Montreal Protocol
1991 Assessment

Report of the

Technology and Economic Assessment Panel

December 1991

MONTREAL PROTOCOL
ON SUBSTANCES THAT DEPLETE
THE OZONE LAYER

1991 ASSESSMENT

REPORT OF THE

TECHNOLOGY AND ECONOMIC
ASSESSMENT PANEL

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REPORT OF THE 1991 TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

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REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

EXECUTIVE SUMMARY

Introduction

This is the second Technology and Economic Assessment conducted for the Montreal Protocol.

The 1991 Assessment combined the Technology and Economic Panel, expanded participation of developing country experts, and added two senior advisors who serve on the Panel but not on a Technical Options Committee. The five Technical Options Committees and the Economics Committee reports are the primary basis for this document[1]. Over 240 experts from 38 countries[2] were members of these committees. Hundreds of additional experts served as advisors to the six committees and as peer reviewers.

The Assessment describes current uses and quantities of controlled substances, estimates the technically feasible phaseout dates, estimates the quantity and time period for use of transitional substitutes, and specifically describes the implications of 1997 or earlier phaseouts.

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[1] The Technology and Economic Assessment Panel is chaired by Dr Stephen O Andersen (United States of America) and Mr Steve Lee-Bapty (United Kingdom). The six Technical and Economic Options Committees are: (i) Refrigeration, Air Conditioning and Heat Pumps, chaired by Dr L Kuijpers (The Netherlands), Mr P Vodianitskaia (Brazil) (Dr J Kanyua (Kenya)); (ii) Flexible and Rigid Foams, chaired by Ms J Lupinacci (USA) and Mr P Vieira (Brazil); (iii) Solvents, Coatings and Adhesives, chaired by Dr S O Andersen (USA) and Mr J Corona (Mexico); (iv) Aerosols Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride, chaired by Ms A Hinwood (Australia) and Mr J Pons Pons (Venezuela); (v) Halons, chaired by Mr G Taylor (Canada) and Major E T Morehouse, USAF (USA); and (vi) Economic Options, chaired by Dr R Van Slooten (UK) and Mrs M Holmes-Hanek (Bahamas). The two senior advisers on the Technology and Economic Assessment Panel were Dr A Ibrahim (Egypt) and Mr M Ruales Carranza (Ecuador).

The Executive Summary and Chapters 1-6 of the report were written by the Technology and Economic Assessment Panel, while Chapters 7-12 are the Executive Summaries of the six Technical and Economic Options Committees.

[2] Australia, Austria, Bahamas, Belgium, Brazil, Canada, Chile, China, Denmark, Ecuador, Egypt, France, Germany, India, Indonesia, Italy, Japan, Jordan, Kenya, Malaysia, Mexico, Netherlands, New Zealand, Nigeria, Norway, Papua New Guinea, Singapore, South Korea, Sweden, Switzerland, Trinidad and Tobago, Tunisia, Uganda, USSR, United Kingdom, United States, Venezuela and Yugoslavia.

Progress in Protecting the Ozone Layer

The 1989 Technical Options Reports outlined both commercial and emerging technologies to protect the ozone layer. Experts on the 1989 Assessment identified the technologies that existed then and described important emerging technologies.

Since the 1989 Assessment technology advances have made early reductions more feasible - largely because industry and consumers have acted more quickly to reduce their dependence on ozone-depleting substances than was anticipated. Also since 1989 developing countries have demonstrated the ability to phase out controlled substances when technology is available.

Since 1986 there has been a dramatic worldwide drop in the production of CFCs and halons - a drop that reflects worldwide concern for the ozone layer. CFC production is 40 percent below 1986 levels; at this rate of progress, consumption[3] will be reduced by 50% in 1992 - a three-year advance on the requirements of the Amended Protocol.

ESTIMATED PHASEOUT PROGRESS

Product	Percent cut in production between 1986 and 1991
CFC 11	37%
CFC 12	41%
CFC-113	41%
CFC 114	70%
CFC-115	15%
TOTAL CFC	40%

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[3] The Montreal Protocol defines consumption as production plus imports minus exports and therefore does not limit the use of recycled material. This definition of consumption is used throughout this report.

The CFC global 1991 market has changed in comparison with the 1986 market as follows:

Use	Percent Decline
Propellants	58%
Cleaning agents	41%
Blowing agents	35%
Polyurethane	30%
Phenolic	65%
Extruded polystyrene	
Sheets	90%
Boards	32%
Polyolefin	35%
Refrigerants	7%
Total Market	40%

n.b. categories do not total as not all applications are covered.

Production of halon 1211 and halon 1301 peaked in 1988 and is now declining. Production of halon 2402 within Organization of Economic Cooperation and Development (OECD) nations has virtually ceased.

Many countries have national legislation that is more stringent than the Protocol[4]. Several large CFC/halon production facilities have been closed, and more closures are planned. The world's largest manufacturer of CFCs has announced that it will close its facilities by 1997.

Several multinational and other companies are eliminating the use of controlled substances far faster than even the most stringent regulation. By January 1992, the first companies will have eliminated the use of CFC-113 solvents in all their worldwide operations; halon and CFC recycling will be accepted worldwide; the first HFC-134a automobile air conditioners will be commercialized, and many other ozone-safe technologies will be available. The first HFC-134a domestic refrigerators will be commercialized in 1992. The international fire protection community has virtually eliminated halon emissions caused by discharge testing, and halon emissions during training and in servicing equipment have been drastically reduced. Educational programs by fire protection associations are proving successful as users move to alternative fire protection measures, where feasible, and voluntarily limit halon use to essential applications.

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[4] These include Australia, Austria, Canada, Denmark, Finland, Germany, Luxembourg, Netherlands, Norway, Singapore, Sweden, Switzerland, the United States and the European Community.

Technical Feasibility of Early Phaseout

In developed countries, it is technically feasible to phase out virtually all consumption[5] of CFCs and halons by 1995-1997, 1,1,1-trichloroethane as early as 1995 and no later than 2000, and carbon tetrachloride in the vast majority of applications by 1995 with final phaseout by 1997. These technically feasible phaseouts are shown graphically in Figures 1, 2, and 3.

These rapid phaseout schedules require that the results of toxicity tests, environmental assessments, and risk analyses conclude that the transitional substances HCFC-123, HCFC-124, HCFC-141b, and the alternative substance HFC-134a, can be safely used for refrigeration, air conditioning, insulating foam, and for some aerosol, sterilization, and minor solvent uses; that these HCFCs and HFC are environmentally acceptable; and that they are commercially available in adequate quantities. A rapid phaseout will also require increased short-term use of currently available HCFCs -22 and -142b.

The 1995 phaseout of 1,1,1-trichloroethane in developed countries depends on worldwide technical cooperation of industry leading to very rapid dissemination and adoption of technologies among many thousands of small users. Without cooperation the phaseout could take until 2000.

A 1997 phaseout is technically feasible for refrigeration and air conditioning but with increased costs. Costs of early retirement of equipment could be several billion dollars (U.S.) and disproportionately more for a faster phaseout. Whether or not early retirement is necessary will depend on success of recycling and recovery at disposal and on the development of technology for simple retrofitting of equipment. Technology for retrofit of vehicle air conditioning systems is particularly important in some countries.

Halons

The halon phaseout is contingent on the use of recycled halons as the primary supply of those agents. An orderly transition to alternative fire protection measures, establishment of procedures to adequately manage the bank of halons, and increased efforts to develop transitional and eventual replacement fire extinguishing agents may minimize the loss of fire protection capability represented by the halon phaseout.

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[5] As defined by the Montreal Protocol.

The Halon Technical Options Committee did not explicitly consider a halon phaseout earlier than 1997. However, their report provides estimates of the size of the halon bank based on production phaseout in 1995, 1997, and 2000. The existing bank of halon 1211 may be sufficient to maintain equipment that remains in service and provide into the next century small quantities for the most essential applications. The bank of halon 1301 may be adequate not only to maintain systems that remain in service for up to 45 years after production ceases but also to supply the most essential new applications (no more than 10% of 1986 level of installations for up to 30 years after production ceases). Although halon bank management has not been demonstrated, military and civilian users are moving in that direction. Future production of halon for essential uses under the terms of the Protocol may be necessary if halon banks are depleted and if no environmentally acceptable alternatives and substitutes are available. Cooperation of the fire protection community will continue to be essential. Criteria for identifying essential halon uses have been developed by the Halons Technical Options Committee.

The potential risk to human life posed by the phaseout of halons is of concern. Parties to the Protocol must make decisions based on an integrated overview that balances the threat of stratospheric ozone depletion against threats from fire or explosion.

Phaseout in Developing Countries

It is technically and economically feasible to phase out many applications of controlled substances in developing countries on the same schedule as developed countries. With adequate financing and technical assistance, ozone-depleting substances can be phased out in nonmedical aerosol products, electronics manufacturing, and flexible and noninsulating foam by 1992-1995.

Developing countries may need additional time for some applications. In some instances, the information, training, and infrastructure required to phase out a use are not available; in other instances developing countries may need to preserve the useful life of capital dependent on CFCs.

Financial assistance and training through the Fund are critical. With proper support, it is technically and economically feasible for most developing countries to phase out consumption of controlled substances in the more difficult applications within five to eight years after developed countries.

Most developing countries have low levels of both halon consumption and banked halon. It may therefore be desirable to ensure that recovered halon from developed countries that is suitable for recycle are made available for use in developing countries, to provide for recharge and service of existing fire protection equipment. It is desirable to ensure that national and international regulatory barriers to such transfer are minimised.

Some Important Implications of a 1997 Phaseout

The costs of a 1997 phaseout are higher than a 2000 phaseout, particularly in refrigeration and air conditioning. Up to half of the additional cost can be attributed to retrofitting vehicle air conditioners in the United States and Japan. The cost of an early phaseout will depend on the number of systems that may need to be retrofitted and on the cost of each retrofit. Costs may decrease with further development of retrofit technology.

The commercial availability of substitutes and alternatives for several small, but important, uses of controlled substances is uncertain. These important uses include oral inhalant drug products, precision cleaning, and drying of high technology products. In the next assessment, Parties will want to consider technical developments related to early retirement of capital.

Transitional Substances

HCFCs are required for existing applications and to phase out CFCs. Table ES-1 shows some requirements for specific applications.

The overall ODP impact of transitional substances will be minimised if HCFCs with the lowest ODP are selected and used only where no other alternatives are available. The Science Assessment is providing new estimates of ODPs.

The selection of technologies to replace the use of controlled substances should be made to minimise energy consumption as well as ozone depletion. The energy efficiency of foams and refrigeration equipment has a greater influence on climate change than the emissions of particular substances used in those applications. A study by Alternative Fluorocarbons Environmental Acceptability Study (AFEAS) and the United States Department of Energy (U.S.DOE) developed a methodology for calculating the Total Equivalent Warming Impact (TEWI) of various alternatives for insulating foam, refrigeration and air conditioning, and solvents.

TABLE ES-1: HCFCs FOR EXISTING AND REPLACEMENT CFC USES

Sector	1997 HCFC use (ktonnes)	Percent Replaced[6]	Most likely HCFCs
Foams	150	56%	22, 123, 141b, 142b
Refrig/AC[7]			
Existing[8]	149	n.a.	22, 142b
Replace CFC	86	45%[9]	22, 123, 124, 142b
Auto retrofit	0-40[10]	0-30%	22, 124
Aerosol Products	20[11]	5-8%	22, 142b
Sterilants	0-15	50-75%	124
Fire fighting	0-7	0-28%	123
Solvents	18-50	3-8%	141b, 225
TOTAL	423-517[13]		

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[6] Percent of CFC used in this application in 1986 replaced by HCFCs in 1997.

[7] In 1997, 75 percent of HCFC used in refrigeration and air conditioning is expected to be HCFC-22. The rest will be HCFC-123, HCFC-142b, and HCFC-124.

[8] These are refrigeration and air conditioning applications that currently use HCFC-22, including HCFC-22 used in refrigerant mixtures.

[9] It is estimated that 45% of current CFC use will be replaced by HCFCs, 45% by HFCs, and 10% by ammonia.

[10] The amount of HCFC used for vehicle air conditioners depends on the timing of the introduction of HFC-134a in new vehicles, the success of recycling, and the possible use of HCFC in retrofitting. If used, HCFC for vehicle air conditioning will decline to small levels by 2005 when most cars that use CFC air conditioners will be retired or not valuable enough to service (in 2005, cars with CFC-12 will be 10 years or older).

[11] In 1989, 20 kilotonnes of HCFCs were used in industrial and consumer aerosol products. It is expected that total use in 1997 will be between 20 and 30 kilotonnes with an increasing portion used in industrial applications. HFC-134a and HFC-227 could ultimately replace all industrial uses and medical applications.

[12] It is estimated that approximately 25 to 50 % of 1986 CFC/Ethylene Oxide (EO) sterilisation will be replaced by CO_2/EO, pure EO, or alternatives not using EO.

[13] Includes the 149 kilotonnes used in existing HCFC-22 applications.

HCFCs will have to be available for a reasonable time to take into account that: 1) chemicals will only be produced if plant investment can be recovered, 2) users incur costs for transition into and out of HCFC use, and 3) HCFCs are needed for service during the useful life of the equipment. Refrigeration equipment has a long life and therefore requires HCFC for service. Foam production and solvent operations require less time and cost to switch to new chemicals.

HCFC transitional substances can be eliminated in some applications faster than in others. Long advance notice of phaseout regulations would avoid the sale of equipment dependent on transitional substances within 15 or 20 years of the final phaseout and thus avoid costs of retrofit or early retirement. Based on the impressive record of technical progress to date and on the intensity of industry efforts to find final alternatives to ozone-depleting substances, it may be possible for users to phase out these chemicals faster. Future Technical Assessments should evaluate the rate of technical progress and prospects for eliminating transitional substances.

Technical and Environmental Uncertainty

The rate of technological progress has been rapid, but not all questions about acceptability of substitutes have been resolved (e.g., more toxicity testing underway, further applications testing, regulatory approval of inhalant drug products, the best technology to retrofit equipment, etc.). The Assessment cannot rule out the possibility that in the future, exemptions may be needed if controlled substances are phased out in 1997 although it cannot state now that any exemptions will be required.

There is no perfect substitute. Each substitute has difficult trade-offs in performance, ODP of transitional substances, GWP, energy efficiency, and toxicity. Trade-offs can be minimized and mitigated by recycling and bank management, by limiting the use of transitional or high GWP options to only where necessary, and by limiting occupational exposures.

Developing Country Concerns

Developing countries must address special problems if they are to meet earlier phaseout dates.

> It is critical to successful phaseout that technologies are available to developing countries, that supporting technical assistance and training is provided, and that adequate financial assistance is forthcoming.
>
> It is expected that technologies will be made available through existing channels and mechanisms and supported by the Multilateral Interim Fund. Suitable technologies are clearly available for many aerosol, foam, and solvents applications.

Many users in developing countries may not know about available substitutes and alternatives. The development of adequate channels for the collection and distribution of information is crucial to the successful transfer of technology and phaseout of controlled substances in developing countries.

Some developing countries may experience difficulties in limiting occupational exposures or release of toxic chemicals and may therefore want to choose alternatives that have high exposure limits and minimum wastestreams.

Chemical alternatives including HCFCs, HFCs and hydrocarbons are becoming available through commercial channels both as imports and for production.

There is a concern that producers in developed countries with fast-shrinking domestic markets could sell excess controlled substances in developing countries or that obsolete equipment dependent on controlled substances will be sold into developing country markets.

Recovery and recycling at equipment disposal and managing banks of controlled substances will be difficult in developing countries because of infrastructure, training and the handling of small quantities of controlled substances that cumulatively are significant. It will be important for developing countries to implement containment and recycling of controlled substances in order to serve their own needs and to eliminate unnecessary emissions.

Several developing countries are entering into innovative technology cooperation projects that may be useful models for others to follow. For example:

Mexico and China have announced the goal of phasing out controlled substances on the timetable for developed countries under the Montreal Protocol. The Mexican government and industry are forming partnerships with the U.S. Environmental Protection Agency (EPA), the Industry Cooperative for Ozone Layer Protection (ICOLP), and Northern Telecom to phase out solvents. Similar partnerships may speed elimination in other developing countries.

The Government of Thailand has announced a new partnership with the U.S. EPA, the Japanese Ministry of International Trade and Industry (MITI), and several Japanese and American industry associations to encourage and coordinate the phaseout in Thailand of solvents controlled by the Protocol. This project responds to the fact that solvents constitute 40 percent of Thailand's CFC use, and that up to 97 percent of solvent use is by Japanese and U.S. companies, and joint ventures.

Refrigeration research and development through joint research programs with industry and other governments is on-going in several developing countries including Brazil and China. The goal is to identify suitable alternatives for each country's specific situation and needs.

Decisions Required in 1995 for a 1997 Phaseout

A 1997 phaseout would require an assessment in 1994 at the latest, to address the following:

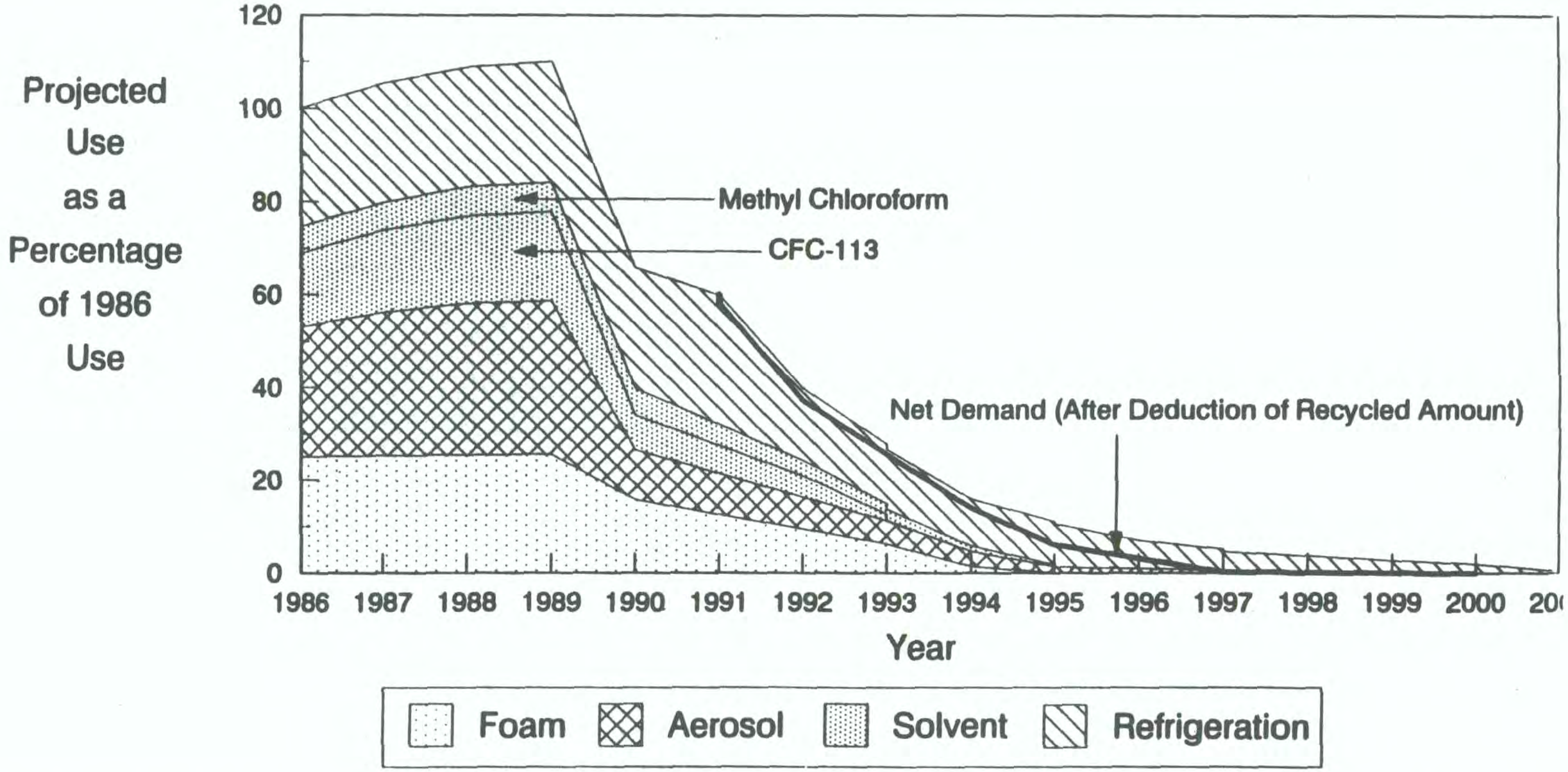
Some important applications do not currently have identified alternatives: up to 5 percent of the population could use oral inhalant drug products which now use CFCs but alternative propellants may not be approved by 1997; no suitable alternatives have yet been commercialized for some precision cleaning, adhesives, electronic manufacturing and fire protection.

A 1997 or earlier phaseout of halons will require adequate arrangements for management of the bank. Progress in such bank management will need to be reviewed.

The special fire protection concerns of developing countries should be carefully evaluated if an early phaseout of halon is considered.

Refrigeration and air conditioning systems are expensive capital investments with long product lives. Based on 1991 calculations, recycling alone is not expected to provide sufficient CFC for service in all countries. Retrofit technology should be reassessed.

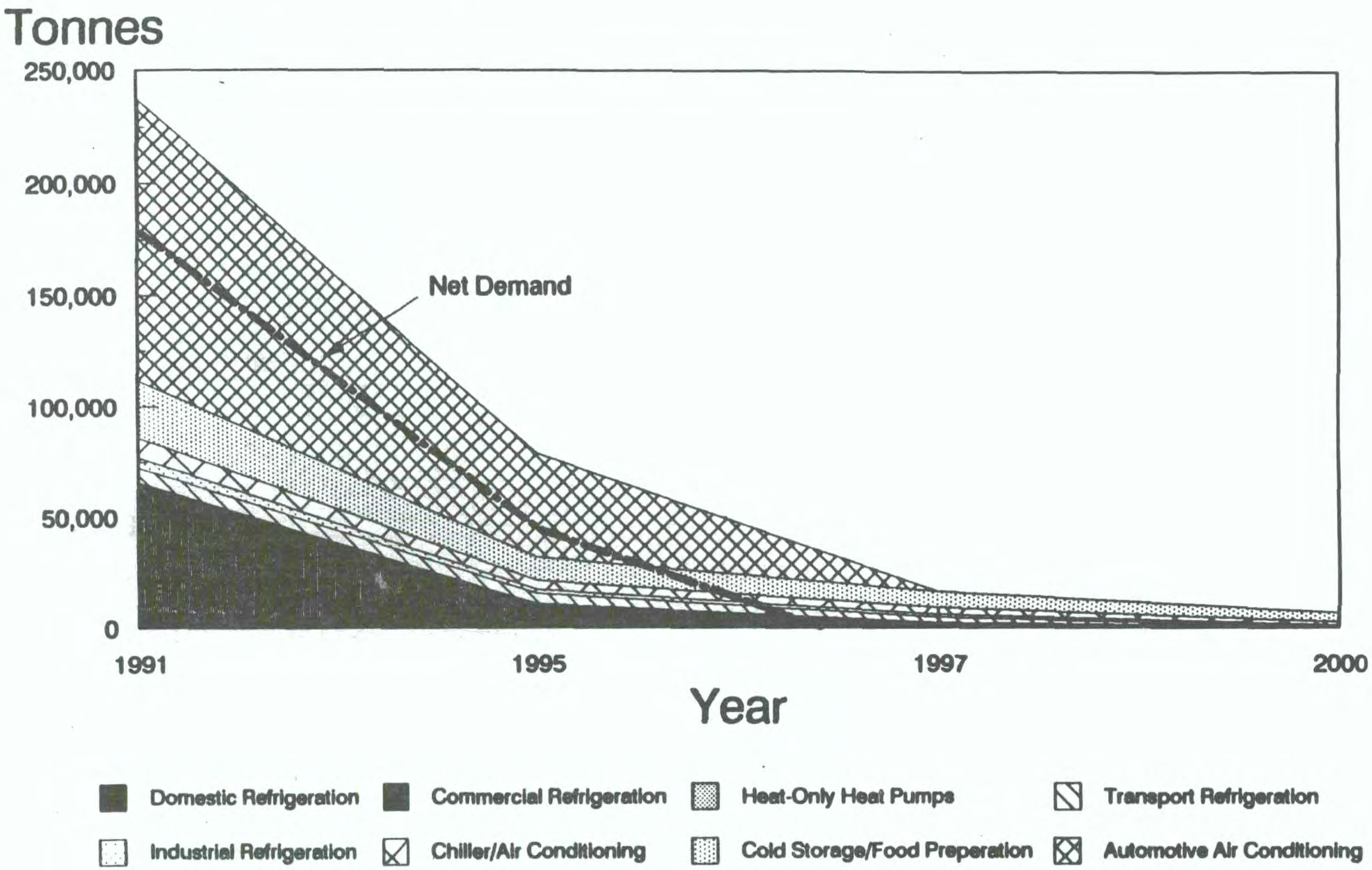
Technically Feasible Production Phaseout for CFC and 1,1,1-Trichloroethane



Note 1: The amounts of CFC used in sterilants and miscellaneous uses is small and cannot be depicted in the scale used. Some of the Technical Options Committees agreed upon a range of phaseout dates. This chart presents the technically optimistic case.

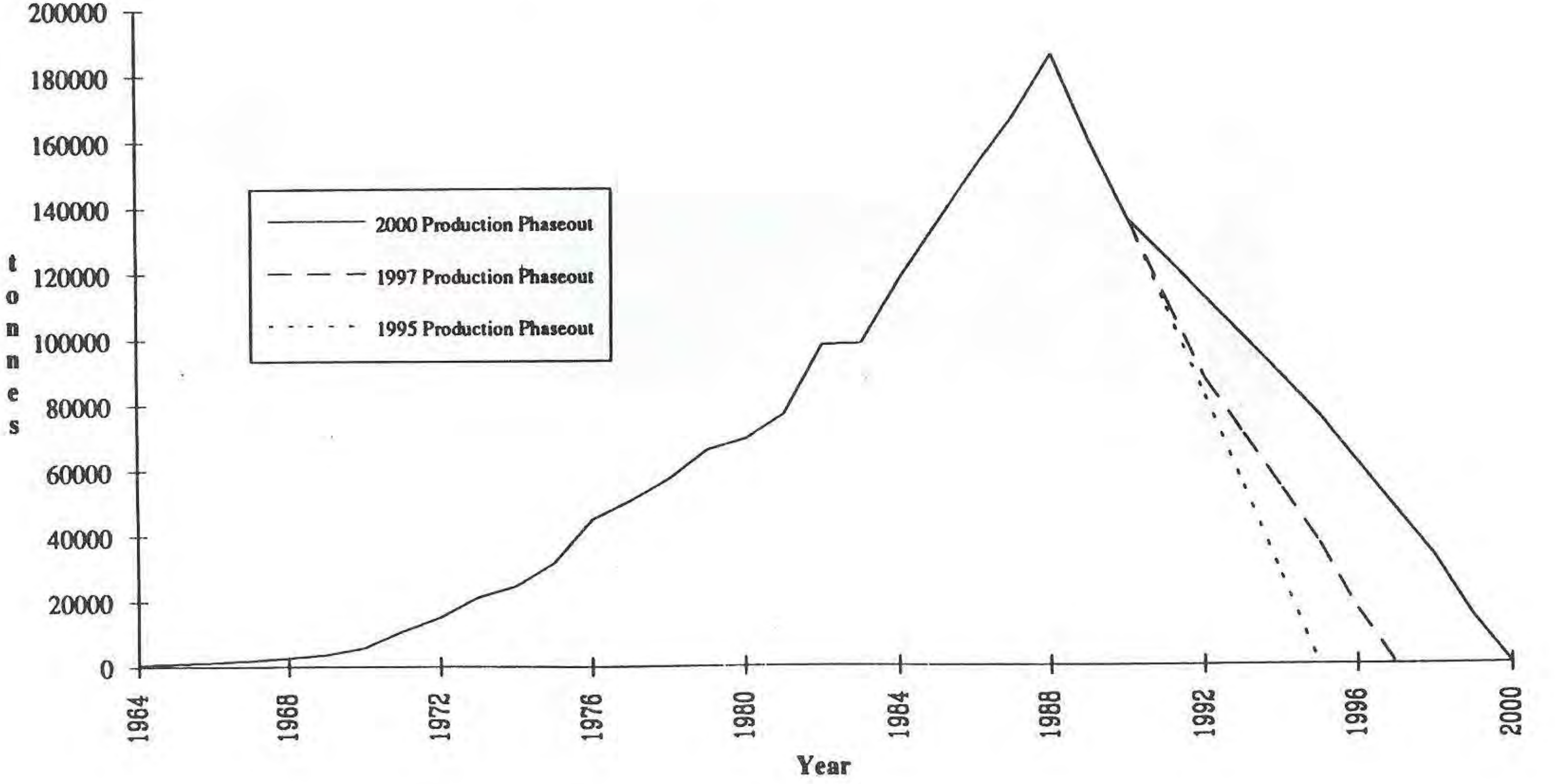
Note 2: The use of controlled substances is presented on an ODP weighted basis.

CFC for Refrigeration in Developed Countries



Note: Net demand is equal to the total demand minus the recycled CFC available. Therefore, the net demand is the amo of new CFC which must be produced. Accelerated retrofit begins in mid-1996 reflecting the inadequate supply of recycled CFC when production of virgin CFC is halted in 1997. After 1997, the equipment that cannot be serviced with recycled CFC is retrofitted or retired.

Production Phaseout Projection for Halons (ODP weighted)



CHAPTER ONE: INTRODUCTION

1.1 OZONE DEPLETION AND ITS EFFECTS

Early in the 1970s Sherwood Rowland and Mario Molina, investigating the fate of chlorofluorocarbons (CFCs) after emission, published a hypothesis that, due to their inherent chemical stability, they do not break down in the troposphere but survive long enough to enter the stratosphere, where they are eventually broken down by the action of ultraviolet light. One breakdown product, chlorine, acting as a catalyst, reacts with stratospheric ozone (O_3), to produce molecular oxygen (O_2), thus reducing ozone concentrations. Although the stratospheric "ozone layer" contains only a minute proportion of ozone, it is the earth's only defense against certain forms of solar radiation, notably UV(B). Increased UV(B) would increase skin cancer and eye disorders in humans and animals, suppress the immune system, reduce crop yields and interfere with the plankton at the bottom of the food chain. These are set out in the Report of the Environmental Effects Assessment.

The theory of ozone depletion is now fully accepted by the scientific community and, after much refinement and substantial supporting evidence, has led to national and international action to protect the ozone layer.

1.2 THE VIENNA CONVENTION

In 1985 the Vienna Convention for the Protection of the Ozone Layer was adopted. It provides for coordination of scientific research, exchange of information and the adoption of Protocols covering any regulatory or other further action which might be agreed.

1.3 THE MONTREAL PROTOCOL

1.3.1 The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in 1987 by 25 countries, and entered into force on 1 January 1989. Before its 1990 revision (see Section 1.5) the Protocol required each Party's production and consumption of CFCs -11, -12, -113, -114 and -115 first to be frozen at 1986 levels and ultimately reduced to 50% of 1986 levels by 1998. Production and consumption of halons 1211, 1301 and 2402 were to be restricted to 1986 levels.

1.3.2 There are several important provisions in the Protocol for developing countries, in recognition of their special situation. These include a 10 year grace period in implementing the control measures contained in the Protocol, and providing them with the necessary technology. Such countries are referred to as "Parties operating under Paragraph 1 of Article 5", or "Article 5 countries". To qualify, they must be developing countries, be Parties to the Protocol, and have an annual per capita consumption of CFCs and halons below 0.3 kilogrammes.

1.3.3 Another vital aspect of the Protocol is the provision for its revision. The Protocol can be "amended", under the terms of the Vienna Convention, with the amendments binding only on those Parties who ratify them. Its control measures can also be "adjusted", by decision, which is then binding on all Parties. Adjustments are limited (apart from adjustments to the Ozone Depletion Potentials of different chemicals) to altering the reduction schedules which apply to substances already controlled under the Protocol. The Protocol's Parties must base these decisions on available scientific, environmental, technical and economic assessments, taking place at least every 4 years. The first review of the Protocol's control measures took place in 1990, on the basis of the 1989 assessments.

1.4 THE 1989 ASSESSMENT PROCESS

The 1989 Assessment was set up in 1988, before the Protocol formally entered into force in January 1989, and was confirmed by the first Meeting of the Parties in May 1989 in Helsinki. The four assessments, covering the science, environmental effects, technology and economics, were considered by the Protocol's Open Ended Working Group, in preparation for the Second Meeting of the Parties in London in June 1990.

1.5 THE LONDON ADJUSTMENTS AND AMENDMENT TO THE PROTOCOL

The Parties agreed at their 1990 London meeting to revise the Protocol and to expedite its implementation, and adopted a resolution on transitional substances. In the light of increasing scientific and public concern over ozone depletion, empirical evidence of global depletion, confirmation that CFCs and other man made ozone depleting substances were a major factor in creating the Antarctic "ozone hole" and greatly improved prospects for replacing such substances, significant changes to the Protocol were approved.

1.5.1 Adjustments to the Control Measures for CFCs and Halons

By decision, the control measures were adjusted to provide for the phase-out of CFC and halon production and consumption (but not use) by the year 2000, with exemptions for production of halons if agreed by the Parties to be necessary for essential uses. An intermediate cut of 50% of 1986 levels by 1995 was also agreed for CFCs and halons, together with an 85% cut, for the CFCs but not the halons, by 1997. These adjustments entered into force early in 1991.

1.5.2 The London Amendment to the Protocol

In addition to the adjustments outlined above, the Parties adopted the London Amendment to the Protocol, phasing out carbon tetrachloride by the end of the century, with an intermediate cut of 85% of 1989 levels by 1995. 1,1,1-trichloroethane (methyl chloroform) is to be frozen at 1989 levels from 1993, cut by 30% by 1995 and 70% by 2000, and phased out by 2005. Other fully halogenated CFCs are to be phased out by 2000, with intermediate cuts, from 1989 levels, of 20% by 1993 and 85% by 1997. The London Amendment is scheduled to enter into force on 1 January 1992, provided that it has been ratified by at least 20 Parties. The full list of controlled and transitional substances under the Protocol is given at Annex A.

1.5.3 Technology Transfer

Despite the 10 year grace period it was recognised that the ability of developing countries to comply with the control measures would depend on effective financial cooperation and the transfer of technology. The Parties committed themselves to taking every practicable step to ensure transfer of the best available, environmentally safe substitutes and related technologies under fair and most favourable conditions, to Article 5 countries.

1.5.4 The Financial Mechanism

The Parties also agreed to set up a financial mechanism, including a multilateral fund, to meet the incremental costs for Article 5 countries of compliance with the control measures. An Interim Multilateral Ozone Fund (IMOF) was established for financing the incremental costs of Article 5 countries in adhering to the provisions of the Protocol during the period 1991-1993. The amount pledged for this interim period was US$160 million, rising to US$200 million on China's accession to the Protocol, and to US$240 million once India also joins.

1.6 THE LONDON RESOLUTION ON TRANSITIONAL SUBSTANCES

The 1990 Protocol Amendment introduced the concept of transitional substances, such as hydrochlorofluorocarbons (HCFCs). These are chemical replacements for CFCs and other controlled substances which have a small potential to deplete stratospheric ozone compared to the controlled substances. They will be necessary in some applications, in the short to medium term, to enable a rapid phaseout of the controlled substances to take place. These substances are not controlled under the Protocol, but Parties must report data on their production and trade. At the Second Meeting of the Protocol Parties a non-binding Resolution on transitional substances was adopted, applying guidelines to facilitate first their adoption where necessary and subsequently their timely substitution by non-ozone depleting and more environmentally suitable alternative substances and technologies. These guidelines cover: the limitation of transitional substances to those applications where non-ozone depleting and more environmentally suitable alternative substances or technologies are not available, and where controlled or transitional substances are currently used; their selection according to ozone depletion and other environmental, safety and economic considerations; the maximisation of emission control systems, recovery and recycling; and their eventual collection and destruction. The Resolution also provided for a regular review of the use of transitional substances, with a view to their replacement by non ozone-depleting and more environmentally suitable alternatives as the scientific evidence requires, said at the time to be no later than 2040 and, if possible, no later than 2020.

1.7 THE 1991 ASSESSMENT

1.7.1 The 1990 Mandate for the 1991 Assessment

The revised Protocol specifically states that the situation for CFCs and 1,1,1-trichloroethane shall be reviewed by the Parties in 1992, to determine the feasibility of an acceleration of the reduction schedules for these substances. The Parties decided, in 1990, to convene members of the Assessment Panels to review new information, and consider its inclusion in reports in time for consideration by the Fourth Meeting of the Parties to be held in 1992. The Technology Panel was specifically requested:

> to evaluate the need for transitional substances in specific applications;
>
> to analyze the quantity of controlled substances required by Article 5 countries for their basic domestic needs, both at present and in the future, and the likely availability of such supplies;
>
> to compare the toxicology, flammability, energy efficiency and other environmental and health and safety considerations of chemical substitutes, with an analysis of the likely availability of substitutes for medical uses.

