties may wish to consider the advantages of not promoting or financing it as a substitute for ODS. The Task Force estimated that the 2002 annual use and emissions of nPB were 5,000 to 10,000 metric tonnes, with the "most likely" use and emissions in 2010 to be 40,000 metric tonnes plus or minus 20,000 metric tonnes, depending on the results of pending toxicity testing and the price trends of nPB and the solvents it may replace. In addition, the Task Force apportioned the "upper bound" emissions to specific geographical regions as requested by the SAP.

TEAP proposed that Parties control all substances with a chemical structure likely to deplete the ozone layer significantly and allow their production and consumption by adjustment of the control schedule or by essential-use exemption, after review of scientific and technical information provided by the company proposing their production. The Scientific and Technology Assessment Panels further suggested that industries proposing new substances likely to have an ozone-depletion potential could support independent research to obtain information on the substances' ozone-depletion potential, which could then be directly submitted to the Ozone Secretariat.

In 2001, the Thirteenth Meeting of the Parties in Colombo decided in Decision XIII/5 to:

- request the Secretariat to keep an up-to-date list of new substances reported by the Parties on the UNEP website and to distribute the current version of the list to all Parties about six weeks in advance of the meeting of the Open-Ended Working Group and the Meeting of the Parties;

- ask the Secretariat to request a Party that has an enterprise producing a listed substance to request that enterprise to undertake a preliminary assessment of the substance's ODP following procedures to be developed by the Scientific Assessment Panel, submit toxicological data on the listed substance if available, and, further, to request the Party to report the outcome of the request to the Secretariat;

- call on Parties to encourage their enterprises to conduct the preliminary assessment of the ODP within one year of the request of the Secretariat and, in cases where the substance is produced in more than one territory, to request the Secretariat to notify the Parties concerned in order to promote the co-ordination of the assessment;

- request the Secretariat to notify the Scientific Assessment Panel of the outcome of the preliminary assessment of the ODP to enable the Panel to review the assessment for each new substance in its annual report to the Parties, and to recommend to the Parties when a more detailed assessment of the ODP of a listed substance may be warranted.

The Thirteenth MOP also decided in Decision XIII/7 to request Parties to inform industry and users about the concerns surrounding the use and emissions of nPB and the potential threat that these might pose to the ozone layer; urge industry and users to consider limiting its use to applications where more economically feasible and environmentally friendly alternatives were not available; and to urge them also to take care to minimise exposure and emissions during use and disposal. It requested the TEAP to report annually on nPB use and emissions.

In 2002, Parties reported four new substances: hexachlorobutadiene and nPB (reported by Canada), 6-bromo-2-methoxy naphthalene (reported by The Netherlands), and halon 1202 (reported by Israel).

In June 2003, the US EPA published a Notice of Proposed Rulemaking regarding nPB and in October 2003 clarified and corrected a number of statements in the preamble of the proposed rule.[7] EPA proposed that nPB be listed under its Significant New Alternatives Policy (SNAP) program as an acceptable substitute for CFC-113, HCFC-141b, and methyl chloroform in a limited number of specific applications where emissions can be tightly controlled for both environmental and exposure concerns. Furthermore, EPA proposed to require that nPB solvents be only listed as acceptable if iso-propyl bromide (iPB) be limited to 0.05% by weight.

> "While we (EPA) find that nPB has a short atmospheric lifetime and low ozone depletion potential when emitted from locations in the continental U.S., the Agency cautions that significant use of nPB closer to the equator poses significant risks to the stratospheric ozone layer. Further, if workplace exposure to nPB is poorly controlled, it may increase health risks to workers. In the interim, until the Occupational Safety and Health Administration (OSHA) develops a mandatory workplace exposure limit under Section 6 of the Occupational Safety and Health Act, the Agency

[7] Federal Register: June 3, 2003 (Volume 68, Number 106) Proposed Rules, pages 22283-33316. Federal Register: October 2, 2003 (Volume 68, Number 191) Proposed Rules, pages 56809-56810.

recommends that users of nPB adhere to an acceptable exposure limit of 25 parts per million (ppm) over an eight-hour time-weighted average."

Since 2003, TEAP and its CTOC has reported the updates of nPB under Decision XIII/7 with general information on production, consumption and emissions, as well as toxicity data and regulatory actions in the 2005 and 2006 TEAP Progress Reports. In view of the fact that this is not a controlled substance, no accurate production and emissions estimates are available because there is no yearly reporting by the Parties. The US EPA final rulemaking on nPB has not yet been published.

The SAP 2006 Assessment Report includes the latest estimates of the latitude-specific ODPs. The ODPs of nPB are 0.1 for tropical emissions and 0.02-0.03 for emissions restricted to northern mid-latitudes, unchanged from the previous assessment. The ODP for nPB, when used and emitted in the tropics is comparable to the ODPs of other substances already controlled by the Montreal Protocol.

In 2006, Honeywell proposed a new refrigerant blend of tetrafluoropropylene with CF_3I as a minor ingredient. Other companies, including DuPont, also announced the development of low GWP refrigerants as a substitute for HFC-134a, but have not yet publicly disclosed chemical and technical properties. The Honeywell refrigerant blend is one of at least four possible options to satisfy the EC F-gas MAC Directive (2006/40) that requires a phase-out of HFC-134a use in air conditioning systems installed in new vehicles sold in the European Union. The F-gas MAC Directive requires that vehicle air conditioning use refrigerants with GWP<150 by 1 January 2011 for new "type" vehicle models and by 1 January 2017 for all new vehicles. Refrigerant options for MAC application ODP and GWP disclosed by manufacturers include carbon dioxide (CO_2: ODP = 0, GWP = 1), the Honeywell blend (ODP >0 but not disclosed, GWP < 10), the DuPont blend (ODP = 0, GWP < 40), and HFC-152a (ODP = 0, GWP = 120). Energy efficiency compared to HFC-134a systems will depend on climate conditions and regulatory and market requirements for vehicle fuel efficiency, but are likely be more or less comparable for all options. Further testing is underway to produce more precise data.

The 2006 SAP presents the latest estimate of the ODP for CF_3I, and cautions that it could have a significant impact on the ozone layer if widely emitted. The upper-limit ODPs for CF_3I are 0.018 for tropical emissions and 0.011 for mid-latitude emissions. The previous SAP report had an upper limit of 0.008. TEAP and its Refrigeration TOC has not yet estimated the possible future fleet of automobiles, the likely penetration of air conditioning systems, the portion of new vehicle air conditioners that may use the Honeywell ODS blend, the likely service practices, and the total possible emissions under the worst case scenario.

Parties may wish to re-consider the earlier proposal by the SAP and TEAP of phasing out all ODSs pending full assessment by the Science, Environmental Effects, and Technology and Economics Assessment Panels. Production and consumption of specific chemicals proved to be harmless to the ozone layer could be permitted after the assessment through an adjustment of the Protocol.