1.7.2 Convening the 1991 Assessment Panels

In convening members of the Panels, it was decided to amalgamate the Technology Panel with the Economics Panel, so as to enable each to benefit from the ongoing work of the other. Thus the Technology and Economic Assessment Panel consists of the chairs of the Economic Options Committee, the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee, the Flexible and Rigid Foams Technical Options Committee, the Solvents, Coatings and Adhesives Technical Options Committee, the Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride Technical Options Committee, and the Halons Technical Options Committee, as well as some Senior Advisors.

1.7.3 The 1991 Review of the Mandate

The Third Meeting of the Protocol Parties, in June 1991, requested the Assessment Panels, and in particular the Technology and Economic Assessment Panel, to evaluate, without prejudice to Article 5 of the Protocol, the implications, in particular for developing countries, of the possibilities and difficulties of an earlier phaseout of the controlled substances, for example the implications of a 1997 phaseout. The Parties also asked the Panel to compile a list of trade names of substances controlled by the Protocol. The Panels were also requested, while taking the London Resolution into account, to identify the specific areas where the transitional substances are required in order to facilitate the earliest possible phaseout of controlled substances. Quantities needed in such areas, and in areas currently served by transitional substances, are to be assessed. The panels are also asked to identify those transitional substances with the lowest ozone depletion potential required for these areas and to suggest, if possible, a feasible timetable for their elimination.

1.7.4 Report of the Technology and Economic Assessment Panel

This Report of the Technology and Economic Assessment Panel contains in Chapters 7-12 the executive summaries of the Reports of the following Technical and Economic Options Committees:

The Economic Options Committee,

The Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee,

The Flexible and Rigid Foams Technical Options Committee,

The Solvents, Coatings and Adhesives Technical Options Committee,

The Aerosol Products, Sterilants, Miscellaneous Uses, and Carbon Tetrachloride Technical Options Committee,

The Halons Technical Options Committee.

This report also contains chapters on: the current production and uses of controlled substances, with principal alternatives and phaseout schedules; the requirements for transitional substances needed for the rapid phaseout of controlled substances; the status of chemical substitutes, with prospects for their commercialisation; the need for dissemination of information and technology transfer; and the particular concerns of developing countries. Annex A lists controlled and transitional substances specified in the Montreal Protocol; Annex B describes the nomenclature used to identify controlled and alternative substances; Annex C provisionally lists company trade names for CFCs and 1,1,1-trichloroethane; Annex D gives some examples of national legislation providing for phaseout schedules more rapid than those in the Protocol; while Annex E provides preliminary information on methyl bromide, identified in the Science Assessment Report as a contributor to ozone depletion.

The composition of the Technology and Economic Assessment Panel, and of the different Technical and Economic Options Committees, is shown at Annex F.

CHAPTER TWO: CONTROLLED SUBSTANCES

2.1 OVERVIEW

Substances controlled under the Montreal Protocol are used in a number of applications, including refrigeration and air conditioning, rigid and flexible foam, solvent cleaning, aerosol products, sterilisation, and a number of other miscellaneous uses.

Estimates provided to the U.S.EPA by chemical companies and estimates of the Technical Options Committees show that CFC production is now 60% of the base 1986 level. The data, shown in Tables 2.1 and 2.2, are the best available at this time. Data for Eastern Europe and some developing countries are not yet accurately compiled. Each sector has calculated approximate end use CFC reductions which may not exactly match CFC producer estimates.

TABLE 2.1

CFC Worldwide Market Estimates Compared to 1986, by Product

Product	1986 Market (kilotonnes)	1991 Market (kilotonnes)	Percentage of 1986 Market
CFC-11	415	263	63%
CFC-12	441	259	59%
CFC-113	241	143	59%
CFC-114	18	5	30%
CFC-115	13	11	85%
TOTAL	1128	681	60%

TABLE 2.2

Worldwide Estimates of CFC Use by Industry, Compared to 1986

Application	Percent of 1986 Total Uses	Reduction Since 1986
Propellants	28%	58%
Cleaning	21%	41%
All Foam Blowing	26%	35%
All Polyurethane		30%
Phenolic		65%
Ext. polysty. sht.		90%
Boards		32%
Polyolefin		35%
Refrigerants	23%	7%[1]
Other	2%	
Total		40%

[1] Reductions in refrigeration due primarily to containment and recycling.

2.2 REFRIGERATION

2.2.1 Current Use of CFCs in Refrigeration

Chlorofluorocarbons are used worldwide in many refrigeration applications. The commonly used CFC refrigerants are CFC-11, CFC-12, CFC-13, CFC-114, and CFC-115.

In 1991, 260,000 tonnes of CFCs were used in refrigeration, air conditioning, and heat pumps worldwide. Forty percent of this was used in refrigeration. Slightly more than 10,000 tonnes have been recovered from equipment upon service and disposal in 1991.

2.2.2 Principal Substitutes and Alternatives for CFC Use in Refrigeration, Air Conditioning, and Heat Pumps

Several options exist to reduce and eliminate CFCs in new refrigeration, air conditioning, and heat pump equipment. The options can be grouped according to the different sectors and to the expected time frame of their use. Table 2.3 presents the main alternatives in this sector.

Table 2.3
CFC Alternatives in the Refrigeration Sector

Refrigeration Sector	Immediate/ Short Term	Mid Term	Long Term	Retrofit
Domestic Refrigerators and Freezers	Absorption Mixtures	Blends HCFC-22 HFC-134a HFC-152a Mixtures	Alternative Cycles Ethers HFC-134a HFC Mixtures Hydrocarbons	Blends HCFCs
Commercial Refrigeration Including Display Cases and Vending Machines	HCFC-22	Blends HCFC-22 HFC-32 HFC-134a Mixtures	Alternative Cycles Ethers Ammonia HFC Mixtures HFC-125 HFC-134a	HCFC-22 HFC-134a Mixtures
Cold Storage & Food Processing	Ammonia HCFC-22	Ammonia HCFC-22	Ammonia HFCs	Blends HCFC-22
Industrial Refrigeration Including Chemical, Pharmaceutical and Ice Making	Ammonia HCFC-22 Hydrocarbons	Ammonia HCFC-22 HFC-134a Hydrocarbons	Ammonia HFCs	HCFC-22 HFC-134a
Chillers	Absorption HCFC-22	Ammonia HCFC-22 HCFC-123 HCFC-124 HFC-134a HFC-152a	Ethers HFCs	Blends HCFC-123 HCFC-124 HFC-134a
Transport Refrigeration (Truck, Ship, Rail)	HCFC-22	HCFC-22 HFC-134a Mixtures	HFCs	HCFC-22 HFC-134a Mixtures
Mobile Air Conditioning		HFC-134a Ternary Blend	Alternative Cycles HFCs	Blends HFC-134a
Heat Pumps (Cooling/ Heating & Heating Only)	HCFC-22	Ammonia HC-160 HFC-134a HFC-152a HCFC-123	Ammonia HFCs HC-160	HCFC-22 HCFC-123 HFC-134a

2.2.3 Anticipated Phaseout Timetable for Refrigeration, Air Conditioning, and Heat Pumps

Several CFC alternatives are being evaluated for refrigeration, air conditioning, and heat pumps. Key factors which will influence the timing and the rate of CFC replacement include:

- lifetime of the equipment and servicing needs
- retrofit possibilities for existing equipment
- product energy efficiency
- toxicity, flammability, and environmental concerns.

The phaseout dates shown in Table 2.4 are anticipated for the developed countries, if HFCs and HCFCs are commercially available in sufficient quantities.

2.2.4 Implications of an Accelerated Phaseout

An earlier phaseout than 2000 will cause problems for the servicing of existing equipment, but aggressive recycling programs and retrofit can minimise the cost of obsolescence of equipment. A 1997 phaseout is estimated to cost about an additional US$ 6.2 billion (of which US$2.8 billion is attributed to automotive air conditioning) compared to a 2000 phaseout. Earlier phaseouts than 1997 would cost disproportionately more.

2.3 FOAMS

2.3.1 Production and Use of CFCs in Foam

CFC-11, CFC-12, CFC-113, and CFC-114 are all used to some extent in the manufacture of the four main types of foam:

- polyurethane foam
- phenolic foam
- extruded polystyrene foam
- polyolefins.

These foams are used in a variety of foam plastic products. Building and appliance insulation represents 88 percent of CFCs in foams. Other products include cushioning materials, packaging, and microcellular foams.

The foam industry used approximately 267,400 metric tonnes of CFCs worldwide in 1986 to produce these four types of foam. Global CFC consumption in all foam sectors declined by 35 percent between 1986 and 1990, to 174,150 metric tonnes.

Table 2.4
CFC Refrigeration Usage and Feasible Phaseout Dates

Refrigeration Sector	1991 CFC Use (Metric Tonnes)	Technically Feasible Phaseout
Domestic Refrigerators and Freezers	9,000[a]	1997
Commercial Refrigeration including display cases and vending machines	55,200[b]	1997 with 2,000 tons supplied by recycling; US$ 500 million retrofit
Cold Storage & Food Processing	28,500	1997 with US$ 1 billion retrofit
Industrial Refrigeration including Chemical Pharmaceutical, and Ice Making	5,000	1997 with US$ 250 million retrofit
Chillers	7,900[c]	1997 with US$ 800 million retrofit
Transport Refrigeration (truck, ship, rail)	7,000[d]	1997 with US$ 700 million retrofit
Mobile Air Conditioning	147,000[e]	1997 with US$ 1.8 billion to US$ 30.8 billion retrofit
Heat Pumps (cooling/ heating & heating only)	1,000	1997 with US$ 150 million retrofit

[a] 120,000 tonnes banked in existing systems.

[b] Taking into account the CFC amounts in mixtures.

[c] 23,000 tonnes banked in existing systems; 7,900 tonnes includes new systems and service.

[d] 60,000 tonnes banked in 120,000 existing systems; 7,000 tonnes includes new systems and service.

[e] 600,000 tonnes banked in existing systems.

2.3.2 Principal Substitutes for CFC Use in Foam

Table 2.6 summarises the alternatives available and currently under research by the foam industry.

2.3.3 Anticipated CFC Phaseout Timetable and Implications for an Earlier Phaseout

The use of HCFCs in foam plastics presents the quickest path to elimination of CFCs, in developed countries in 1995, while some developing countries may require additional time to achieve CFC reductions. The applications that will rely most on HCFCs include polyurethane, phenolic and extruded polystyrene insulation products, and certain polyolefin packaging and polyurethane integral skin for automotive product applications. It is estimated that approximately 150,000 tonnes of HCFCs per year would be required to achieve a CFC phaseout in foam plastics in developed countries in 1995.

There are considerable uncertainties affecting the timing and the rate of CFC replacement. These include: toxicity, flammability, environmental acceptability, and product energy efficiency.

Based on current technology, many foam manufacturers have few options other than HCFCs. Foam insulation products without CFC or HCFC would have poorer physical properties, poorer fire performance properties, higher cost, and poorer insulating value compared to those made with CFCs.

Table 2.5 presents the projected phaseout dates for CFC use in the foam sector.

Table 2.5
CFC Phaseout Dates in the Foams Sector

Foams Sector	1990 use estimate (metric tonnes)	Technically Feasible Phase Out
Polyurethane Foam	140,200[a]	1994/1995
Phenolic Foam	2,700[b]	1995
Extruded Polystyrene Foam Sheet	nil[c]	1991
Extruded Polystyrene Foam Boardstock	12,000[d]	1993
Polyolefins	12,350[e]	1993

[a] Primarily CFC-11 used in applications such as cushioning and insulation.

[b] Primarily CFC-11 and CFC-113 used in applications such as insulating materials in buildings.

[c] CFCs are no longer thought to be used in food servicing and packaging.

[d] Insulation products using primarly CFC-12.

[e] A variety of protective packaging and flotation products using CFC-11, CFC-12, and CFC-114.

Table 2.6: CFC Alternatives Available to the Foam Industry

Type of Foam	CFC Alternatives		
	Immediate	Short/Intermediate Term	Long Term
Polyurethane:			
Rigid: Appliance	Reduced CFC-11, 100% CO_2	HCFC-141b, HCFC-123, perfluorocarbon*, HCFC-22, HCFC-22/HCFC-142b blends	HFCs, fluorinated ether, vacuum panels, perfluorocarbon*, hexafluorobutane
Boardstock/Flex-Faced Lamination	Reduced CFC-11, 100% CO_2, pentane, 2-chloropropane**, HCFC-22/HCFC-142b blends	HCFC-141b, HCFC-123, HCFC-22, HCFC-22/HCFC-142b blends, perfluorocarbon*	HFCs, fluorinated ether
Sandwich Panels	Reduced CFC-11, 100% CO_2, pentane, HCFC-22/HCFC-142b blends, HCFC-22	HCFC-141b, HCFC-123, HCFC-22, HCFC-22/HCFC-142b blends	HFCs, fluorinated ether, vacuum panels
Spray	Reduced CFC-11, 100% CO_2, HCFC-22	HCFC-141b, HCFC-123	HFCs, fluorinated ether
Slabstock	Reduced CFC-11, pentane	HCFC-141b, HCFC-123, HCFC-22, HCFC-22/HCFC-142b blends	HFCs, fluorinated ether
Pipe	100% CO_2, HCFC-22, HCFC-22/HCFC-142b blends, methyl chloroform	HCFC-141b, HCFC-123, HCFC-22	HFCs, fluorinated ether, 100% CO_2
Flex: Slab	Extended-range polyols, softening agents, methylene chloride, methyl chloroform, acetone, AB Technology, increased density	HCFCs***	Dissolved CO_2, reduced barometric pressure
Moulded	Methylene chloride, increased density, methyl chloroform, extended range polyols	HCFCs***	
Integral Skin	HCFC-22, hydrocarbons, water substitution, methylene chloride, air loading, high active polyol, 100% CO_2	HCFC-141b, HCFC-123	100% CO_2, HFCs
Phenolic	Hydrocarbons, HCFC-22/HCFC-142b blends	HCFC-141b, HCFC-123, HCFC-22/HCFC-142b blends	HFCs
Extruded Polystyrene:			
Sheets	HCFC-22, hydrocarbons, 100% CO_2, HFC-152a	HFC-152a, HFC-134a, hydrocarbons, 100% CO_2	100% CO_2, hydrocarbons, Atmospheric gases/resins, HFC-152a, HFC-134a
Boards	HCFC-22, HCFC-142b	HCFC-142b, HCFC-124, HCFC-22	HFCs
Polyolefin	Hydrocarbons, HCFC-22, HCFC-142b, 100% CO_2	100% CO_2, inorganic gases, HFCs, hydrocarbons	

* To be used as an additive or a co-blowing agent.
** Proprietary technology.
*** Not likely to be used.

2.4 SOLVENTS

2.4.1 Production and Use of CFCs in Solvent Applications

CFC-113 is used in electronics, metal, precision and dry cleaning, and for aerosol solvent products. The level of usage and the amounts of CFC-113 used vary with each application. In 1990, the worldwide consumption of CFC-113 was approximately 178,000 metric tonnes.

2.4.2 Production and Use of 1,1,1-Trichloroethane

1,1,1-trichloroethane is widely used in solvent, coatings, and adhesive applications. In 1988, the consumption of 1,1,1-trichloroethane in the U.S., Western Europe, and Japan was approximately 582,000 metric tonnes. The solvent uses of 1,1,1-trichloroethane are metal, precision and dry cleaning.

2.4.3 Principal Substitutes and Alternatives for CFC-113 and 1,1,1-Trichloroethane

The substitutes and alternative processes which can be used to eliminate the use of CFC-113 and 1,1,1-trichloroethane in solvent applications are presented in Table 2.7.

2.4.4 Anticipated Phaseout Schedule and Implications for CFC-113 and 1,1,1-Trichloroethane Use in Solvents

The consensus findings of the UNEP Solvents, Coatings, and Adhesives Technical Options Committee on the technical feasibility of phasing out the use of CFC-113 and 1,1,1-trichloroethane are presented in Table 2.8.

All dates imply phaseout by December 31 of the year stated. The range of technically feasible phaseout dates reflect uncertainties in the commercial availability of some alternatives and substitutes and differences in the expert judgements of committee members. Accelerated phaseouts will require the development of some new technologies.

Early phaseout of 1,1,1-trichloroethane will depend on the very rapid dissemination and adoption of technologies for the replacement among many thousands of small users.

Table 2.7
CFC-113 and 1,1,1-trichloroethane Uses and Alternatives in the Solvents Sector

Solvents Sector	1989 use estimate (metric tonnes)	Substitutes and alternatives for CFC-113	Substitutes and alternatives for 1,1,1-trichloroethane
Electronics Cleaning	54,000 (1,1,1 -trichloroethane) 147,000 (CFC-113)	-- No-clean (low-solid fluxes, controlled atmospheric soldering) -- Aqueous cleaning -- Hydrocarbon/surfactant-based solvents -- Organic solvents -- Chlorinated solvents -- HCFCs -- Conservation and recycling	-- No-clean (low-solid fluxes, controlled atmospheric soldering) -- Aqueous cleaning -- Hydrocarbon/surfactant-based solvents -- Organic solvents -- Chlorinated solvents -- HCFCs -- Conservation and recycling
Metal Cleaning	152,000 (1,1,1 -trichloroethane) 21,000 (CFC-113)	-- Aqueous cleaning -- Hydrocarbon/surfactant-based solvents -- Petroleum distillates -- Chlorinated solvents -- HCFCs -- Conservation and recycling	-- Aqueous cleaning -- Hydrocarbon/surfactant-based solvents -- Petroleum distillates -- Chlorinated solvents -- HCFCs -- Conservation and recycling
Precision Cleaning	228,000 (1,1,1 -trichloroethane) 32,000 (CFC-113)	-- Aqueous cleaning -- Hydrocarbon/surfactant-based solvents -- Perfluorocarbons -- Organic solvents -- Aliphatic hydrocarbons -- Chlorinated solvents -- HCFCs -- Super criticl fluids -- Conservation and recycling	-- Aqueous cleaning -- Hydrocarbon/surfactant-based solvents -- Perfluorocarbons -- Organic solvents -- Aliphatic hydrocarbons -- Chlorinated solvents -- HCFCs -- Super critical fluids -- Conservation and recycling
Dry Cleaning	10,500 (CFC-113)	-- Perchloroethylene -- White spirit (Stoddard solvent) -- HCFC-225 -- Conservation and recycling	
Aerosol Application	40,000 (1,1,1 -trichloroethane) 20,000 (CFC-113)	-- Petroleum distillates -- HCFCs -- Alternative delivery systems	-- Petroleum distillates -- HCFCs -- Alternative delivery systems -- Water-based systems
Coatings and Inks	21,000 (1,1,1-trichloroethane)		-- High-solid coatings -- Water-based coatings and inks -- Powder coatings
Adhesives	48,000 (1,1,1-trichloroethane)		-- Water based -- Hot melt -- Radiation cured -- Powder based -- Organic solvent based -- High solids

TABLE 2.8

TECHNICALLY FEASIBLE PHASEOUT SCHEDULE

Category of User	CFC-113	1,1,1-trichloroethane
Developed countries with stringent national legislation[a]	1990-1992	1992-1994
Other developed countries and developing countries with strong technology transfer partnerships and/or aggressive regulatory regimes[b]	1993-1997	1995-2000
Other developing countries	1995-2000	1997-2002

[a] These include Austria, Germany, Norway, Sweden, and Switzerland, who have already scheduled accelerated phase-outs of ozone-depleting compounds. Such countries consume around 5 percent of the world production of CFC-113 and 1,1,1-trichloroethane in a representative variety of uses - but not all uses. Some of these countries will allow exemptions for particular essential applications if no environmentally acceptable alternative or substitute is available.

[b] Developing countries with strong technology transfer partnerships and/or aggressive regulatory regimes include countries like Mexico, Singapore, and Thailand. The phase-out can occur quickly in developing countries where the major quantity of ozone-depleting solvents are used by subsidiaries of multinational companies that have announced dates by which they will stop producing, selling, distributing, or using CFCs worldwide.

2.5 AEROSOL PRODUCTS

2.5.1 Production and Use

CFCs have been used extensively as a propellant in aerosol products; CFCs and 1,1,1-trichloroethane have also been used as a solvent and as the active ingredient. In the mid-1970s the use of CFC-11 and -12 in aerosols accounted for about 60 percent of the total use of these chemicals worldwide. Due to mandatory and voluntary reduction programmes in various countries, this use has been substantially reduced. However, use in aerosol products is still substantial, accounting for some 115,000 metric tonnes, a reduction of some 58 percent from 1986 (approximately 20 percent of current use of controlled CFCs).

In countries which have implemented phaseout programmes, the remaining aerosol uses are principally in the industrial and pharmaceutical sectors.

2.5.2 Alternatives and Substitutes

There is a wide variety of alternatives and substitutes available for CFCs and 1,1,1-trichloroethane in aerosol products. The optimal choice will vary with the product under consideration. Each alternative has its own unique set of properties such as solvency, performance characteristics and costs.

The majority of aerosol producers have or are likely to turn to hydrocarbons. This requires reformulation, retrofitting and sometimes plant relocation (because of the increased explosion and fire risk associated with the use of these chemicals). In most countries the conversion to non-CFC propellant products is well underway. The most difficult challenge is to eliminate CFC propellants from oral inhalant drug products. Powder administration methods have been commercialized for some drugs, however, for many patients, powder inhalers are not a satisfactory alternative to the pressurized inhaler. The amount of CFCs currently used in oral inhalant drug products worldwide is 5,000-6,000 metric tonnes per year.

It is also considered difficult to eliminate CFCs from certain aerosol products used in specialized industrial or technical applications. Substitution with hydrocarbons, dimethyl ether, compressed gases, HCFCs or HFCs should be possible; however, flammability risks must be fully considered.

Table 2.9 presents various alternatives for the aerosols sector.

2.5.3 Anticipated Phaseout Time Frame

A reduction to some 15,000 tonnes of CFCs used in aerosol products worldwide should be technically possible by 1995.

Table 2.10 summarizes the technically feasible phaseout dates for specific aerosol products.

Table 2.9

CFC Alternatives in the Aerosols Sector

Alternative propellants	Alternative solvents	Pressurized liquid dispensing	Alternative Aerosol Systems
-- hydrocarbons (propane, n-butane, iso-butane, iso-pentane -- dimethyl ether -- compressed gases (CO_2, N_2, N_2O, compressed air) -- HCFC-22/142b -- HCFC-123, 124, 141b -- HFC-152a/134a/227	-- water -- chlorinated solvents (e.g., methylene chloride, trichloroethylene -- alcohols (iso-propylalcohol, ethanol, n-propanol)	-- bag-in-can systems -- piston-can systems	-- finger and trigger pumps -- mechanical pressure dispensers (e.g., compressed air or contacting bladders) -- sticks (deodorants and antiperspirants, insect repellents) -- roller, brush, cloth -- coils and heated mats (insecticides and insect repellents) -- Powder inhaler

Table 2.10

Aerosol Products and Technically Feasible Phaseout Dates

Aerosol Product	Earliest Feasible Phaseout Date
Cosmetic	1991-1992
Solvents	1995
Pesticides	1991-1992
Oral inhalant drug products	1997-2000

2.5.4 Implications of an Accelerated Phaseout

With the exception of oral inhalant drug products and certain small uses in developing countries, acceleration of the CFC phaseout from the year 2000 to 1997 would have a negligible impact providing transitional substances are available.

In the majority of developing countries, there is an economic incentive to use hydrocarbon propellants rather than CFCs. Lack of economic resources, land and trained personnel may constitute the main local obstacles for replacement of CFCs.

The grace period for Article 5 countries should ensure that new propellants will be introduced where flammability currently limits the use of hydrocarbons as propellants.

2.6 STERILANTS

2.6.1 Production and Use

A mixture of CFC-12 and ethylene oxide (EO) (88 percent CFC-12 and 12 percent EO) termed 12/88 is widely used by medical device manufacturers, contract services, and hospitals for gas sterilisation of medical equipment and devices.

Using CFC-12 reduces the flammability and explosion risks of EO. The total use of CFC-12 worldwide for sterilisation is estimated to be approximately 18-20,000 tonnes.

2.6.2 Alternatives and Substitutes

Table 2.11 presents currently available and emerging alternatives for replacing CFC-12 use in sterilants.

Table 2.11

Alternatives to CFC-12 in Sterilant Applications

Currently Available Alternatives	Emerging Alternatives
-- Steam sterilization -- 100% EO -- Carbon dioxide/EO (10/90) and other carbon dioxide mixtures -- Formaldehyde -- Radiation -- Good housekeeping/optimization -- Recovery/recycling	-- HCFC/EO -- Gas plasma -- Chlorine dioxide -- Vapour phase hydrogen peroxide

2.6.3 Anticipated Phaseout Time Frame

The use of CFC for sterilisation in developed countries can be phased out during the first half of the 1990s and not later than the end of 1995. In developing countries the substitution will probably be slower unless special efforts are made.

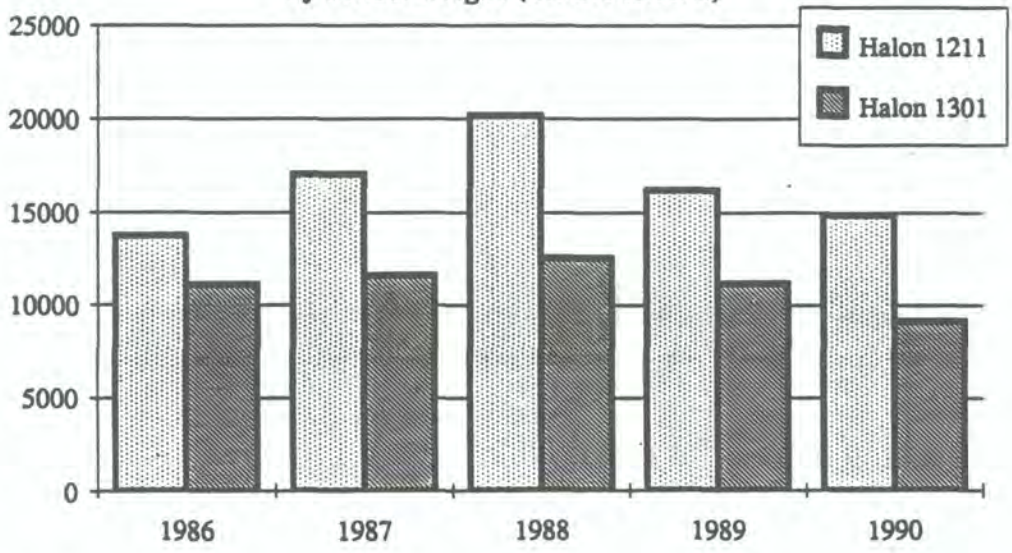
2.7 HALONS

2.7.1 Production and Use of Halons

Halon 1301 in fixed fire protection systems is primarily used to protect vital electronics facilities such as computer rooms and communications equipment rooms. Other significant applications include: repositories of cultural heritage, shipboard machinery spaces, and pipeline pumping stations. Halon 1211 portable fire extinguishers have been used in computer rooms, museums, art galleries, vehicles, and in offices for photocopy machines, personal computers, and other electronic equipment.

Production of halon 1211 and halon 1301 peaked in 1988 and is now declining. 1986 production of halon 2402 has been estimated at 1000 tonnes. Production of halon 2402 within OECD nations has virtually ceased.

Estimated World Production of Halons - 1986 to 1990
by actual weight (metric tonnes)



2.7.2 Replacements and Alternative Technologies for Halon

Developing general purpose, zero-ODP, direct replacements having attributes equal to those of the present halons may not be possible. However, clean halon replacements with lower ODPs for selected specific uses are a realistic goal, particularly if trade-offs are acceptable in fire extinguishing capability, toxicity, and/or other characteristics.

Rather than providing protection against hazards, good engineering practice dictates that, where possible, hazards should be designed out of facilities. Active fire extinguishing systems which perform the same function as halon systems should not be considered as the only alternative to halon systems. A combination of prevention, inherent design, minimisation of personnel exposure, passive protection, other fire protection systems, equipment duplication, detection, and manual intervention should all be considered.

2.7.3 The Halon Bank as a Source of Supply

The quantities of halons banked in extinguishing systems containers, portable extinguishers, and mobile units is far greater than the quantities emitted each year for extinguishing fires, discharge testing, training, and unwanted discharges.

Bank management consists of keeping track of halon quantities identified at each stage: initial filling, installing, recovery, recycling (or destruction), and recharging.

Procurement policies by government agencies and other halon users requiring use of recycled halons for recharge or initial fill will provide a strong motivation to establish bank management facilities. Procedures which are flexible and motivating enough must be developed specifically for existing fixed systems and portable extinguishers as well as for new systems and equipment.

2.7.4 Anticipated Phaseout Date for Halons

The requirement to produce new halons for essential uses can be avoided if sufficient incentive is provided and investment is made in halon recycling, banking facilities, and use of halon alternatives.

The bank of halon 1211 should be sufficient to maintain existing equipment using recycled halon. However, for some early years after production phaseout, some equipment may have to be taken out of service to ensure maintenance quantities of halon 1211 for more important applications.

It is estimated that the bank of halon 1301 will be adequate to maintain existing equipment for 45 years after production ceases. Moreover, it appears that recycled halon 1301 could be provided for new equipment after new production is curtailed (see Appendix C of the Halon Technical Options Report).

It should be noted that the estimates provided for the bank will likely be affected by various new factors such as an early phaseout of production, the efficiency of recycling programs, the possible growth of use in developing countries, the commercialization of acceptable replacement chemicals, and the uncertainty of the rate of decommissioning of halon fire equipment in the developed countries.

2.7.5 Implications of 1997 Halon Production Phaseout

An orderly transition to alternative fire protection measures, establishment of procedures to adequately manage the bank of halons, and increased efforts to develop transitional and eventual replacement fire extinguishing agents with the beneficial characteristics of the present halons are all steps that may minimize the loss of fire protection capability represented by the phaseout of halons. The risk to human life is the crux of the problem and as such a decision based on an integrated overview that balances threat from ozone depletion and threat from fire or explosion must be made.

2.8 CARBON TETRACHLORIDE

2.8.1 Production and Use

Carbon tetrachloride (CTC) is used primarily as feedstock for production of CFCs -11 and -12. It is also used as a feedstock for production of pharmaceutical and agricultural chemicals; as a catalyst promoter in oil refineries; and as a process solvent for materials undergoing chlorination (chlorinated rubber and pharmaceutical). In some of these applications virtually all CTC may be destroyed or recycled. CTC is still used in some countries as a solvent in aerosol products, metal cleaning and spot removing; as a solvent and carrier in coatings; in laboratory uses; and as a fire extinguishing agent.

A list of carbon tetrachloride uses and alternatives for these applications is shown in Table 2.12.

In 1988 CTC production capacity was about 1,000,000 tonnes worldwide. In 1987, the U.S. consumed 97 percent of available carbon tetrachloride in the production of CFCs -11 and -12. CTC production for Western Europe was estimated to be 409,000 metric tonnes in 1987, 94 percent of which was used to produce CFCs -11 and -12. It is believed that carbon tetrachloride is used in Eastern Europe, Southeast Asia, and the USSR for purposes other than CFC production.

TABLE 2.12

CARBON TETRACHLORIDE USES AND SUBSTITUTES

Use	Substitute
Feedstock	--
Metal Degreasing	Aqueous Cleaning HCFC-Based Solvents Terpene Solvents Alcohol-Based Solvents Petroleum-Based Solvents
Dry Cleaning	Perchloroethylene Petroleum-Based Distillates
Pesticide Delivery	Glycol Ethers Chlorinated Solvents
Grain Fumigant Solvent	Other Solvents
Pharmaceutical Production	Glycol Ethers Recovery and Recycling
Industrial Paint Manufacture	Glycol Ethers NMP (N-methyl-2-pyrrolidone) MEK (Methyl Ethyl Ketone) DBE (Dibasic Esters)
Solvent for Waxes, Oils, Fats, Resins	MEK NMP Glycol Ethers DBE
Fire Extinguishing Agent	Dry Chemical CO_2 Water
Laboratory Agent	Other Solvents

2.8.2 Substitutes for Carbon Tetrachloride

Most carbon tetrachloride is used in the manufacture of CFCs or other chemicals. Non-feedstock uses such as solvent cleaning, laboratory use and miscellaneous solvent applications have a number of substitutes as outlined in section 2.4

In its application as an inert solvent in chlorination reactions no substitute has yet been identified. It should be possible, by application of best available technology, to reduce CTC emissions to an insignificant level.

2.8.3 Anticipated Phaseout

The phaseout requirements under the protocol apply only to the small percent of carbon tetrachloride production not used as a feedstock.

Alternatives are still being sought for some low volume use. It should be possible to phase out CTC use in non feedstock applications by the year 1995 and in specialty use by 1997.

Elimination of CTC used as a solvent for pharmaceutical production will require time for regulatory approval.

2.8.4 Implications of 1997 Phaseout

There are no major technical reasons which would preclude the phaseout of CTC as early as 1995 with the exception of minor uses.

In cases where alternatives cannot be found for essential applications or the time frame for approval is lengthy, continued use may be required with appropriate recovery and recycling controls.

2.9 MISCELLANEOUS USES

2.9.1 Production and Use

CFCs are used for a variety of other uses. These include:

- Food freezing
- Tobacco expansion
- Fumigants
- Laboratory testing
- Leak detection
- Wind tunnels
- Graphite purification
- Biological extraction processes
- Thermostats/thermometers
- Insulated windows
- Cancer therapy
- Repair of piping
- Manufacture of medical products
- Solar tracking systems

These miscellaneous uses are believed to consume, on a global basis, a very small percentage of CFCs. There are probably many other small applications.

2.9.2 Anticipated Phaseout and Implications

Most miscellaneous uses of CFCs can be abandoned in order to comply with an accelerated phaseout. Processes or alternative substances that do not require CFCs are available for many of the important miscellaneous uses. Some very low volume uses such as in laboratory procedures and linear accelerator uses may require controlled substances from inventory or recycling until suitable replacements are available.

2.10 "ESSENTIAL USE" IN THE MONTREAL PROTOCOL

The idea of essential use was only introduced into the Montreal Protocol for the controls on halons, providing for the identification of essential uses for which additional production of halons may be permitted beyond the phaseout date of 2000. The Parties are obliged, by 1 January 1993, to adopt a decision identifying essential uses, if any, for the purposes of this provision.

2.10.1 Essential Use Criteria

- **Technical essentiality** - The first judgement is whether a particular substance is essential to accomplish a particular activity. This is a technical assessment. An example is whether or not alternative propellants are acceptable for oral inhalent drug products, and whether powder administration offers equivalent treatment of respiratory disease in all cases.

- **The essentiality of particular activities** - The second judgement is whether or not an activity which requires a particular substance is itself essential. Food preservation and medical treatment are examples of activities which may be considered essential, and which might therefore meet this criterion in any cases for which use of controlled substances is technically essential.

The Halons Technical Options Committee has suggested that essential activities are those where a critical need exists which would otherwise result in serious impairment of an essential service to society, or pose an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential uses to society. This could be adapted to provide criteria for the assessment of essential uses of other controlled substances. It could be applied either by specific use controls or by limiting the total availability of substances to the amounts thought necessary to meet the needs of essential uses, and allowing the market to decide on precise areas of use.

- **Non-availability from existing stocks** - A third factor is whether or not new production is needed to supply the necessary substance for the essential activity. It appears that essential applications of halons can be satisfied by the use of halons already produced - to the extent that the produced halons are available within the same Party.

Production of a controlled substance is only essential where **all three criteria are met.** However there may be cases where it is technically possible to forego the use of controlled substances in an essential activity but where the cost would be enormous. An example might be a recently installed refrigerated blood storage facility which needs a small amount of its refrigerant to avoid having to replace the entire plant.

2.10.2 Essential Uses of Halons - Conclusions from the Halons Technical Options Report

Further to Decision II/3 of the Parties, the Halons Technical Options Committee has been considering the availability of substitutes for halons, the need to define essential uses of halons, methods of implementation and, if there is such a need, the identification of such uses.

The Committee states that the term 'essential' should be qualified in that it is not the halon that is essential, but rather it is the essentiality of a particular facility or equipment, protected by halon equipment, that is of concern.

The Halons Technical Options Committee recognizes that there are fire/explosion risk scenarios for which current fire protection technology cannot provide adequate protection without the use of halons or halon-like replacement extinguishants. These uses involve an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential services to society. At the same time, the Committee is of the qualified opinion that with proper management, the future needs of essential uses can be satisfied by redeployment of existing, banked halons until such time, beyond the turn of the century, as the bank expires. The Committee also notes that application specific, replacement extinguishing agents, are currently under development. In the long term, use of these extinguishing agents, and others that may be developed in the future, may satisfy the needs of essential uses and restore the capability to provide fire protection with similar desirable characteristics to those of the present halons for other important facilities.