11 Military Leadership and Technical Progress in Developed Countries[8]

At the time the Montreal Protocol was signed in 1987, virtually every military system in the developed countries relied on ODS for their manufacture, maintenance and operation. Since then, most countries have made impressive progress in eliminating ODS applications. The primary remaining military ODS use is for halon in applications considered to be critical to operations, lacking technically or economically feasible alternatives, or have not yet been budgeted or scheduled for retrofit or retirement. CFC refrigerants continue to be used in Naval ships because the refrigeration plants were designed specifically to use a particular refrigerant, the plant is sized according to the needs of the ship, the acoustic signature of the ship would be changed by using an alternative, or because the cost of removing the plant and replacing it is cost prohibitive. For example, in some ship designs, the hull of the ship must be opened in order to remove the plant. In non-Article 5 countries, these applications continue to be satisfied by recycling existing stocks of ODS. A small number of uses have been met through Essential Use Exemptions previously granted by Parties to the Russian Federation for halon 2402 in specific applications, for ODS solvents to clean torpedoes in Poland, and to the United States for methyl chloroform in manufacture of civilian and military rockets.

Information about military ODS uses and implementation of alternatives is not as readily available as for the commercial sector. However, many countries have provided detailed technical information on uses and alternatives that have been published in TEAP and TOC reports, publications of the US Environmental Protection Agency, the US Department of Defense, UNEP DTIE, and in the proceedings of four global conferences on alternatives and substitutes for military applications held in the United States and Belgium. A workshop on alternatives to halon in military applications is planned for later this year or early next year, most likely in Brussels.

11.1 Uncertain Technical Progress in Developing Countries

There is currently little information available to TEAP from developing countries about military ODS usage or efforts to implement alternatives. Sources of information have included participants in TOCs, military

[8] This report updates the status of the military phase-out. The complete history of the first 20 years of military phaseout under the Montreal Protocol is being compiled by K. Madhava Sarma, Stephen O. Andersen, Thomas Morehouse and Kristen Taddonio and will be published in 2008 by UNEP.

workshops and essential use nominations. There has been close co-operation between developed and developing nation military organisations through bilateral and multi-lateral military-to-military exchange projects. Workshops co-sponsored by military organisations from Australia, Canada, the EC and the United States along with the Multilateral Fund and industry and environmental NGOs have invited and financed participation by developing nation military representatives.

There were four workshops on the Military Role in Implementing the Montreal Protocol. The first in 1991 in Williamsburg, VA, the second in 1994 in Brussels, Belgium, the third in Vienna, Virginia in 1997, and the latest in Brussels, Belgium in 2001. Participation included China, India, the Russian Federation, and other developed and developing countries. Military-to-military technology co-operation projects were sponsored by developed countries involving Mexico, Thailand, Turkey, and Malaysia. UNEP sponsored workshops that included military involvement were: one in India, and another involving militaries of the Gulf region held in Amman, Jordan. In September 1996, the US, Canada and Australia sponsored a Defense Environmental Workshop for nations of the Asia Pacific Indian Ocean region with a focus on ODS. Virtually all participating countries sent representatives of their military and environmental ministries. In June 1997, the same tri-lateral group sponsored a conference for nations of the Western Hemisphere. In November 1997, a global conference on military uses of ODSs was organised in conjunction with the annual Conference on Ozone Protection Technologies in Baltimore, Maryland. The United States (U.S.) Navy and Defense Logistics Agency provided training on the use of halon recycling equipment, halon banking strategies and halon alternatives in a number of non-Article 5 countries, including India and China. There have been significant efforts over the years to spread awareness of the Montreal Protocol and the availability of measures militaries can take to manage the phase-out.

Parties operating under Article 5 may wish to engage their military organisations to report ODS uses and efforts to implement alternatives.

11.2 Continuing Mission-Critical Uses

There are a few continuing mission-critical uses that militaries are meeting through recycling of existing ODS banks. They are mostly halons and refrigerants used in weapons systems or used to support combat operations. The applications include aviation, shipboard, ground combat vehicles and in some cases critical facilities.

Aviation

There are 7 primary aviation uses of halon in both civilian and military:

- Portable extinguishers
- Cargo compartments, including a new requirement to protect class D cargo holds in commercial aircraft
- Engine Nacelles and Auxiliary Power Units (APU)
- Lavatory waste bins
- Dry Bays
- Fuel Tank Inerting Systems
- Ground Support equipment

The first 3 applications on the list, portables, cargo compartments, and lavatory waste bins are essentially identical in civil and military aircraft. Except for lavatories, and portables, halon remains the only fire protection agent used for civil aviation, including for new aircraft being designed today for future production. Dry bays, fuel tank inerting and ground support, are military specific. Engine nacelles and APUs are the same for some classes of military aircraft but not for others. Transport aircraft are often, but not always, variants of commercial aircraft. Combat aircraft (e.g., fighters, bombers) are unique to the military.

Portable Extinguishers

Halon (mostly 1211, but in some cases halon 2402) is used on all civil and some military aircraft. The military has converted some of its halon handhelds on rotary wing aircraft to CO_2, however since CO_2 does not provide comparable performance to halon adoption has been limited.

Engine Nacelles and Auxiliary Power Units

The military has begun producing the first modern aircraft not using halon in engine nacelles. Specifically, the V-22, the upgraded H-1 helicopter and the F-18E/F Navy fighter uses HFC-125; and the F-18E/F uses inert gas generators. The U.S. Air Force's new F-22 fighter will use HFC-125 for both engine nacelles and auxiliary power units. The UK is procuring a reconnaissance aircraft with HFC-125 engine nacelle systems. These halon-free designs should provide confidence to the commercial sector and regulatory authorities that alternatives are practical and effective.

Dry Bays

Dry bays are the interstitial spaces within aircraft structures adjacent to fuel tanks, that contain electrical cables, hydraulic lines or other equipment and which can be the source of fires or explosions should the fuel tanks be ruptured by incoming rounds or fragments. These areas are of particular concern to the military because unlike civilian aircraft, military aircraft expect to be shot at. The U.S. Navy has implemented inert gas generators aboard the F-18E/F and V-22.

Fuel Tank Inerting

Two types of aircraft deployed by a dozen or more countries use halon during combat to inert the ullage space in their fuel tanks within wing structures to prevent explosion in the event that the fuel tanks are penetrated by bullets or missiles. The most widely used aircraft with this feature is the F-16, which is operated by a large number of countries around the world.

Cargo Compartments

Some cargo compartments on military transport aircraft have halon systems installed. Only a few types of aircraft are included, and quantities are small.

Lavatory Waste Bins

There are approved HFC-227ea and HFC-236fa systems for this application which were developed under the direction of the international halon working group. It is easily retrofitted into existing aircraft, however uptake in the military sector has been minimal so far.

Ground Support

Halon 1211 is used by some countries in wheeled extinguishers placed adjacent to aircraft parking spaces for "first response" in the event of a ground incident. If operational imperatives require it, an aircraft can take off following a small pooled-fuel fire in an engine nacelle which has been extinguished by halon. The same fire extinguished with other non-gaseous agents may result in grounding of the aircraft until a more extensive examination of the engine is performed.

Fire trucks or "Crash-Rescue Vehicles" use a combination of agents. Some military services use halon 1211, while others have removed the halon and converted the vehicles to dry powder or AFFF (aqueous film forming foam) or a combination of both. The rational for the switch was if the fire is too large to be extinguished with wheeled halon extinguishers, secondary damage caused by the use of a powder agent is irrelevant compared to the damage caused by the fire. Also, halon 1211 is often used on aircraft carrier decks.

The U.S. Army provides ground protection for rotary wing aircraft using dry powder and CAF (compressed air foam). However, it is unclear how widespread this practice is and other military organisations likely continue to rely on halon. Foam is favoured over dry powder because it provides better throw and presents less of a problem with residue. However, it is likely that halon 1211 is used by some military organisations.

Ships and Submarines

The choice of fire protection for ships and submarines is very platform specific, and a solution for one vessel or application is not necessarily a solution for all. This is because fire protection decisions are based on a risk management strategy and includes a wide range of factors such as platform configuration and fire loading. For example, the UK Royal Navy uses halon in the machinery spaces of some of its submarines but not in others; Dutch submarines do; U.S. submarines do not. Lessons learned by one nation or military service can provide important data to others considering alternatives. For example, the Canadian Navy has conducted a fire risk assessment of all spaces on their ships and has determined that all halon systems can either be removed or replaced with a non-ODS agent. However, halon alternatives generally require additional space and add weight. On board ships, limited space often precludes adoption of alternatives. On submarines, confined spaces and highly integrated designs limit adoption of alternatives.

The use of halons in ships and submarines falls into the following broad categories:

- Machinery Spaces (occupied and unoccupied)
- Machinery (Engine) Enclosures
- Electrical Spaces
- Flammable Liquid Storage Spaces
- Machinery Spaces

Naval vessel machinery spaces are normally occupied so must continue to be occupied in order to maintain the capability of the ships. Therefore, an effective safe extinguishing system that will allow continued occupation is needed.

The U.S. Navy uses halon 1301 with manual AFFF bilge sprinkler backup. Manual fire fighting in these spaces is provided by AFFF hose reels, CO_2 portables, and dry powder portables. New construction vessels will be halon-free, using water mist and HFC-227ea.

The Canadian Navy protects machinery spaces in most ships, such as the Halifax class, with single shot halons systems, but is studying replacing these halon systems with Fine Water Spray systems similar to those planned for machinery enclosures. Space limitations are the most significant concern since any retrofit will be limited to the space currently occupied by the halon systems.

Denmark is using Inergen or Argonite (inert gases) in total flooding systems. It occupies eight times the volume of halon, and therefore is not practical on submarines or on ships with limited cargo areas, but Denmark finds the space and weight penalty acceptable on its surface ships.

Machinery (Engine) Enclosures

Gas turbine engines and in some cases diesel engines, are enclosed for acoustic attenuation. These enclosures are supplied by the equipment manufacturers, and come with an integral, pre-packaged fire protection system. Halon was the industry standard, so retrofitting an alternative can be problematic. However new vessels use either water mist or HFC-227ea.

Electrical Spaces

Halons are not widely used in electrical spaces. Carbon dioxide and fresh water hoses are more typical. Power to affected equipment is normally disabled by occupants, and not by automatic switches connected to fire detection systems.

Flammable Liquid Storage Spaces

Halon 1301 or CO_2 is currently used in some vessels. There are concerns over expanded use of CO_2 for reasons of personnel safety. HFC-227ea is the favoured alternative by the U.S. Navy.

Ground Combat Vehicles

Halons are used in ground combat vehicles for the following applications:

- Crew Compartments
- Engine Compartments
- Portable Extinguishers (Inside and Outside the Crew Compartment)
- Crew Compartments of Ground Combat Vehicles

A number of countries, including Canada, Germany, India, Israel, Russia, the U.K. and the U.S, use halon 1301 total flooding systems for explosion suppression in crew compartments of ground combat vehicle vehicles. These systems activate in less than 250 milliseconds to protect the crew from fire and explosion resulting from combat. Tests and battlefield experiences show significantly improved crew survival rates in vehicles equipped with these systems. The US Army developed a non-halon crew compartment explosion suppression system that is deployed on the Stryker Armored Vehicle. The US

Marine Corps plans on using the same non-halon technology in its new Expeditionary fighting Vehicle (formerly known as the Advanced Amphibious Assault Vehicle (AAAV). Russia currently uses halon 2402 in crew compartments. There are some indications that the Russian Federation may be converting these systems to halon 1301.

Engine Compartments

The U.S. Army and U.K. Army have converted many of their ground combat vehicle engine compartment systems from halon to sodium bicarbonate dry powder or HFC-227ea. The U.S. Army's new Styker Armored Vehicle uses HFC-125 for the engine compartment system.

Germany has adopted nitrogen systems, which occupy approximately twice the space as existing halon systems. Germany is able to use nitrogen, because their systems were originally designed for a double shot of halon to provide the safety of being able to extinguish a fire in the event of re-ignition or to extinguish a second fire caused by combat occurring before the vehicle can exit the battlefield for service. A single shot of nitrogen can be accommodated within the same space. Some military organisations consider a single shot inadequate protection for the crew and reject the nitrogen solution. HFC-125, HFC-227ea and HFC-236fa require approximately the same space as halon, and therefore allow for a double shot. Denmark is using HFC-227ea for engine compartments, but continues to use halon 1301 for crew compartments.

Conversion of engine compartments has been found to be economically feasible in a substantial number of countries where the conversion work is undertaken during scheduled maintenance or upgrade programmes.

Portable Extinguishers

Portable halon fire extinguishers have been replaced by CO2 extinguishers in ground combat vehicles where the operating scenario permits the crew to dismount. However, this solution is inappropriate in some configurations where the CO2 , which tends to pool in low areas, accumulates at potentially fatal concentrations in the breathing zone of passengers or crew. For this application, the US Army developed and is currently fielding a 50%-50% water – potassium acetate extinguisher that fits in the existing space as the original halon 1301 extinguisher. Externally mounted extinguishers can readily be replaced with powder or other alternatives.

Facilities

Halon in facilities has largely been eliminated in developed countries. Not in kind sprinkler or fine water spray systems have replaced most of the halon systems, including in rooms containing computers and other electronic equipment.

In cases where facilities cannot be adequately protected with water sprinkler systems alone, halon can be replaced or retrofitted with inert gases (Argonite or Intergen), or HFC-227ea.

The halon removed from facilities, especially the halon 1301 total flooding systems, has become the primary source of recycled halon for support of continuing uses in weapons platforms.

11.3 Refrigerants

Some shipboard CFC refrigerant applications will remain for the foreseeable future due to a lack of economically viable retrofit options and high retrofit costs where alternatives are available.