Although use of halons is desirable in a wide range of facilities, where their important characteristics are valuable, the Committee is of the opinion that establishing a list of essential uses is neither appropriate nor necessary at this time. However, because the importance of protecting the ozone layer is critical, the following criteria should be satisfied before reaching the conclusion that a new installation is an essential halon use:

> A critical need must exist to minimize damage due to fire, explosions or extinguishing agent application, which would otherwise result in serious impairment of an essential service to society, or pose an unacceptable threat to life, the environment, or national security, **AND** all other appropriate fire protection measures have been taken.
>
> Time to make appropriate changes in national fire codes, standards and regulations will be necessary before fully and safely applying these criteria.

Cooperation at the international level is necessary to ensure that one nation's surplus halon is exported to meet the needs of another nation, rather than destroyed. This is particularly important for meeting the special needs of developing countries, who will not have adequate halon banks to support their essential uses, and the Parties should consider special measures to address these needs.

The requirement to produce new halons for essential uses can be avoided if sufficient incentive is provided and investment is made in halon recycling, banking facilities, and halon alternatives utilization. Although it may be necessary to reconsider this issue in the future, the combination of successful bank management, and the proper utilization of lower and zero ODP halon alternatives, offers the best potential to eliminate the need for a production exemption for essential uses in the foreseeable future.

At this time a bank management and recycling infrastructure is not in place, and the status of replacement agents is only in the early stages of development. Therefore, the Committee believes that it is inappropriate to make a decision on the need for additional production after the phaseout year at this time, and recommends that the subject be re-evaluated at a later date.

2.10.3 Possible Essential Uses for CFCs

It is possible that CFC production will be needed for essential uses, if CFCs are phased out by 1997, because there may be some low-volume uses which continue to meet the essential use criteria set out in paragraph 2.10.1 above. This should be investigated in future assessments.

2.10.4 Inadvertent Production of Controlled Substances

Controlled substances are inadvertently and sometimes unavoidably produced as a consequence of various chemical processes. Furthermore, carbon tetrachloride, 1,1,1-trichloroethane and CFCs are feedstocks for many important chemicals and chemical products including some of the transitional substances. Much of the inadvertently produced substance can be used as feedstock in the production of other chemicals or can be destroyed, but even feedstock uses result in unavoidable emissions. Because such emissions are unavoidable and are an essential consequence of continued production of chlorinated solvents, chloromethane, vinyl chloride and other products, the Protocol may need provisions or interpretation which allow for this continued "production" and emission after phaseout, under terms of best available control technology and waste minimisation.

CHAPTER THREE: TRANSITIONAL SUBSTANCES

3.1 INTRODUCTION

The 1990 Protocol Amendment introduced the concept of "transitional substances": partially halogenated ozone depleting compounds with shorter lifetimes than the controlled substances and lower ODPs. This concept does not include mixtures or blends which contain controlled substances. The Amended Protocol lists as transitional substances 34 HCFCs, containing hydrogen as well as chlorine, fluorine and carbon (see Annex 2). There are other substances such as HBFCs, containing hydrogen, bromine, fluorine and carbon, which are not currently classified by the Protocol as "transitional substances".

Transitional substances do less damage to the ozone layer than the fully halogenated compounds, as their lifetimes are shorter. Their relative instability can lead to breakdown in the lower atmosphere, thus limiting the damage done to stratospheric ozone. Typically, HCFCs have ozone depletion potentials between 0.02 and 0.11. HBFCs can have higher ODPs, within a range of 0.25 to 1.4, although these values are less well established than those for HCFCs.

HCFC-22 is already widely used, in refrigeration, air conditioning, as an aerosol propellant, in foam blowing and in a number of other smaller applications. HCFC-142b is also used, in relatively small quantities, for foam blowing, in refrigeration, as an ingredient in aerosol products and for other miscellaneous applications. HCFCs are also seen as a significant short term replacement for CFCs in many applications. Similarities between CFCs and HCFCs mean that the adaptation of CFC-using technologies to HCFCs is easier than developing new technologies, and can be achieved more quickly. In such applications the use of HCFCs is necessary for the fastest possible elimination of CFCs. In several sectors, accelerated CFC phaseout schedules are possible only if HCFCs are available.

3.2 TRANSITIONAL SUBSTANCES UNDER THE MONTREAL PROTOCOL

Despite their relatively low ODPs, there is serious concern that an increase in HCFC emissions could contribute substantially to ozone depletion. In response to this concern, the 1990 Protocol Amendment requires all Parties to report data on their production, imports and exports of the 34 listed HCFCs. A resolution was also adopted, voluntarily limiting the use of transitional substances to the rapid elimination of controlled substances. The Governments and European Communities represented at the Second Meeting of the Parties to the Montreal Protocol resolved:

"1. To apply the following guidelines to facilitate the adoption of transitional substances with a low ozone-depletion potential, such as hydrochlorofluorocarbons (HCFCs), where necessary, and their timely substitution by non-ozone depleting and more environmentally suitable alternative substances or technologies:

> (a) Use of transitional substances should be limited to those applications where other more environmentally suitable alternative substances or technologies are not available;
>
> (b) Use of transitional substances should not be outside the areas of application currently met by the controlled and transitional substances, except in rare cases for the protection of human life or human health;
>
> (c) Transitional substances should be selected in a manner that minimizes ozone depletion, in addition to meeting other environmental, safety and economic considerations;
>
> (d) Emission control systems, recovery and recycling should, to the degree possible, be employed in order to minimize emissions to the atmosphere;
>
> (e) Transitional substances should, to the degree possible, be collected and prudently destroyed at the end of their final use:

"2. To review regularly the use of transitional substances, their contribution to ozone depletion and global warming, and the availability of alternative products and application technologies, with a view to their replacement by non-ozone depleting and more environmentally suitable alternatives and as the scientific evidence requires: at present this should be no later than 2040 and, if possible, no later than 2020."

HBFCs are not specifically mentioned in the Protocol or the resolution. Although HBFCs, with higher ODPs, are inappropriate as replacements for CFCs, they may be environmentally desirable replacements for halons in any essential applications. Substitution of HBFCs for halons could be consistent with the intent of the resolution if the only alternative is continued or resumed halon production.

3.3 THE KEY HCFCs AND THEIR ENVIRONMENTAL IMPLICATIONS

3.3.1 For new HCFCs to contribute to the early elimination of CFCs they must have the potential to become commercially available earlier than other more environmentally suitable alternative substances or technologies. The time needed for toxicology testing is an important limiting factor, and may effectively restrict use of HCFCs to those where such testing is complete or in progress. Table 3.1 lists such substances, together with their Ozone Depletion Potentials.

TABLE 3.1
HCFCs CURRENTLY AVAILABLE OR UNDERGOING TOXICITY TESTING

SUBSTANCE	ESTIMATED COMPLETION OF TOXICITY TESTING	ODP
HCFC-22	Completed	0.055
HCFC-142b	Completed	0.065
HCFC-123	1992	0.02
HCFC-141b	1993	0.11
HCFC-124	1995	0.022
HCFC-225ca	1996	0.025
HCFC-225cb	1996	0.033

NOTE: Dates for the completion of toxicity testing are those forecast by the Program for Alternative Fluorocarbon Toxicity Testing. Intermediate results and increased testing requirements can alter these schedules. The suitability of substances for applications where exposures are low can often be determined before testing is fully complete. HCFC-123 and HCFC-141b are commercially available for some applications.

3.3.2 The selection of technologies to replace the use of controlled substances should be made to minimise energy consumption as well as ozone depletion. The energy efficiency of foams and refrigeration equipment has a greater influence on climate change than the direct emissions of particular substances used in those applications. This is covered in more detail in Chapter 4.

3.4 APPLICATIONS FOR WHICH TRANSITIONAL SUBSTANCES ARE NEEDED

Table 3.2 shows those applications, currently using either controlled or transitional substances, for which transitional substances are considered to be an appropriate short to medium term solution, taking into account the terms of the London Resolution. Table 3.3 shows the maximum quantities of transitional substances which are expected to be needed by developed countries in those applications in 1997, assuming a 1997 phaseout of controlled substances.

TABLE 3.2 APPLICATIONS WHERE TRANSITIONAL SUBSTANCES ARE NEEDED

	HCFC-22	HBFC-22B1	HCFC-123	HCFC-124	HBFC-124B1	HCFC-141B	HCFC-142B	Blends containing HCFCs -22, -124 or HFC-152a	HCFC-225
ODP	0.055	1.4	0.02	0.022	0.25	0.11	0.065		0.025/ 0.033
Applications Aerosol Products[1]	Yes		Possible			Possible	Yes		
Sterilants				Possible					
Tobacco Expansion			Possible						
Fire Extinguishants		Possible	Possible		Possible				
Domestic Refrigeration	Possible						Possible	Possible	
Commercial Refrigeration	Yes							Possible	
Unit Area Air Conditioners	Yes								
Chillers	Yes		Yes	Yes		Possible			
Auto AC								Possible	
Cold Storage and Industrial Refrigeration	Yes								
Transport Refrigeration	Yes							Possible	
Heat Pumps	Yes								
Electronic and Metal Cleaning Solvents			Possible			Yes			Yes
Dry Cleaning Solvents									Yes
Polyurethane Foams	Yes		Yes			Yes	Yes		
Phenolic Foams	Yes		Yes			Yes	Yes		
Polystyrene Foams	Yes			Yes			Yes		
Polyolefin Foams	Yes						Yes		

[1] HCFCs are needed only in certain aerosol products which must be non-flammable. Substitutes and alternatives are available for most uses and more non ozone depleting substitutes are being developed.

TABLE 3.3 Projected Use of Transitional Substances in 1997

APPLICATION	USE IN METRIC TONNES	ODP
Foams	150,000	0.02 - 0.11
Refrigeration	235,000 to 275,000	~0.05
Aerosols	20,000	0.05
Sterilants	0 - 15,000	0.022
Fire Fighting	0 - 7,000	0.02 - 1.4
Solvents	18,000 - 50,000	0.02 - 0.11
TOTAL	423,000 - 517,000	

3.5 POSSIBLE PHASEOUT OF TRANSITIONAL SUBSTANCES

Various substances and technologies which may have the potential to eliminate use of HCFCs are under development, including technologies for applying HFC-134a to new areas of application, new HFCs such as HFC-32, and alternative technologies such as adsorption and absorption refrigeration, vacuum panels, and no-clean options for metal forming. However, some of this work is at an early stage of development, and it is not possible at this time to determine when they will be available or whether they will prove technically or economically viable and energy efficient.

As commercial availability of a range of HCFCs is essential for the early elimination of CFCs, it is important to consider the conditions under which it is economic for the necessary investment in their production and use to be made. The minimum length of time needed for a new HCFC to be used is influenced by: 1) the fact that chemicals will only be produced if plant investment can be recovered or converted to produce other substances; 2) the costs to users of transition into and out of HCFC use; and 3) the requirement of HCFC for service during the useful life of equipment. Refrigeration equipment has a long service life and equipment using HCFCs will require HCFC refrigerant for service. Foam production and solvent operations require less time and cost to switch to new chemicals and do not require chemical supply after manufacture.

It will be possible to eliminate HCFC transitional substances in some applications faster than others. Long advance notice of phaseout regulations would avoid the sale of equipment dependent on transitional substances within 15 or 20 years of the final phaseout, and so avoid the costs of retrofit or earlier retirement of that equipment. Based on the impressive record of technical progress to date, and on the intensity of industry efforts to find final alternatives to ozone depleting substances, it may be possible for users to phase out these chemicals relatively quickly. Future assessments should evaluate the rate of technical progress and prospects for eliminating transitional substances.

3.6 POSSIBLE CONTROLS ON TRANSITIONAL SUBSTANCES

The form of control of HCFCs is likely to have implications for the speed of the investment necessary to facilitate the adoption of HCFCs where this is considered appropriate.

- **Early Decisions** - Uncertainty over the environmental acceptability of transitional substances and possible regulation may be inhibiting investment, in the production of transitional substances and in the development of technologies needed for their use. Even the development of technologies which do not use either controlled or transitional substances can be inhibited because the prospect of technology using transitional substances discourages investment in technology that would only be profitable if transitional substances were not acceptable. The earlier decisions are made on the form and stringency of controls, the sooner industry can decide on the necessary investments.

- **Stability** - If controls are put in place with a high degree of confidence that they will not be subject to frequent unnecessary change, this will encourage the necessary investment.

- **A World-Wide Solution** - Elimination of controlled substances may be more rapid and economically efficient if the same form of control applies to all economies. Investment in development of the whole range of alternative substances and technologies will be more attractive if the markets to which they apply are large, rather than fragmented.

- **Rapid Phase-out of Controlled Substances** - The concept of transitional substances is designed to enable the rapid elimination of controlled substances. A one year delay in phasing out a CFC in a particular application could have a similar environmental impact to 20 years of use of an HCFC with one twentieth the ODP.

- **A Return on Investment** - Controls which too stringently limit transitional substances may inhibit investment which is considered necessary to manufacture HCFCs to replace CFCs, because there may be insufficient time to achieve a return on the capital invested.

- **Market Mechanisms or Command and Control** - A system of quantitative controls on production and/or consumption is already in place for controlled substances. Similar controls for transitional substances may be relatively economically efficient, but may also benefit from limitations on use, to those applications set out in Table 3.2.

3.7 TRANSITIONAL SUBSTANCES IN DEVELOPING COUNTRIES

The Montreal Protocol is at present a one stage process, calling for the elimination of controlled substances by certain dates. Article 5 countries may implement the controls on production and consumption up to ten years later. They will also benefit from expeditious transfer of the best available environmentally safe technologies, under fair and most favourable conditions, and have the incremental costs of their compliance with the Protocol met by the Multilateral Fund.

Should transitional substances be subject to controls, the Protocol will become a two stage process. The first will be replacing controlled substances with a variety of transitional and other substances and alternative technologies, while the second will be moving away from the use of transitional substances. If transitional substances are regulated, the Parties will need to consider whether, and if so how, this will apply to developing countries. In particular, a relatively short period between requirements for developing countries to move into and then out of transitional substances may result in the premature retirement of capital, with possible implications for the Multilateral Fund.

CHAPTER FOUR:
ACCEPTABILITY & COMMERCIALISATION OF SUBSTITUTES

4.1 STATUS OF COMMERCIALISATION OF CHEMICAL SUBSTITUTES

4.1.1 Availability of Non-fluorocarbon Chemical Replacements

Application of the technical solutions for the elimination of controlled substances described in this report clearly depends on the availability of adequate supplies. Many chemical replacements, such as hydrocarbons for aerosols, industrial refrigeration or certain types of foam, non-fluorocarbon solvents, and carbon dioxide for fire-fighting, are all commercially available in large quantities. In general, the additional demand for them is small, compared with the size of their overall markets. Moreover, the technology for their production is mature, and is often available throughout the developed and the developing world. Such products and the technology for their production are generally available (The technology for <u>using</u> these substances as replacements for controlled substances is a different matter, and is addressed elsewhere in this report). Nevertheless there can be temporary or localised shortages. One particular example is the availability of deodorised LPG, needed for aerosol production. Where deodorised hydrocarbons are not locally available, deodorising equipment may need to be installed at the aerosol production plant.

4.1.3 Availability of HCFC-22, HCFC-142b and HFC-152a

Among the HCFC and HFC alternatives, only HCFC-22, HCFC-142b and HFC-152a are currently available, and can be made available in larger quantities at relatively short notice. HCFC-22 is already available in large quantities and is produced in several developing countries. Production technology for these chemicals is fully mature, and is ready for transfer to developing countries, where demand exists. Although HCFC-22 and HCFC-142b are important substitutes for CFCs in several areas, there will be only limited need for any additional production capacity. This is particularly so in view of the existence of "swing" plants - in both developed and developing countries - which can be readily converted away from production of CFC-11 and CFC-12 towards HCFC-22 production.

4.1.4 Availability of HFC-134a

Some production capacity for HFC-134a is already in existence and more is under construction or planned. This major investment by the chemical industry reflects the early identification of this chemical as a replacement for CFC-12 in domestic refrigeration and automotive air conditioning, which provide a substantial market, even at the expected higher costs of production and higher price. The assured availability of the chemical in turn allows research and development into its application in smaller volume applications, where low demand would not necessarily justify production of a new chemical. Thus in several areas, there is a bias towards investigating the possible use of HFC-134a rather than other new chemicals, because HFC-134a will be available, and the work will not be wasted. At the same time, the similarity in technical performance between CFC-12 and HFC-134a itself provides a disincentive to undertake further work on potential new replacements for CFC-12, unless they appear to give substantial improvements, for instance in energy efficiency.

4.1.5 Availability of New Products

There are other substitutes which could also be produced in large quantities, for instance HFC-32, HCFC-123, HFC-125 and HCFC-141b. There are substantial markets, particularly in foam blowing, air conditioning and refrigeration, for one or more of these chemicals. If production were to take place, then several other uses, such as solvent cleaning, sterilisation and fire-fighting, could confidently be explored, resulting in the early elimination of CFCs in a wide range of applications. However, the availability of some of these technically suitable substances is uncertain, due to concern over their acceptability in terms of worker and consumer safety, and the environment. There are a few other products, such as HCFC-124 and HCFC-225, which could be produced either as speciality chemicals or as by-products of other chemicals, in smaller volumes for more limited uses.

4.1.6 Halon Replacements

For clarity, two terms must be defined. A "replacement" agent is a halon-type, gaseous or volatile, clean fire extinguishant, explosion suppression agent and/or inertion agent. An "alternative" agent is a not in kind, non halon like agent (eg carbon dioxide, water, foam and dry powder extinguishants). Halon replacement chemicals are not at the same advanced stage of development as many CFC replacements for refrigeration, solvents and other applications. Furthermore, considerable work must be done on systems engineering, approval testing must be performed and standards developed after acceptable replacements are identified.

The need for halon replacements to serve vital roles in safety and fire/explosion protection in many applications will continue despite the development of new non-halon alternatives. The halon bank is expected to serve a portion of these needs for a period of time, however replacements are needed to ensure wise allocation of banked material with minimal environmental impact and to allow eventual orderly phaseout of halon use without unacceptable threats to safety. Replacements are also needed to avoid any future production requirement for "essential" use and of course will become increasingly vital as the bank is exhausted.

4.2 TOXICOLOGY OF SUBSTITUTES

4.2.1 The Need to Reduce Uncertainty

The risk posed by the production and use of any chemical is a combination of its toxicity and the exposure levels likely to be encountered by workers, consumers and the environment. Manufacturers will invest in the production of a chemical only when they are confident that exposure can be kept within acceptable limits.

4.2.2 The Process of Toxicity Investigation

The toxicology of newly commercialised chemicals is usually investigated by those who first intend to manufacture them and place them on the market. Several studies are undertaken to provide information on the possible effects of the chemical. From the results, exposure limits and other precautions in the use of the chemical are recommended. The process takes place under the scrutiny of regulatory agencies, who may require further testing or may establish their own exposure limits or specific use restrictions. Regulatory agencies may not approve the use of some chemicals depending on the results of standardised studies.

4.2.3 Programme for Alternative Fluorocarbon Toxicity Testing

Toxicity testing is very time consuming and expensive. It is reliant on the availability of scarce qualified personnel, laboratory facilities, test animals and quantities of the substance for testing. In 1987 the world's major CFC producers created a cooperative research programme to develop the toxicology data for possible substitute fluorocarbons. The member companies of the Programme for Alternative Fluorocarbon Toxicity Testing (PAFT) are: Akzo Chemicals BV (Netherlands); Allied-Signal Inc. (USA); Asahi Glass Co., Ltd. (Japan); Atochem (France); Atochem North America (USA); Central Glass Co., Ltd. (Japan); Daikin Industries Ltd. (Japan); E. I. DuPont de Nemours & Co., Inc. (USA); Hoechst AG (Germany); ICI Chemicals & Polymers, Ltd. (UK); Montefluos S.p.A. (Italy); Rhone Poulenc Chemicals (UK); Showa Denko KK (Japan); Solvay & Cie (Belgium/Germany); and Ulsan Chemicals Ltd. (Rep of Korea).

4.2.4 The Work of PAFT

PAFT's purpose is to obtain toxicological information, integrating the results of any previous work already done, to perform a careful hazard assessment including elements of acute, sub-chronic, developmental, reproductive and chronic toxicity/carcinogenicity/genotoxicity studies, and environment studies. Thus PAFT identifies which studies have been done and which are still needed, contracts out the work itself (which may be to the laboratories of its member companies) and makes the results available to all of its member companies.

This represents a considerable saving in time, cost and other scarce resources, compared with a situation where each company, hoping to be first on the market with a particular chemical, has to do all of the work separately. Different PAFT sub-programmes are investigating the toxicity of HFC-134a, HCFC-123, HCFC-141b, HCFC-124, HFC-125, and HCFCs -225ca and -225cb, at a total cost approaching US$30 million.

4.2.5 Interim Results for HFC-134a, HCFC-123 and HCFC-141b

Testing of HFC-134a, HCFC-123 and HCFC-141b is due for completion in 1992/3. Of these chemicals, HCFC-141b and particularly HFC-134a appear to be acceptable to use in general industrial applications at relatively high exposure levels, while relatively stringent exposure limits are recommended for HCFC-123. In particular, dissection of the male rats exposed to HCFC-123 over a two year period shows an excess of benign testicular and pancreatic tumours over those present in the control group. These results are however not conclusive. Although there is an excess of tumours in the males there is a substantial increase in survival rates, as against those in the control group. Results from dissection of the females are not available at the time of writing.

4.2.6 Further Preliminary Indications

Of the remaining chemicals under investigation by PAFT, preliminary results on HCFC-124 are encouraging. Progress on HFC-125 is hampered by a shortage of test material, and it is too early to predict the outcomes. Preliminary results from testing HCFC-225 are inconclusive.

4.2.7 The Prospect for Further New Substitutes

Depending on the interim results, the course of toxicity testing takes several years and costs between US$ 3 and 5 million per substance. As substitution for the majority of uses for the controlled substances is achieved, the incentive for testing of further substances will be reduced. It is unlikely that any testing programmes not already started can be completed by 1997 in time for a direct substitution from CFCs to new substances. Under the guidelines of the London Resolution on transitional substances, HCFCs are only to be used where they, or the controlled substances, have been used in the past, and then only for a transitional period. Markets for any new HCFCs, other than HCFCs -22, -123, -124, -141b, -142b, and -225 ca&cb, could therefore be restricted to the temporary replacement of one or more of the higher ODP HCFCs. So it is unlikely that any more HCFCs will be developed. There may well, however, be a role for further HFCs in the eventual replacement of HCFCs. For example, at the time of writing, discussions are underway within PAFT over a programme to study the toxicology of HFC-32.

4.3 ENVIRONMENTAL ACCEPTABILITY OF SUBSTITUTES - OZONE DEPLETION

A major source of uncertainty over the future availability of HCFCs is the degree to which the damage they do to the ozone layer is considered acceptable. The Science Assessment Panel has re-examined the ODPs of the different HCFCs. Meanwhile, the London Resolution on transitional substances, agreed by governments at the Second Meeting of the Protocol Parties in 1990, sets out voluntary guidelines for the responsible use of HCFCs, as outlined in Chapter 3.

4.4 ENVIRONMENTAL ACCEPTABILITY OF SUBSTITUTES - GLOBAL WARMING

4.4.1 Direct and Indirect Global Warming Impacts

While the Science Assessment Panel is considering the Global Warming Potentials of different chemicals, the overall impact of such chemicals depends on two further technical variables. The first is the amount of each substance that is likely to be emitted. The second is the amount of energy consumption implied by the use of different substances and technologies.

4.4.2 The Time Horizon of GWP Comparisons

Determination of Global Warming Potentials is a fairly new area of investigation and there are great difficulties associated with making quantitative comparisons. One of the more complex areas is the time horizon over which comparisons are to be made. For instance, over a 500 year time horizon, a tonne of HCFC-22 has the same impact on global warming as about 500 tonnes of CO_2. Over a 100 year time horizon, HCFC-22 is, tonne for tonne, about 1500 times as potent a greenhouse gas as CO_2. It is necessary to consider calculations for both time horizons. Although use of the longer time horizon incorporate the maximum total warming potential of CO_2 as well as other substances, some policy makers may prefer to take their decisions based on the effects over a shorter period. As the time horizon is extended, uncertainties over the assumptions made increase.

4.4.3 Improvements in Energy Efficiency

There are further difficulties in making comparisons between the direct impacts of chemicals which replace controlled substances on global warming, and the indirect impacts of implied CO_2 emission. The pace of technological change in all areas where controlled or transitional substances are used is extraordinarily rapid. The need to eliminate ozone depleting substances has provoked considerable activity in the search for alternatives, and this activity continues. Much of this concerns the optimisation of energy efficiency in the application of different technologies. As progress is made, this alters the comparison between direct and indirect global warming impacts. It may be that the trend towards greater energy efficiency will lead to the relative importance of the indirect impacts becoming less over time, unless such progress is matched by efforts to reduce the amount of replacement chemicals used or emitted.

4.4.4 Global Warming and the Concept of Transitional Substances

The justification for using transitional substances in some applications is that they can be brought to the market more quickly than non ozone depleting technologies. To the extent that the technology for their application is better developed, it may be that it is closer to the optimum energy efficiency than the alternatives. If so then comparisons based on current technology will overestimate energy consumption, and therefore the global warming implications, for future use of the less developed non ozone depleting technologies. Nevertheless, use of the transitional substances is indeed closer to the market, and their direct global warming impacts are substantially less than those of the CFCs. Even if, therefore, the comparison between use of these substances and the use of alternative technologies were to shift in favour of the latter over time, the justification for using transitional substances in the interim exists in terms of global warming just as it does in terms of ozone depletion.

4.4.5 The AFEAS/U.S.DOE Study of Total Equivalent Warming Impacts

A study on "Energy and Global Warming Impacts of CFC Alternative Technologies" has recently been carried out for AFEAS (Alternative Fluorocarbons Environmental Acceptability Study) and the US Department of Energy. The primary objective of the study is to develop representative indications of the relative energy use, associated CO_2 emissions, and total equivalent warming impact (TEWI) of viable options to replace CFCs in their major energy-related application areas. The areas studied are refrigeration and air conditioning, insulating foams and cleaning processes. The preliminary results of the study are taken into account in the Options Reports and their executive summaries, which appear later in this report, for the different sectors covered. The Executive Summary of the Refrigeration and Air Conditioning section of the AFEAS/U.S.DOE study is attached as an appendix to the Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee.

4.4.5.1 - Improvements in TEWI from eliminating CFCs - The AFEAS/U.S.DOE study introduces the concept of Total Equivalent Warming Impact (TEWI) as the sum of the direct and indirect effects for each technology considered. The results are presented in terms of reductions from the base-line represented by use of the CFC-based technology which is being replaced. A number of general conclusions for each of the major applications areas were made. Replacement of CFCs by HCFCs or HFCs showed reductions in the TEWI of between 10% and 98%, based on previously estimated GWPs. The reductions were greatest in applications with high chemical emissions, such as solvent cleaning, automotive air conditioning and commercial building roof insulation.

4.4.5.2 Relative Importance of Direct and Indirect Impacts - Where HCFC and HFC technologies are used, there is wide variation between the relative importance of the direct (chemical emission) and indirect (energy use) contributions to the TEWI, ranging from 2-3% direct impact for domestic refrigeration equipment to 98% direct impact for batch cleaning.

4.4.5.3 - Not-In-Kind Technologies - Some "not-in-kind" technologies, such as no-clean alternatives to solvents, showed substantial TEWI reductions. Most not-in-kind insulation options revealed greater energy use for equal insulation thickness than the HCFC or HFC technologies. However, it was considered that future developments in some not-in-kind technologies showed promise for future energy savings.

4.4.5.4 - The Scope for Further TEWI Reductions - Future opportunities for reductions in TEWI were addressed. For those applications where the TEWI was dominated by the indirect energy-use impacts, such as household refrigeration, commercial chillers and insulation applications, further TEWI reductions were most likely to be achieved through selection of the most energy efficient options and by further reductions in emissions. Where the direct impacts dominate, such as in solvent cleaning, automotive air conditioning and retail refrigeration, future savings are more likely to come from improved containment techniques or the adoption of not-in-kind technologies. Cleaning industries were identified as being generally on course for making early reductions in TEWI based on such measures.

4.4.6 The Need for Future Work

The Technology and Economic Assessment Panel regards the methodology adopted for the AFEAS/U.S.DOE study as an extremely useful tool, particularly in making comparisons between the relative global warming impacts of transitional and non ozone depleting technologies, and in identifying where future TEWI improvements can be made. The comparison between the baseline CFC-based technologies and a range of alternatives is particularly helpful in establishing the methodology. Should similar work be undertaken in future, various questions will need more consideration, including the time-horizon over which comparisons should be made, the full range and prospects for the development of not-in-kind technologies, and the need to compare the most energy-efficient means of applying different technologies.

4.4.7 Global Warming and Ozone Depletion

Finally, assessments of such work need to bear in mind that HCFCs, but not HFCs, are transitional substances under the Protocol because of their ability to deplete stratospheric ozone. Analysis of comparative Total Equivalent Warming Impacts is useful within the climate change debate itself. But it cannot determine whether it is environmentally better to tolerate the ozone depletion effect of an HCFC, or to tolerate the greater TEWI of a non ozone depleting alternative.

CHAPTER FIVE:
INFORMATION REQUIREMENTS FOR TECHNOLOGY TRANSFER

5.1 INTRODUCTION

It is important that information be efficiently generated, managed and disseminated to inform, encourage and coordinate the efforts of those actively engaged in the process of substituting for ozone depleting substances. A number of government and private industry information programmes have been initiated, but the existing sources of information are not yet adequate. Providing information exchange should be a top priority for the Protocol.

The types of information needed include environmental health and safety information; and data on technical properties, systems performance, conservation, recycling, service, regulation and standards. The market for this information includes government agencies, companies, educational establishments and the general public.

5.2 INFORMATION EXCHANGE UNDER THE VIENNA CONVENTION

Under the Vienna Convention, its Parties have agreed:

> to cooperate by means of systematic observations, research and information exchange in order to better understand and assess the effects of human activities on the ozone layer, and the effects on human health and the environment from modification of the ozone layer;
>
> to facilitate and encourage the exchange of scientific, technical, socio-economic, commercial and legal information (as elaborated in Annex II of the Convention);
>
> to cooperate in promoting the development and transfer of technology and knowledge; and
>
> to transmit information on the measures adopted by them in implementation of the Convention and its Protocols.

5.3 INFORMATION EXCHANGE UNDER THE MONTREAL PROTOCOL

Under the Montreal Protocol, its Parties, already Party to the Vienna Convention, have further committed themselves to report production, import and export data for controlled and transitional substances to the Secretariat. They have also agreed to exchange technological information and to promote public awareness of ozone depleting substances.

Under Article 7 of the amended Protocol, each Party must report to the Secretariat:

(1) statistical data on its production, imports and exports of controlled substances in Annex A for the year 1986, or the best possible estimates;

(2) annual data on production, imports and exports of each of the controlled substances in Annex B and each of the transitional substances in Group I of Annex C for the year 1989, or the best possible estimates; and,

(3) concerning all the listed substances, annual production figures and, separately, the amounts used for feedstock, the amounts destroyed by technologies approved by the Parties, and imports and exports to Parties and non-Parties respectively.

Under Article 9 of the Montreal Protocol, Parties must cooperate in promoting public awareness of ozone depleting substances and promoting research, development and exchange of information on:

1. best technologies for improving the containment, recovery, recycling or destruction of controlled and transitional substances, or otherwise reducing their emissions;

2. possible alternatives to controlled substances, to products containing such substances, and to products manufactured with them; and

3. costs and benefits of relevant control strategies.

Under Article 12(c) of the Montreal Protocol, the Secretariat is required to prepare and distribute regular reports to the Parties based on the information received pursuant to both Articles 7 and 9. In its most recent report, the Secretariat noted that difficulties in reporting the required data stemmed from the lack of records on individual chemicals or the lack of expertise, logistical support or adequate financing to fulfil data reporting obligations. The Secretariat is working to have controlled substances distinguished under the Customs Cooperation Council in its revision of the Harmonised Commodity System. It also recommends that specific country studies report difficulties of data reporting to inform necessary remedies. (See UNEP/OzL.Pro.3/5, 23 May 1991.)

At the Third Meeting of the Parties, a more comprehensive data reporting format was adopted, to reflect the increased data requirements under the revised Protocol. It was recognised that the reporting of data by the Parties was, in many cases, late and incomplete.

5.4 DISSEMINATION MECHANISMS

There are already a large number of mechanisms and organisations that disseminate information relating to alternative technologies. Information exchange will occur both voluntarily and as a matter of obligation of the Parties (see Box 5-1). Private information exchange will take place as suppliers of alternatives and substitutes provide information to their client firms, as companies ready themselves for non ozone depleting production processes, as parent corporations revise their policies, and as industry and trade groups alter their product "specifications".

The Parties may fulfil their information exchange obligations individually, jointly, or through competent international bodies. The Parties have established the Interim Multilateral Ozone Fund (IMOF) to finance, inter alia, an information clearing-house, to assist in the preparation of country specific studies to identify Article 5 countries' specific needs, to facilitate technical co-operation to meet these needs and to distribute information and relevant materials, and hold workshops, training sessions, and other related activities for the benefit of Parties that are developing nations (Article 10).

5.4.1 The Clearing-House Function of the Montreal Protocol

UNEP has established its Industry and Environment Office in Paris, France, as the clearing-house of the Multilateral Fund, where Parties may access scientific and technical literature, up-to-date technical innovations/options, replicable best technology, standard project applications, lists of international experts, inventories of domestic laws and government approval processes, and details of relevant training opportunities. Individual consultancies are essential for modifying existing production processes and to respond flexibly to the specific problems of end-users.

5.4.2 The Economic and Technical Options Committees

The Economic and Technical Options Committees make a major contribution to information exchange and technology transfer. The process of assembling their Reports brings together substantial numbers of interested parties from industry, industrial associations, national governments, international organisations, environmental organisations and academia. It is a process of information generation and exchange which benefits both those taking part and those who will read the Reports. These wider benefits are important for the phaseout of controlled substances.

Box 5-1

VARIOUS INFORMATION SOURCES

PROTOCOL OBLIGATIONS

Type of Information	Information Location
Consumption, Production, Import and Export Data	UNEP in Nairobi
Technological Information Country Studies Expert Lists Industry Research Results Training Opportunities	UNEP/IEO in Paris Parties to the Protocol

PRIVATE SECTOR ACTIVITIES

Organisation	Activity
Suppliers	Product Information to Customers & Others
Manufacturers	Change Production Lines
Trade Associations	Alter Specifications & Share Information
Parent Companies	Revise Manufacturing and Procurement policies

NGO ACTIVITIES

Environmental, Industrial, Scientific, Technical and Professional NGOs.	Publications, Conferences, Partnerships, Training Courses

NATIONAL GOVERNMENT ACTIVITIES

Sponsor Domestic Research and Information Programmes
Promulgate Relevant Laws and Regulations
Regulatory Framework for Monitoring and Enforcement
Prepare ODS Phaseout Projects
Sponsor Projects Bilaterally
Report Required Data

5.4.3 Industry Collaborative Mechanisms to Meet Common Information Needs of Parties

Scientific questions regarding the relative merits of proposed chemical substitutes range from the safety (toxicity and flammability) of candidate alternatives to their effects on global environmental conditions (including degradation products, effects on stratospheric and tropospheric ozone and contribution to global warming). Two research consortia study the environmental, health and safety characteristics of proposed CFC alternatives.

In 1987 the world's major CFC producers created the Programme for Alternative Fluorocarbon Toxicity Testing (PAFT)[a] to develop the toxicology data for candidate substitute fluorocarbons, as outlined in greater detail in Chapter 4. Research is conducted at 12 laboratories in Europe, Japan and the United States and is divided into four sequenced sub-programmes.

PAFT's goal is to integrate past and present toxicological information to perform a careful hazard assessment including acute, sub-chronic, developmental and chronic toxicity/ carcinogenicity/ genotoxicity studies, and environmental studies.

A second cooperative program, Alternative Fluorocarbons Environmental Acceptability Study (AFEAS)[b], was initiated in December 1988 by 12 chemical producers. Its goal is to assess the potential environmental impacts of CFC alternative fluorocarbons (HCFCs and HFCs) produced or under development by the companies funding AFEAS. Phase 1 results were presented at the UNEP meeting in Nairobi in August 1989 and were incorporated as an appendix to the Scientific Assessment of Stratospheric Ozone (1989). Based on the first AFEAS report, scientific advisors to UNEP concluded that industry is justified in proceeding rapidly toward commercialization of substitute chemicals, and endorsed an accelerated research programme to ensure the environmental acceptability of all proposed HCFCs and HFCs.