All CFC systems on EU ships and submarines will have been converted to HFC alternatives by the end of 2008 because of a legal mandate. Conversion of CFC-12 and 114 systems is relatively straightforward and economically feasible during major maintenance periods. HCFC refrigerants have found more widespread use than CFCs in recent years and their replacement is more problematic, but is being done in the UK.

Although non-fluorocarbon refrigerants such as hydrocarbons and ammonia are also playing an important role in the commercial sector phase-out, use in military applications is unlikely due to flammability and safety concerns in a battlefield environment.

11.4 Solvents

Methyl chloroform available under an Essential Use exemption is used to manufacture solid rocket motors for propelling large payloads into space. These rockets carry military and civil communications and other scientific and commercial equipment into space on behalf of many countries and companies world-wide. Large research and development investments have been made to identify and validate alternatives.

Canada, Germany, Norway, Sweden, the UK and the United States reported that they have virtually eliminated the use of ozone-depleting solvents in other military applications. One possible exception is for the cleaning of oxygen systems where solvent toxicity is a concern or where solvent residues cannot be entirely removed.

Cleaning of Oxygen Systems

Although CFC-113 or HCFC-225 were historically considered to be the only solvents suitable for cleaning oxygen in specific aerospace, submarine, and medical applications, aqueous cleaning options have been successfully developed and implemented. Aqueous cleaning is used by Lockheed Martin for manufacturing new aircraft and missile oxygen systems and the U.S. Air Force for some aircraft oxygen system maintenance. NASA/Kennedy Space Center uses aqueous solutions for cleaning oxygen bulk storage and transfer systems for rocket motors, and the U.S. Navy uses aqueous cleaning processes for cleaning the tubing in oxygen systems on ships and submarines. Germany's Lufthansa airline is using isopropyl alcohol (IPA) to clean the oxygen systems in their commercial aircraft fleet. Sweden has reported using a solvent blend for oxygen system cleaning consisting of 95% ethanol. However, small amounts of CFC-113 and HCFC-225 continue to be used for some in-situ cleaning of oxygen systems having complex geometries.

11.5 Special Circumstances of Legacy Equipment

Military systems tend to have very long development and operational lifetimes, lasting half a century or longer in both developed and developing countries. The systems are highly integrated, their designs are highly constrained in terms of space and weight, and modification costs are generally very high. While military organisations tend to be reluctant to disclose actual program costs, informal communications reveal that militaries have spent in aggregate over one billion U.S. dollars equivalent for research, retrofit and ODS stockpile management.

The mission-critical applications described above that are not related to manufacturing are used in legacy systems. Most new systems are being designed without halon or ODS refrigerants. The time scales for the development, production and operational life for military systems is far longer than the time provided for ODS production and consumption phase-out by the Montreal Protocol. And while some systems have been successfully modified during their operational lives to eliminate the need for ODS, the technical hurdles and economic realities to phase-out legacy system ODS use for others have so far proven insurmountable.

Some of the most technically difficult retrofits are for fire protection systems in aircraft, crew protection systems for ground combat vehicles and shipboard machinery spaces. These applications are common to developed and developing countries.

In the 1989 Halon Technical Options Committee report, military experts provided detailed descriptions of weapons system applications for halons that would persist beyond a phase-out date, and predicted new halon production would not likely be necessary provided that existing inventories of halon were managed in a way that preserved them for ongoing military requirements. These estimates and predictions made by the HTOC in 1989 and again in 2002 appear to remain valid today.

It is likely that some ODS will continue to be necessary for legacy systems until mid-century, without technical breakthroughs that can produce additional technically and economically feasible alternatives suitable for the most challenging applications. Currently, after considerable research effort by both governments and industry, such breakthroughs do not appear to be forthcoming.

11.6 Adequate ODS Banks by Some, but not All, Parties

Halon banking systems are operated by a number of developed and developing countries. In developed countries, there appears to be adequate supplies of halon 1301 to meet critical defence needs. Supplies of halon 1211 are less clearly in surplus with some indications of a shortage in some countries. However, this is probably less likely to impact on the defence sector than on the commercial aviation sector.

There is growing concern about the availability of halon 2402 outside of Russia to support existing uses such as aircraft and military vehicles. In particular, India has reported a growing shortage that could be problematic. India also reported that halon 2402 systems are being routinely converted to halon 1301 to improve safety and help ensure future supplies.

11.7 Importance of Flexibility in Logistical Supply, Recovery/Recycle, and Destruction

While overall global halon supplies appear to be adequate for mission-critical uses, they are not always located in the areas where they are needed. Transnational shipment of halon for use and for reconditioning to allow re-use had become an occasional problem for military organisations. To date, essential use exemptions for military uses have only been approved for fire protection in the Russian Federation, cleaning of torpedoes in Poland, and manufacture of solid rocket motors in the United States. However, as global supplies decline, the need for flexibility in moving halon stocks to locations they are needed is becoming increasingly important. Such flexibility may become a consideration to minimise the likelihood a Party would submit an essential use nomination in order to secure domestic stocks of halon to meet critical military needs when other Parties might have surpluses. Barriers exist to international shipment of halons and refrigerants between Parties, even for military applications considered mission critical and necessary for life safety. Some countries prohibit the export and/or import of recovered ODSs and some have cumbersome approval procedures that can be problematic in the event of national security emergencies.

11.8 Summary

Military organisations have invested significant effort and funding, and have made great strides to reduce their dependence on ODS. Modifications to existing systems and practices have been made where technically and economically feasible alternatives exist. Very few new systems continue to rely on ODS. These are limited to aviation applications which the military shares with the civilian sector, and a few unique critical military uses. For those applications that continue to need ODS, military operators of reserve stocks have been diligent in their management of those stocks to prevent leakage and ensure the ODS are only used for approved critical applications.

To ensure continued responsible use of ODS and discourage the need for essential use nominations, Parties may wish to consider:

- Encourage Parties to collect and recycle ODS for military-continuing or critical uses

- Requiring best practices for ODS recovery/recycling, storage, reuse and destruction

- Encourage flexibility that will enable transnational shipment necessary to supply recycled ODS for military-critical needs

12 TEAP and TOC Membership Information

12.1 TEAP Member Biographies

The following contains the background information for all TEAP members as at January 2006.

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Radhey S. Agarwal, Co-chair of the Refrigeration, Air-conditioning, and Heat Pumps Technical Options Committee since 1996, is the Professor of Mechanical Engineering at the Indian Institute of Technology (IIT Delhi), Delhi, India. He co-chaired the 2003 HCFC Task Force and the 2004 Chiller Task Force. IIT Delhi makes in-kind contribution for wages. Costs of travel, communication, and other expenses related to participation in the TEAP and the Refrigeration TOC, and relevant Montreal Protocol meetings are paid by UNEP's Ozone Secretariat.

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Programs and Toxic Substances in a division that registers bio-pesticides, including potential substitutes for methyl bromide. The U.S. EPA makes in-kind contributions of wages, travel, communication, and other expenses and some travel is sponsored by the U.S. DoD. With approval of its government ethics officer, EPA allows expenses to be paid by other governments and organisations such as the United Nations Environment Programme (UNEP).

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Paul Ashford, Co-chair of the Rigid and Flexible Foams Technical Options Committee since 1998 is the owner and managing director of Caleb Management Services, a consulting company working in the sustainability arena. He co-chaired the “TEAP Supplemental Report to the IPCC/TEAP Special Report: Safeguarding the ozone layer and the global climate system: issues related to hydrofluorocarbons and Perfluorocarbons”. Until 1994, he worked for BP chemicals in the division that developed licensed foam technology using ODS and its alternatives. He has over 25 years direct experience of foam related technical issues and is active in several studies informing future policy development for the foam sector.

His funding for TEAP activities, which includes some sponsorship of time, is provided under contract by the Department of Trade and Industry in the UK. Much of his recent work on banks and emissions, performed to inform both IPCC and TEAP processes has been supported by the US EPA. There is increasing cross-over with IPCC and UNFCCC in support of emissions reporting by Governments. Other related non-TEAP work is covered under separate contracts from relevant commissioning organisations including international agencies (e.g. UNEP DTIE), governments, industry associations and corporate clients. Most work with private clients relates to the lifecycle assessment of products based on ODS alternatives.

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Jonathan Banks, Chair of the QPS Task Force, is a private consultant. He was a member of the 1992 Methyl Bromide Assessment and from 1993 to 1998 and 2001 to 2005 co-chaired the Methyl Bromide TOC. Previously, he worked for Australian Commonwealth Scientific and Industrial Research Organization (CSIRO). He is co-owner of an organic apple orchard and serves on agricultural community and marketing associations and he is the inventor of carbonyl sulfide, which is an alternative to methyl bromide in some applications. His spouse is co-owner of their orchard. He serves on some national committees concerned with ODS and their control, and he receives contracts from UN, UNEP, and other institutions and companies related to methyl bromide alternatives and grain storage technology--including fumigation technology and recapture systems for methyl bromide. In 2005 he received support from UNEP for TEAP and MBTOC activities. Previous funding has been through grants or contracts from the Department of Environment and Heritage, Australia and from UNEP.

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Mohamed Besri, Co-chair of the Methyl Bromide Technical Options Committee since 2005, is Professor of Plant Pathology and Integrated Diseases Management at the Hassan II Institute of Agronomy and Veterinary Medicine, Rabat and was previously Dean of the Faculty of Agriculture and the Graduate School. He is mainly working on alternatives to Methyl Bromide for vegetable production. He is a consultant for many agricultural organizations, including the UN Food and Agricultural Organization (FAO), US Agency for International Development (USAID), UNDP, UNEP, the International Centre for Advanced Mediterranean Agronomic Studies (ICAMAS), Greenpeace, Foreign Agricultural Disease Eradication Support (FADES), GTZ, the European Union, World Bank, and the Inter Academy Council (IAC). He is member of many international executive committees and governing boards particularly of the International Association for the Plant Protection Sciences (IAPPS) and of the International Association for Biological control (IOBC) and was President of the Arab Society for Plant Protection. Costs of travel, communication, and other expenses related to participation in the TEAP, its Methyl Bromide TOC, and relevant Montreal Protocol meetings, are paid by UNEP’s Ozone Secretariat.

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David Catchpole, Co-chair of the Halons Technical Options Committee since 2005, works part time for Petrotechnical Resources Alaska (PRA), a company that provides consulting services to oil companies in Alaska. From 1991 to 2004 he was a member of the HTOC. Until 1999, he was an employee of BP Exploration Alaska, where he worked for the environmental department on alternatives to halon and on halon banking. Mr. Catchpole advises BP Exploration Alaska on fire detection and halon issues as his main activity for PRA. Funding for participation by Mr. Catchpole on the HTOC is provided by the United States Environmental Protection Agency and the United States Department of Defense. Mr. Catchpole also receives funding support for halon related activities from BP Exploration Alaska and the Halon Recycling Corporation, which is a not-for-profit industry coalition.

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Dr. Biao Jiang, Co-chair of the Chemicals Technical Options Committee since 2005, is Professor of Chemistry of Shanghai Institute of Organic Chemistry, Chinese Academy Of Sciences and a member of editorial advisory board of Chemical Communication, Royal Society of Chemistry, United Kingdom. Professor Jiang involves in the research of the development new methodology of organic synthesis, medicinal chemistry, fluorine chemistry as well as organic process research and development of clean chemistry. Costs of travel, communication, and other expenses related to participation in the TEAP, its Chemicals TOC, and relevant Montreal Protocol meetings, are paid by UNEP's Ozone Secretariat.

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Lambert Kuijpers, Co-chair of the Technology and Economic Assessment Panel since 1992 and Co-chair of the Refrigeration, Air-conditioning and Heat Pumps Technical Options Committee since 1989, works on a part-time basis for the Department "Technology for Sustainable Development" at the Technical University Eindhoven, The Netherlands. He co-chaired the 1996, 1999, 2002, and 2005 Replenishment Task Forces, the 2002 Task Force on Destruction Technologies and the 2003 Task Force on HCFCs. He served on the Steering Committee to the "IPCC/TEAP Special Report "Safeguarding the ozone layer and the global climate system: issues related to Hydrofluorocarbons and Perfluorocarbons" and he co-chaired the Task Force for the TEAP Supplementary Report to the IPCC/TEAP Special Report. He also chaired the 2004 TEAP Basic Domestic Needs Task Force and the 2004 Chiller Task Force. Until 1993, he worked for Philips in the development of refrigeration, air conditioning, and heat pump systems to use alternatives to ozone-depleting substances. He is supported (through the UNEP

Ozone Secretariat) by the European Commission and some EU governments for all his activities related to the TEAP and the Refrigeration TOC (including follow-ups to the IPCC/TEAP Special Report, the IPCC AR4 and his participation on the Science Assessment Panel). He is a consultant to governmental and non-governmental organisations, such as the World Bank, UNEP DTIE and the Multilateral Fund (for the 2006 Expert Meeting). Dr. Kuijpers is also an advisor to the Re/genT Company, Netherlands (R&D of components and equipment for refrigeration, air-conditioning and heating).

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Michelle Marcotte, Co-chair of the Methyl Bromide Technical Options Committee since 2005, is a consultant to governments and agri-food companies in agri-environmental issues, food technology, regulatory affairs, and radiation processing. She was a member of 1992 Methyl Bromide Assessment and subsequent Methyl Bromide Technical Options Committees until 2004. Until 1993, she worked for Nordion (now MDS Nordion) a supplier of radiation processing equipment, which is an alternative to the use of methyl bromide in some commodity applications. Michelle's spouse works for the United States Department of Agriculture as a manager of research into alternatives to methyl bromide in pre-plant and post-harvest applications and is a member of the MBTOC. In the field of methyl bromide alternatives, Michelle Marcotte has published case studies in pest control in food processing facilities, in stored commodities, in alternatives for quarantine, and in greenhouse use. She is a member of Canadian Industry-Government Methyl Bromide Working Groups and the Canada - US Methyl Bromide Working Group. She has consulted for the Canadian and United States governments on methyl bromide and other issues and for the International Atomic Energy Agency (IAEA) and USAID on irradiation as an alternative to methyl bromide and trade. She consulted directly with companies or through organizations in eight countries. Consulting fees and costs of travel and other expenses for participation on MBTOC are paid by the Government of Canada.