The second phase of research sponsored by AFEAS began on January 1, 1990 with a research programme of three years and a total funding of 6 million US dollars.

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[a] Chairmanship of PAFT rotates among the different member companies. Contact can be made through any member.

[b] SPA-AFEAS, INC. can be contacted at The West Tower - Suite 400, 1333 H Street NW, Washington, CC 20005, USA.

5.5 SECTOR PROFILES

The Technical Options Committees recognise that information is essential for the introduction of new technologies. The following issues were identified as the most important in the Technical Committee Reports:

5.5.1 Refrigeration, Air-conditioning and Heat Pumps

A variety of data is required to evaluate a potential alternative refrigerant. The thermophysical (i.e., thermodynamic and transport) properties of a fluid determine its potential energy efficiency and heating or cooling capacity in equipment and are essential for equipment design. Properties related to health and safety (toxicity and flammability) can determine whether a fluid is suitable for a particular application. Data on materials compatibility are required to design reliable equipment. The ozone depletion potential, greenhouse warming potential, and atmospheric lifetime will determine whether a fluid is considered as an environmentally acceptable alternative to CFCs.

There are already a large number of mechanisms and organizations available to disseminate information relating to alternative refrigerants and refrigeration technologies. Organisations that are expected to play prominent roles include: UNEP, the International Institute of Refrigeration (IIR), the International Energy Agency (IEA), the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE), and various other international and national associations.

In several countries, support from government agencies and others is being provided to coordinate and leverage industry's own resources in order to phase out CFCs in a timely manner. Notable examples of these efforts include the new generation refrigeration research in Japan, the joint research program on the reduction of CFC emissions in refrigeration and air conditioning in Germany, the IEA research project on thermophysical properties, and the materials compatibility and lubricant research programme in the U.S.

There are many excellent opportunities for future cooperation and coordination among international parties. Examples of opportunities for additional cooperative research include environmental and health effects, technology development and deployment, standardization, and training. UNEP and the International Institute of Refrigeration (IIR, both located in Paris) are developing an International DataBase dedicated to the refrigeration, air-conditioning and heat pump field (e.g. regulations, scientific, technological and commercial data, industrial property information). Effective international research efforts are needed in these areas to help ease the transition from CFCs to the transitional chemicals and to non ozone depleting alternatives.

5.5.2 Solvents, Coatings and Adhesives

Technology transfer should present few difficulties in the electronics industry. A wealth of information has been published. However, language may be a barrier in nations which do not have a tradition of English as a first or second language.

An example of a collaborative approach to the common information needs of the Parties may be found within the solvents industry. It has created an organization called ICOLP (Industry Cooperative for Ozone Layer Protection) that produces a data base called OZONET. OZONET is an on-line, computerized database designed to provide users of CFC compounds with information on substitute processes, materials and technologies relevant to solvents. It is now being linked to other related databases, such as those managed by UNEP in Paris and may provide a model for sharing information on other uses of ozone depleting substances. The database resides in the General Electric Information Services network and is accessible from more than 750 cities in 35 countries worldwide. It can be accessed from more than 90% of the world's business telephones (OZONET Fact Sheet) and user fees have been approved as a viable expenditure under the Multilateral Fund. Data from OZONET will be included in the ICPIC Ozone augmentation being carried out by the UNEP Industry and Education Office and the US EPA.

5.5.3 Flexible and Rigid Foam

The speed and effectiveness of information and technology dissemination depends upon a number of factors such as:

- an existing base of skilled labour, technicians and technical courses
- the presence of appropriate technical fora such as industry associations;
- the level of support and commitment from the government;
- the presence of international companies through subsidiaries, representatives, or licensees;
- the level of cooperation between research institutions - locally or abroad - and the industries.

There is no single recipe for an effective system designed to disseminate information. Specific country designs will largely depend upon a combination of the aforementioned factors.

Regardless of the degree to which a current information and technology dissemination network is developed, governments - through their economic and scientific branches - must play a leading role in organising national resources. It is only through organised action that the transition process will be cost effective.

5.5.4 Aerosols, Sterilants and Miscellaneous Uses

The technology for aerosols is relatively mature. As a result, information and technology transfer are affected by similar variables to those mentioned above. With regard to sterilisation, the substitution process is not as advanced as it is for aerosols. Technologies differ from country to country according to local regulations and codes of practice e.g. formaldehyde is accepted as a steriliser in some countries while it is not used in others. There are also wide differences between end-users, which can be either industrial facilities or hospitals. Therefore, substitution decisions will be affected by the information and technology transfer mechanisms and their interaction with the end-users.

Miscellaneous uses, with their niche applications, also require that the proper information is passed to the regulatory bodies to facilitate the identification of potential problem areas. This process is not yet completed.

5.5.5 Halons

Fire protection organisations, through educational programmes, changes in technical standards and various other means, have played a major role in making it known that use of halons must be drastically reduced and, wherever possible, alternative fire protection measures employed.

5.6 THE TYPES OF INFORMATION NEEDED

The successful elimination of ozone depleting substances depends on the widespread dissemination of information and technology. This is a much wider question than access for producers and users of ozone depleting substances to patents for producing or using replacement chemicals. The company concerned with the adoption of new technology needs to know:

(a) that replacement technology exists;

(b) from whom technology and knowhow is available,

(c) whether patents apply or whether the technology is in the public domain,

(d) how much the technology will cost; and

(f) what sources of funding are available.

This report cannot provide all of this information - each case is different. Companies vary in their size, ownership, sales to developed country markets, profitability and access to investment capital, and in the amount of international competition they face. They are located in countries which vary in the degree of government control over the economy, and the extent to which government takes an active part in environmental protection. Some countries have access to the Multilateral Fund, others have access to the Global Environmental Facility and some have neither. The technologies themselves are different in the extent of patent protection, the need for specialised knowledge, the scale of investment needed, the future running costs and the extent and pace of anticipated further development. Getting the right information and technology to each company is a major challenge for the Protocol Parties, for the Implementing Agencies of the Multilateral Fund, for individual governments and for the companies themselves.

5.7 SOURCES OF INFORMATION

Developing country companies which are subsidiaries of multinational companies will gain access to information and technology through their corporate information networks. In many cases, multinational companies are not expected to apply to the Multilateral Fund for assistance in converting away from ozone depleting technologies. Those developing country companies which are active in developed country markets will also gain access to some information, through their operation in such markets.

Information on alternatives and substitutes to ozone depleting substances is contained in this report and, more particularly, in the reports of the different Technical Options Committees. Widespread and timely dissemination of these reports is therefore of great value. Also the members of these Committees are useful contacts for those seeking technical information.

5.8 CONCLUSIONS FOR THE MULTILATERAL FUND

5.8.1 The Economic Options Report recommends standardisation of the paperwork required to secure technical assistance, so as to achieve fast turn-around on information requests and early access to financial assistance from the IMOF. To this end, a systematic, routine, "off-the-shelf" application process with expeditious agency treatment is recommended. This process would be facilitated by making the following information packets available to Article 5 countries.

(i) **An initial information Packet** that includes the Montreal Protocol Handbook, a checklist for evaluation of costs and opportunities of being a Party to the Protocol, an outline of the data reporting and customs requirements, and a description of "off-the-shelf application procedures" for assistance from the IMOF.

(ii) **A Computer Information Networking Packet** that describes how to link up to existing computerised databases (ICPIC, OZONET, etc).

(iii) **An Initial Country Profile Packet** that facilitates the routine and comparable reporting of the local controlled substance industry/consumer configuration, relevant trade groups, domestic policies and government agencies.

(iv) **An Application for Assistance Packet** that simplifies application, screening, selection and monitoring the use of IMOF financial assistance. This Packet would build on the Initial Country Profile Packet.

(v) **A Model Ozone Office Packet** that describes typical personnel and equipment required to set up an effective national ozone office to coordinate information and administrative efforts regarding ozone layer protection. The costs of establishing national ozone offices would be financed under the Parties' commitment to information exchange, technology transfer, and infrastructural development required for Article 5 countries to meet their obligations under the Protocol.

5.8.2 The barriers to effective technology transfer remain a substantial concern. However, the IMOF is designed to tackle these problems. The information clearing-house services being undertaken by the UNEP Paris Office, the technical assistance role being undertaken by the UNDP and the investment project financing role being undertaken by the World Bank have been put in place to make effective technology transfer a reality.

The mechanisms are in place. It remains to ensure that they work properly. Inter alia, that means making sure that operational plans are well-founded, that operating procedures are well-defined and widely agreed, and that the requisite resources are made available to the implementing agencies.

CHAPTER SIX:
DEVELOPING COUNTRY CONCERNS

6.1 INTRODUCTION

Many developing countries have become Parties to the Montreal Protocol. In recognition of this support and of the cost of complying with the Protocol, the Parties addressed in Article 5 the special circumstances of developing countries. Those developing countries with an annual per capita consumption of CFCs and halons below 0.3 kg. qualify for the special provisions of Article 5(1). Table 6.1 identifies countries currently eligible for assistance under the Interim Multilateral Fund.

TABLE 6.1
ARTICLE 5 MONTREAL PROTOCOL PARTIES

Argentina

Bangladesh

Brazil

Burkina Faso

Cameroon

Chile

China

Costa Rica

Ecuador

Egypt

Fiji

Gambia

Ghana

Guatamala

Iran

Jordan

Kenya

Libya

Malawi

Malaysia

Maldives

Mexico

Nigeria

Panama

Philippines

Sri Lanka

Syrian Arab Republic

Thailand

Togo

Trinidad and Tobago

Tunisia

Turkey

Uganda

Uruguay

Venezuela

Yugoslavia

Zambia

The special provisions for developing countries qualifying under Article 5 are:

- A ten year grace period with respect to the phaseout schedule;
- Authorization to expand consumption of ODS, but only to "meet basic domestic needs" and only if per capita consumption does not exceed 0.3 kg./year;
- Access to "the best available environmentally safe substitutes and related technologies";
- Financing by the Interim Multilateral Ozone Fund.

6.2 PRODUCTION BY DEVELOPING COUNTRIES

Controlled substances are produced in Argentina, Brazil, People's Republic of China, India, Mexico and Venezuela (see Table 6.2). Except in India and China, production occurs through directly owned subsidiaries of American, European, and Japanese chemical firms.

In the short term, developing countries can continue imports from developed countries and increase production within existing plant capacity to capture an increasing share of the developing country market. By the time developed countries phase out their CFC use and halt production, developing countries can be self-sufficient in CFCs because their aerosol propellants will have been eliminated and foam and solvent uses reduced. As CFC use in developing countries continues to decline, facilities in developing countries can switch CFC-11 and CFC-12 production to HCFC-22 where plant design allows - older facilities will in any case be nearing the end of their economic life. A CFC facility converted to HCFC-22 production has half the annual output, which is an advantage because HCFC-22 will replace only a portion of CFC use and only as a transitional substance. HCFC-22 facilities can be retired after their useful economic lifetime possibly using the final HCFC-22 output as a feedstock for chemical and plastic production.

Table 6.2
CURRENT PRODUCTION AND CONSUMPTION OF CONTROLLED SUBSTANCES IN SELECTED DEVELOPING COUNTRIES[a] (Amounts in Metric Tonnes)

	Production/ Capacity	Consumption	Source[b]
Argentina	3,560/10,000	3,680	Du Pont
Brazil	20,500/37,000	25,600	USEPA
Chile	nil	1,150	Du Pont
Ecuador	nil	725	USEPA/ World Bank
Egypt	nil	2,375	USEPA
Guatemala	nil	200	Du Pont
India	6,000/26,100[c]	10,000	Overseas Development Administration (ODA)/U.K.
Jordan	nil	300	UNEP
Kenya	nil	365	UNEP
Mexico	9,500/21,000	17,350	SEDUE/USEPA
Morocco	nil	500	World Bank
People's Republic of China	25,000/47,500[d]	32,500	UNDP
Thailand	nil	5,000	UNEP/SIDA
Trinidad & Tobago	nil	310	Du Pont
Tunisia	nil	750	UNEP
Turkey	nil	4,325	World Bank
Venezuela	4,030/10,000	5,030	World Bank
Yugoslavia	nil	4,080	Du Pont
Estimated Other Developing Countries	nil	4,080	Du Pont
Total Developing Countries	68,590/151,000	193,000	

[a] Data on controlled substances include CFCs, halons, and 1,1,1,-trichloroethane.

[b] Some data was obtained from completed country case studies and country programs underway. Other data have been supplied by the E.I. Du Pont de Nemours Company to ICF Incorporated.

[c] Average of the data received.

[d] Does not include 1,1,1-trichloroethane. Data on 1,1,1-trichloroethane production is not available.

6.3 CONSUMPTION BY END USE

The portion of use of controlled substances for refrigeration foam, aerosols and solvents varies from country to country. Demand for controlled substances comes from two main sources: manufacturers of products made with or containing these compounds (e.g., refrigeration equipment, foam products, electronic equipment, and aerosols) and users of bulk-controlled substances for after-market activities (e.g., recharge of refrigeration equipment). The distribution of CFC use in Brazil, China, Ecuador, Egypt, Kenya, and Mexico is shown in Table 6.3.

Table 6.3
Distribution of CFC Use by Country End Use
Percent

	Refrigerants	Foam	Aerosol Products	Solvents	Others
Brazil	47%	40%	1%	7%	5%
China	17%	62%	17%	4%	--
Ecuador	15%	9%	73%	--	3%
Egypt	39%	36%	25%	<1%	--
Kenya	25%	13%	62%	--	--
Mexico	59%	20%	12%	5%	4%
Average	42%	23%	30%	--	--
Range	25-66%	9-40%	1-73%	<1-7%	3-6%

source: Country Studies (figures apply to recent but different years).

6.4 CASE STUDIES AND COUNTRY PROGRAMMES

At least 15 country studies have been completed or are under way (Table 6.4). These studies identify many examples of innovation and progress by Article 5 countries.

Brazil, Columbia, Mexico and Venezuela have decided not to use CFCs in aerosol products except in essential medical products. These decisions are supported by national legislation.

Egypt has reduced the use of CFCs in aerosols to two percent of 1986 level (30 tons compared to 1500 tons in 1986). Egypt banned the use of CFCs in aerosol products by January 1, 1991; special temporary exception may be granted.

Brazil and China have extensive research and development programmes on CFC alternatives. China and the US EPA entered a bilateral agreement to evaluate CFC substitutes for household refrigerators. The project will test foam blowing and refrigerant alternatives.

Table 6.4
COUNTRY CASE STUDIES AND COUNTRY PROGRAMMES[a]

Developing Country	Cooperation Provided by:
Brazil	U.S. EPA
Chile	National Agency/UNEP
Ecuador	U.S. EPA/ World Bank
Egypt	U.S. EPA/ World Bank
India	U.K. Overseas Development Administration (ODA)
Kenya	Sweden/UNEP
Malaysia	Canadian International Development Administration (CIDA)
Mexico	U.S. EPA
People's Republic of China	UNDP
Philippines	EC
Thailand	UNEP/World Bank
Tunisia	World Bank
Turkey	World Bank
Venezuela	National Agency
Yugoslavia	World Bank

[a] Other country case studies and programs are being proposed or are underway.

Mexico was the first country to ratify the Montreal Protocol and Mexico's environmental ministry (SEDUE) has entered 10 voluntary agreements with industry groups to phase out CFCs and halons. One such agreement with the Mexican Aerosols Institute has already achieved the goal of replacing 96 percent of 1986 Mexican CFC aerosol propellants with hydrocarbons. Mexico moved faster than many OECD countries in eliminating cosmetic aerosol uses. In 1991 Mexico announced that it will follow the same phaseout schedule for controlled substances as required of developed countries under the Montreal Protocol.

In Singapore, 13 of the 25 largest CFC using electronics firms have invested in a cooperative recycling program. A 44 percent reduction in the use of CFCs from 1989 to 1990 was achieved.

Thailand is establishing a technology transfer center and demonstration project and is simultaneously offering tax-reduction incentives for equipment used for CFC recovery and recycling. Thailand, the United States, and Japan have formed a partnership to organize and encourage the phaseout of solvents controlled under the Protocol.

Argentina, Brazil, Cameroon, Chile, Columbia, Ecuador, Egypt, Ghana, India, Jordan, Kenya, Malaysia, Mexico, Nigeria, Panama, Thailand, Trinidad and Tobago, Tunisia, Turkey, Venezuela, and Yugoslavia all cited competition in export markets as a major motivating force for reducing CFC use.

6.5 ACCELERATED PHASEOUT SCHEDULE

China and Mexico have announced their intention of phasing out controlled substances on the schedule for developed countries under the Montreal Protocol. The Technical and Economic Options Committees identified several reasons why other Article 5 countries may choose to phase out more quickly than required:

- Customers in developing countries and export markets are increasingly concerned about the environment and demand products that do not harm the ozone layer.

- Some products cost less to produce without CFCs and are therefore more competitive in world markets.

- Technologies used in developing countries must be up to date to assure compatibility and marketability for exports.

- Manufacturers in developing countries who import or use components adapted to CFC-free technologies, which originate from developed countries, need to switch to CFC-free technology.

- Many multinational companies have worldwide corporate policies to halt the use of CFCs and halons. These companies may require that their suppliers certify that their products neither contain nor are produced with controlled and in some cases transitional substances.

- It is less expensive to eliminate controlled substances from some applications now rather than later, if cost of retrofitting, servicing of old equipment, and the possible ultimate disposal of stocks of controlled substances are considered.

6.6 SPECIAL CIRCUMSTANCES AND CONCERNS OF DEVELOPING COUNTRIES

6.6.1 Energy Regulations

In the next few years, energy demand in many developing countries will exceed generation capacity, principally because of a shortage of capital for investments and fuel purchases. Energy regulations must be coordinated with CFC phaseouts to ensure that energy efficiency will be at least maintained and possibly improved.

6.6.2 Cost Increases

Some alternatives and substitutes require new capital investment or may have higher manufacturing and operating costs. Cost increases will require the successful implementation of the Multilateral Fund to ensure affordable prices for the local market. For example, the refrigerant for household refrigerators will cost 5 to 7 times more than current substances, and the new lubricant about 15 times more. A typical refrigerator will, at least in the early years, cost 10-15 percent more because of compressor modification, more expensive refrigerants and insulating foam, and other changes.

6.6.3 Differences Between Developing Countries

Developing countries differ in production and consumption patterns, skill levels, infrastructure, and government technology programs. Most African countries, for example, do not manufacture products using CFCs. Other countries such as Brazil, which is the world's largest exporter of refrigerator compressors, and China, which has a rapidly developing refrigerator manufacturing industry, are among those where the high use of CFCs can be reduced. Similarly, Singapore's domestic electronics manufacturing sector can with adequate financing reduce its use of CFC solvents as quickly as industry in developed countries. Thailand, however, cannot make such decisions itself since its electronics companies are primarily foreign owned or are joint ventures.

6.6.4 Infrastructure

Eliminating ozone depleting substances in developing countries requires information and training, adequate financing, access to technology, engineering services and project coordinators. In particular education and training across all industry sectors must be a high priority. Service training for refrigeration, air conditioning, and fire equipment is particularly important. Another priority is setting up knowledge centers where they do not exist, and finding ways for knowledge centers in developing countries and industrialized nations to cooperate. Such cooperation is critical for forming local expert networks, publishing training material, and assuring test quantities of substitutes to all developing countries.

6.6.5 Emerging Technologies

If a developed country is generating technologies that use alternative substances, developing countries can delay that selection until the technology emerges. To ensure that decisions are made wisely and rapidly and are realistic, developing countries should be provided with all the necessary information and should be encouraged to increase their participation in international working groups.

6.6.6 Transitional Substances

The Montreal Protocol is at present a one stage process, calling for the elimination of controlled substances by certain dates. Should transitional substances be subject to controls, the Protocol will become a two stage process, first replacing controlled substances with a variety of transitional and other substances and alternative technologies, and subsequently moving away from the use of transitional substances. If transitional substances are regulated, the Parties will need to consider whether, and if so how, this will apply to the developing countries. In particular, a relatively short period between requirements for developing countries to move into and then out of transitional substances may result in the premature retirement of capital, with possible implications for the Multilateral Fund.

6.6.7 Aggressive Marketing

Aggressive marketing of bulk controlled substances has been reported in Mexico, Brazil and China; and of products containing controlled substances in Poland, Thailand, Malaysia and India. Aggressive marketing typically occurs when there is excess production capacity or when governments limit local sales in the exporting country. This may be done by:

- Producers with shrinking domestic markets;

- Companies in countries not Party to the Protocol who may intensify marketing of listed products containing controlled substances before the import prohibition;

- Owners and manufacturers of equipment and product components dependent on controlled substances, including solvent cleaners, foam blowing equipment, halon fire protection equipment, and refrigeration and air conditioning compressors;

- Companies with stocks which cannot be sold within their own countries due to domestic regulation.

Such aggressive marketing will result in greater depletion of the ozone layer, unfair competition for local suppliers, and greater cost when such equipment is replaced.

6.6.8 Cooperative Practices to Speed Ozone Layer Protection

- Government Commitment and Leadership
  Governments in developing countries can coordinate, monitor, mandate, and encourage stratospheric ozone protection. Active cooperation among governmental agencies (Environment, Industry, Trade, Finance, Science) scientific institutions, and industry can be instrumental in the transition in the near term and will initiate important working relationships to address other environmental issues in the long term.

- Industrial Involvement
  Companies involved in the production, consumption, service, and disposal of products that use controlled substances can be involved in decisions regarding choice of alternatives, phase in schedules, estimates of investments, education, and training programs, etc. For example, in Egypt, Mexico, and Singapore there are voluntary agreements between government and industry to control ozone depleting substances.

- Public Awareness
  Customer acceptance of new technologies can be enhanced by seminars, trade fairs, conferences, and training programs, where NGOs can play an important role.

- Careful Alternatives Selection
  Whenever possible, phased development programs should be developed to give priority to proven, technically fit, environmentally acceptable, cost effective, and commercially available alternatives.

6.7 DEVELOPING COUNTRY CONCERNS FOR SPECIFIC APPLICATIONS

6.7.1 Halons

In developing countries, halon is often used to protect substantial investment in sophisticated, high technology equipment. Not only is the equipment expensive but it often requires scarce foreign currency reserves. Halon 1211 and 1301 are used in commercial applications in these countries to protect computer facilities, tape libraries, industrial plant control rooms, telecommunications sites and other electronic equipment facilities.

Developing countries that use nuclear power, produce military equipment such as aircraft and submarines, and fabricate and launch rockets, satellites, and missiles also require halon. High technology equipment (particularly telecommunications and military) is often purchased by developing countries as a turnkey package including halon-based fire protection systems.

The quantity of halon currently banked by developing countries is not substantial and may not be adequate to meet their essential needs in the future. The need for banks of halon is underscored by the lack of water supply infrastructure for fire fighting in developing countries and the lack of monitoring and sprinkler systems.

The following would assist developing countries in protecting their present investment in halon systems and assist in reducing dependency in the future:

(a) Provide funding for technology transfer from national fire protection organisations in developed countries. This could include training courses, seminars, etc. that would be provided in the nation seeking assistance;

(b) Provide assistance when new, environmentally acceptable, clean extinguishing agents become available to upgrade existing systems and equipment in as economical manner as possible;

(c) For multinational corporations with subsidiary operations and/or joint ventures in developing countries, ensure that their subsidiaries are included in corporate policies and practices to reduce halon use to the same degree as is being followed in developed countries;

(d) Ensure that recovered halons from the developed countries that are suitable for recycle are made available for use in developing countries to provide for recharge and service of existing halon fire protection equipment.

6.7.2 Aerosol Products

In many countries CFC propellants have not been replaced in cosmetic products despite the economic incentive to use hydrocarbon propellants instead of CFCs.

This incentive varies widely from country to country. Suitable mixtures of propane and butane may be difficult to obtain either because they are stenched or because their composition changes with different deliveries. In countries which import propane and butane there may not be a clear operation cost advantage to offset the investment required for propellant changeover. The economic advantage is also affected by the availability of:

- Suitable land for industrial development. An aerosol factory that uses flammable propellants will require separated space for the gas tanks and gassing rooms;

- Technology for installation and maintenance of explosion proof electrical equipment, early fire suppression systems, flammable gas detectors, etc.;
- Sufficient financing - which is often restricted by high interest rates, lack of hard currency, trade controls, and complicated application procedures;
- Adequately trained personnel.

Public awareness of the CFC/aerosol product issue is widespread in urban areas of developing countries, where aerosol marketers have been forced to publicize the ozone friendliness of their products. Because of public concern for the ozone layer, many developing country governments have required aerosol fillers to stop the use of CFCs.

The range of products manufactured by developing countries is generally narrower than in developed countries. Many specialties such as tire inflators, foam insulators, horn blowers, chewing gum removers, etc., are not normally produced either because they have a very small market or because they are too sophisticated to manufacture. Production of medical aerosols is mostly for products like topical anesthetics, and lubricants for medical equipment.

Propellants other than hydrocarbons and CFCs are not often used in developing countries. CO_2, which is widely available, needs special filling equipment and can introduce corrosion problems if mixed with solvents that are not totally free of water. HCFC-22 is available in many countries, but is costly, and its high vapor pressure mandates careful reformulation. HCFC-22 will probably be used only where government regulations totally prohibit the use of CFC-12.

In developing countries with open economies the aerosol industry is represented by major marketing multinational firms: Johnson Wax, Bayer, Gillette, L'Oreal, etc. The relatively few local ventures will either market their brands, or act as contract fillers.

6.7.3 Sterilants

Many developing countries have serious medical service deficiencies and the improvement of public health conditions is of national priority. Although the size and degree of sophistication of medical services differs significantly from country to country, there are hospitals in each country using advanced sterilization techniques and equipment.

Several nations have industrial size sterilization facilities for the production of disposables as well as hospital size sterilization units used for temperature sensitive items.

Distribution of sterilization gases is through the compressed gas companies, which are usually subsidiaries or affiliates of multinational corporations. Personnel working in these firms are well aware of the role CFCs play in the destruction of the ozone layer.

There may be an economic incentive to move from 12/88 ethylene oxide EO/CFC mixtures to 10/90 EO/CO_2 in large sterilization units, though some retrofitting will be required to compensate for the higher pressure of the CO_2 mixture. For new installations the use of EO with nitrogen purging may also be the preferred alternative in hospital settings. For industrial units EO already has a wide market penetration.

Consumption of 12/88 EO/CFC mixtures in industrial size units is twice the amount used in hospital applications, but industrial use is rapidly being phased out in developing countries in favor of other alternatives. It is important that no new industrial size 12/88 facilities are installed in developing countries. Most multinational corporations in the sterilization business have a corporate commitment to the substitution of CFCs worldwide, but smaller firms could be tempted to purchase 12/88 units that require a significantly lower initial investment.

The hospital users of sterilant gas 12/88 currently have few immediately available alternatives. New EO sterilizers should be selected that are capable of using the alternative gas mixtures. Good distribution of information should help to reduce consumption of CFCs for sterilization in developing countries. Information should be circulated through medical associations, equipment suppliers, compressed gas distributors and government agencies. Nations that are producing 12/88 will have to import the HCFC part of the new EO/HCFC blends at least temporarily.

6.7.4 Carbon Tetrachloride (CTC)

The use of CTC in developing countries is small and is principally for cleaning applications. Alternatives already exist and are widely available as discussed in the UNEP Solvents, Coatings, and Adhesives Technical Options Report.

Some developing countries have small chlorinated rubber manufacturing facilities. A few other facilities using outdated technologies may also exist.

6.7.5 Foams

The small size of developing country plastic manufacturing facilities offers a unique opportunity to test and certify alternate foam products and technologies under actual production conditions. The conditions necessary in developing countries to make such test programs successful include:

- technical and financial cooperation of the international community including finance for the additional business risks associated with experimentation which is of world-wide benefit;
- existence of industries capable of rapidly and effectively switching feed stocks and technologies, within time frames comparable to developed countries;
- experienced and skilled technicians and operators who are knowledgeable about new feed stocks, technologies, and products.

6.7.6 Refrigeration

Developing countries use a larger portion of CFCs in the refrigeration and foam sectors than the portion used in developed countries. Industry fragmentation, and the importance of the informal sector in both manufacturing and servicing, make consumption control difficult and costly. Export opportunities for finished goods and refrigeration components, and the availability of financing under the Protocol, will lead to an earlier phaseout by Article 5 countries.

Developing countries need projects that will; establish local infrastructure, transfer technical information between local and international experts, improve servicing practices, and assure the development of local solutions in accordance with specific needs.

Costs to developing countries in the refrigeration and air conditioning sector can be minimized by shifting new equipment to substitutes when possible, by establishing recycling programs where use is concentrated enough to be cost-effective, and by avoiding expensive retrofits of existing equipment.

6.7.7 Solvents, Coatings, and Adhesives

There are seven important and distinguishable approaches for technology transfer to eliminate CFC-113 and 1,1,1-trichloroethane use in developing countries. In most countries, several of these approaches will be undertaken simultaneously. There may be substantial cost and technical efficiency advantages of coordination by national governments and industry associations.

1. Local suppliers now serving the developing country solvent-using industry are often agents for multinational supply companies and normal technology diffusion will help in these markets.

2. International, regional, and national conferences and workshops can connect suppliers with customers and can help build supply and service infrastructures.

3. Industry associations, federal and regional development authorities, technical centers, and universities can help collect and distribute technical information, review and initiate product tests, and can help build user-groups to implement new ozone safe technology.

4. International technology transfer partnerships like the U.S. EPA, SEDUE, Northern Telecom, and ICOLP project can have significant advantages by providing objective information, internships and other training, and on-site consultation using experts who have already selected and implemented technology to replace ozone depleting solvents.

5. MITI and the U.S. EPA will encourage and organize projects to phase out CFC-113 and 1,1,1-trichloroethane use by multinational corporations and joint venturers operating facilities in Thailand and Southeast Asia, and to provide technical assistance to domestic companies using these solvents.

6. Multinational companies frequently specify product performance of the assemblies and components they purchase in developing countries and often already offer technical assistance to their subcontractors and suppliers. In several cases, multinational companies are requiring all suppliers to certify that their products do not contain and are not made with ozone depleting substances.

7. Multinational companies that are expanding operations in developing countries are building state-of-the-art factories that do not use CFCs and 1,1,1-trichloroethane. These projects engage local companies to supply and service the new technology, and train domestic workers in the new technology. Coordination and participation of experts in projects to convert domestic companies would be desirable.

Environmental protection and worker safety are special concerns in the transfer of technology to developing countries. New alternatives and substitutes such as no-clean flux and controlled atmosphere soldering are inherently safer than existing technology because they use smaller quantities of the generally safe materials now used. However, aqueous and semi-aqueous cleaning technology may have substantial problems including disposal, pollution of water supplies, and increased energy consumption and its associated environmental effects. Waste disposal from electronics and metal cleaning, adhesives and coatings, and other uses of CFC-113 and 1,1,1-trichloroethane is already a serious concern in most developing countries.

6.8 IMPLICATIONS OF AN EARLIER PHASEOUT IN DEVELOPING COUNTRIES

It is technically and economically feasible to phase out most applications of ozone-depleting substances in developing countries on the same schedule as developed countries. With adequate financing and technical assistance ozone depleting substances can be phased out in non-medical aerosol products, electronics manufacturing, and flexible and non-insulating foam by 1992-1994.

Developing countries may need additional time for some applications. In some instances, the information, training, and infrastructure needed to phase out a use are not available; in other instances developing countries may need to preserve the useful life of capital dependent on CFCs. Financial assistance and training through the Fund are critical for the resolution of these problems. With proper support, it is technically and economically feasible for most developing countries to phase out consumption of controlled substances, even in the more difficult areas of application, within five to eight years after developed countries.

Therefore, the earlier the phaseout in developed countries, the earlier developing countries will be able to phase out controlled substances. The barriers to rapid phaseout in developing countries are largely informational and administrative, rather than technical or economic. The phaseout in developed countries will represent a point at which all technical barriers have been overcome, and it is the dissemination of this technology to, and throughout, developing countries which may take a further 5 to 8 years in the more difficult applications.

The report of the Economic Options Committee suggests that an accelerated phaseout in developing countries may cost less than phaseout over an extended period. Because of economic growth the amount of equipment which has to be converted, and the costs of doing so, increase over time.

Considering the present low levels of consumption and banked quantities of halon in developing countries, there is a case for maintaining a less rapid phaseout of halon consumption.

Developing countries may experience difficulties in limiting occupational exposures or release of toxic chemicals and may therefore want to choose alternatives that have high exposure limits and minimum wastestreams.

It is critical to successful phaseout for developing countries that technologies are available, that supporting technical assistance and training is provided, and that adequate financial assistance is forthcoming. It is expected that technologies will be made available through existing channels and mechanisms and supported by the Interim Multilateral Fund. Suitable technologies are clearly available for many aerosol product, foam, and solvent applications.

The development of adequate channels for the collection and distribution of information is essential for the successful transfer of technology and phaseout of controlled substances in developing countries. Full development of the clearing house role of the Multilateral Fund is essential.

CHAPTER SEVEN: EXECUTIVE SUMMARY
REFRIGERATION, AIR CONDITIONING AND HEAT PUMPS

In refrigeration, air conditioning and heat pumps, one of the most important applications of fluorocarbon refrigerants is found. This sector includes end uses such as domestic and commercial refrigeration, cold storage and food processing, industrial and transport refrigeration, and stationary and automotive air conditioning. This report presents options for eliminating CFC refrigerants and investigates the viability of HCFC and HFC replacement refrigerants in each of these end uses. Each end use is considered individually in a separate section of the report. Other sections of the report describe available refrigerant data for the design of equipment, the importance of refrigeration conservation programs, considerations specific to Article 5 countries, refrigerant usage forecasts, and the need for information dissemination and research coordination.

Staff members from over 90 organizations, representing 18 countries authored the various sections of the report. A broad consensus was reached on the conclusions for each of the separate sections. Several cross-cutting conclusions, relevant to all refrigeration, air conditioning, and heat pump applications, are summarized below:

* Both the Ozone Depletion Potential (ODP) and the energy efficiency of substitutes and alternative technologies are determining factors in the selection of replacement refrigerants. Compared to the direct Global Warming Potential (GWP) of the replacement chemicals, the global warming of the carbon dioxide emitted in operating the equipment is greater by at least one order of magnitude. In domestic refrigeration the direct GWP will be in the order of 1-2% of the Total Equivalent Warming Impact (TEWI). As a complement to discussions on energy efficiency in the separate chapters of the Options Report, an executive summary of the AFEAS refrigeration study is attached to this report.

* In applications operated at high evaporation temperatures, a phaseout of CFCs is strongly related to the availability and use of HFC-134a. These applications include mobile airconditioning equipment, some stationary air conditioning (water- and air-cooled) equipment, and domestic appliances. Much of the work being done to develop compressors for domestic appliances is committed to HFC-134a, where there is progress in the optimisation of energy efficiency. In the developed countries, a gradual phaseout of CFCs in newly produced domestic appliances is thus expected to take place in the 1992 to 1996 timeframe. The same goes for mobile airconditioning, where a complete CFC phaseout (made possible by HFC-134a) for new equipment is expected to be completed by the end of 1995.

* There are many other refrigeration applications where CFCs can be rapidly phased out by means of substitution with HCFCs (mainly HCFC-22, -123 and -124, including mixtures with these). For most of these applications, no suitable alternatives or substitutes have been identified except these HCFCs. HCFCs are, however, defined under the Montreal Protocol as "transitional substances." HCFCs are generally accepted as the solution for a rapid CFC phaseout. The costs of the transition from CFC to HCFC refrigerants will be high due to retrofitting and obsolescence. There has to be confidence at the user level that the operation of the equipment can be guaranteed for a reasonably long period, otherwise there will be prolonged CFC use awaiting "more certain solutions". In this framework, effort should be made to lower the cost of transition to the next generation of refrigerants (the post-HCFCs) by developing next generation chemicals which are compatible with or need minor retrofits compared to the HCFC equipment.

* After identification of the future substitutes for HCFCs, development until commercial availability will cost additional time, since it involves toxicity and environmental testing, pilot plant constructions, development of materials and lubricants, equipment and product (re-)design etc. A phaseout date for transitional substances in new equipment has to take into account the future availability of the substitutes as well. Transitional substances should remain available during the lifetime of the equipment that has been manufactured to run on them. This will minimize the cost of capital replacement by allowing existing equipment to function using the original, transitional chemicals. Efforts to identify and develop alternatives to HCFCs need to be much encouraged and accelerated, should the elimination of HCFCs in new equipment be considered for the mid term (2005- 2015). It should be emphasized that no reliable options have been presented to date.

* From 1992 to 2000, not-in-kind technologies, such as absorption and adsorption/desorption processes or evaporative cooling, will take a small part of the existing fluorocarbon market. Most of the applications will, however, continue to rely on the vapor compression cycle, using HCFCs and HFCs, which will provide the most energy efficient short term alternative.