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Thomas Morehouse, Senior Expert Member for Military Issues since 1997, is a Research Adjunct at the Institute for Defense Analyses (IDA), Washington D.C., USA. From 1989 until 1996 he co-chaired the Halons TOC. From 1986 to 1989 he was an officer in the United States Air Force responsible for developing alternatives to halon. From 1989 until 1994 his responsibilities as an Air Force officer included broader environmental and energy policy issues for the U.S. Department of Defense. Tom's spouse works for the U.S. National Oceanographic and Atmospheric Administration (NOAA) in a position that plans long term spending for NOAA, including research and operations affecting stratospheric ozone and climate. IDA makes in-kind contributions of communications and miscellaneous expenses. Funding for wages and travel is provided by grants from the Department of Defense and the Environmental Protection Agency. IDA is a not-for-profit Federally Funded Research Center (FFRDC) that undertakes work exclusively for the US Department of Defense. He also occasionally consults independently to corporate clients, national laboratories and other government agencies on environmental and energy related issues.

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Marta Pizano, Co-chair of the Methyl Bromide Technical Options Committee since 2005, is a consultant on methyl bromide alternatives for cut flowers and has actively promoted methyl bromide alternatives among growers in many countries. She is a regular consultant for the Montreal Protocol Multilateral Fund (MLF) and its implementing agencies. In this capacity, she has contributed to the methyl bromide phase-out programs in nearly twenty Article 5 countries around the world. She is a frequent speaker at national and international methyl bromide conferences and has authored numerous articles and publications on alternatives to this fumigant, including a thorough manual on successful flower growing without methyl bromide published by UNEP. Costs of travel, communication, and other expenses related to participation in the TEAP, its Methyl Bromide TOC, and relevant Montreal Protocol meetings, are paid by UNEP's Ozone Secretariat.

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Jose Pons Pons, Co-chair of the Technology and Economic Assessment Panel since 2003 and Co-chair Medical Products Technical Options Committee since 1991. He co-chaired the 2002 Task Force on Collection, Recovery and Storage, the 1999 Replenishment Task Forces, and served on the Steering Committee to the "IPCC/TEAP Special Report Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons". He is President and co-owner of Spray Quimica. His spouse is also co-owner of Spray Quimica. Spray Quimica is an aerosol products filler who produces its own brand products and does contract filling for third parties. Jose is chair of the Venezuelan Aerosol Association. Spray Quimica, purchases HCFCs and HFCs for some of its products. Costs of travel expenses related to participation in the TEAP, its CTOC and MTOC, and relevant Montreal Protocol meetings, are paid by UNEP's Ozone Secretariat. Spray Quimica makes in-kind contributions of wage, and miscellaneous and communication expenses.

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Dr Ian Porter, Co-chair of the Methyl Bromide Technical Options Committee since 2005, is the Statewide Leader of Plant Pathology with the Victorian Department of Primary Industries (DPI). He is a member of a number of National Committees regulating ODS, has led the Australian research program on methyl bromide alternatives for soils and has 26 years experience in researching sustainable methods for soil disinfestation of plant pathogens. He has been a member of MBTOC since 1997 and acted as the lead consultant for UNEP in developing programmes to assist China and CEIT countries to replace methyl bromide. The Victorian DPI makes in-kind contributions to attend MBTOC and UNEP meetings. The Victorian Department of Primary Industries sponsors the time of his participation. The Australian Federal Government Research Funds and the Ozone Secretariat have provided funds to support travel and expenses for MBTOC activities.

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Prof. Miguel W. Quintero, Co-chair of the Foams Technical Options Committee since 2002, is professor at the Chemical Engineering Department at Universidad de los Andes in Bogota, Colombia, in the areas of polymer processing and transport phenomena. He is also a regular consultant for the Montreal Protocol's implementing agencies. Mr. Quintero worked 21 years until 2000 for Dow Chemical at the Research & Development and Technical Service & Development departments in the area of rigid polyurethane foam. He owns stock in companies that now or previously manufactured ozone-depleting substances and products made with or containing ozone-depleting substances and their substitutes and alternatives. His time in dealing with TEAP and TOC issues is covered by Universidad de los Andes. Costs of travel expenses related to participation in the TEAP, its Foam TOC, and relevant Montreal Protocol meetings, are paid by UNEP's Ozone Secretariat.

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Dr. Rae, Co-chair of the Chemicals Technical Options Committee since 2005, is Honorary Professorial Fellow at the University of Melbourne, Australia, and a member of advisory bodies for several Australian government agencies, including on implementation issues for the Montreal Protocol and the Stockholm Convention. He also co-chaired the 2001 and 2004 Process Agent Task Forces. His spouse owns stock in a company that distributes ODSs and ODS alternatives. He is a member of the POPs Review Committee for the Stockholm Convention. On occasions, he acts as consultant to government agencies and to universities and companies and he has been an expert witness in a case involving alleged patent infringement involving HFC-134a and its lubricants. He contributes the time for his own participation in TEAP activities. The Australian Government Department of the Environment and Heritage finances the cost of travel and accommodation for Dr. Rae's attendance at meetings of CTOC, TEAP, OEWG and MOP.

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K. Madhava Sarma, Senior Expert Member since 2001, retired in 2000, after nine years as Executive Secretary, Ozone Secretariat, UNEP. Earlier, he was a senior official in the Ministry of Environment and Forests (MOEF), Government of India and held various senior positions in a state government in India. He works occasionally as a consultant to UNEP and is an unpaid member of the Technical and Finance Committee of the Ozone Cell, MOEF, Government of India. He is working on a research and writing project on technology transfer and change for the protection of the ozone layer financed by the Global Environmental Facility (GEF) and the International Network for Environmental Enforcement and Compliance (INECE). Costs of travel, communication, and other expenses related to participation in the TEAP and relevant Montreal Protocol meetings, are paid by UNEP's Ozone Secretariat.

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Helen Tope, Co-chair Medical Technical Options Committee since 1995, is an independent consultant to government and non-governmental organisations on greenhouse gases and ozone-depleting substances and alternative technologies. Until mid-2006, Helen worked as a Senior Policy Officer Global Issues (climate and ozone layer protection), EPA Victoria, Australia. EPA Victoria has an interest in protecting the ozone layer for the benefit of public health. Helen has no stock in companies with significant involvement in matters of the Montreal Protocol. Helen's spouse is an independent consultant working in areas of environmental engineering and energy efficiency for mining, oil and gas, and other interests. EPA Victoria made in-kind contributions of wage and miscellaneous expenses. The Ozone Secretariat provides a grant for travel, communication, and other expenses of the Medical Technical Options Committee out of funds granted to the Secretariat unconditionally by the International Pharmaceutical Aerosol Consortium (IPAC). IPAC is a non-profit corporation.