* In many Article 5 countries, export opportunities for finished goods and availability of refrigeration components will probably lead to an early CFC phaseout (earlier than given by the ten year grace period) if major barriers can be removed. These barriers can be lowered by establishing local infrastructure, by technical information transfer between local and international experts and by information clearing

houses, by improved servicing practices and by funding and offering incentives to assure the development of local solutions in accordance with specific needs.

* Whether the phaseout date for CFCs is technically feasible, depends strongly on the success of collecting and using recycled and reclaimed refrigerants in existing equipment. Aggressive recovery programs can help avoid the high economic costs of equipment obsolescence and retirement. Recovery programs should be actively supported by governments, adequately using financial instruments and legal measures; these should also apply to the final destruction of CFCs. Whether recovery will be successful is too uncertain to precisely forecast scenarios and economic costs as a function of a CFC phaseout date. Nevertheless, a scenario is presented assuming optimum conditions for recovery and the resulting net demand for CFCs, HCFCs, and HFCs over the next decade.

* In all sections of the report estimates have been made on the global demand for CFCs, HCFCs and HFCs for the period 1991 to 2005. These estimates are based on the assumption that CFCs will be phased out in the 1995-2000 timeframe, more accelerated than according to the amended London Protocol. For these estimates the automotive air conditioning sector has assumed a 1997 phaseout which will require a substantial number of retrofits.

For refrigeration, air conditioning and heat pumps the following observations are made:

- Global net CFC demand will decrease from 260,000 in 1991 to 100,000 tonnes in the year 1995 (a reduction of 60%), and to roughly 20,000 tonnes in the year 1997, which amount is almost only used by Article 5 countries (in refrigeration, 1991 consumption is more or less equal to the 1986 Montreal Protocol reference consumption level).

- CFC demand will be reduced by 80% in the year 1995, and by virtually 100% in the year 1997 in the developed countries, assuming that all recovered and recycled CFCs will be used in the developed countries.

- In the year 2000, slightly more than 5,500 tonnes of CFCs are estimated to be used in the Article 5 countries (2% of the total, global 1991 consumption).

- The global HCFC demand (mainly HCFC-22) will remain roughly constant during the period 1991 to 1997 (roughly 230,000 tonnes) and decrease after 1997. In case HCFCs will be used as retrofit refrigerants for automotive airconditioning, there will be a 10% increase in the 1997-2002 period. Net HCFC demand will be less than 180,000 tonnes after the year 2005.

- The consumption (and emission) of HFCs (mainly HFC-134a) is estimated to grow to 230,000 tonnes in the year 2005, of which amount 20% will be used in present Article 5 countries. Half of the amount (120,000 tonnes) will be used for automotive air conditioning. About 15% (33,000 tonnes) is estimated to be used in domestic refrigeration, 50% of this in developed, and the other 50% in Article 5 countries.

* Compared to a CFC phaseout in the year 2000, a phaseout in the year 1997 would imply higher costs in the order of US $ 3,400 million for the whole refrigeration, stationary airconditioning and heat pump sector. For mobile airconditioning, a CFC phaseout in the year 1997 would imply higher costs in the order US $ 2,800 million, since it involves retrofitting of 13 million vehicles in the developed countries. These costs are based on the present status of replacement technology and could reduce with significant improvements in it.

  The above implies that, compared to a phaseout in the year 2000, a 1997 CFC phaseout will involve higher costs, estimated at a level of US $ 6,200 million for the whole refrigeration, air conditioning and heat pump sector. These costs will be incurred over a four to six year period at maximum (dependent on lifetime, servicing possibilities etc.) which would be equal to US $ 1.1 to 1.6 billion more per year. Costs of a phaseout earlier than by 1997 are difficult to determine, but will be highly disproportional with the earlier year.

Domestic Refrigeration

In the majority of units in domestic refrigeration, both refrigerators and freezers, CFC-12 is used as the working fluid. Significant progress has been made in the past two years in identifying and commercializing a suitable replacement for CFC-12.

HFC-134a appears to be the prime choice and virtually all compressor manufacturers have centered their efforts on redesigning compressors for this refrigerant. The result has been that in laboratory testing HFC-134a compressors have demonstrated efficiencies comparable to CFC-12. Moreover, ester-based lubricants have passed reliability tests with satisfactory results. However, lubricant development is still one of the topics much attention is focused on.

In certain parts of the world, appliance manufacturers are now planning full scale commercialization of new, HFC-134a operated refrigerators which process will start in 1992 (e.g. in Europe). In this way, it will be technically feasible to eliminate CFC-12 in refrigerators by using HFC-134a in the 1994-96 timeframe if adequate component supplies are available. The phaseout of CFC-12 in domestic refrigerators must take into account the energy efficiency of new refrigerants; the indirect contribution to global warming of these products is far more important than the direct one (nearly two orders of magnitude).

It should be noted that, compared to CFC-12 units, HFC-134a refrigerators, at the current level of development (status as recorded the middle of 1991), consume from one percent less to seven percent more energy in equivalent product tests. These figures might slightly improve with more sophisticated optimized designs. The energy efficiency decrease is one of the main reasons that in other countries (as e.g. the United States, where energy efficiency standards are mandatory under federal regulation), some manufacturers prefer HFC-134a but others are considering blends such as the ternary mixture of HCFC-22, HFC-152a and HCFC-124 and the pure HFC-152a. These other refrigerants might be better replacements if higher energy efficiencies can be realized. In refrigerator performance tests undertaken thus far, HCFC-152a's energy consumption is 4 percent less to 3 percent greater than CFC-12 while the ternary blend achieves 1 percent less energy to 6 percent greater energy consumption than CFC-12. These consumption values relate to tests with appliances and compressors at their current level of development (status being the middle of 1991).

Refrigerant mixtures have also been considered in combination with cycle changes, such as proposed and tested by Lorenz and Meutzner. Presently, the theoretical values have not been attained in experimental testing and demonstrated efficiency values are proprietary information. Not-in-kind technologies, like fossil fueled absorption, may take a small part of the market. Other options, such as the Stirling cycle, might also become viable in the long-term, but only if high energy efficiency has been demonstrated[1].

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[1] Theoretical analysis shows higher efficiency only below -60°C.

CFC consumption for domestic refrigeration is expected to decrease by 80% in the 1991-1995 period and expected to be eliminated before the year 1997 in the developed countries. Nevertheless, the need for CFCs in domestic refrigeration may further increase by 50% compared to 1990 in the Article 5 countries. However, also in these countries a CFC phaseout is expected to start soon and to be completed somewhere in the 2000-2005 timeframe. It can reasonably be expected that compared to a 2000 phaseout, an earlier phaseout as e.g. in

1997, would only marginally contribute to higher economic costs in the developed countries (higher costs for servicing only).

Commercial Refrigeration

It is technically feasible to reduce CFC consumption (primarily CFC-12 and R-502) in commercial refrigeration by 80 percent by 1995 and then completely phaseout its global use by the year 2000. It is expected that, in developed countries, a CFC phaseout will be possible in the year 1997 (when Article 5 countries will still need small amounts of CFCs). The above will be achieved through a combination of chemical substitution, alternative technologies, retrofitting existing systems, and refrigerant conservation (e.g. small amounts of CFCs will be needed for servicing even after the year 2000, but they can be supplied through reclamation).

HCFC-22 is the most common replacement refrigerant in new equipment. In some cases HFC-134a, ammonia and alternative technologies like absorption, resorption, and air cycles are also being studied. However, application of HFC-134a forms no realistic option in low temperature applications.

It may be possible to retrofit existing commercial refrigeration systems for use with HCFC-22 and blends containing HCFC-22. There are are two types of blends: medium pressure blends to replace CFC-12 and high pressure blends to replace R-502. In this way CFC-12 will become available from equipment that is retrofitted and should be a significant source of supply to avoid early retirements (maybe also for other refrigeration sectors).

Refrigerant conservation is of greatest importance to commercial refrigeration. The last two years have demonstrated reduction of CFC emissions by switching over from CFC-12 and R-502 to HCFC-22, improved design and service to reduce leaks and piping fractures, and improved recovery, recycle, and reclamation practices.

Twelve thousand tonnes of CFCs will be required for service in 1995 decreasing to a small amount after the year 2000, which can be supplied through reclamation. In contrast, the quantity of HCFC-22 consumed will likely increase from 12 thousand tonnes in 1991-92 to 30 thousand tonnes over the next five years, but then decrease due to increased recycling. Transitional substances like HCFC-22 and blends containing HCFC-22 will play a vital role in the timely phaseout of CFCs. For example, in developed countries, new equipment has already begun to shift out of CFC-12 into HCFC-22 and this process should be completed before the middle of the decade.

A 1997 phaseout will lead to accelerated retrofitting and early retirement of existing CFC-12 and R-502 systems. Cost is estimated at a level of US $ 500 million; this cost may be reduced when more accurate estimates about HFC-134a retrofits can be made.

Cold Storage and Food Processing

Cold storage and food processing mainly include the following application areas:

- Storage of food and other perishable products below ambient temperature, including chilled storage from the freezing point to approximately 10 C, and long term storage at deep frozen condition (-18 - -28 C). Lately, very low storage temperatures (below -50 C, superfreeze) have been introduced in some countries for high valued quality products.
- The cooling/ freezing process, where raw material, semi-finished products and ready prepared food are brought from ambient or production temperatures to the storage or distribution temperature level.
- Refrigeration in the dairies and the dairy industry, in the production of beer and other beverages, and in several other sectors of the food industry.

The systems are in general large, ranging from 100 kW to several MW refrigeration effect. An average system may have a refrigerant charge of several metric tonnes. Ammonia is the most commonly used refrigerant, and it is believed to account for roughly 60% of a total consumption volume estimated at 130-140,000 metric tonnes per year.

CFC use is estimated at the order of 30,000 tonnes/year, evenly distributed between CFC-12 and R-502. HCFC consumption is of similar magnitude, maybe slightly less. Annual turnover may be in the order of US $ 3-5 billion, of which a little less than US $ 1 billion regards systems with controlled refrigerants. The market increase is estimated at 2-3% per year.

Article 5 countries are believed to account for 5-105 of the refrigerant consumption. Ammonia and CFC-12 are the dominating refrigerants, while HCFC-22 and R-502 are less common. CFC consumption in these countries is estimated at roughly 3000 tonnes per year.

In new equipment, CFC refrigerants will be replaced by ammonia and HCFC-22, and to a lesser extent, by new refrigerants towards the end of the decade. Presenting no harm to the environment, and being technically suited for most applications within the sector, ammonia has gained renewed interest in many countries. On the other hand, it is presently ruled out in some countries for legal reasons, due to its toxicity. In some cases, HCFC-22 may be the most economic and practical non-CFC choice, irrespective of prevailing regulations. Therefore, availability of HCFC-22 will be a cornerstone of an expeditious CFC phaseout worldwide in this sector. In the developed, industrialized countries, the cold storage sector will have transferred completely to non-CFC fluids in new systems before 1995. A time lag of 5 to 10 years may be expected for most LDCs. For cost and availability reasons, as well as system robustness and reliability, ammonia is particularly well suited for the Article 5 countries.

Future consumption of CFC and HCFC refrigerants will be substantially reduced through improved maintenance and refrigerant recovery when systems are serviced, retrofitted and disposed of (the upcoming ban on venting CFC and HCFC refrigerants into the atmosphere in the USA and most western countries and requirements on refrigerant recovery will have a considerable impact on the refrigerant demand). Equal to most of the commercial equipment, more than 65% of the current refrigerant consumption in cold storage is assumed to be used for servicing purposes. Reclaimed refrigerant available for reuse may considerably extend the operational life of many CFC systems.

Nevertheless, many technically viable systems will have to be retrofitted for use with alternative refrigerants. Ammonia and HCFC-22 are the most promising candidates for retrofit. Refrigerant blends, which are tailored to replace CFC-12 and R-502 respectively, may gain some success. However, their market penetration may be hampered by a general reluctance within the industry regarding the application of refrigerant mixtures. An early retirement of a certain part of the existing stock of equipment must be expected.

Alternative technology is not likely to become of significance in the short to mid term. The CFC demand in the industrialized world will probably halve by 1995, and once more in the five years thereafter. It is assumed that the remaining amount may be covered through reuse, and that there will be no demand for new CFC refrigerants after this date. In the Article 5 countries, a certain increase in CFC consumption seems to be likely in the short term. Eventually, the consumption will also decline in these countries, and will probably be back at current level, or below, by the year 2000.

After an immediate increase, the consumption of HCFC-22 is expected to decline, as a result from reduced emission, which will more than compensate for the increased use in new systems. Therefore, a consumption value similar to the current level may be expected by the turn of the century. Only a minor use of the new refrigerants is expected before 2000 in the cold storage sector.

A 1997 phaseout will significantly reduce the time available for system retrofit and for the implementation of a refrigerant reclaiming service network, and a substantial number of systems may have to be taken out of service. The economic impact will then be in the order of US $ 1 billion. An early elimination (earlier than in the 2005-2015 timeframe) of HCFC-22 will have much greater economic consequences. Refrigerating systems with a market value of about US $ 20-25 billion will be affected. The cost related to retrofit and replacement may add up to US $ 10 billion, as an order of magnitude.

It is not believed that the transfer to alternative refrigerants will affect the energy consumption value of the cold storage sector as a whole, in a significant way.

Industrial Refrigeration

Industrial refrigeration end uses industries include chemical, pharmaceutical, petrochemical, and metallurgical. It is also used extensively in sports facilities, ice making, and other miscellaneous end uses. Current CFC consumption in these industries and uses is estimated at approximately 5,000 tonnes per year, of which the developing countries are believed to account for 10 percent. HCFC-22 is consumed at a rate of 2-3 times that of the CFCs. Ammonia consumption is believed to be similar to or slightly less than that of HCFC-22. Hydrocarbon refrigerants are frequently used by industries that handle flammables.

Options to replace CFCs in new equipment include HCFC-22, ammonia, hydrocarbons and HFCs. Industry prefers HCFC-22 and ammonia for some applications. It is technically feasible to eliminate the use of CFCs in new equipment by 1995 for most applications. For example, complete conversions to ammonia and hydrocarbons are technically possible and many companies consider these options to be best. However, these options may not be accepted everywhere due to regulatory constraints and lack of experience in some countries. Therefore, HCFC-22 is urgently needed to speed a CFC phaseout. Chlorine-free halocarbons suitable for the entire industrial sector may be available towards the end of the decade.

Existing systems can be retrofitted first of all for use with alternative refrigerants, HCFC-22 and ammonia, and then with new chemicals after 1995. In general, non-azeotropic mixtures are not considered to be viable alternatives by the industry, however, they are studied for some peculiar applications.

Refrigerant can be conserved by improved maintenance and recovery at system service, retrofit and disposal. A small quantity of CFC required for service purposes after 1997 and 2000 can be supplied by reuse of recovered fluid. This will require practicable procedures and routines for large scale refrigerant recycling and reclamation and economic motivation for refrigerant recovery.

Future refrigerant demand for the industrial sector estimated by a "best guess" scenario is 60 percent of the 1990 consumption before 1995 and only 15 percent (700 tonnes) at the end of the decade. At the same time, 1,650 tonnes of CFC is expected to be recovered at decommissioning of industrial systems, and will be available for reuse. By 2005 the CFC demand in industrial systems will be eliminated.

The use of HCFC-22 is forecasted to increase temporarily in the early and mid-nineties as it replaces CFC in both new and existing systems. However, after the mid-nineties a decline is expected, as a result of reduced emission during service and operation, and a transfer to ammonia, hydrocarbons and new chemicals. By 2000 the demand for HCFC-22 is estimated at 10,000 tonnes, which is 20 percent below current consumption level. By 2005, a reduction of 40 percent is foreseen. Recovery and reuse is expected to substantially reduce the demand for HCFC-22 production. Significant uses of the new refrigerants is expected from 1995. Consumption will grow at a modest rate, reaching approximately 800 tonnes by 2000, and 2,600 tonnes by 2005.

Industrial CFC consumption in developing countries probably will not change much before 2000 unless stimulated by technology transfer and financing. For cost and availability reasons, ammonia technology is very well suited for developing countries. This technology should be promoted, and those countries which are already familiar with it should be encouraged to expand their use, taking advantage of ongoing development in developed countries. Any new technology should, however, be mature before it is transferred to a developing country and great importance should be attached to the training of local engineers and technicians.

A 1997 phaseout will lead to increased pressure to recycle and retrofit existing equipment. According to the CFC demand forecast, such a phaseout will result in 10 percent of the remaining CFC-using equipment stock being affected, thus resulting in an additional cost compared to the original phaseout date of US$ 250 million (this includes US$ 10-20 million for early replacement in developing countries). This figure applies for extended system retrofit/replacement exclusively.

The economical consequences of an early HCFC-22 phaseout may be illustrated by the fact that systems with a value of probably more than US$ 10 billion will be affected.

This underscores the need to allow HCFC-22 to service existing equipment until a drop-in replacement can be developed. A minor decrease of 2-3 percent in energy efficiency may be expected.

Air Conditioners and Heat Pumps (Air-Cooled)

Unitary air-cooled air conditioners and heat pumps, ranging in capacity from 2.0 kW to 420 kW, comprise the majority of air conditioning equipment sold worldwide. Virtually all are electrically driven vapour-compression cycle machines using, in nearly every case, HCFC-22 as a working fluid. An estimated 1,400 million kW of unitary products are operating worldwide (considering the diversity of loads and that some equipment will be idle at any given time, unitary equipment accounts for an estimated average power demand of about 50,000 MW). This represents about 330,000 tonnes of HCFC-22. Of the total 137,000 tonnes of HCFC-22 used in both new and existing unitary air conditioners and heat pumps in 1990, about 25 percent was used for new equipment, leaving 75 percent to service existing products.

Nearly all unitary systems use HCFC-22 because it is an efficient refrigerant, that meets all toxicity and flammability requirements is thermodynamically suited to pressure and temperature ranges typically encountered in this equipment, and is compatible with all common construction materials and nearly all commonly used lubricants.

A promising non-chlorinated replacement for HCFC-22 is HFC-134a, but potential thermodynamic and chemical incompatibility problems must first be resolved. Because of these issues, retrofitting HCFC-22 unitary machines with HFC-134a is not practical today.

Other alternative candidates to HCFC-22 have been proposed, such as HFC-32, HFC-125 or HFC-143a, either by themselves or in mixtures, but very little performance data exist on these alternatives in actual unitary equipment. HFC-32, either alone or in blends, might become an attractive option assuming that research and development efforts will be accelerated and will yield positive results.

Alternate cycles, primarily the absorption cycle (water or ammonia refrigerant, water/ lithium bromide double effect cycles)) and Vuilleumier and electric Stirling cycles (non-fluorocarbon refrigerants) are being actively studied. However, higher cost,generally lower efficiencies, increased maintenance requirements, reliability issues, and safety concerns in the ammonia systems have slowed broader application of these options; some of these systems are currently considered impractical (e.g. Stirling). Evaporative cooling/desiccant systems exist, but are practical only in limited geographical areas.

Significant reductions in HCFC-22 usage can be anticipated if stringent changes in service practices, along with mandatory recovery and recycling, are enforced. A possible elimination of HCFC-22 in this sector will directly depend on the acceptability and availability of an alternative, which has not been clearly identified.

Air Conditioning (Water Cooled Systems)

Chillers for commercial building air conditioning using water to transfer heat from conditioned spaces may be categorized by the type of compressor used: centrifugal compressor systems and positive displacement compressor systems (i.e., reciprocating, screw, scroll). The principal refrigerants of concern are CFC-11 with its alternative HCFC-123, and CFC-12 with its alternatives HFC-134a, and HCFC-22.

CFC-11 and HCFC-123 are considered low pressure refrigerants and are suitable for centrifugal systems only. The other refrigerants are high pressure refrigerants used in all types of compressors where their volume flow rate characteristics allow system size to be minimized. The range of water-cooled water chillers varies widely from 7 kW to 35,000 kW. The larger machines typically are centrifugal chillers. In a number of units, positive displacement compressor systems are dominant worldwide. Positive displacement applications cover the lower end of the capacity range.

To serve the essential objectives of minimizing environmental impact and providing water chilling machines for commercial building air conditioning, it is advocated that CFC-11 and -12 be replaced in new chillers using HCFC-22, HCFC-123, and HFC-134a as soon as possible. These refrigerants will be necessary until suitable replacements are found exhibiting equal or better performance and acceptable system cost.

HCFC-22 is the most economically acceptable fluid presently available for use in positive displacement compressor water chillers and is used in very large centrifugals. HCFC-22 water cooled chillers are commercially available up to 4,200 kW, as are centrifugal chillers above 1,000 kW. At this time, no substitute for HCFC-22 is known for use in existing equipment. HCFC-123 has a low ODP and GWP, but also has a low exposure level, recommended by various chemical manufacturers (10 ppm), and is still undergoing toxic tests. It offers high efficiency close to that of CFC-11 which it replaces. It is the only alternative for existing CFC-11 centrifugal chillers in the range of 350 to 10,000 kW.

HFC-134a, with zero ODP, is the current replacement for CFC-12. It is useful primarily in centrifugal chillers, both air and water cooled, in the range of 350 to 4,200 kW. Although workable in positive displacement machines, it suffers a significant equipment cost disadvantage relative to HCFC-22.

The combination of long equipment life (more than 25 years), large base of installed equipment, high capital investment required from the building owner, and increasing concerns about greenhouse warming make it particularly difficult to develop an orderly, cost effective refrigerant transition plan for this equipment category.

HCFCs are critical to permit the most rapid transition away from CFCs in this sector. Restrictions on the production of new chillers which use HCFCs as refrigerants would undermine this goal. Such restrictions may discourage both developing and developed nations from making an early transition from CFCs to HCFCs. The result will be to prolong CFC usage while the search continues for "perfect refrigerants." It is preferable instead to support HCFC technologies now and permit adequate supplies to retrofit equipment and keep it in operation, and to shift new equipment out of HCFCs when a more environmentally acceptable alternative becomes available.
A CFC phaseout by 1997 will be more difficult than one by the year 2000, will require more reclaimed CFC refrigerants to be available and will lead to more retrofits and/or early retirement of equipment (a very rough estimate indicates at extra costs in the order of US $ 800 million).

Transport Refrigeration and Airconditioning

The transport refrigeration market includes road transport, railcars, ships and intermodal containers for the transport of refrigerated cargoes, and also refrigeration and airconditioning on board all types of ships. In this market there is a pool of refrigerants estimated at 23,000 tonnes of CFCs and 33,000 tonnes of HCFC-22, with annual requirements for new manufacture and maintenance of 7,000 tonnes of CFCs and 19,000 tonnes of HCFC-22.

It is anticipated that CFC annual demand will fall to about 3,000 tonnes by 1997, and around 300 tonnes by 2000. HCFC and HFC use are estmated to decrease slightly by the year 2000, to around 17,500 tonnes. These changes are dependent on the continuing availability of HCFC-22 well into the next century.

The reductions in HCFC use are dependent on achievable improvements in maintenance and repair procedures. All the data above is based on best estimates from experts familar with the equipment, and not on detailed statistical surveys.

Air conditioning and food stores on ships and railcars are expected to convert to HCFC-22 for new equipment. Container refrigeration units and truck refrigeration units are expected to become available in due course for use with either HCFC-22 or HFC-134a, as are air conditioning units for buses and coaches.

The reductions to be achieved in CFC use depend on the solving of many technical problems, which are the subject of much currently ongoing development work. There are no exactly equivalent retrofit replacement fluids. For a fast phaseout of CFCs a secure mid term future for the availability of HCFC-22 is needed. Without this, the necessary economic incentives for development and purchase of new equipment will not exist.

Compared to a CFC phaseout in the year 2000, a phaseout of these chemicals in the year 1997 would imply extra costs. Estimates made at present can only be rough and yield a value between US $ 500 and 1000 million (assumed US $ 700 million); this value may decrease as HFC-134a retrofits become more common and may yield less compatibility problems.

Automotive Air Conditioning

The elimination of the use of CFC-12 in mobile air conditioning is one of the most important aspects the automobile industry is committed to. This will be accomplished via a combination of conservation, recycling and reclamation during servicing and disposal, and replacing CFC-12 with HFC-134a in new equipment. The CFC phaseout in new equipment will have been completed before the end of 1995.

Assuming that the implementation of HFC-134a proceeds as planned, the major challenge that remains for the industry is what to do with the existing CFC-12 vehicles as the supply of CFC-12 vanishes. Although there exists a lack of consensus on the best CFC phaseout schedule, it is generally conceded that retrofitting these vehicles to accept a non-CFC refrigerant will be necessary. To this end, manufacturers are closely cooperating with chemical companies and governmental agencies to identify potential retrofit refrigerants and lubricants. There are two refrigerants which are under investigation at present: (1) HFC-134a and (2) a blend of HCFC-22, HFC-152a and HCFC-124.

Currently, however, no refrigerant exists to replace CFC-12 without significant retrofit costs. The cost estimates vary from an upper value of US $ 1000-2500 (complete system replacement with HFC-134a compatible compounds) to a value of US $ 217 for a "compromise" retrofit, a procedure still to be developed (this in addition to the normal average repair cost which is in the order of US $ 200). Thus, retrofitting will more than double the cost of maintaining an operational air conditioning system. Of the 225 million vehicles which are in use in the developed countries (59% in the US) and are operated on CFC-12 in the year 1997, 111 million are forecast to require retrofitting. This assuming the CFC phaseout dates of the 1990 amended Protocol, which implies a staggering societal cost of US $ 24.1 billion (the actual cost will likely fall between retrofit costs and the obsolescence value of the systems, estimated in the range of US $ 55-107 billion).

By 1997, if no feasible retrofit solution is found by that time, the global demand for additional CFC-12 for service (above that available from refrigerant recycling, will be approximately 0.24 kg per year per vehicle in service. This translates to 63,000 tonnes in the developed world in 1997, diminishing, as this fleet ages, to 47,000 tonnes by the year 2000.

It appears that, whether or not a retrofit solution is found to service existing CFC-12 vehicles, the cost to society (or to the individual consumer) to eliminate CFC-12 will be significant. Compared to a CFC phaseout in the year 2000, an earlier phaseout date would imply that more pieces of equipment will have to be retrofitted. In case of a phaseout in the year 1997, it can be calculated that 13 million more retrofits will have to be carried out in the developed countries which represents a value of US$ 2.8 billion.

Heat Pumps

Heat pumps for heating only and heat recovery come in all sizes from around one kW for single room heaters to several megawatts for district heating systems and industrial applications. Total installed heating capacity is approximately 9,100 MW, and total refrigerant volume is close to 9,100 tonnes. CFCs make up 60 percent of the total, while HCFCs account for the remainder. Annual refrigerant consumption is 1,700 tonnes. Vapour compression systems comprise almost 100 percent of the heat pumps; the rest are absorption machines. Research is currently being conducted to develop high performance vapour compression and absorption, as well as hybrid cycle machines. Products will be commercially available at the earliest by the late-1990s.

In new equipment HCFC-22, HFC-134a, and possibly HFC-152a will be the primary replacement for CFC-12. HCFC-123 seems to be a potential alternative to CFC-11. HCC-160 (ethylchloride) is a replacement candidate for CFC-114. Until production capacity for HFC-134a has increased, and in lieu of other alternatives, HCFC-22 will be one of the best short-range substitutes. In the medium-term HFC-134a appears to be the most feasible choice. In the medium- to long-term, both ammonia and HFC-152a and mixtures are strong candidates. No technical obstacles exist to all new equipment shifting out of CFCs by 1995.

Retrofit of existing equipment will be feasible but, in most cases, relatively expensive. The only refrigerants in the short-run to replace CFC-12 and R-502, to some extent, are HCFC-22 and HFC-152a. HCFC-123 and HFC-134a can be used instead of CFC-11 and CFC-12, respectively, but system alterations will be costly.

The total cost of shifting the phaseout date from year 2000 to 1997 is estimated to be in the order of US $ 150 million.

Heat pumps are scarcely used in developing countries, and are assumed to be of negligible influence on consumption volumes. This might change towards the turn of the century as demand for more sophisticated heating devices increases in the Soviet Union, China, and Eastern Europe. Alternatives will be fully available by the time these markets develop.

Forecasts indicate that the total refrigerant demand in the year 2000 will be close to 3,100 tonnes, of which HFCs are expected to make up roughly 70 percent.

It is assumed that 70 percent of the refrigerant pool in scrapped equipment will be recovered. By the year 2000, approximately 475 tonnes of CFC and 300 tonnes of HCFC can be recovered. To allow for a 1997 phaseout, recycled CFCs from service and from retired equipment can serve equipment that remains in service.

Refrigerant Conservation

The objective of a refrigerant conservation program is to minimize refrigerant emission to the atmosphere and to recover refrigerant from existing systems for reuse in the same or other systems.

Several refrigerant conservation programs are already underway:

* Recovery and recycling of CFC-12 from mobile air conditioning systems (MACs) is being implemented on a mandatory or voluntary basis in a number of countries (similar laws are in effect in the United States and in many European and Scandinavian countries, and in Canada, Australia, and New Zealand).

* Public awareness of the domestic refrigerator as the main source of CFC emission, urges governments and local authorities to take actions. Although domestic refrigerators and freezers contain very small quantities of CFC-12 refrigerant - and larger quantities of CFC-11 as the foaming agent in the cabinet insulation - major programs are under way in many countries to reduce the amount of CFCs used in these products and to recover and reclaim refrigerant when appliances are serviced or discarded. This also within the framework of programs for

the recovery of all materials used in domestic appliances. The cost of recovery of CFCs is very high from the refrigerators' insulating foam in particular; however, it should be born in mind that the number of appliances in use is great and the total amount of CFC in them thus is large.

A general remark is that CFC refrigerant recovery is efficient and economic with larger systems, which provide larger volumes. Refrigerant that is recovered at disposal and from units that are being retrofitted also provides a substantial pool of CFCs that can be used to service equipment following a production phaseout.

In any recycling program, though, several critical technical issues must be properly addressed. First, care must be taken so that recovered refrigerant is adequately reprocessed through recycling or reclamation so that contaminants are removed. In this regard, standards on refrigerant purity for different systems have been established, and standards on performance of refrigerant recycle/reclaim equipment have been developed. Second, care must also be taken not to mix refrigerants or to use one of the alternative refrigerants in equipment designed for a CFC refrigerant. The problem of mixing or misusing refrigerants exists in all countries, but may be most severe in the developing countries where service technicians have received less training in minimizing the risks of refrigerant and equipment contamination.

Developing Countries Aspects

CFC use in developing countries differs from its use in industrialized nations because developing countries have the largest proportion of their CFC use in the refrigeration sector (averaged 63% of their demand, compared to 25% globally) and also in the foam sectors (averaged 20% compared to 25% globally). Industry is more fragmented, and the informal sector is important in both manufacturing and servicing. These factors make consumption control more difficult and costly.

Developing countries are working to protect the ozone layer as part of the international community effort and the obligations of the Montreal Protocol. Export opportunities for finished goods and refrigeration components, and the availability of financing under the Protocol will probably lead to an earlier phaseout by Article 5 countries if major barriers are successfully removed.

Barriers to an earlier phaseout can be lowered by establishing local infrastructure, by technical information transfer between local and international experts, by improved servicing practices, and by funding and offering incentives to assure the development of local solutions in accordance with specific needs.

Overall costs to developing countries in this sector can be minimized by shifting new equipment to substitutes as soon as possible, by establishing recycling programs where use is concentrated enough to be cost-effective, and by avoiding expensive retrofits of existing capital. Earlier phaseout schedules would require an accelerated investment schedule under Protocol funding.

Information Dissemination and Research Coordination

Information associated with the development and application of alternative refrigerants and technologies, and the coordination of research and information dissemination activities could contribute to an orderly and economically sound transition to more environmentally acceptable refrigerants and technologies. This information is needed by government agencies, companies, teaching institutions, and the general public.

The types of information needed by the air conditioning and refrigeration industries include environmental data, health and safety information, refrigerant property data, systems performance information, conservation, recycling, and service information, and regulatory and standards information.

There are already a large number of mechanisms and organizations available to disseminate information relating to alternative refrigerants and refrigeration technologies. Organizations that are expected to play prominent roles include: UNEP, IIR, IEA, ASHRAE, and various national associations (as e.g. DKV, RIB, AFF, DRA, JAR, JRAIA and ARI).

In several countries, support from government agencies and others is being provided to coordinate and leverage industry's own resources in order to phaseout CFCs in a timely manner. Notable examples of these efforts include the new generation refrigeration research in Japan, the joint research programme on the reduction of CFC emissions in refrigeration and air conditioning in Germany, the IEA research project on thermophysical properties, the Program for Alternative Fluorocarbon Testing (PAFT), the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS), and the materials compatibility and lubricant research program in the U.S.

There are many excellent opportunities for further cooperation and coordination among international parties. Examples of opportunities for additional cooperative research may include environmental and health effects, technology development and deployment, standardization, and training. UNEP and the International Institute of Refrigeration (IIR, both located in Paris) are developing together an International Data Base dedicated to the refrigeration, air conditioning and heat pump field (e.g. regulations, scientific, technological and commercial data, industrial property information). Effective international research efforts are needed in these areas to help ease the transition period from CFCs to the transitional chemicals. These efforts can be patterned after the many successful national and international efforts now underway in the air conditioning and refrigeration fields.

Refrigerant Data

As can be concluded from the above, the vast majority of present refrigeration, heat pump and air conditioning equipment utilizes the vapour compression cycle because of its simplicity and efficiency. This cycle will continue to be the dominant equipment design using chemicals that replace the fully halogenated chlorofluorocarbons. The properties of refrigerants for use in the vapour compression cycle are considered in the refrigeration report.

A refrigerant must satisfy a set of criteria, including environmental acceptability, chemical stability, health and safety (including toxicity), thermophysical properties (economy and efficiency), and materials and lubricant compatibility. Many fluids and fluid types have been used as refrigerants in the past. In certain applications ammonia has formed and still forms an important option; the importance may again increase in future. However, the halocarbons dominate today because their unique combination of properties seemed to best satisfy these sometimes conflicting requirements until it was discovered that they are destroying the ozone layer. CFCs accumulate in the atmosphere and cause unacceptable environmental harm.

Because of the success of the CFC refrigerants, most of the efforts to develop replacement refrigerants have focused on a set of hydrogen containing, but otherwise similar, compounds. Theoretical studies indicate that simple molecules of relatively low molecular mass and with normal boiling points similar to present working fluids would be excellent refrigerants. These fluids include HFCs 134a, 152a, 125, and 23, and HCFCs 123, 22, 141b, 142b, and 124. Mixtures of these fluids are also good candidate replacement refrigerants for CFCs. These fluids are the most likely choices for the short- to mid-term replacement of CFCs. Although receiving little attention, HFCs 134, 32, and 143a also deserve consideration and, for applications where highly flammable fluids can be used, propane, butane, and isobutane. Additional classes of fluids such as the fluorinated propanes and fluorinated ethers, show some promise as refrigerants; such fluids, however, are in the very early stages of development and may not be available in large quantities for 3 to 5 years.

A variety of data is required to evaluate a potential alternative refrigerant. The thermophysical (i.e., thermodynamic and transport) properties of a fluid determine its potential energy efficiency and heating or cooling capacity in equipment and are essential for equipment design. Properties related to health and safety (toxicity and flammability) can determine whether a fluid is suitable for a particular application. Data on materials compatibility are required to design reliable equipment. The ozone depletion potential (ODP), greenhouse warming potential (GWP), and atmospheric life-time will determine whether a fluid be considered as an environmentally acceptable alternative to the CFCs.

Only simple parameters such as normal boiling point and molecular structure are needed to conduct a coarse screening among many candidates, while a fluid in widespread commercial use requires extensive, accurate data of all types. In the refrigeration report, the needed data are described and categorized, and the available data are summarized for the leading candidate refrigerants.

The greatest uncertainty in selecting, developing, and commercializing alternative refrigerants is the relative weight to be given to ozone depletion potential, greenhouse warming potential, cycle efficiency, and safety factors such as flammability. This weighting is an economic, technical, and environmental calculation subject to political decisions. Since this uncertainty will not likely be soon resolved, a wide range of possible alternative refrigerants must be explored.

Global Scenarios of the Consumption

In each of the sections of the report estimates have been made on the demand for fluorocarbons and the amounts which can be recovered. These estmates are based on the assumption that CFCs will be phased out in the 1995-2000 timeframe, following a more accelerated scheme than described in the amended London Protocol. This phaseout carries with it a certain amount of costs due to retrofitting and obsolescence; in the various sections estimates have been presented how much more a 1997 phaseout would cost compared to a phaseout in the year 2000.

Estimates in all sections are based on phaseout around the year 1997, on the other hand, for automotive air conditioning the estimates are based on a phaseout specifically in the year 1997. This implies that a substantial amount of retrofits (either using HFC-134a or HCFC blends, which increases the amounts needed compared to normal servicing) has to be carried out.