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Dr. Verdonik, Co-chair of the Halons Technical Options Committee since 2005, is the Director, Environmental Programs, Hughes Associates, Baltimore, MD, USA. From 1991 to 2004 he was a member of the HTOC. He is a consultant in fire protection and environmental management to the US Department of Defense, the US Army, the US EPA and corporate clients. Dan's wife works for the United States Army as a civilian environmental protection specialist. Funding for participation by Dr. Verdonik on the HTOC is provided by the United States Environmental Protection Agency and the Department of Defense.

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Dr. Masaaki Yamabe, Co-Chair of the Chemical Technical Options Committee since 2005, is research coordinator (Environment and Energy) at the AIST. He also co-chaired the 2004 Process Agent Task Force. He was a member of the Solvents TOC during 1990-1996. Until 1999, Dr. Yamabe was Director of Central Research for Asahi Glass Company, which previously produced CFCs, methyl chloroform, and carbon tetrachloride, and currently produces and distributes HCFC, carbon tetrachloride, and HFCs. He is the co-inventor of HCFC-225, which is controlled under the Montreal Protocol as a transitional substance in the phase-out of ozone-depleting substances and is a substitute for CFC-113 in solvent and process agent applications. He owns stock in Asahi Glass Company that produces ozone-depleting substances and their substitutes. He also works for the Japan Industrial Conference for Ozone Layer and Climate Protection (JICOP) as a senior advisor. AIST pays wages, travelling and other expenses.

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12.2 TEAP-TOC Membership Lists, status December 2006

Technology and Economic Assessment Panel (TEAP)

Co-chairs	**Affiliation**	**Country**
Stephen O. Andersen	Environmental Protection Agency	USA
Lambert Kuijpers	Technical University Eindhoven	Netherlands
Jose Pons Pons	Spray Quimica	Venezuela

Senior Expert Members	**Affiliation**	**Country**
Thomas Morehouse	Institute for Defense Analyses	USA
K. Madhava Sarma	Consultant	India
Shiqiu Zhang	Peking University	China

TOC Chairs	**Affiliation**	**Country**
Radhey S. Agarwal	Indian Institute of Technology Delhi	India
Paul Ashford	Caleb Management Services	UK
Jonathan Banks	Consultant	Australia
Mohamed Besri	Institut Agronomique et Vétérinaire Hassan II	Morocco
David Catchpole	Petrotechnical Resources Alaska	UK
Biao Jiang	Shanghai Institute of Organic Chemistry	China
Michelle Marcotte	Marcotte Consulting LLC and Marcotte Consulting Inc	Canada
Marta Pizano	Consultant	Colombia
Ian Porter	Department of Primary Industries	Australia
Miguel Quintero	Universidad de los Andes	Colombia
Ian Rae	University of Melbourne	Australia
Helen Tope	Energy International Australia	Australia
Ashley Woodcock	Wythenshawe Hospital	UK
Daniel Verdonik	Hughes Associates	USA
Masaaki Yamabe	National Institute of Advanced Industrial Science and Technology	Japan

TEAP Chemicals Technical Options Committee (CTOC)

Co-chairs	**Affiliation**	**Country**
Ian Rae	University of Melbourne	Australia
Masaaki Yamabe	National Institute of Advanced Industrial Science and Technology	Japan
Biao Jiang	Shanghai Institute of Organic Chemistry	China

Members	**Affiliation**	**Country**
D. D. Arora	Tata Energy Research Institute	India
Steven Bernhardt	Honeywell	USA
Olga Blinova	Russian Scientific Center “Applied Chemistry”	Russia
Nick Campbell	Arkema Group	France
Bruno Costes	Airbus	France
Jianxin Hu	Center of Environmental Sciences, Beijing University	China
A.A. Khan	Indian Institute of Chemical Technology	India
Michael Kishimba	University of Dar es Sallam	Tanzania
Abid Merchant	DuPont	USA
Koichi Mizuno	National Institute of Advanced Industrial Science and Technology	Japan
Claudia Paratori	Environmental Consultant	Chile

Hans Porre	Teijin Twaron	Netherlands
Patrice Rollet	Avantec, Dehon Group	France
Shuniti Samejima	Asahi Glass Foundation	Japan
John Stemniski	Consultant	USA
Fatima Al-Shatti	Kuwait Petroleum Corporation	Kuwait
Peter Verge	Boeing Manufacturing	USA
Robert Nee Yive	University of Mauritius	Mauritius

TEAP Flexible and Rigid Foams Technical Options Committee (FTOC)

Co-chairs	**Affiliation**	**Country**
Paul Ashford	Caleb Management Services	UK
Miguel Quintero	Universidad de los Andes	Colombia

Members	**Affiliation**	**Country**
Kyoshi Hara	JUFA	Japan
Mike Hayslett	Maytag/AHAM	USA
Mike Jeffs	ISOPA	Belgium
Shigeru Wakana	Dow	Japan
Suzie Kocchi	Environmental Protection Agency	USA
Candido Lomba	ABRIPUR	Brazil
Yehia Lotfi	Technocom	Egypt
Christoph Meurer	Solvay	Germany
Mudumbai Sarangapani	Polyurethane Council of India	India
Ulrich Schmidt	Haltermann/Dow	Germany
Bert Veenendaal	RAPPA	USA
Mark Weick	Dow	USA
Dave Williams	Honeywell	USA
Jinhuang Wu	Huntsman	USA
Qiang Xu	Shanghai Haohai Chemical Corporation	China
Allen Zhang	Owens Corning	China

TEAP Halons Technical Options Committee (HTOC)

Co-chairs	**Affiliation**	**Country**
David V. Catchpole	Petrotechnical Resources Alaska	UK
Daniel P. Verdonik	Hughes Associates	USA

Members	**Affiliation**	**Country**
Ahmad AL-Khatib	Ministry of Environment	Jordan
Geok Kwang Boo	Civil Defence Force	Singapore
Fareed Bushehri	UNEP	Bahrain
Seunghwan (Charles) Choi	Hanju Chemical Co., Ltd.	South Korea
Michelle Collins	Consultant	USA
Andrew Greig	Protection Projects Inc.	South Africa
Matsuo Ishiyama	Halon Recycling & Support Committee	Japan
H.S. Kaprwan	Consultant	India
Nikolai P. Kopylov	All Russian Research Institute for Fire Protection	Russia
Barbara Kucnerowicz-Polak	State Fire Services Headquarters	Poland
David Liddy	Ministry of Defence	UK
Bella Maranion	USA EPA	USA

John O'Sullivan, MBE	British Airways	UK
Erik Pedersen	World Bank	Denmark
Donald Thomson	MOPIA	Canada
Robert Wickham	Wickham Associates	USA
Kaixuan Zhou	CAAC-AAD	China