Combination of the above estimates yields the following figures for the refrigeration, airconditioning and heat pump sector as a whole:

'000 tonnes of refrigerant

	1991	1995	1997	2000	2005
CFC demand, developed	111.8	31.7	16.1	6.5	2.2
CFC demand, Art 5	12.1	9.6	8.6	5.7	2.9
CFC recovered	10.4	13.6	16.7	15.2	13.0
CFC net demand, all countries (excl. mobile AC)	113.5	27.7	8.0	-3.0	-7.9
CFC net demand: mobile AC	147.2	70.0	10.8	8.0	4.5

	1991	1995	1997	2000	2005
HCFC demand, devlp'd	196.3	223.7	228.7	208.0	179.6
HCFC demand, Art 5	31.3	35.5	39.5	36.7	35.9
HCFC recovered	4.0	25.9	33.0	38.6	35.9
HCFC net demand, all countries (excl. mobile AC)	223.6	233.3	235.2	206.1	179.6
HCFC demand: mobile AC [a]	-	-	40.5	30.2	19.5

	1991	1995	1997	2000	2005
HFC demand, developed	1.0	38.2	55.9	67.7	99.0
HFC demand, Art. 5	-	1.1	5.4	13.5	26.4
HFC recovered	-	-	0.2	7.6	14.0
HFC net demand, all countries (excl. mobile AC)	1.0	39.3	61.1	73.6	111.4
HFC net demand: mobile AC [b]	-	37.5	99.0	105.3	122.0

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[a] assumes HCFCs are used as retrofit refrigerants in mobile AC

[b] assumes HFCs are used as retrofit refrigerant in mobile AC

nb: only one of these assumptions will become reality

The following observations are made:

1. Global consumption of CFCs will be reduced by 60% in the period from 1991 to 1995 and by another 30% in the period from 1995 to 1997, which yields a consumption of about 8% of 1991 in the year 1997 (the consumption in 1991 can be assumed to be equal to the one of 1986 in refrigeration, 1986 being the reference year in the Montreal Protocol).

2. Equal to the developed countries, there is a continuous decrease in CFC demand in the Article 5 countries in 1991-2005. The largest demand in Article 5 countries after the year 2000 is expected to come from automotive air conditioning. In case it would be possible to use the recovered amounts of CFCs (recovered in the developed countries) in the Article 5 countries, a CFC phaseout is assumed to be possible in the Article 5 countries by the year 2003.

3. CFC demand in the developed countries decreases to about 15% of the 1991 consumption in the year 1997. Would all recovered CFCs be used in the developed countries a CFC phaseout by the year 1997 would be feasible.

4. Due to the use of HFC-134a in new AC equipment in cars (a process which will be completed before the year 1996) the CFC demand for automotive air conditioning is reduced by more than 50% in the year 1995 compared to 1991. Nevertheless, it is estimated that, globally, 70,000 tonnes of CFCs will still be required in automotive air conditioning in the year 1995.

5. Already at present refrigeration and air conditioning is an important user of HCFCs, maily HCFC-22. Recovery of HCFCs is estimated to definitely play a role in the 1991-1995 timeframe. As a result, this yields a 5% growth in HCFC consumption from 1991 to 1997 only (in spite of the growth scenarios for the demand, applied in the calculations for all application areas). In case an HCFC blend would be used as a retrofit refrigerant in automotive air conditioning, it would increase the global HCFC consumption by 15-20% in the 1997-2005 period.

6. HCFC demand is expected to decrease after the year 1997, by about 4% per year. This forecast bases on the assumption of a high degree of recovery and reclaim, and not on the phasing in of non chlorine containing substitutes for HCFC-22. Should reliable substitute candidates have been identified, these figures will show a faster decrease after the 1997-2000 period (dependent on when substitute candidates for new equipment could be commercialized).

7 In the year 2005, HFC demand in the developed world will be smaller than the consumption of CFCs in 1991, in spite of the growth assumed in the market. This is mainly ascribed to better recovery and reclaim practices. However, taking into account a growing demand from the Article 5 countries, the net HFC consumption will be larger (in tonnes) than the present day net CFC demand (1991) after the year 2005.

8. Automotive air conditioning will be the largest user of HFC refrigerants, in particular when HFC refrigerants will be used as the retrofit refrigerant in existing equipment (after the year 1996).

9. Without taking into account retrofits in automotive air conditioning, the automotive HFC consumption is equal in magnitude to the entire refrigeration, stationary air conditioning and heat pump HFC market (1997-2000).

10. Domestic refrigeration gets a more important part of the refrigerant market in the future (even not taking into account possible use of fluorocarbons in foams), due to a large increase of the consumption of Article 5 countries. It is estimated that, by the year 2005, domestic refrigeration will use 15% of the global HFC demand as refrigerants (where it used 4-5% of the total CFC demand as refrigerants in the 1987- 1991 period).

Compared to a 2000 CFC phaseout, a 1997 CFC phaseout carries with it certain extra costs due to more retrofitting and more obsolescence which have been estimated for the various application areas as follows (US dollars):

Domestic Refrigeration - no significant increase
Commercial Refrigeration - 500 million
Cold Storage - 1000 million
Industrial Refrigeration - 250 million
Air Conditioning (chillers) - 800 million
Transport Refrigeration - 700 million
Automotive Air Conditioning - 2800 million
Heat Pumps (heating) - 150 million

Total Costs - USD 6.2 billion

CHAPTER EIGHT: EXECUTIVE SUMMARY
FLEXIBLE AND RIGID FOAMS

Consumption of fully halogenated chlorofluorocarbons (CFCs) by the foam plastics manufacturing industry is extremely varied. An assortment of CFCs, such CFC-11, CFC-12, CFC-113 and CFC-114, have been used in numerous foam plastic product applications.

In 1990, building and appliance insulation applications consumed about 140,000 metric tonnes, which is equivalent to 80 percent of the CFCs used in foam plastics that year, while the remainder was spread among other product applications, such as cushioning, packaging, flotation and microcellular foams.

This report details the available technical options that can be implemented by each foam market segment to completely eliminate CFC usage known as of 1991. Updates on the progress of each market segment in reducing CFC consumption since 1986 (summarised in Figure ES-1) are also provided.

However, it should be noted that specific technical options and the extent of CFC reduction achieved to date are quite different for each foam application and market sector.

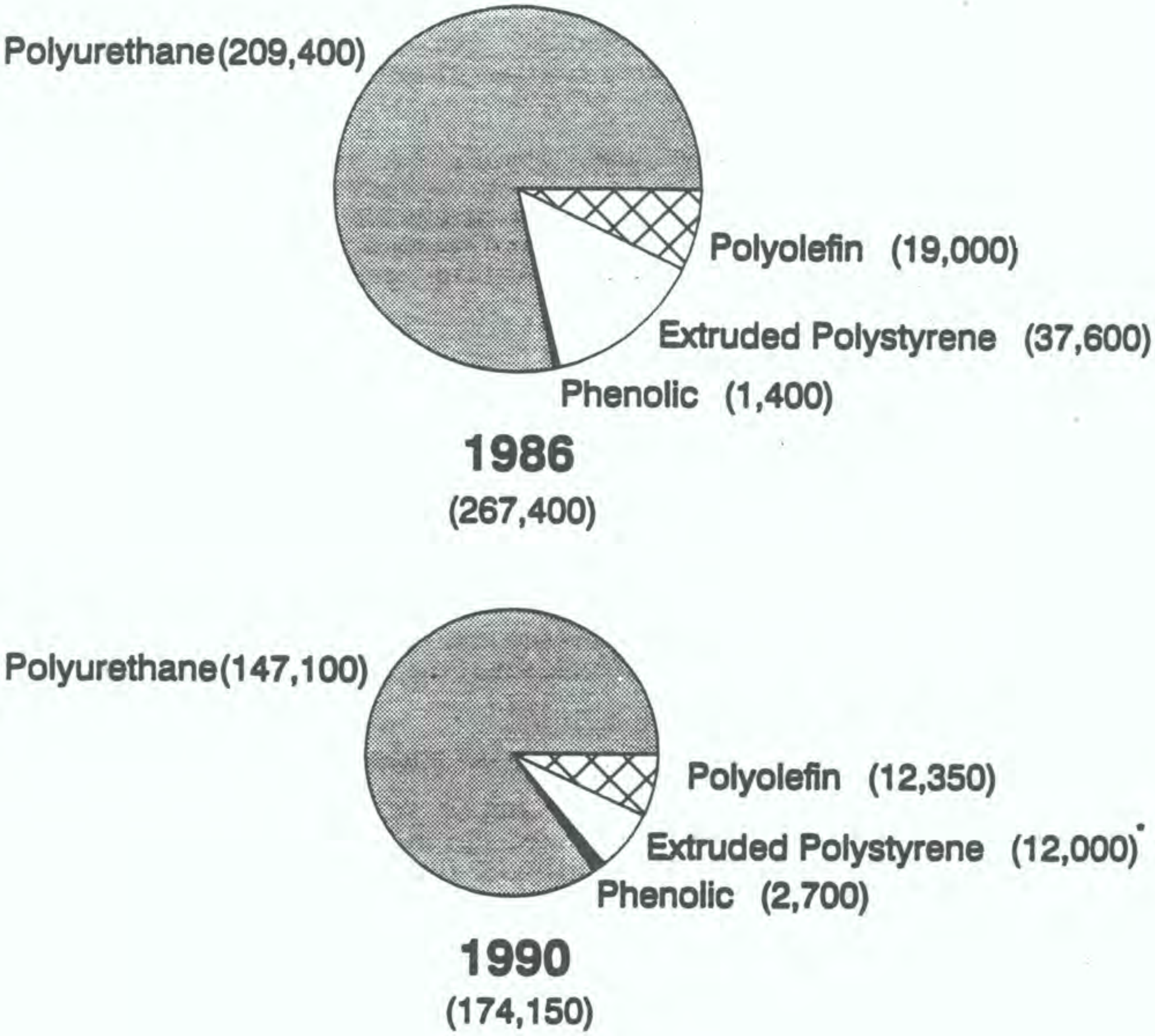
Consequently, key factors affecting the total elimination of CFCs from the foam plastics manufacturing industry are also discussed.

Status of CFC Reductions and Projected Phaseout Schedule

Global CFC consumption has been reduced in every market sector since 1986, despite industry growth during the last five years. Reductions have been achieved by CFC conservation, product reformulation, direct substitution of CFCs with other blowing agents, and the use of new manufacturing technologies.

Global CFC consumption in all foam sectors has declined by about 35 percent, from 267,000 tonnes in 1986 to 174,000 tonnes in 1990. In general, the greatest reductions in CFC consumption have been achieved by developed nations. As discussed later, developing countries also are working to achieve similar CFC reductions but may require additional time as the Montreal Protocol suggests.

Figure ES-1. CFC Consumption by Foam Sector: 1986 vs. 1990 (tonnes)



* This figure represents the amount of CFCs used worldwide in extruded polystyrene boardstock production. A virtual phaseout of CFCs has been achieved in the extruded polystyrene sheet industry in developed countries, while a small undetermined amount of CFCs is assumed to be used for sheet production in developing countries.

Phaseout dates discussed below focus on developed countries. Specific industry sector reductions and phaseout schedules include the following:

A 77% reduction in CFC use for flexible polyurethane foam -- Polyurethane foam industry sectors achieving the highest percentage of reductions include the flexible slabstock and moulded foam, integral skin, and packaging markets. By 1994, the majority of the worldwide producers in these sectors will have eliminated the use of CFCs.

A 6% reduction in CFC use for polyurethane foam insulation -- Despite 20 to 25 percent growth in the polyurethane foam insulation sector since 1986, CFC consumption has been cut by six percent. This equates to an average 30 percent reduction in CFC consumption per tonne of foam. A virtual phaseout of CFCs should be technically achievable by 1995 -- assuming HCFCs are both commercially viable and available.

An average 20% cut in CFC consumption per tonne of foam for phenolic foam insulation products -- The phenolic sector has, in fact, grown in its CFC consumption since 1986, but this has been from a base of less than 2,000 tonnes. Phenolic foam growth has been primarily at the expense of other CFC-containing insulation products. Therefore, to gain a true picture of phenolic foam's contribution to the foam plastic insulation industry's net reduction in CFC usage, evaluations must include a comparison of the respective progress being made with advancing product technologies. The industry estimates that a total elimination of CFCs is possible by 1995, but again this is contingent on both the commercial viability and availability of HCFCs.

A 32% reduction in CFC use for extruded polystyrene boardstock insulation -- Global CFC consumption in extruded polystyrene boardstock insulation foam has been declining since 1988 when the worldwide industry committed to convert from CFC-12 to HCFC-142b/HCFC-22 blends and other alternatives. The industry sector predicts a complete conversion by the end of 1993.

A 35% cut in CFC usage for polyolefin packaging -- It is technically possible to have complete conversion of most polyolefin foam products to new blowing agent systems using hydrocarbons and HCFCs by the end of 1993.

Extruded polystyrene packaging nears complete phaseout of CFCs -- Since 1988, global CFC consumption has been declining rapidly in extruded polystyrene packaging foams. A virtual phaseout has been achieved in developed countries.

Developing Country Issues

Due to the diversity of developing countries, their specific needs will vary. Consequently, even with technology proven in developed countries, some developing countries may require additional time to achieve CFC reductions whilst other developing nations have committed to phaseout schedules similar to those of developed countries.

The extra time may be needed for some developing countries to:

- evaluate CFC replacement technologies;
- establish national government support and policy; and
- coordinate government and industry activities.

Even when uncertainties surrounding CFC alternatives are resolved, additional time may also be required to facilitate the transfer and implementation of replacement technologies.

Both the capital and operating costs associated with the conversion to CFC substitute technologies should be considered for funding under the Multilateral Fund.

Key Factors Affecting Further Reductions in CFC Use

The global foam plastics industry is evaluating a variety of potential CFC alternatives; however, there are considerable uncertainties affecting several of these options at this time. This section summarises these key factors and uncertainties, and discusses the possible impact on the timing and the rate of CFC replacement.

Toxicity

Concerns over human health impacts of CFC substitutes include:

- worker and consumer exposure to alternative blowing agents; and
- exposure to possible decomposition products formed in foams.

Two of the key short/intermediate term CFC alternatives, HCFC-123 and HCFC-141b, are still undergoing toxicity testing. Final results will not be fully known until 1992-93.

The preliminary toxicity findings on HCFC-123 and the decomposition products from HCFC-123 and HCFC-141b in polyurethane formulations and foams are examples of the uncertainties still existing and affecting the commercialisation of these products.

In addition, some non-HCFC substitutes, such as methylene chloride, have toxicity concerns and are strictly regulated in some areas.

Flammability

Some CFC alternatives, such as HCFC-142b, HCFC-141b, HFC-152a, acetone, pentane and other hydrocarbons, present varying degrees of flammability. The procedure required for their handling will depend on the degree of flammability; in some instances, flammability may limit the use of a CFC substitute.

In order to safely use flammable alternatives, it is necessary to complete the evaluation of these critical areas:

- manufacturing risks from ignition;
- storage and transportation of foam products; and
- finished product fire performance.

Environmental Concerns

It is necessary to consider environmental effects, such as stratospheric ozone depletion, ground level air pollution, global warming, and tropospheric degradation products, when choosing CFC substitutes.

Ozone Depletion Potential

The HCFCs identified or used as CFC substitutes in foam manufacturing have a much lower ozone depletion potential (ODP) than CFCs. However, their unrestricted, long term use would contribute significant amounts of chlorine to the stratosphere.

ODP values vary among the different HCFCs; for instance, the ODP of HCFC-141b had been estimated to be 0.10; however with new scientific data, the ODP may be adjusted upwards. In contrast, HCFC-123 has an ODP of 0.02.

HCFCs are viewed as transitional alternatives to be used while non-ODP, chlorine-free alternatives are developed. In insulation applications, where HCFCs are crucial, efforts are being made to minimise the ozone depleting impact of the blowing agent by judicious foam formulation and to eliminate HCFC use as quickly as possible.

Tropospheric/Ground Level Air Concerns

CFCs are organic chemicals which react negligibly in the lower atmosphere. However, some CFC alternatives, such as pentane, butane, and other hydrocarbons, are classified as volatile organic compounds (VOCs) because they undergo photochemical reactions in the lower atmosphere and contribute to smog formation.

As a result, even though these alternatives can find applications in many foam sectors, they may be strictly regulated on a regional basis. For example, the US strictly regulates emissions of hydrocarbons. Ultimately, regional regulations may restrict the use of these CFC substitutes even though they are technically feasible options.

The tropospheric degradation of HCFCs and HFCs is being assessed by AFEAS.

Global Warming Potential

The global warming potential (GWP) of a compound is a function of its atmospheric lifetime and its ability to absorb infrared radiation. CFCs have high GWPs.

The leading CFC substitutes have lower GWPs. The relative ability of a CFC substitute to act as a greenhouse gas together with its total emission volume into the atmosphere will affect the choice of alternatives.

While CFCs and CFC substitutes have GWPs, the major contributor to global warming is carbon dioxide produced by the burning of fossil fuels. In their report, the US Department of Energy and AFEAS have determined that the energy efficiency of HCFC-blown foam insulations can reduce fossil fuel consumption sufficiently to decrease the overall global warming effect from use of HCFCs in these foams.

Insulation Efficiency

The use of alternative blowing agents or non-CFC insulation materials in insulation products can impact the energy efficiency of the finished product.

In general, the drop-in replacement of CFCs with HCFCs or other alternative blowing agents resulted in products which were poorer insulators. However, once CFC substitutes had been selected, research and development efforts were focused on reformulation around the chosen substitute and modifications to the foam technology. This effort has resulted in products with equivalent insulation efficiency.

Ultimately, the acceptability of alternative blowing agents is dependent upon the performance, cost-effectiveness and competitiveness of the finished product in a particular application. The market price of any alternative system is often the determining factor as to whether a substitute can be used and sold competitively on the market. This has already been found to be a significant barrier to substitution, particularly in recessionary environments.

For applications requiring high insulation efficiency, the choice of alternatives is more limited. If reliability and commercialisation problems can be overcome, new products, such as composite vacuum panels for refrigerators, could offer both increased energy efficiency and the elimination of CFCs.

National and Regional Legislation

While the global foam plastics industry is committed to totally eliminating CFCs from all product formulations in the minimum practical time-period (as previously detailed on page ES-3), industry efforts may be affected by differing national and regional legislation regulating the phaseout of CFCs. This legislative diversity and inconsistency can create obstacles that impede the implementation of a smooth transition plan to CFC substitutes, particularly for companies serving multinational markets.

Adhering to the regulatory stipulations of international agreements, such as The Montreal Protocol, offers a more effective and efficient phaseout strategy for the industry worldwide.

Conclusions

For the near term, the use of HCFCs presents the quickest path to complete elimination of CFCs in foam plastic product formulations, as presented in Table ES-1. However, uncertainties about HCFCs' impact on human health and ozone depletion may hamper the commercial availability of these alternative blowing agents -- leading to a slow down of the phaseout of CFCs.

For the polyurethane, phenolic and polystyrene foam insulation sectors, such as appliance, boardstock, and other insulation applications, replacing CFCs in the near term will require the commercialisation of HCFC-141b and HCFC-123 and the continued availability of HCFC-22 and HCFC-142b.

The CFC phaseout rate in insulation applications will be dependent upon the ultimate cost of HCFCs and the competition of more cost-effective. CFC-based products still on the market.

In the extruded polystyrene insulation sector, a worldwide transition from CFC-12 to HCFC-142b and HCFC-142b/HCFC-22 blends has been slowed due to the uncertainties surrounding the environmental acceptability of those HCFCs. Consequently, manufacturers in some nations, particularly developing countries, have been reluctant to make capital commitments to the conversion process. Manufacturers are hesitant because they are not confident that this will be the final conversion process.

Similarly, many chemical manufacturers have been cautious about making capital investment decisions to build increased capacity or new facilities for HCFC-141b and/or HCFC-123 due to these uncertainties.

The use of HCFCs, such as HCFC-141b, HCFC-123, HCFC-124, HCFC-142b and HCFC-22, can immediately reduce the negative impact of CFCs on the ozone layer. At the same time, these alternative blowing agents can offer industries and governments the required time to evaluate the technical feasibility, cost-effectiveness and environmental acceptability of long term options currently under consideration to replace HCFCs.

It must be recognized that not all options being evaluated as long term solutions will be feasible. Concerns related to technical barriers, toxicity, economics, commercial availability, equipment developments, safety or environmental impact may limit or eliminate some options presently being considered.

Failure to allow industry to use HCFCs as transitional substitutes in the near term will result in continued use of CFC-11 and CFC-12 for several more years. This consequence poses more harm to the ozone layer than the introduction of HCFCs with a time constraint for acceptable use.

Table ES-1. CFC Alternatives Available to the Foam Industry

Type of Foam	CFC Alternatives		
	Immediate	Short/Intermediate Term	Long Term
Polyurethane:			
Rigid: Appliance	Reduced CFC-11, 100% CO_2	HCFC-141b, HCFC-123, perfluorocarbon*, HCFC-22, HCFC-22/HCFC-142b blends	HFCs, fluorinated ether, vacuum panels, perfluorocarbon*, hexafluorobutane
Boardstock/Flex-Faced Lamination	Reduced CFC-11, 100% CO_2, pentane, 2-chloropropane**, HCFC-22/HCFC-142b blends	HCFC-141b, HCFC-123, HCFC-22, HCFC-22/HCFC-142b blends, perfluorocarbon*	HFCs, fluorinated ether
Sandwich Panels	Reduced CFC-11, 100% CO_2, pentane, HCFC-22/HCFC-142b blends, HCFC-22	HCFC-141b, HCFC-123, HCFC-22, HCFC-22/HCFC-142b blends	HFCs, fluorinated ether, vacuum panels
Spray	Reduced CFC-11, 100% CO_2, HCFC-22	HCFC-141b, HCFC-123	HFCs, fluorinated ether
Slabstock	Reduced CFC-11, pentane	HCFC-141b, HCFC-123, HCFC-22, HCFC-22/HCFC-142b blends	HFCs, fluorinated ether
Pipe	100% CO_2, HCFC-22, HCFC-22/HCFC-142b blends, methyl chloroform	HCFC-141b, HCFC-123, HCFC-22	HFCs, fluorinated ether, 100% CO_2
Flex: Slab	Extended-range polyols, softening agents, methylene chloride, methyl chloroform, acetone, AB Technology, increased density	HCFCs***	Dissolved CO_2, reduced barometric pressure
Moulded	Methylene chloride, increased density, methyl chloroform, extended range polyols	HCFCs***	
Integral Skin	HCFC-22, hydrocarbons, water substitution, methylene chloride, air loading, high active polyol, 100% CO_2	HCFC-141b, HCFC-123	100% CO_2, HFCs
Phenolic	Hydrocarbons, HCFC-22/HCFC-142b blends	HCFC-141b, HCFC-123, HCFC-22/HCFC-142b blends	HFCs
Extruded Polystyrene:			
Sheets	HCFC-22, hydrocarbons, 100% CO_2, HFC-152a	HFC-152a, HFC-134a, hydrocarbons, 100% CO_2	100% CO_2, hydrocarbons, Atmospheric gases/resins, HFC-152a, HFC-134a
Boards	HCFC-22, HCFC-142b	HCFC-142b, HCFC-124, HCFC-22	HFCs
Polyolefin	Hydrocarbons, HCFC-22, HCFC-142b, 100% CO_2	100% CO_2, inorganic gases, HFCs, hydrocarbons	

* To be used as an additive or a co-blowing agent.
** Proprietary technology.
*** Not likely to be used.

Estimation of Future HCFC Use by the Foam Industry

Making accurate estimates of the quantities of HCFCs likely to be needed for achieving a quick phaseout of CFCs in the foam industry is difficult because the baseline is constantly changing. Growth in the foam plastics industry (particularly in insulation sectors) has been estimated at roughly five percent annually.

Many companies have been making individual judgements on the best choice of CFC alternatives for their own particular situation. Taking all factors into consideration, especially the uncertainties about the commercial acceptability of HCFCs, some companies have made decisions to move to immediately available non-HCFC alternatives like pentane and 100 percent water blown formulations.

These corporate decisions are often made based on the following criteria:

- the ability of the finished product to be cost-effective and competitive in the market;
- the ability to adjust thickness to compensate for efficiency losses; and
- the impact of national and regional legislation requiring immediate elimination of CFCs in many foam applications.

As noted, estimating an accurate level of current HCFC use or the demand in the future is difficult, but the foam plastic product applications that will rely the most on HCFCs to achieve the quickest phaseout of CFCs can be identified. These applications include polyurethane, phenolic and polystyrene insulation products, and certain polyolefin packaging and polyurethane integral skin for automotive product applications (presented in Table ES-2).

As stated in the 1989 Foam Technical Assessment, it still is anticipated that a virtual elimination of CFCs worldwide in all foam uses is technically achievable in developed countries around 1995 under the assumption that HCFCs are available and commercialised around 1993.

Without the HCFCs, many foam manufacturers have few other options based on current technology. Foam manufacturers, particularly those that produce insulation products, would have to offer products without CFCs or HCFCs. In turn, the products may have poorer physical properties, poorer fire performance properties, higher cost, and poorer insulating value compared to those made with CFCs.

Table ES-2. Importance that HCFC Substitution Will Play in Each Foam Sector

Sector	HCFC Importance in the Phaseout of CFCs	Estimated CFC Phaseout Date*
Polyurethane		
Rigid		
Appliance	★★★	1995
Construction	★★★	1995
Transport	★★★	1995
Packaging	★	1991
Integral Skin	★★	1993
Flexible	★	1993
Phenolic	★★★	1995
Extruded Polystyrene		
Sheet	★	1988**-1990
Board	★★★	1993
Polyolefin	★★	1993

★★★	Very important
★★	Important for some applications
★	Not very important

[*] Assumes availability and use of HCFCs.

[**] Portion of industry that converted to HCFC-22 is in the process of phasing out.

It has been projected, based on the current CFC market and the importance of HCFCs in insulation and other special end use categories that <u>150,000 tonnes of HCFCs per year</u> would be required to achieve a CFC phaseout in foam plastics in the developed countries in 1995.

CHAPTER NINE: EXECUTIVE SUMMARY
SOLVENTS, COATINGS, AND ADHESIVES

The Montreal Protocol on Substances that Deplete the Ozone Layer as revised in London in June, 1990 will eliminate the production of some ozone-depleting chemicals including chlorofluorocarbon 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113) and 1,1,1-trichloroethane (methyl chloroform). CFC-113 and 1,1,1-trichloroethane are widely used as solvents to clean electronics assemblies, delicate instruments and surfaces (defined as precision cleaning applications in this report), metal parts and surfaces, and in adhesives, coatings, and inks. CFC-113 and 1,1,1-trichloroethane are also used in certain countries to dry clean clothes and other fabrics. In addition, there are a variety of miscellaneous uses for these two solvents.

This report discusses the solvent, coatings, and adhesives uses of CFC-113 and 1,1,1-trichloroethane and the technical feasibility of replacing them with alternative chemicals, processes, or substitutes. The report draws on the experience of "head start"[1] countries implementing accelerated national phaseout regulations, companies implementing accelerated phaseout schedules, and on the advice of numerous technical experts from many parts of the world.

This report is organised according to the major industry application areas that use CFC-113 and 1,1,1-trichloroethane.[2] For each application area, the report examines the extent of CFC-113 and 1,1,1-trichloroethane use and the alternatives that can replace CFC-113 and 1,1,1-trichloroethane in solvent cleaning, coatings, and adhesive uses worldwide.

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[1] "Head-start" countries including Austria, Germany, Norway, Sweden, and Switzerland have already scheduled accelerated phase-outs of ozone-depleting compounds (e.g., 1993-95) and have organized their domestic industry to meet these goals. These "head-start" countries consume around five percent of the world production of CFC-113 and 1,1,1-trichloroethane in a representative variety of uses - but not all uses. Some of these countries will allow exemptions for particular essential applications for limited periods of time if no environmentally acceptable alternative or substitute is available.

[2] The phase-out of carbon tetrachloride was considered by the Miscellaneous Uses Technical Options Committee and is included as Appendix I of this report.

Technical Feasibility of a CFC-113 and 1,1,1-Trichloroethane Phaseout

The Solvents, Coatings, and Adhesives Technical Options Committee used the definition that it is technically feasible to phase out the use of CFC-113 or 1,1,1-trichloroethane in an application when known or emerging technology has demonstrated cleaning, coating or adhesive performance sufficient to maintain or improve product quality (performance, reliability, and durability) or when not-in-kind or process changes can eliminate the use of the ozone-depleting substance.

The consensus finding of the UNEP Solvents, Coatings, and Adhesives Technical Options Committee is that it is technically feasible to phase out CFC-113 and 1,1,1-trichloroethane on the schedule presented in Table ES-1. This schedule may be logistically and financially difficult, but could be achieved with appropriate government and industry priorities and financial support.

A 1997 phaseout of CFC-113 is technically feasible but will require greater cooperation and some early retirement of equipment. For 1,1,1-trichloroethane, it is technically feasible but logistically difficult. It may require changes in processes; substantial not-in-kind substitution would entail early retirement of equipment and new technology in certain areas.

A 1997 phaseout would require prompt decisions to enable suppliers and customers time to select, manufacture, and implement the new processes, equipment, or chemicals. It can take several years for some or many solvent users to form the process conversion team and to identify, evaluate, select, specify, purchase, install, start-up, and qualify the equipment and processes.

Caveats and Elaboration on the Phaseout Schedule

Parties to the Protocol have instructed the Technical and Economic Assessment Committees to estimate the technical feasibility of phasing out substances that deplete the ozone layer. However, it is important for Parties to recognize that the actual pace of the phaseout will depend on more than technical feasibility. The pace of the phaseout will depend on environmental necessity and regulatory requirements, corporate priority, business circumstances, capital availability and interest rates, technical feasibility, equipment availability, logistical and supply considerations, access to information, and training.

The pace of the phaseout is contingent upon the manufacturing process (e.g., in-line vs. batch cleaning, adhesive cure time), the type of operation (e.g., cold vs. hot cleaning, static-charge vs. uncharged painting), the scale of production, the production capability, and other factors.

TABLE ES-1

TECHNICALLY FEASIBLE PHASEOUT SCHEDULE

Category of User	CFC-113	1,1,1-trichloroethane
Developed -- "head-start" countries[a]	1990-1992	1992-1994
Other developed countries and developing countries with strong technology transfer partnerships and/or aggressive regulatory regimes[b]	1993-1997	1995-2000
Other developing countries	1995-2000	1997-2002

All dates imply phaseout by December 31 of the year stated. The range of technically feasible phaseout dates reflects uncertainties in the commercial availability of some alternatives and substitutes and differences in the expert judgements of committee members. Accelerated phaseouts will require the development of some new technologies.

[a] "Head-start" countries including Austria, Germany, Norway, Sweden, and Switzerland have already scheduled accelerated phaseouts of ozone-depleting compounds and have organized their domestic industry to meet these goals. These "head-start" countries consume around 5 percent of the world production of CFC-113 and 1,1,1-trichloroethane in a representative variety of uses - but not all uses. Some of these countries will allow exemptions for particular essential applications if no environmentally acceptable alternative or substitute is available.

[b] Developing countries with strong technology transfer partnerships and/or aggressive regulatory regimes include countries like Mexico, Singapore, and Thailand. The phaseout can occur quickly in developing countries where the major quantity of ozone-depleting solvents are used by subsidiaries of multinational companies that have announced dates by which they will stop producing, selling, distributing, or using CFCs worldwide.

Logistical availability of chemicals and equipment will affect the actual rate of technical substitution. The Committee is particularly concerned that manufacturers of alternatives and substitutes worldwide may not be able to meet the demand for cleaning and process equipment and chemicals if the Protocol schedules lower production limits too soon after the Protocol is revised.

Business and financial circumstances including capital investment finance terms, import taxes, and investment incentives will also affect the pace of investment. Whether a factory is small or large, part of a multinational enterprise or an independent operation in a developed or developing country, an original equipment manufacturer or a subcontractor, and other circumstances will affect the access to information, incentive for change and autonomy of decision making. In some countries trade and other restrictions or requirements to requalify military and civilian products may slow the adoption of technology.

The Committee has found that many corporate managers are not yet sufficiently motivated to begin the phaseout. Furthermore, suppliers worldwide have reinforced this finding by reporting that the sale of new technology is surprisingly slow. The Committee is concerned that the suppliers of the new technology and chemicals that are reporting slow sales today will be overwhelmed by orders as the Protocol later restricts production of ozone-depleting substances.

National Experience in Phasing out the Use of CFC-113 and 1,1,1-Trichloroethane

Developed Countries: The phaseout of ozone-depleting solvents is occurring rapidly in developed countries. The "head start" countries such as Austria, Germany, Norway, Sweden and Switzerland have aggressive phaseout policies. The Swedish Environmental Protection Agency reports that on January 1, 1991 the use of CFC-113 for electronics, metal, and precision cleaning sectors was reduced by 99.5 percent from 1986 levels. CFC-113 use in dry cleaning is permitted until January 1, 1995. Swedish industry expects to phase out the use of 1,1,1-trichloroethane by January 1, 1995. German legislation calls for the phaseout of the use of CFC-113 and 1,1,1-trichloroethane by December 1992. In the United States, the use of CFC-113 is declining at a more rapid pace than that specified by the Montreal Protocol London Amendments.

Developing Countries: Strong cooperation, including financial assistance through the Interim Multilateral Fund, can help to phase out CFC-113 and 1,1,1-trichloroethane in some developing countries at the same time as in developed countries. For example, Mexico is implementing a programme to eliminate CFC-113 and 1,1,1-trichloroethane solvent use from its manufacturing industries by 2000. Northern Telecom, the Industry Cooperative for Ozone Layer Protection (ICOLP), and the U.S. EPA will provide technical support to the Mexican Government and industry to implement this programme.

The United States Environmental Protection Agency and the Ministry of International Trade and Industry (MITI) in Japan have announced that they will form new and precedent-setting partnerships for ozone layer protection. The partnership will encourage, jointly coordinate, and assist the efforts to phase out ozone-depleting solvents in South-East Asian countries. These precedents may encourage other governments and industry associations in developed countries to assist in similar technology transfer projects.

Corporate Experience in Phasing out the Use of CFC-113 and 1,1,1-Trichloroethane

Protection of the stratospheric ozone layer has become an important policy objective for companies that now use ozone-depleting solvents. These companies are acting out of concern for the environment and in response to economic incentives (e.g., price increases, chemical shortages, and prudent investment criteria) resulting from local, national and global regulation. These corporate policies confirm that large markets exist for substitutes and alternatives and reinforce the judgment of the Committee that phaseouts are technically and economically feasible. Many of these corporate policies also offer assistance in technology transfer to developing countries.

Two years ago only a few multinational corporations had announced goals to reduce and eliminate CFC and halon use. Now many including Apple Computer, AT&T, Boeing, British Aerospace Dynamics, Canon, Digital Equipment, Ericsson Telecom, Hitachi, IBM, Intel, Matsushita Refrigeration Company, 3M Corporation, Motorola, Nippon Electric Company (NEC), Nippondenso, Nissan Motors, Nissin Electric, Northern Telecom, Pratt and Whitney, Raytheon, Sanyo, Seiko-Epson, Sharp Corporation, Shiseido, Siemens, Texas Instruments, Toshiba, Toyota, and other major manufacturers will phase out CFC by 1995. Members of the Japan Camera Industry Association will phase out at least 95 percent of CFC-113 by 1995. Digital Equipment Corporation and Northern Telecom have set a new standard of corporate responsibility by donating patented technology for use without charge. The Digital technology is a demonstrated, highly sophisticated aqueous cleaning system that can be used for cleaning printed wiring assemblies. The Northern Telecom technology is a cleanliness tester for printed circuit boards assembled with no-clean flux.

Some of these companies have announced that they will also phase out 1,1,1-trichloroethane as early as 1993. These include Intel, 3M Corporation, and Raytheon. These companies indicated that the phaseout of these ODSs will occur on an accelerated schedule in all their facilities worldwide. These companies will transfer the information and technology for substitution of these materials to their subsidiaries and joint venture partners including facilities in nations that are not yet Party to the Protocol. These policies reassure developing countries that they can be at the forefront of new technology development and implementation and, furthermore, that in many cases corporate financing will be available in their countries. General Electric Company of the U.K. has designated the GEC Hirst Research Centre as the central information and technology dissemination facility for all the company subsidiaries worldwide.

A group of companies in North America, Europe and Japan formed the Industry Cooperative for Ozone Layer Protection (ICOLP) to share technical information on alternatives to ozone-depleting solvents. Japanese industry formed a group with similar objectives--the Japan Industrial Conference for Ozone Layer Protection (JICOP). The Technology for Clean Electronics (TRE) Project sponsored by the Scandinavian countries was formed to coordinate the exchange of non-proprietary information on alternative technologies, substances, and processes to eliminate ozone-depleting solvents; to act as a clearinghouse for information on alternatives. TRE will release the results of its evaluation of alternative cleaning and assembly technologies to countries worldwide.

One example of ICOLP's activities is the development and support of an alternative technologies electronic database called "OZONET." OZONET is accessible worldwide and has up-to-date information on the alternatives to ozone-depleting solvents. ICOLP has organized an effective programme to cooperate on the information dissemination efforts such as OZONET and on organising experts from member companies to share information to facilitate a CFC-113 and 1,1,1-trichloroethane phaseout in the electronics industry.

The metal cleaning industry, however, is not as well organized to match cleaning challenges to proven alternatives. Therefore, the Committee recommends that ICOLP more effectively involve companies doing metal cleaning. The U.S. Center for Emission Control intends to actively participate in this area. Effective cooperation in the metal cleaning industry could accelerate the phaseout by one to three years by:

- identifying the best technologies and avoiding redundant efforts
- by encouraging adequate supplies of equipment and chemicals
- by streamlining the resolution of application engineering problems which might arise.

New corporate and government procurement policies have also begun to discourage purchase of products dependent on CFC-113 and 1,1,1-trichloroethane use. Companies are also working simultaneously with their subcontractors and suppliers to assist their adoption of alternatives. At least three multinational companies (AT&T, IBM, and Nissin Electric) have policies to halt the purchase of products and components manufactured with CFCs after they phase out their use. These companies are providing technical assistance to help their suppliers worldwide in meeting this demand.

The U.S. Secretary of Defense has directed U.S. Armed Forces to eliminate the use of CFCs and halons and to avoid the purchase of products that depend on these chemicals. This policy is primarily in support of environmental protection, but recognises the strategic importance of avoiding dependence on chemicals that may be unavailable or expensive. Changes in military procurement are speeding elimination of CFC and 1,1,1-trichloroethane usage because the military is such an influential customer and its procurement standards are often followed for civilian manufacturing industry guidelines.

The U.S. Department of Energy (DOE) and the U.S. Air Force have a head start on elimination of halogenated solvents. The Air Force has evaluated a wide variety of innovative technologies to replace CFC-113 and 1,1,1-trichloroethane and has implemented these technologies at some of their facilities. The U.S. Government has funded a project to ensure that new projects can be transferred throughout the world. This head start has prepared the DOE and the Air Force to move more rapidly than other users.

Technical Options to Phase Out CFC-113 and 1,1,1-Trichloroethane

There is no single substitute for all uses of CFC-113. However, most solvent use areas have one or more available alternatives that can be adopted. In electronics cleaning, precision cleaning, and metal cleaning applications, there are a variety of alternative solvents and processes available that offer cleaning performance equal to, or better than, CFC-113 and that have acceptable costs. In the electronics industry options such as low-solids flux and controlled atmosphere soldering have been developed that eliminate the need for cleaning. Under certain circumstances, existing vapour degreasing equipment, with suitable engineering modifications, can be used for aqueous and semi-aqueous cleaning. Rinsing, water treatment, drying, and wastewater treatment may be required. This may help both small and large manufacturers to reduce the cost of eliminating ozone-depleting substances. New solvent cleaning machines have also been developed that minimize solvent emissions. Some of the emission reduction means developed for such new cleaning machines are easily field retrofittable at low cost and can immediately and substantially reduce emissions from existing solvent cleaning machines. The dry cleaning industry has a number of conservation and recovery methods that will minimize solvent use.

Like CFC-113, there is no single substitute for all uses of 1,1,1-trichloroethane. Because companies have only recently begun the search for substitutes and alternatives to 1,1,1-trichloroethane, there is less consensus on which options are best and some applications do not yet have commercially available alternatives and substitutes. The phaseout of 1,1,1-trichloroethane may require more time than that of CFC-113 because many 1,1,1-trichloroethane uses are in large-scale high-volume production and because of the large variety of uses, including diverse soils and materials to be cleaned. Nonetheless, there are steps that can be taken to reduce significantly the emissions of 1,1,1-trichloroethane from existing operations and to eliminate the use altogether from many applications where cost effective or not-in-kind substitutes are available to eliminate the use. For example, options such as vapourising cutting oils, ultrasonic drawing and forming, and oil burn-off eliminate 1,1,1-trichloroethane use in certain metal cleaning operations. Aqueous and semi-aqueous cleaning is often effective and affordable. In the adhesive, coatings, inks, and miscellaneous use sectors, some alternative technologies are commercially available while others are emerging. It is expected that alternatives will be found for most of these adhesives, coatings, and inks applications by the end of the phaseout period.

Metal Cleaning: This sector uses an estimated 55 percent of the world's annual production of 1,1,1-trichloroethane. Since the 1987 Montreal Protocol, there has been a shift to 1,1,1-trichloroethane from CFC-113 for limited applications by many users worldwide. There is a large aqueous cleaning sector already in the metal cleaning industry that can expand to absorb some current uses of 1,1,1-trichloroethane. Semi-aqueous systems, based on natural or synthetic substances will provide parallel options to aqueous cleaners. However, new drying methods may be needed to avoid corrosion when cleaning with water and must ensure complete drying of complex parts. The non-specific nature of 1,1,1-trichloroethane has allowed its wide use for all types of substrates and soils. With water based cleaners each soil must be matched to a particular type of cleaner. The phaseout of 1,1,1-trichloroethane might also cause some users to return to chlorinated solvents and non-halogenated organic solvents. In these cases, the use of new, low emission equipment will be essential to minimize worker exposure. There is less opportunity for "no-clean" technologies in the metal cleaning industries than in electronics cleaning but vapourising forming oils, ultrasonic metal extrusion, and electropolishing have been successfully applied to production processes and many cleaning steps can be eliminated or consolidated.

Electronics Industry: A wide variety of replacement chemicals and processes are commercially available. Alternative processes such as aqueous and semi-aqueous cleaning, alcohol, no-clean fluxes and controlled atmosphere soldering are widely accepted by industry over the last few years. Users of CFC-113 and 1,1,1-trichloroethane in these applications have a clear set of alternatives to choose from. Some military customers in the United States, United Kingdom, Germany, Sweden, and elsewhere have already authorized the use of some of these alternatives.

Precision Cleaning: Precision cleaning of delicate metal and optical components is another important use of CFC-113 and 1,1,1-trichloroethane. In certain precision cleaning operations, water based cleaning may not be feasible. In these cases it may be necessary to use alternative chemicals such as alcohol or transitional hydrochlorofluorocarbon (HCFC) materials. HCFCs have ozone-depletion potentials significantly lower than CFCs. These HCFCs are produced in pilot quantities and are being evaluated for a small percentage of precision cleaning uses where more environmentally acceptable alternatives have not been found. It is projected that these materials will be commercially available over the next several years assuming toxicity evaluations confirm their acceptability for use as solvents.

Adhesives: The phaseout of adhesive uses of 1,1,1-trichloroethane depends on a mix of commercially available and emerging technologies. Adhesive applications are more dependent on emerging technologies than are cleaning and coatings applications. Commercially available alternatives include hydrocarbon solvent based adhesives, water based adhesives, hot melt systems, and solvent recovery systems in continuous operations. Emerging technologies include radiation cured adhesives, "high solids" adhesives, powders, and reactive liquids. It is likely that any phaseout will occur more rapidly in cleaning applications than in the adhesives applications, though 3M Company (a large adhesive manufacturer) has announced a goal of 1,1,1-trichloroethane phaseout by the end of 1992.

The structure and character of the adhesive market differs in the United States, Europe and Japan. The do-it-yourself and small shop market is very large in the United States but not in Europe and Japan. In the United States adhesive manufacturers are reluctant to replace nonflammable 1,1,1-trichloroethane with flammable solvents due to liability concerns. The elimination of 1,1,1-trichloroethane in adhesives applications will take place more quickly if flammable solvents can be safely used. Alternative polymers could be developed to overcome the problems. For example, new polymers could improve the properties of water based contact adhesives.

Coatings and Inks: The phaseout of 1,1,1-trichloroethane use will take place through the use of commercially available technologies. Alternatives include water based coatings and inks, high solids coatings, and powder coatings. Accelerated applications technology and intensive development of formulations are required for the final phaseout of 1,1,1-trichloroethane solvent based coatings and inks.

Dry Cleaning: Dry cleaning is a relatively minor application of CFC-113 and 1,1,1-trichloroethane. There are numerous operating and maintenance procedures that can be implemented to reduce use in existing dry cleaning machines. New tight equipment currently on the market has extremely low emissions. Alternative solvents have been commercialized for use on most fabrics and are used in many countries. At present, perchloroethylene is the only practical alternative to CFC-113 in most dry cleaning applications. White spirit is another alternative to CFC-113 for cleaning most fabrics. White spirit will probably not be widely used, however, due to their flammability. HCFC-225 is a promising alternative for dry cleaning. 1,1,1-Trichloroethane and CFC-113 use in dry cleaning could also be reduced by establishing centralized cleaning facilities at which technical and procedural controls on solvent use could be implemented.

Miscellaneous Uses: 1,1,1-Trichloroethane and CFC-113 are utilized in a number of miscellaneous applications that are documented in this report. Alternatives are available to eliminate the use of ozone-depleting chemicals for most miscellaneous applications including carriers for coating and impregnation, vapour soldering, component drying, riveting and machining, fabric protection, semiconductor manufacturing and mould release agents. Some of these alternatives may have other environmental or safety concerns such as atmospheric pollution effects (VOC) and flammability. There are a few miscellaneous uses that do not have any commercially available alternatives and in a very few cases there are no currently available technologies that can be substituted for 1,1,1-trichloroethane and CFC-113 applications. These include pre-surgical skin cleaning and other small medical applications, motion picture film cleaning, flushing of oxygen lines, and coatings and adhesives for unusual markets such as Los Angeles, USA, where Volatile Organic Compounds (VOCs) are drastically restricted.

Potential Uses of HCFC Solvents

All but three of the Committee members estimate that HCFCs may replace two to five percent of 1986 CFC-113 and 1,1,1-trichloroethane uses as transitional substances and where no other alternatives or substitutes are currently available. Three committee members estimate that HCFCs may replace three to eight percent of 1986 CFC-113 and 1,1,1-trichloroethane. The higher estimate by three committee members reflects judgements about the portion of use in certain difficult-to-eliminate applications, the likely timing and availability of substitutes and alternatives, and concern that HCFCs may not be manufactured if the quantity demanded is too low. These applications include dry cleaning of special fabrics, some precision bearing and parts cleaning, and drying of certain metals. HCFCs will be used as transitional substances if they are not restricted by national or international legislation, if they can be easily qualified for military or civilian products manufactured to strict standards, or if they can be easily used in existing equipment with tight emission controls. HCFCs should only replace 1,1,1-trichloroethane on a transitional basis when the ODP is substantially lower than that of 1,1,1-trichloroethane.

Among the HCFCs, HCFC-225, which has the lowest ODP and highest boiling point, is the leading transitional substance to replace CFC-113 and 1,1,1-trichloroethane. On completion of satisfactory toxicity testing, it will be commercially available in two to four years. HCFC-123 and HCFC-141b may also be used in limited applications if emission rates from equipment can be reduced to environmentally acceptable levels and if they are necessary for cleaning some precision parts. HCFC-123 has a low ODP, but based on toxicity testing, some manufacturers are voluntarily recommending interim exposure limits of 5 to 10 ppm pending final evaluation of toxicity. HCFC-141b has the highest ODP of the HCFCs being considered, but its recommended exposure limit is 500 ppm. Although both HCFC-123 and HCFC-141b will be commercially produced by the end of 1991, only HCFC-141b is recommended by its suppliers for use in cleaning operations. HCFC-141b should not be considered as a substitute for 1,1,1-trichloroethane because their ODPs are comparable. The use of HCFCs in these limited applications should only be required for a limited period until environmentally safe alternatives become available.

Environmental Risk of Options is Uncertain

This document is primarily a technical assessment of alternatives to replace the use of CFC-113 and 1,1,1-trichloroethane. It is not a risk assessment but does contain general descriptions of environment, health, and safety issues of the acceptability of a substitute to replace CFC-113 and 1,1,1-trichloroethane.

Some of the options for the regulated substances might be deemed hazardous under national regulations. Nonetheless, the use of some hazardous chemicals is permitted by governmental authorities with proper work place controls, waste treatment, and/or disposal. In cases where such precautions are not taken it may be prudent to select cleaning options that do not depend on work place controls and waste treatment.

The carcinogenicity, mutagenicity (genotoxicity), acute, chronic, and developmental toxicity, neurotoxicity, and ecotoxicity of the alternative compounds that could be used in cleaning applications should be evaluated prior to their use. Waste solvent or waste water should be properly treated, disposed of, or destroyed to prevent the creation of new environmental problems in solving concerns about stratospheric ozone-depletion.

There are governmental and industry projects underway to study the human health and environmental implications of alternatives and substitutes to CFCs and 1,1,1-trichloroethane. For example, international manufacturers of new chemical alternatives to CFCs have formed several separate research consortia to conduct toxicity studies on partially-halogenated substitute chemicals (HFCs and HCFCs). The consortia, Program for Alternative Fluorocarbon Toxicity Testing (PAFT-1, -2, -3 and -4) are developing toxicity profiles on HCFC and HFC substitutes with broad commercial potential. Long term testing (two-year bioassays for these same chemicals) has begun or will soon begin with results of these tests available by 1992-95. The results of the tests will be evaluated by national governments in determining the acceptability of use of that chemical in that country. Individual manufacturers are also undertaking toxicity studies of other potential chemical alternatives.

Another consortium called Alternative Fluorocarbon Environmental Acceptability Study (AFEAS) is working to estimate ozone-depletion potential (ODP); to calculate global warming potential (GWP); to study mechanisms for atmospheric decomposition; to evaluate the atmospheric decomposition of products and their potential health and environmental effects; and to estimate their global warming impacts. A recent AFEAS study was sponsored by manufacturers of CFCs to evaluate the differences in energy consumption for alternative cleaning processes and for chemical cleaning processes.

The United States Environmental Protection Agency (EPA) is currently establishing a framework for evaluating the environmental impacts and trade-offs of current and future potential alternatives to ozone-depleting substances to ensure that substitutes for ozone-depleting substances will not cause other environmental problems as part of its implementation of national legislation.

The environmental risk characterization for the substitutes will involve a comprehensive analysis based on the following criteria: ozone-depleting potential, flammability, toxicity, exposure effects, energy efficiency, degradation impacts, air, water, solid waste/hazardous waste pollution effects, and global warming potential. The results of this U.S. work may be useful to other countries.

Conclusions

The Committee has drawn the following conclusions regarding a technically feasible phaseout schedule for CFC-113 and 1,1,1-trichloroethane use:

1. Phaseout of CFC-113 and 1,1,1-trichloroethane use is technically feasible according to the schedule specified in exhibit ES-1.

2. Strong government-industry interaction has enabled countries with aggressive phaseout goals (e.g., Sweden and Germany) to virtually phase out the use of CFC-113. German regulations call for phasing out the solvent use of CFC-113 and 1,1,1-trichloroethane by December 1992. German industry believes that it is possible to phase out the use of 1,1,1-trichloroethane by 1992, but it is requesting exceptions in uses for which the requirements cannot be fulfilled without high expenditures and/or without further damage to the environment. The Inter-Nordic project on Technology for Clean Electronics conducted by the Swedish Institute for Engineering Research has achieved impressive results. It has set up a verification regime for new alternative technologies to ozone-depleting solvent based technologies.

3. Opportunities exist for improved cleaning performance and innovation through the use of substitutes for CFC-113 and 1,1,1-trichloroethane. Industry will select alternatives based on the best technology for each application.

4. Multinational and national electronics manufacturers who announced new corporate policies to promptly phase out 1,1,1-trichloroethane and CFC-113 use have been successful in meeting their goals. By December 1991 Northern Telecom and Ericsson will have halted CFC solvent use worldwide.

5. HCFCs, which are transitional substances as defined by the Montreal Protocol, may need to be used for a limited period in certain uses where no other environmentally acceptable alternatives are available. HCFC-141b should not be considered as a substitute for 1,1,1-trichloroethane because their ODPs are comparable.

   All but three of the committee members estimate that HCFCs may replace two to five percent of 1986 CFC-113 and 1,1,1-trichloroethane applications as transitional substances and where no other alternatives or substitutes are currently available. Three committee members estimate that HCFCs may replace three to eight percent of 1986 CFC-113 and 1,1,1-trichloroethane applications.

6. No-clean, aqueous, alcohol, and hydrocarbon/surfactant (sometimes referred to as semi-aqueous) processes have been proven in production environments and have been accepted as substitutes for ozone-depleting solvents.

7. Existing vapour degreasing equipment in certain circumstances may be modified to enable use of the tank for aqueous and semi-aqueous cleaning. Utilisation of vapour degreasers as a tank for aqueous and semi-aqueous cleaners, with suitable engineering modifications is possible. This may help small and large manufacturers with a number of cleaners, to reduce the cost of shifting to alternatives. Electronics manufacturers with aqueous cleaning systems and associated water treatment facilities already in place can improve their cleaning system to remove all types of flux residues by placing a semi-aqueous module in front of the existing equipment.

8. Tightly closed solvent equipment for metal, electronics, precision, and dry cleaning that minimise emissions and worker exposure levels is manufactured in Europe, Japan and North America. The Committee strongly recommends widespread use of this type of equipment. Simple, low-cost, and quickly installed emission reduction retrofits should be considered for immediate use while alternatives to phase out CFC-113 and 1,1,1-trichloroethane are being implemented. Emissions reductions ranging from 20 to 50 percent are achievable. Application of best available technology can enable overall emission reductions up to 90 percent.

9. Work place controls and effective waste treatment and/or disposal services for certain alternatives may not be available in all locations. In these circumstances it may be prudent to select cleaning options that do not depend on work place controls and waste treatment.

10. Human health and environmental effects of the alternative compounds must be evaluated before their use. Waste solvent or waste water should be properly treated, disposed of or destroyed to prevent creating new environmental problems. More evaluation is needed and is being conducted by a number of industry groups and national regulatory agencies. Stringent German regulations, which have been put into force with short deadlines, may not

allow evaluation time for German users to test substitutes carefully.

11. The AFEAS/U.S. Department of Energy (U.S. DOE) study on global warming impacts of the phaseout of ozone-depleting substances has introduced the valuable concept of "total equivalent warming impact" (TEWI), a systems approach evaluating the direct (emissions) and indirect (energy) contribution to global warming. The AFEAS/U.S. DOE study of solvent alternatives concluded that: (a) all alternatives and substitutes have dramatically lower Total Equivalent Warming Impacts (TEWI) than CFC-113 use; (b) solvent systems using alternative solvents have calculated TEWI less than or equal to aqueous and semi-aqueous systems (water recycle and heat recovery were not considered in most scenarios); and (c) solvent emissions are substantial contributors to TEWI unless machines are fitted with technology to achieve lowest achievable emissions. It also concluded that aqueous and semi-aqueous systems can use more energy, and that the most inherently energy efficient process is usually a no-clean process. The study recommends that emissions and energy consumption be minimized by operating machines only when needed, using heat pumps in boiling solvent based systems, using closed loop systems and/or heat exchangers for aqueous or semi-aqueous cleaning, and modifying equipment for better control of solvent emissions.

    The Committee concluded that there are exceptions to the AFEAS conclusion that aqueous and semi-aqueous processes use more energy. The energy efficiency of aqueous and semi-aqueous processes can be higher than with solvents by carefully planning operations, selecting operating cycles, and using recycled (hot) water and heat recovery. However, a subsequent drying of parts rinsed in water can result in higher energy consumption than with solvents.

12. Information about alternatives to ozone-depleting solvents is critical in accelerating their phaseout. It is essential therefore to make existing information dissemination tools, such as the ICOLP OZONET database, widely available. Seminars and trade fairs where technology suppliers and buyers have an opportunity to exchange information are also essential in this effort.

13. An earlier phaseout date in developing countries will require the cooperation of their industry, the support of multinational corporations involved in these sectors, and the availability of resources under the Multilateral Fund.

CHAPTER TEN: EXECUTIVE SUMMARY
AEROSOL PRODUCTS, STERILANTS, MISCELLANEOUS USES, AND CARBON TETRACHLORIDE

Aerosols Products

Chlorofluorocarbons (CFCs) have been used extensively in aerosol products, mainly as a propellant but also as the solvent or active ingredient. In 1989 some 180,000 tonnes of CFCs were used worldwide in aerosol products, a reduction of some 120,000 tonnes since 1986. Additional reductions of CFC propellants have occurred since 1989 and CFC use in Chemical Manufacturers Association (CMA) reporting countries is estimated to be under 30,000 tonnes for 1991. For non CMA reporting countries an estimated 85,000 tonnes will be used in 1991. Substantial work is being carried out to reformulate the products which still use CFCs. In countries which have implemented phase out programs the remaining aerosol product uses are principally in the industrial and pharmaceutical sectors.

There are a wide variety of alternatives available to substitute CFCs in virtually all aerosol products. The optimal choice of alternative depends on the specific product under consideration. Each alternative has its own unique set of properties which need to be taken into consideration. These include toxicity, flammability, solvency, performance characteristics and cost.

Among currently available chemicals, the most commonly used substitutes for CFCs in aerosols are the flammable propellants, butane, propane and dimethyl ether. Their use requires precautionary measures to be taken during production, storage and transportation to prevent fire and explosion.

The majority of producers of non-medical aerosols have already or are likely to turn to hydrocarbons. This requires reformulation, retrofitting and sometimes relocation. Generally it has taken about one to three years to convert plant and formulations. In most countries this process is well under way.

In some countries strict regulations concerning the handling of flammable products have limited the use of these flammable propellants. Some countries require, for safety reasons, that hydrocarbons be "stenched" before shipment, making them suitable for aerosol filling purposes only after subsequent purification.

Currently available non-flammable propellant substitutes include compressed gases (such as CO_2 and air) and HCFC-22, alone or in mixtures. It must be noted, however, that if the product concentrate is flammable, a non-flammable propellant may not yield a non-flammable aerosol product.

Because of its price and its chlorine content (potential for ozone depletion), HCFC-22 is being used principally as a replacement for CFCs in products where conversion to flammable propellants has not been possible, for example electronic cleaners, mould release agents and freezants. HCFCs are regarded as transitional substances and at the second meeting of the Parties in June 1990, a resolution was adopted stating that HCFCs should only be used where no environmentally acceptable alternatives are available. By the end of this century, world aerosol use of HCFCs is, therefore, not expected to exceed 25 000 tonnes per year.

Non-propellant mechanical alternatives can also be used to apply or administer products that currently use CFCs. These include other spray dispensers such as finger pumps, trigger pumps, mechanical pressure dispensers, as well as methods such as solid sticks, roll-ons, brushes, pads, shakers, powder inhalers, nebulizers and plain powders.

New chemicals under consideration as possible substitutes for CFCs in aerosols include HCFCs -123, -124, -141b, HFCs -134a, -227 and -125. Their high cost may limit application to speciality products. In addition, the toxicology of these substances must be completed.

Non flammable chlorinated solvents such as 1,1,1-trichloroethane (methyl chloroform, MCF) and methylene chloride are used as solvents and are also substitutes for CFCs in aerosol products. The recent addition of 1,1,1-trichloroethane as a controlled substance to the Montreal Protocol, however, precludes its long term use as an alternative. Since its current usage is significant, reformulation will be required.

Alternatives to CFC-113 and 1,1,1-trichloroethane are considered separately in the UNEP Technical Options Report on Solvents.

Within the category of aerosols, specific medical products are recognized as the most difficult to substitute. Reductions can be made within this category if CFCs are used only where no alternatives can be used. Inhalant drug products often called medical or metered dose inhalers (MDI's) are the most difficult aerosol medical product to substitute. Powder administration methods are already on the market and may achieve wider market penetration than at present, but may not be a suitable alternative for all patients or drug products. It should be noted that inhalant drug products are important as treatments for asthma which currently affects some 5% of the world's population.

Some of the new HCFCs and HFCs may serve as substitutes in propellant medical products. All aerosol inhalant drug products, formulated with a new propellant will need time for extensive toxicological, clinical and product stability testing as well as approval from the appropriate health regulatory authorities. Manufacturers are conducting tests, but it is still unclear when, or if, substitution will be possible.

Inhalant drug products consume 5-6,000 tonnes of CFCs per year. No net reduction in the use of CFCs in these products is likely before the mid to late 1990s as the demand for inhalant drug products is expected to increase due to the increased prevalence and diagnosis of asthma. Consideration also needs to be given to an anticipated growth in the use of these products in developing countries.

Certain industrial and technical speciality aerosol products which currently use CFCs may also be difficult to substitute where flammable propellants are unable to be used for reasons of safety. Examples of these are aerosol sprays used in the servicing of electrical or electronic equipment. For these applications it is technically feasible to eliminate CFC use within the next few years. This process is already under way, using non flammable HCFCs as alternative propellants.

The quantity of CFCs consumed for industrial and technical speciality products in 1990 is believed to be under 10,000 tonnes in CMA reporting countries and up to 20,000 tonnes worldwide. A significant amount of CFCs are still used in Eastern European and Asian countries.

In conclusion, with the exception of inhalant drug products and specific industrial uses, CFCs used in aerosol products can be eliminated through substitution by currently available chemical or product alternatives. A reduction to some 15,000 tonnes worldwide is technically possible by 1995.

Sterilants

A mixture of CFC-12 and ethylene oxide (EO) is widely used by medical device manufacturers, contract services and hospitals for gas sterilization of medical equipment and devices. EO can be used in a 100% form (termed 100% EO) or diluted with other gases. EO (the sterilizing agent) is toxic, mutagenic, a suspected carcinogen, flammable and explosive. The use of 100% EO, therefore requires stringent safety precautions. In order to reduce flammability and explosion risks, EO is diluted with CFC12 to form a mixture of 12% (by weight) EO and 88% CFC-12 (commonly known as "12/88") and due to its potential health hazards must also be used with great care.

EO has the ability to penetrate a wide variety of packaging materials. This attribute is vital to the handling, storage and transport of products that are sterilized prior to their use. EO is especially useful for sterilizing heat and moisture sensitive products such as plastic catheters, electrical devices and non-metal implants. With recent developments in medical surgery, the quantity of such products has increased dramatically.

Methods for sterilizing medical equipment/devices have developed differently in different countries due to codes and regulations on fire protection and occupational safety, liability considerations, local suppliers of sterilization equipment and medical traditions.

The total use of CFC-12 worldwide for sterilization is estimated to be approximately 18,000 - 20,000 tonnes. 12/88 is used to some extent in at least 60 countries.

There are a number of options currently available to substitute CFCs in the sterilization of heat and moisture sensitive equipment in hospitals and industrial facilities.

Industry options include the use of 100% EO, mixtures of CO_2 or Nitrogen and EO and radiation sterilization. Hospital options include the use of 100% EO (single charge units), CO_2/EO gas mixtures, contract sterilization services (if available) and use of more steam compatible reuseable items.

The most difficult problem in phasing out the CFC/EO mixture is the sterilization of heat/moisture sensitive medical devices in hospitals. To reduce the use of 12/88, devices tolerating temperatures above 121°C and high concentration of moisture can be steam sterilized. Devices tolerating temperatures above 60°C may be sterilized with formaldehyde. Devices such as catheters and some fibre optics which are not tolerant of these temperatures and moisture levels have EO as the only effective, well established sterilant.

Larger medical device manufacturers and contract sterilization services often prefer to use 100% EO for products that cannot withstand steam sterilization instead of 12/88, because of a lower cost. Whenever product compatibility can be achieved, industry also favours radiation sterilization techniques, because this process is reliable, simple to control and readily validated. Many materials are, however, damaged when exposed to radiation. In addition, radiation facilities are costly to build and operate. The percentage of medical products currently being sterilized with 12/88 which could be reformulated to be compatible with radiation is believed to be small.

Most industrial and commercial users of 12/88 could convert to 100% EO. Existing 12/88 sterilization chambers can be used. Such a conversion, however, requires extensive and costly retrofitting for safety, including possible relocation within the hospital or plant or construction of a new facility.

Another well known alternative diluent for EO is carbon dioxide (CO_2) used in various proportions. One commercially available mixture with CO_2 is a mixture of 10% EO and 90% CO_2 (commonly known as 10/90). Another CO_2 mixture widely used in European hospitals is 15%EO/85%CO_2 used in sterilizers of German manufacture. This ratio can, however, change during use due to differences in vapour pressure between CO_2 and EO. Recent (1991) flammability data indicate that the maximum EO concentration may be lowered, probably in the range of 8.0 to 9.0 per cent.

10/90 requires equipment tolerating a much higher pressure than a comparable 12/88 process. These would be cost savings from not having to buy CFC-12 or its potential replacement chemicals.

Some small and medium size industrial and commercial facilities may prefer to convert to 10/90, because of a lower overall investment cost when compared with 100% EO. It is estimated that less than half of the hospital 12/88 sterilizers in use today are certified to work at the higher pressure needed for 10/90.

For non heat and moisture sensitive products, steam sterilization is widely used both in hospitals and by manufacturers because it is non-toxic economical, safe, and well accepted.

Surgical instruments and devices are often prepackaged in trays or sets for specific surgical procedures. Separating devices that can withstand steam sterilization (working at or above 121°C) from heat and moisture sensitive items can decrease the number of products to be EO sterilized.

In countries where formaldehyde is accepted, heat and moisture tolerant devices can be sterilized with formaldehyde, leaving a small number of devices that require EO sterilization. These can be sterilized either at the hospitals with 100% EO in small sterilizers; or, by the manufacturer; or, a third party sterilizing0 facility.

In some countries formaldehyde is not accepted, as is the case in the USA due to the chemical's status as a suspected carcinogen. In large hospitals in these countries the number of devices which need EO sterilization may preclude the use of small sterilizing units. One choice for these hospitals is to convert to 10/90 sterilization (with adequate training of personnel and proper equipment). This alternative is rejected by some as being a short term solution involving safety risks for personnel and patients or complex logistic problems to deal with single charge cylinders, as well as potential problems with polymerization and product compatibility. Many of these potential problems are being resolved. Another alternative, is to convert to 100% EO with the same type of precautionary measures as those used by manufacturers. A third option, is off-site contract sterilization.

Several producers have announced that they will commercialize new mixtures involving HCFC or HFC blended with EO. These blends are "drop-in" replacements for 12/88 in existing equipment, and could also be used in 10/90 equipment without changes. Such mixtures could play a critical role in hospitals which are currently using the 12/88 mixture. Extensive data has been obtained relating to material compatability, toxicity, aeration characteristics, penetration characteristics and sterilization efficacy. However, additional data may be required to obtain government regulatory compliance.

Substitutes are expected to be on the market in the early 1990s, well before 1995. The cost of the mixtures may exceed today's price of 12/88. Add-on engineering systems are available for recycling CFC-12 in sterilant gas applications. These systems or similar systems will also be available for recovery and recycling of substitute HCFCs and HFCs. These systems are quite complex and expensive, however, with the higher prices of substitute diluents, recovery systems may offer an attractive economic payback for industrial or large hospital users.

In conclusion, by using a combination of existing techniques, the current use of CFC-12 for sterilization can be substantially reduced and can be phased out not later than 1995, in developed countries.

Miscellaneous Uses

CFCs are used for a variety of other miscellaneous uses such as food freezing, tobacco expansion, fumigation, leak detection and cancer treatment. One use worth mentioning is the use of CFCs in laboratory procedures, for example, standard methods for analyzing oil call for either the use of CFCs or the use of carbon tetrachloride. New standard methods are therefore required.

The miscellaneous uses mentioned in this report are believed to consume, on a global basis, only a very small amount of CFCs. However, it is important to be aware of these and other miscellaneous uses when considering controls.

Carbon Tetrachloride

The primary use of carbon tetrachloride (CTC) is as a feedstock for the production of CFCs -11 and -12. As the use of these chemicals is phased out, the production of CTC will also be progressively reduced by means of plant closure and in many cases by switching production units to other uses.

There are some other feedstock uses of CTC which are allowed under the Montreal Protocol and are regarded by industry as essential. These include its use as a feedstock material for production of key pharmaceutical and agricultural chemicals and as a catalyst promoter in oil refineries. In these applications CTC is destroyed.

Involuntary production will continue to a limited extent, however, as CTC is a by-product in many chlorohydrocarbon production units. The majority of this material is recycled or consumed within the production complex.

It is essential to understand the distinction between allowable feedstock uses (where CTC is chemically transformed or destroyed) and dispersive uses (such as use as a process solvent where CTC remains unchanged).

CTC is designated as a probable 'human carcinogen' in many countries and therefore, in most countries its dispersive use is limited.

The main dispersive use is as a solvent for materials undergoing chlorination, the majority being used in the production of chlorinated rubber and small quantities being used as a process solvent in pharmaceutical manufacture.

In these applications, no alternatives have yet been identified. In order to find alternatives each chlorination reaction has to be evaluated and in many cases alternatives will be found.

Where CTC is used as a process solvent in the pharmaceutical industry, alternatives could require extensive approval over a 5-7 year time frame. In cases where alternatives cannot be found or the time frame for approval is lengthy, continued use may be required with appropriate recovery/recycling controls.

No other major uses of CTC have been identified where alternatives are not or will not become available. A very small application which will be difficult to replace is the analytical use of CTC for example, as an Infra red solvent in oil sample analysis.

Given the above, there is no reason the production of CTC for dispersive uses cannot be phased out by 1997.

It is recognized CTC is used in developing countries as a cleaning solvent. Alternatives for this application are widely available. Reference should be made to the UNEP Solvents Technical Options Report for clarification of its use and options for substitution.

Implications of An Accelerated Phase Out

Aerosol Products

With the exception of aerosol inhalant drug products and certain small uses in developing countries, acceleration of the CFC phase out from the year 2000 to 1997 would have a negligible impact providing transitional substances are available for a significant period of time following the CFC phase out. This condition is required to provide the time needed to cover the marketing cycle of products that have replaced non-flammable aerosols which previously used CFCs as propellants.

The availability of a ten year delay for CFC phase out in developing countries should ensure that new propellants will have time to be introduced as CFC replacements for those products where flammability currently limits the use of propellants that do not deplete the ozone layer.

In the majority of developing countries there is an economic incentive to use hydrocarbon propellants rather than CFCs. Lack of economic resources, land and trained personnel may constitute the main local obstacles for the replacement of CFCs.

One of the main efforts in the process of replacing CFCs in the aerosol industry of developing countries should be directed to ensure that safety standards at the manufacturing plant and at the consumer level are maintained.

Sterilants

There are no major technical reasons to preclude an accelerated CFC phase out. The continuous availability of EO either alone or mixed with CO_2 and the encouraging announcements made regarding the development of drop in chemicals, support this statement. The availability of transitional substances is a necessary condition until the non ozone depleting substances or alternative technologies are proven and meet the relevant regulatory approvals.

For large sterilization units there are economic advantages in eliminating CFCs as EO diluents. This may be done by making the necessary investments in an installation designed to avoid fire and explosion hazards in exchange for future reduced operation expenses gained by using 100% EO. Smaller units that need non-flammable mixtures for safe sterilization will continue to use CFCs until drop in chemicals become available. These units are important to improve health standards, but the 10 year delay granted to developing countries shall allow for a smooth introduction of drop-in chemicals and retrofitting of large units that still use 12/88.

Miscellaneous Uses

Most miscellaneous uses of CFCs can be abandoned in order to comply with an accelerated CFC phase out. For many of the miscellaneous uses, processes or alternative substances that do not require CFCs, are available. Some low volume uses such as in laboratory procedures and in linear accelerators used for cancer therapy may require continued use from recycled material or inventory until suitable replacements are available.

The number of niche markets in developing countries, grouped under this heading and the diversities between such countries make it difficult to generalize. Several miscellaneous uses have been reported for developing countries, such as food freezing and leak detection, however, it seems reasonable to assume that these uses can be phased out in the ten year period following the same process as in developed countries.

Carbon Tetrachloride

Provided that carbon tetrachloride (CTC) is recognized by users as a controlled substance and that appropriate work is carried out to facilitate its substitution in dispersive uses, there are no major technical reasons which would preclude its phase out in 1997. In the cases where alternatives cannot be found or the time frame for approval is lengthy, continued use may be required with appropriate recovery and recycling controls.

The grace period should provide ample room for developing countries to adopt the same measures as in developed countries. The availability of funding will speed up this process which has already occurred in most developing countries.

Summary of Technical Options Either Under Consideration or Currently Used

These options for reduction or substitution of controlled substances will be dependent on the specific application.