Consulting Experts	**Affiliation**	**Country**
Tom Cortina	HARC	USA
Steve McCormick	United States Army	USA
Paulo Jorge	Embraer	Brazil
Vasily Pivovarov	All Russian Research Institute for Fire Protection	Russia
Jawad Rida	National Concorde Est.	Jordan
Mark Robin	DuPont	USA
Joseph Senecal	Kidde-Fenwal	USA
Ronald S. Sheinson	Naval Research Laboratory - Department of the Navy	USA
Ronald Sibley	Defense Supply Center, Richmond	USA

TEAP Medical Technical Options Committee (MTOC)

Co-chairs	**Affiliation**	**Country**
Jose Pons Pons	Spray Quimica	Venezuela
Helen Tope	Energy International Australia	Australia
Ashley Woodcock	University Hospital of South Manchester	UK

Members	**Affiliation**	**Country**
Emmanual Addo-Yobo	Kwame Nkrumah University of Science and Technology	Ghana
Paul Atkins	Oriel Therapeutics	USA
Sidney Braman	Rhode Island Hospital	USA
Yingyun Cai	Zhongshan Hospital	China
Nick Campbell	Arkema SA	France
Hisbello Campos	Centro de Referencia Prof. Helio Fraga, Ministry of Health	Brazil
Christer Carling	Private Consultant	Sweden
Mike Devoy	Schering	Germany
Charles Hancock	Charles O. Hancock Associates	USA
Eamonn Hoxey	Johnson & Johnson	UK
Javaid Khan	The Aga Khan University	Pakistan
Robert Meyer	Food and Drug Administration	USA
Hideo Mori	Otsuka Pharmaceutical Company	Japan
Robert Morrissey	Johnson & Johnson	USA
Tunde Otulana	Aradigm Corporation	USA
John Pritchard	AstraZeneca	UK
Raj Singh	The Chest Centre	India
Roland Stechert	Boehringer Ingelheim (Schweiz)	Switzerland
Adam Wanner	University of Miami	USA
Kristine Whorlow	National Asthma Council Australia	Australia
You Yizhong	Journal of Aerosol Communication	China

TEAP Methyl Bromide Technical Options Committee (MBTOC)

Co-chairs	Affiliation	Country
Mohamed Besri	Institut Agronomique et Vétérinaire Hassan II	Morocco
Michelle Marcotte	Marcotte Consulting	Canada
Marta Pizano	Consultant	Colombia
Ian Porter	Department of Primary Industries	Australia

Members	Affiliation	Country
Marten Barel	Consultant	Netherlands
Jonathan Banks	Consultant	Australia
Chris Bell	Central Science Laboratory	UK
Antonio Bello	Centro de Ciencias Medioambientales	Spain
Aocheng Cao	Chinese Academy of Agricultural Sciences	China
Peter Caulkins	USA Environmental Protection Agency	USA
Fabio Chaverri	IRET-Universidad Nacional	Costa Rica
Ricardo Deang	Consultant	Philippines
Patrick Ducom	Ministère de l'Agriculture	France
Abraham Gamliel	Agricultural Research Organisation	Israel
Darka Hamel	Inst. For Plant Protection in Ag. and Forestry	Croatia
Saad Hafez	University of Idaho	USA
George Lazarovits	Agriculture and Agri-Food Canada	Canada
Nahum Marbán Mendoza	Universidad Autónoma de Chapingo	México
Carlos Medeiros	EMBRAPA	Brazil
Melanie Miller	Consultant	Belgium
Andrea Minuto	Agroinnova Universitá di Torino	Italy
Takashi Misumi	MAFF	Japan
Kazufumi Nishi	Nat Institute of Vegetables and Tea Science	Japan
David Okioga	Ministry of Environment and Natural Resources	Kenya
Christoph Reichmuth	BBAGermany	Germany
Jordi Riudavets	IRTA – Department of Plant Protection	Spain
Ariane Elmas Saade	UNDP	Lebanon
John Sansone	SCC Products	USA
Jim Schaub	USA Department of Agriculture	USA
Sally Schneider	USA Department of Agriculture	USA
JL Staphorst	Plant Protection Research Institute	South Africa
Akio Tateya	Japan Fumigation Technology Association	Japan
Robert Taylor	Consultant	UK
Alejandro Valeiro	Department of Agriculture	Argentina
Ken Vick	United States Department of Agriculture	USA
Nick Vink	University of Stellenbosch	South Africa
Chris Watson	IGROX	UK
Jim Wells	Environmental Solutions Group	USA

TEAP Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC)

Co-chair	Affiliation	Country
Radhey S. Agarwal	Indian Institute of Technology Delhi	India
Lambert Kuijpers	Technical University Eindhoven	Netherlands

Members	Affiliation	Country
James A. Baker	Delphi Automotive Systems	USA
Julius Banks	Environmental Protection Agency	USA
Dariusz Butrymowicz	Institute of Fluid Flow Machinery	Poland
James M. Calm	Engineering Consultant	USA
Guangming Chen	Inst. Refrigeration and Cryogenic Eng., Shanghai	China
Denis Clodic	Ecole des Mines	France
Daniel Colbourne	Consultant	UK
Jim Crawford	Trane /American Standard	USA
Sukumar Devotta	National Env. Eng. Research Institute (NEERI)	India
Kenneth E. Hickman	Johnson Controls	USA
Martien Janssen	Re/gent bv	Netherlands
Makoto Kaibara	Matsushita Electric Industrial Corporation	Japan
Ftouh Kallel	Sofrifac	Tunisia
Michael Kauffeld	Karlsruhe University of Applied Sciences	Germany
Fred Keller	Carrier Corporation	USA
Jürgen Köhler	University of Braunschweig	Germany
Holger König	Jaeggi / Guentner	Germany
Edward J. McInerney	Consultant	USA
Petter Nekså	SINTEF Energy Research	Norway
Hezekiah B. Okeyo	Ministry of Industrial Development	Kenya
Andy Pearson	Star Refrigeration	UK
Per Henrik Pedersen	Danish Technological Institute	Denmark
Roberto de A. Peixoto	IMT, Maua Technological Institute	Brazil
Frederique Sauer	Dehon Service	France
Adam M. Sebbit	Makerere University	Uganda
Jongmin Shin	LG Electronics	Rep. Korea
Arnon Simakulthorn	Thai Compressor Manufacturing	Thailand
Aryadi Suwono	Thermodynamic Research Lab Bandung University	Indonesia
Peter Tomlein	Slovak Refrigeration Association	Slovakia
Pham Van Tho	Ministry of Fisheries	Vietnam
Vassily Tselikov	Investment Centre of ODS Phase-out Projects	Russia
Paulo Vodianitskaia	Whirlpool	Brazil
Jianjun Zhang	Zhejian Lantian Env Protection Hi-Tech Co	China
Attila Zoltan	Refrigeration Association	Hungary