Sector	Options
Aerosols	Hydrocarbons Dimethyl Ether(DME) Compressed Gases, CO_2, N_2, N_2O, Air HCFCs 142b/22 HFCs 152a/134a/227 HCFC 123/124/141b Pump Sprays Solid Sticks Roll-ons Brushes/Pads/Shakers/Powder Powder Inhalers Nebulizers
Sterilants	Steam Sterilization 100% Ethylene Oxide CO_2/EO (10/90) and other CO_2 mixtures Formaldehyde HCFC-124/EO, HCFC/HFC/EO Radiation Gas plasma Vapour phase hydrogen peroxide Gaseous Ozone Chlorine Dioxide Electron beam radiation Off-site Sterilisation Good Housekeeping/ Optimisation Recovery/Recycling
Carbon Tetrachloride	Recovery/Recycling Other Solvents (eg. trichlorethylene, methylene chloride and perchlorethylene)
Miscellaneous Uses	
Tobacco Expansion	HCFC-123 Liquid CO_2
Freezants	Cryogenic methods (liquid N_2, CO_2) Air blast freezing Different approach
Analysis of Hydrocarbons	Other Solvents Hexane Infrared Spectroscopy
Dielectric Medium	Sulphur Hexafluoride

CHAPTER ELEVEN: SUMMARY AND CONCLUSIONS
HALONS

Introduction

The Halons are halogenated hydrocarbons that exhibit exceptional fire fighting and explosion prevention/suppression effectiveness. They are electrically nonconductive, dissipate quickly and leave no residue. Halon 1211 and halon 1301 have proven remarkably safe for human exposure.

Historical Development of Halon Usage

In the past twenty years halon 1301 has grown in usage as an agent for use in fixed fire protection systems primarily for the protection of vital electronics facilities, such as computer rooms and communications equipment rooms. Other significant applications for halon 1301 systems have included: repositories of cultural heritage; shipboard machinery spaces and pipeline pumping stations. Halon 1211 has been the halon of choice for portable fire extinguisher usage. In commercial and industrial applications halon 1211 portable fire extinguishers have been used in computer rooms, museums, art galleries and in offices for photocopy machines, personal computers and other electronic equipment.

Use Patterns, Production and Bank Estimates

Fire protection organizations, through educational programs, changes in technical standards and various other means have played an important role in making it known that use of halons must be drastically reduced and wherever possible alternative fire protection measures employed. The effect of these programs can be seen by the fact that production of halon 1211 and halon 1301 peaked in 1988 and is now declining. Production of halon 2402 within OECD nations has virtually ceased.

There are persuasive reasons to consider recycled halons as the prime supply of these agents. The first is to encourage responsible stewardship of the bank of halons and reduce potential ozone depletion. Users should also consider that it may not be economical for producers to continue to manufacture halons as markets continue to decline. There may be a transition phase where costs to produce halons rise dramatically to offset rising costs involved in producing smaller quantities.

The bank of halon 1211 should be sufficient to maintain existing equipment using recycled halon. However, for some early years after production phase-out some equipment may have to be taken out of service to provide maintenance quantities of halon 1211. Following expected shortages of maintenance quantities in the early years after production phase-out, it is expected that small quantities of halon 1211 may be available for new equipment until the bank expires.

It is estimated that the bank of halon 1301 will be adequate to maintain existing equipment for at least 40 years after production ceases. Also, it appears that recycled halon 1301 could be provided for new equipment after new production is curtailed (see Appendix C). It is estimated that for all practical purposes the halon 1301 bank expires 45 years after the production phase-out year.

It should be noted that the estimates provided for the bank will likely be affected by various new factors such as an early phase-out of production, efficiency of recycle programs, possible growth of use in the less developed countries, commercialisation of acceptable replacement chemicals and the uncertainty of the rate of decommissioning of halon fire equipment which could occur in the developed countries.

Fire Protection Alternatives to the Use of Halons

For many cases where halons have been employed there are alternative fire protection methods that can be utilized to reduce risk. The alternative fire protection choices offered in this report may not provide the same level of fire protection offered by the use of the present halons. In some circumstances greater fire loss and risk to people and property may result from the use of the alternatives outlined. However, concerns regarding environmental risk associated with the continued use of halons necessitate the serious evaluation of all other fire protection options.

Explosion Protection

Working spaces, whether manned or not, which may contain dispersed mixtures of fuel and air are at risk of severe loss of property or life should ignition occur. The propagation of flames through such spaces occurs so rapidly that evacuation of personnel is generally not possible. Enclosed spaces are subject to extremely rapid rates of pressure increase leading possibly to explosion of the enclosure. Explosions may lead to fatalities in the immediate area or in areas adjacent to the risk areas. Explosions may cause catastrophic failure of plant components leading to major fires, toxic releases, or environmental damage.

Protection of aerosol fill operations constitutes an important use of halon 1301. This special protection need arose due to the abandonment of the use of non-flammable CFCs as propellants in aerosol products. This transition in propellant technology took place in 1975 as an early outgrowth of the discovery of the catalytic role of chlorine in ozone depletion. Most CFC based propellants were replaced by hydrocarbon formulations which were typically mixtures of propane and isobutane. The advent of combustible propellants coupled with, in many cases, the combustible products being delivered presented an extreme potential hazard in the manufacturing environment.

The discovery of hydrocarbons in areas where extreme low temperature climatic conditions occur has led to the enclosing of hydrocarbon processing facilities. The early detection of hydrocarbon leaks allows the deployment of an inerting agent in to the enclosure prior to the attainment of combustible conditions. The unique flame-inhibiting and low toxicity properties of halon 1301 allow creation of an inert, yet habitable, atmosphere in the enclosure which prevents combustion from occurring should an ignition source be present.

The crew bays of military vehicles, such as armoured personnel carriers and tanks, face a potential mist cloud deflagration threat should one of the vehicle's fuel tanks be penetrated by armour piercing rounds. The main machinery spaces of war ships face a hazard from deflagrations of combustible machinery fluids in both peace time and war time. Halon 1301 deflagration suppression systems are employed in these spaces.

Halon 1301 has the unique property of being able to inert an enclosed space or suppress deflagrations at vapour concentrations which are tolerable to humans. Replacement of halon 1301 in such applications presents a significant challenge in fire or explosion protection situations involving human life safety for at present there are no known alternative agents which have this property.

Halon Emission Reduction Strategies

Avoidable halon releases account for greater halon emissions than those needed for fire protection and explosion prevention. Clearly such releases can be minimized if a concerted effort is made by the fire protection community with support from national governments. In reviewing reduction strategies, the Committee recommends the following:

- Reduce halon usage to essential applications only.

- **Discontinue protection system discharge testing using halon as the test gas.**

- **Discontinue the discharge of portable halon fire extinguishers for training purposes.**

- **Discontinue the discharging to the atmosphere of portable halon extinguishers and system cylinders during equipment servicing.**

- **Encourage users of automatic detection/release equipment to take advantage of the latest technology.**

- **Encourage the application of risk management strategies and good engineering design to take advantage of alternative protection schemes.**

Management of the Bank of Halons

Management of the bank of halons at a national level is possible through the various trades, producers, installers of fixed systems, extinguisher suppliers, companies in charge of filling, recovery or recycling. A national organization could be appointed to manage the bank of halons and should be responsible for certifying the companies involved in the process, in addition to the certification of equipment and installers. Environmental concern and restricted availability of the halons will likely encourage achievement of initiatives to manage the bank of halons.

Management of the banked halons is feasible, only if the following items are addressed:

> Financial assistance and positive national policies are developed to encourage accreditation and investment in recovery and recycle organizations and facilities.
>
> National policies and financial assistance are developed to deal with the storage and eventual destruction of contaminated halons.

In addition, to avoid the paradox of some nations requiring destruction of otherwise recyclable halons, at the same time that the Montreal Protocol allows continued production, it is recommended that international exchange of recyclable and recycled halons be encouraged to reduce requirements for new production of halons.

Halon Replacement Agent Research

The need for halons or halon-like materials to serve vital roles in life safety and fire/explosion protection in many applications will continue despite the development of new non-halon technologies as alternatives to the use of halons. The halon bank is expected to serve a portion of those needs for a period of time; however, replacements are needed now to ensure wise allocation of banked material with minimal environmental impact and to allow an eventual, orderly phaseout of halon use without unacceptable threats to safety. Replacements will also be needed once the bank is exhausted.

For clarity, two terms must be defined. A "replacement" agent is a halon-like, gaseous or volatile, clean fire extinguishant, explosion suppression agent and/or inertion agent. An "alternative" agent is defined as a not-in-kind, non-halon-like agent (e.g., carbon dioxide, water, foam and dry powder extinguishants).

Four requirements make halons difficult to replace: cleanliness/volatility, low ODP, low toxicity and effectiveness. It is relatively easy to find chemical agents that meet any three of these requirements; chemicals that meet all four are much more difficult to identify. Of course, other considerations for replacement agents exist; cost, storage stability and compatibility with engineering materials are among these.

Halon fire extinguishants can be separated into two groups according to their application: halons 1211 and 2402, with higher boiling points, in one group and the more gaseous halon 1301 in the other. Different chemicals will likely be needed for replacement of each group. Halons 1211 and 2402 are usually applied by streaming (direct discharge from a nozzle positioned remote from the fire). Such agents are used in localized applications and are often applied manually. Halon 1301 is most often used in total-flood applications (filling of an enclosed volume with sufficient agent to suppress combustion or explosions following ignition or to "inert" atmospheres to prevent ignition). Both clean streaming agents and clean total-flood agents are needed. Some very specialized applications may be best served by agents that combine characteristics of both types of agents. Other applications are difficult to categorize exactly.

TABLE 1. ANNOUNCED HALON REPLACEMENT CANDIDATES

Candidate	Formula	Application	Reference
HCFC-123	CF_3CHCl_2	Streaming	7
HFC-125	CF_3CHF_2	Total Flood	8
HFC-23	CHF_3	Total Flood/Pressure *	9
HFC-227ea	CF_3CHFCF_3	Streaming/Total Flood	10
HBFC-22B1	CHF_2Br	Streaming/Total Flood	11
HBFC-124B1	CF_3CHBrF	Streaming	12
FC-218	$CF_3CF_2CF_3$	Total Flood	13
FC-3-1-10	$CF_3CF_2CF_2CF_3$	Streaming/Total Flood	14
FC-4-1-12	$CF_3CF_2CF_2CF_2CF_3$	Streaming	15
FC-5-1-14	$CF_3CF_2CF_2CF_2CF_2CF_3$	Streaming	15

* HFC-23 has also been proposed as a pressurizing agent for use in expelling other halon replacement agents.

Work to date indicates that the development of general purpose, zero-ODP, direct replacements having attributes equal to those of the present halons may be unrealistic in the short-term and also possibly in the far-term. On the other hand, clean halon replacements with lower ODPs for selected specific uses are a realistic goal, particularly if trade-offs in fire extinguishment capability, toxicity and/or other characteristics are acceptable. However, there is some concern about the commercial viability of small volume chemicals.

Even though the research on halon alternatives is still in the early stages (as compared to CFCs), several zero- and low-ODP alternatives have been announced. Preliminary research indicates that the zero-ODP candidates have performance characteristics and design criteria that are significantly different from those of halons. Some of the low- ODP alternatives perform very similarly to halons. Such chemicals may prove to be important transitional substances as they may allow for reduced production of halons prior to the phaseout date. After the phaseout date, the use of low-ODP transitional substances may augment usage of banked halons for essential applications.

Uncertainties about future ODP, GWP and toxicity requirements are of great concern in the development and commercial viability of halon replacements. Government funding would shorten the time required for development of halon replacements. In considering the relative environmental issues, halon replacements must be evaluated in terms of existing halons and the roles of these agents. Regulatory actions have been largely based on the excellent progress made in CFC replacements with little recognition of the special role and developmental status of halon replacements.

Though the development of halon replacements continues and although very promising results have been obtained, it is unwise to make decisions based on announcements of candidate agents whose applicability remains to be confirmed and which, for the most part, require significant trade-offs in effectiveness, ODP and/or toxicity. Halon replacement chemicals are not at the same advanced stage of development as are many of the CFC replacements for refrigeration, solvents and other applications. Furthermore, considerable work must be done on systems engineering, approval testing must be performed and standards must be developed after acceptable replacements are identified.

For most applications, significant additional investment in research and development work is required to obtain acceptable agents which approach the efficiency of the existing halons. High-efficiency may require significant chemical suppression, which usually means the presence of bromine (or iodine). At present, very low-ODP, highly effective candidates have not yet been proven, nor have many such candidates even been identified.

Reduction of Military Halon Use

1 Sea Forces

The most probable course of action for world Navies relative to military sea halon 1301 applications would be:

a. Immediately adopt halon conservation practices (discontinue releases of halon for discharge testing or training, utilize recapture/recovery equipment for recharging and servicing).

b. Vintage existing systems. Adopt a policy that what is now owned will be kept (i.e. halon systems now in existence, or to be installed during the next few years, will continue to be supported for the remaining life of the vessel).

c. Minimize new halon installations for the next few years beginning immediately to adopt CO_2 or foam where appropriate.

d. As development/testing/system engineering is completed, specify new gaseous agents (or perhaps fine water mist) in lieu of halon for new installations).

e. Prior to the phase-out year, totally prohibit the incorporation of new halon systems in new ship designs.

Under this course of action, the only need for halon 1301 after the phase-out year will be to support, for their remaining economic life, whatever systems exist at that time. The key question then becomes: "Will the quantities of halon 1301 available to military sea applications (from military stockpiles and/or via priority allocations from the global bank) be sufficient to support existing systems for their remaining life?"

The support required for existing systems will consist essentially of replacement of leaky cylinders, refill cylinders following use on a fire, or refill following accidental or malicious discharges. With the cessation of discharge testing, these continuing "support" requirements will constitute a small percentage of existing systems storage quantities. Additionally, halon quantities available to support existing systems will be continuously replenished as halon is recovered from decommissioned ships and added to the stockpile.

2 Land Forces

The common fear of fires throughout the worlds' Armies is best summarized as follows: "Fire is the hideous, unspeakable nightmare of armour." Not since World War I aviation, where pilots (without parachutes) fought in "tinder boxes" of wood and fabric, surrounded by fuel and ammunition has a fear of a fiery death been shared so universally within the military. It is recommended that the following steps be taken: First replace halon hand-held extinguishers with carbon dioxide or some other environmentally acceptable clean agent. Second, develop evaluation programs for engine compartment substitutes. If these two tasks are pursued, peacetime fire suppression applications and discharges will be addressed. These applications are important because discharge of fire suppression systems in peacetime occur much more than actual combat (wartime) discharges. Third, the design of future combat vehicles should eliminate the need for an on-board fixed halon system in normally occupied areas. Passive design techniques to eliminate the flammables from these areas should be made a top priority for designers. Fourth, for those current applications of halon 1301 in fixed flooding areas of normally occupied areas, consideration should be given to only installing those bottles in times of actual combat and perhaps during live fire exercise or training from a dedicated war reserve. This should be done only until new vehicles without fire suppression systems in normally occupied areas begin to replace the currently fielded vehicles.

3 Air Forces

Many of the halon uses on-board military aircraft are identical to those on civil aircraft, however, some are unique. Because some combat survivability applications contribute to flight safety, many of the uses covered are identical to those found in commercial aviation and are required for flight certification.

Unlike civil aircraft, military aircraft which do not have civil equivalents, such as fighters and bombers, generally do not carry a formal flight certification. Aircraft which are used for both military and civil aviation are flight certified. Flight certification requirements, such as those imposed by the U.K. Civil Aviation Authority (CAA) and the U.S. Federal Aviation Administration (FAA), drive requirements to install halon on civil aircraft and by default, the military versions of those aircraft. Some certification requirements prescribe the use of halon, while other establish performance requirements for which halon is the only currently accepted means of passing the certification standard. Requirements for halon on military aircraft are usually driven by the concerns for survivability. Today, there appears to be little work in progress to find replacements for halon in aviation applications. Clearly, there is commonality between military and civil uses of halon in aviation. Technical solutions applicable to one will go a long way to solving the dependence of the other.

The ability to recycle the halon would greatly reduce the amount needed to maintain the existing fleet. The Federal Aviation Administration in the United States is working on a system to accomplish this. The project is still underway, but early indications are promising. It appears that a reasonably priced system to recover and recycle super pressurized halon 1301 from aircraft fire bottles will soon be commercially available. One of the issues that needs to be addressed is the quality specification for the recycled halon. Most specifications allow for negligible amounts of noncondensable gas (eg. nitrogen). This is a reasonable assuming virgin material delivered from the halon producer. Since the halon must be pressurized with nitrogen after being put in the bottle, it seems unreasonable to require it all to be removed before returning the recycled halon to the bottle. Additional testing is required to determine whether any contaminants surviving the recycling process can be detrimental to extinguishment. The project is nearly complete and the results are promising that halon from non- aviation sources, such as computer rooms, can be recycled into aviation halon bottles.

Comparing the amount of halon needed to service global military aviation requirements to the global bank and assuming a recycling capability, there appears to be an available supply that could last well beyond the expected lifetime of most existing aircraft.

4 Command, Control and Communications Facilities

Military command centres are often housed in facilities that have been specially hardened to withstand the effects of weapons detonations. The communications hubs within these facilities are sealed in special metal enclosures designed to insulate against electromagnetic interference. These occupied areas are often designed to use halon. The reason halons have been the fire protection strategy of choice in these facilities is the same as those cited for commercial data processing or communications facilities. Occupants can tolerate the halon and it does not damage equipment or facilities. The fire threat is primarily because the facility is a target during conflict, which is when the equipment is needed most. Occupant evacuation is usually not an option. These facilities are extremely expensive to construct and even more expensive to modify.

If halon were not an option during the design of the facilities, other fire protection strategies could be employed. One option would be to separate people from the most critical equipment and protect the equipment with carbon dioxide. However, this option would greatly complicate the design and construction of the metal enclosures, from both the blast resistance and electromagnetic isolation standpoints. Given an existing facility, it would be extremely difficult and expensive to modify the facility to eliminate halon.

Unfortunately, there is a little data on the number of facilities or the amount of halon installed. This makes it difficult to estimate the amount of halon needed to service these facilities. However, provided the halon can be recycled, future requirements for new halon should be minimal.

Special Needs of Developing Countries

The Halons Technical Options Committee recognizes that developing countries have shown a willingness to co-operate in the phasing-out of consumption of halons. Considering their present low levels of consumption and banked quantities, maintaining a different time scale is perhaps justifiable for the Less Developed Countries.

The following would assist the developing countries in protecting their present investment in halon systems and assist in reducing dependency in the future:

(a) Provide funding for technology transfer from national fire protection organizations in the developed countries. This could include training courses, seminars, etc. that would be provided in the nation seeking assistance.

(b) Provide assistance when new, environmentally acceptable, clean extinguishing agents become available to upgrade existing systems and equipment in as economical manner as possible.

(c) For multi-national corporations with subsidiary operations and/or joint ventures in developing countries, ensure that their subsidiaries are included in corporate policies and practices to reduce halon use to the same degree as is being followed in developed countries.

(d) Ensure that recovered halons from the developed countries that are suitable for recycle are made available for use in the developing countries to provide for recharge and service of existing halon fire protection equipment.

Decision II/3 of the Parties - Essential Uses and Their Needs

The following responds to the request that the Halons Technical Options Committee function as the ad hoc working group of experts established by Decision II/3 of the Parties.

> **Decision II/3 Halons:** To establish an ad hoc working group of experts to investigate, and make recommendations to the Fourth Meeting of the Parties in 1992 on the availability of substitutes for halons, the need to define essential uses of halons, methods of implementation and, if there is such a need, the identification of such uses.

> **Response:** The term 'essential' should be qualified in that it is not the halon that is essential, but rather it is the essentiality of a particular facility or equipment, protected by halon equipment, that is of concern.

> The Halons Technical Options Committee recognizes that there are fire/explosion risk scenarios for which current fire protection technology cannot provide adequate protection without the use of halons or halon-like replacement extinguishants. These uses involve an unacceptable threat to human life, the environment or national security, or an unacceptable impairment of the ability to provide essential services to society. At the same time, the Committee is of the qualified opinion that with proper management, the future needs of essential uses can be satisfied by redeployment of existing, banked halons until such time, beyond the turn of the century, as the bank expires. The Committee also notes that application specific, replacement extinguishing agents, are currently under development. In the long term, use

of these extinguishing agents, and others that may be developed in the future, may satisfy the needs of essential uses and restore the capability to provide fire protection with similar desirable characteristics to those of the present halons for other important facilities.

Although use of halon is desirable in a wide range of facilities, where the important characteristics indicated above are valuable, the Committee is of the opinion that establishing a list of essential uses is neither appropriate nor necessary at this time. However, because the importance of protecting the ozone layer is critical, the following criteria should be satisfied before reaching the conclusion that a new installation is an essential halon use:

> **A critical need must exist to minimize damage due to fire, explosions or extinguishing agent application, which would otherwise result in serious impairment of an essential service to society, or pose an unacceptable threat to life, the environment, or national security**
>
> **and**
>
> **All other appropriate fire protection measures have been taken.**
>
> **Note: Time to make appropriate changes in national fire codes, standards and regulations will be necessary before fully and safely applying these criteria.**

Cooperation at the international level is necessary to ensure that one nation's surplus halon is exported to meet the needs of another nation, rather than destroyed. This is particularly important for meeting the special needs of less developed nations, who will not have adequate halon banks to support their essential uses, and the Parties should consider special measures to address these needs.

The requirement to produce new halons for essential uses can be avoided if sufficient incentive is provided and investment is made in halon recycling, banking facilities, and halon alternatives utilization. Although it may be necessary to reconsider this issue in the future, the combination of successful bank management, and the proper utilization of lower and zero ODP halon alternatives, offers the best potential to eliminate the need for a production exemption for essential uses in the foreseeable future.

At this time a bank management and recycling infrastructure is not in place, and the status of replacement agents is only in the early stages of development. Therefore, the Committee believes that it is inappropriate to make a decision on the need for additional production after the phase-out year at this time, and recommends that the subject be re-evaluated at a later date.

Decision III/12 of the Parties

Decision III/12 (a) ... to evaluate, without prejudice to Article 5 of the Montreal Protocol, the implications, in particular for developing countries, of the possibilities and difficulties of an earlier phase-out of the controlled substances, for example of the implications of a 1997 phase-out;

Response: Should an earlier phase-out date be required to meet environmental objectives there are persuasive reasons to consider recycled halons as the prime supply of these agents. The first is to encourage responsible stewardship of the bank of halons and reduce potential ozone depletion. Users should also consider that it may not be economical for producers to continue to manufacture halons as markets continue to decline. There may be a transition phase where costs to produce halons rise dramatically to offset rising costs involved in producing smaller quantities.

A major difficulty of an earlier phaseout of production of the halons is that our knowledge of the existing bank is incomplete and future requirements are uncertain as no direct replacement agents have been identified. The final impact of "transitional substances" is uncertain are their environmental acceptability and fire protection usage is still in doubt. It should also be recognized that, as yet, no country has established halon bank management on a national basis. In addition, a problem exists in most developing countries and some developed countries in that existing national halon banks may be inadequate to satisfy future essential needs and the ability to trade recycled halons internationally is uncertain.

The developing countries have shown a willingness to co-operate in the phasing-out of consumption of halons and considering the low levels of consumption and banked quantities maintaining a some difference in a phase-out time scale is perhaps justifiable for the Less Developed Countries.

Decision III/12 (b) ... to identify the specific areas where transitional substances are required to facilitate the earliest possible phase-out of controlled substances, taking into account environmental, technological and economic factors, where no other more environmentally suitable alternatives are available. The quantities likely to be needed for those areas and for those areas of application currently served by transitional substances shall both be assessed;

and

Decision III/12 (c) ... to identify the transitional substances with the lowest potential for ozone depletion required for those areas and suggest, if possible, a technically and economically feasible timetable, indicating associated costs, for the elimination of transitional substances;

Response: Though the development of halon replacements continues and although very promising results have been obtained, it is unwise to make decisions based on announcements of candidate agents whose applicability remains to be confirmed and which, for the most part, require significant trade-offs in effectiveness, ODP and/or toxicity. Halon replacement chemicals are not at the same advanced stage of development as are many of the CFC replacements for refrigeration, solvents and other applications. Furthermore, considerable work must be done on systems engineering, approval testing must be performed and standards must be developed after acceptable replacements are identified. The final impact of "transitional substances" is uncertain as their fire protection usage and environmental acceptability is still in doubt.

Conclusion

An orderly transition to alternative fire protection measures, establishment of procedures to adequately manage the bank of halons and increased efforts to develop transitional and eventual replacement fire extinguishing agents with the beneficial characteristics of the present halons, may minimize the loss of fire protection capability represented by the phaseout of the halons.

As members of a global society, the international fire protection community, as represented by the members of the Halons Technical Options Committee, shares a common concern and recognizes the importance of environmental risk posed by the halons. The risk to human life is the crux of the problem and as such a decision based on an integrated overview that balances threat from ozone depletion and threat from fire or explosion must be made by the Open-Ended Working Group of the Parties.

CHAPTER TWELVE: EXECUTIVE SUMMARY
ECONOMICS

I. OVERVIEW

S.01 Recent developments in the international effort to protect the stratospheric ozone layer reveal both opportunities and dangers. The transition out of ozone-depleting substances is proceeding more rapidly and at a lower economic cost than had been expected. However, recent evidence indicates that the global ozone depletion problem is worse than had been predicted at the times when the Montreal Protocol (1987) and the London Amendments (1990) to it were reached. Furthermore, successes to date should not obscure the difficulties that remain to be surmounted.

S.02 In the light of what has already been achieved, the most important remaining barriers to the successful transfer of ODS-replacing technologies are more likely to be informational, organisational and financial rather than political, technical or economic. Measures to deal with these barriers have been identified and implementation, though at an early state, is underway.

II. LESSONS FROM THE TRANSITION

S.03 Several valuable lessons can be drawn from the experience of implementing the process of ODS substitution. As in any complex social process, there is no guarantee that future events will unfold as they have in the past, but awareness of the main features of the dynamics of the transition as observed so far should guide the Parties as they negotiate the next revisions of the Protocol.

S.04 **LESSON 1. Technological optimism is amply justified by the historical record.** Innovation to replace CFCs has been rapid, effective, and economical. Fears that substantial cutbacks in the use of ozone-depleting substances (ODSs) would reduce the quality and/or increase the price of goods and services previously dependent on CFCs have largely been proven groundless. While the path of technological substitution has not always been smooth, and although it is probable that some setbacks and disappointments will occur between now and the final phase-out of ozone-depleting substances, it has nevertheless been generally true that scientific, engineering, and entrepreneurial innovations have been sufficient to overcome the losses of ODSs. Not only has it been technically possible to replace CFCs in a continuously expanding range of applications, but in many cases it also has been relatively inexpensive or even profitable to do so. And while it may be expensive to substitute for some high-value uses of ODSs as the phase-out deadline approaches, it is only in a few highly specific case that such replacements might prove to be infeasible.

S.05 **LESSON 2. Private sector firms and governments in the developed countries have moved faster than they were required to by the formal regulatory structure of the Montreal Protocol.** There are a variety of reasons for this unexpected development, including the presence of strong and broadly based public sentiment to protect the stratospheric ozone layer, competitive and wider regulatory pressures inducing firms to innovate, and a general sense of responsibility shared by corporate and government leaders. Environmental protection need not be a burden or an impediment to productivity. Protection of the ozone layer has provided an impetus to scientific and industrial progress; and the benefits of focussed research and development appear to have exceeded the cost of those efforts.

S.06 **LESSON 3. A spirit of partnership, cooperation, and devotion to widespead information exchange has greatly speeded the substitution process and lowered its economic cost.** Joint efforts between firms, between private companies and governments, and between the governments themselves are all contributing to the success of the ODS replacement process. Engineering breakthroughs, transfers of technology, and manufacturing innovations are all information-centered processes. The greater the extent of information exchange, the more rapid and efficient is the pace of change. This is illustrated by the success of the electronics industry in moving away from CFC solvents; even though the technical demands for solvents in electronics manufacture are very high, the CFC phase-out will be accomplished in advance of the Protocol's schedule largely because of this industry's active approach to the diffusion and exchange of information. Corporate partnerships may also prove to be a more valuable source of technical assistance and transfer to the developing countries than formal inter-governmental funding mechanisms such as the Interim Multilateral Ozone Fund.

S.07 **LESSON 4. Developing countries have played a major and positive role in the drive to preserve the ozone layer.** Negotiation of the Montreal Protocol and its subsequent revision have brought forth a new spirit of international cooperation to protect the global environment. Individual nations have been able to arrive at a consensus based on scientific appraisal of the threat posed by ODS chemicals, and have been able to codify that consensus in a working international agreement. Recognition of the special circumstances of the developing countries (in the original Protocol) and the establishment of the Interim Multilateral Ozone Fund (in the London Amendment) demonstrate that the developed and developing countries are able to agree on an equitable burden-sharing arrangement. The commitment by the industrialised countries to meet developing countries' incremental costs of compliance with the Montreal Protocol embodies the vital principle that global environmental protection need not be purchased at a price of sacrificing the economic development of the lower income nations. Indeed, the contingent technology transfer process is very likely to prove growth enhancing. In response to this tangible evidence of economic cooperation, developing countries have taken the same type of steps necessary to protect the ozone layer as those taken by the industrialised nations. And even though differences of national interest, industrial structure, and internal policy remain, the ozone protection accord shows that the dual goals of universal economic growth and global environmental protection are not mutually inconsistent.

S.08 The nations that are participants in the effort to control ozone depletion have a unique chance to ride a wave of rapid technological progress at this moment in history. Determination by governments, business organisations, and citizens of the planet to avert catastrophic destruction of the stratospheric ozone shield has resulted in an explosion of scientific, technological, and diplomatic creativity. It is fortunate, in the light of recent scientific evidence on ozone losses already incurred, that the world community can draw on these reservoirs of technical and political success as negotiations proceed on preventing further damage to the ozone layer. However, meeting the challenge to accelerate the ODS phase-out will place heavy demands on these resources and require appropriate incentives to guide their efficient exploitation and replenishment.

III. THE WIDER POLICY CONTEXT

S.09 The forthcoming negotiations during the October 1992 Meeting of the Parties will be influenced by the wider context of current international debates regarding the economics of environmental policies. The key relevant issues are (1) economic efficiency, (2) equity and (3) the inter-play between the established institutions and policies relating to international trade and those newly emerging from negotiations over the ways and means of managing major risks to the global environment.

S.10 **Economic Efficiency.** The main focus of the economic efficiency debate is the real resource cost of realising the objectives of environmental policies. The resource costs of the relevant policy options vary, often by substantial magnitudes. The difficulty of their measurement can also vary by the nature of the implementing measure. For example, regulatory controls tend to provide a high level of certainty in environmental effect, assuming that compliance can be secured, but tend to obscure the resource costs incurred. In comparison, the resource costs of economic, or market-based, instruments tend to be more transparent in that they are more readily reflected in market prices, whilst their accurate calibration, at least initially, can be difficult given the usual deficiencies of information on market dynamics. A practical way forward is to start by calibrating the economic instruments at relatively low values and to increase them gradually in the light of experience towards values that are consistent with the environmental policy objectives. If this can be done within a well-specified and well-publicised policy regime, economic theory and practice suggests that the environmental policy objectives are likely to be realised at minimum resource costs. Whilst this proposition is widely accepted, the process of policy appraisal often results in a policy choice that combines regulatory and economic instruments with a view to drawing on the greater certainty of the former and the greater economic efficiency of the latter.

S.11 In the current climate of environmental policy debate, the Montreal Protocol, as a regime of quantitative regulatory controls, could be subject to scrutiny on the resource costs of compliance. Prospective changes in that regime imply changes in the costs of compliance. However, in the current state of knowledge in the relevant areas of science, environmental effects and economics, it is not possible to closely measure the changes in compliance costs contingent on specific changes in the regime; the same applies to the contingent changes in benefits. This means that any assessments of net benefits can only be broad estimates subject to substantial uncertainty.

S.12 In these circumstances, it is unlikely that the Montreal Protocol's regulatory regime will come under effective pressure from this direction. It is more likely that the debate over the comparative advantages of regulatory and economic instruments will be pressed in the context of national implementation policies designed to achieve the regulatory targets. There could well be pressure on the design of national implementation policies with a view to improving their economic efficiency with clear carry-over implications for the identification and funding of 'incremental costs' under the Interim Multilateral Fund.

S.13 **Equity.** The implementation of environmental policies imposes costs and generates benefits. Those who enjoy the benefits are not necessarily those who carry the cost burden. Even though the environmental policies might increase overall social welfare in the sense that the benefits out-weigh the costs, the issue of equity remains. Therefore, gaining general participation in voluntary environmental agreements, or even effective compliance under statutory regimes, requires careful attention to be given to who gains and who loses and to the role of compensatory mechanisms in securing agreement and effective compliance. These considerations extend to global environmental policies.

S.14 Such policies tend to benefit all people but not necessarily to the same extent; and the distribution of cost burdens do not necessarily conform to the 'polluter pays principle', nor to the incidence of the benefits enjoyed, nor to the capacity to pay. Compensatory schemes cannot fully resolve these equity issues, but they can be essential to the securing of sufficient participation and compliance to ensure the effectiveness of global environmental policies.

S.15 The creation of the Interim Multilateral Fund under the Montreal Protocol is an example of such a scheme. It has the effect of reducing the costs to developing countries of accepting the commitments undertaken by becoming Parties to the Montreal Protocol. The main mechanism is to reduce the cost of securing the transfer to them of those technologies which make it possible for them to eliminate their use of ozone-depleting substances. Whilst recognition of this role of the Fund has been endorsed by its establishment, much remains to be done to ensure its operational effectiveness.

S.16 **International Trade and Environmental Policies.** The inter-relationships between trade and environmental policies have become an active area of debate in the OECD Trade and Environment Committees and within the institutions of the GATT. There is concern from the environmental side that international trade policies do not take the objectives of environmental policies sufficiently into account; and conversely, the trade side is concerned about the tendency for environmental policy regimes to include trade restrictions as a means of enforcing compliance without giving adequate attention to the implications for the objectives of international trade policies. The OECD and GATT discussions should help to clarify the main issues of concern and to signpost the way to greater complementarity between international trade and environmental policies.

S.17 The provisions set out in the Montreal Protocol for the use of trade restrictions in pursuit of its environmental objectives provides a prime example of the concerns of the trade authorities. These trade restrictions were designed to give non-Parties commercial incentives to become Parties to the Montreal Protocol. Over time, it is likely that these measures will have their desired effect. The potential distortions to trade are unlikely to be substantial. But there is concern that the use of trade restrictions might be proposed for policy regimes designed to control other environmental problems, especially that of global warming. Given the magnitude of the global warming issue, the use of trade restrictions to enforce compliance with any abatement control regime for emissions of greenhouse gases could result in trade distortions and welfare costs of serious consequence.

S.18 Whilst attitudes towards the trade restrictions set out in the Montreal Protocol might well be influenced by the wider debate, there is no immediate focus on potentially effective pressure on these provisions. It remains to be seen whether challenges to these trade restrictions will be raised through the GATT complaints procedures in future as they begin to impact on the interests of Non-Parties. The rulings of GATT on such potential challenges cannot be foreseen as they are likely to depend on the highly specific circumstances of individual cases.

S.19 It will be necessary to monitor closely developments in these wider international policy debates for their potential implications for the implementation of the Montreal Protocol. In particular, there is a rapidly evolving need to clarify the implications of trade agreements for the legality of more stringent national and international measures to protect the ozone layer - and other global commons.

IV. CONCLUSIONS

S.20 The 1991 Economic Options Committee has agreed the following statement of its conclusions which is based on the 1989 Economic Panel Report, other materials available to it and its own deliberations.

S.21 **A SENSE OF URGENCY.** New scientific evidence continues to reveal more rapid depletion of the stratospheric ozone layer than indicated by scientific prediction. The implication is that the estimated economic benefits of damage cost avoidance associated with the current ODS phase-out schedules of the Montreal Protocol have increased from what they were prior to this new evidence on ozone depletion (ie the gross economic benefit curve has shifted upwards). However, the economic cost of eliminating the use of ODSs associated with the current phase-out regime have remained unchanged or have decreased (ie the cost curve has remained as it was or more probably has shifted downwards). Another way of putting this is that the benefits of ODS substitution appear to be very high compared with the costs; this implies that any loss of these benefits due to delays of implementation could be expected to greatly exceed the possible cost savings that might accrue from taking the time to fine-tune the response to make it more "cost-effective".

This line of reasoning suggests that the phase-out schedules could be accelerated without diminishing net benefits below that pertaining when the current phase-out regime was agreed by the Parties. However, the extent of any acceleration is also important as the economic cost could be expected to rise if the phase-out period does not allow sufficient time for substitutes and new technologies to become readily available. The available scientific and economic information is insufficient to permit meaningful quantitative estimation of the implied changes in net benefits associated with changes in phase-out schedules. Therefore, the choice of the economically optimal degree of acceleration in the phase-out schedules cannot be determined analytically.

The sense of urgency in curtailing the emissions of ODS chemicals also extends to recycling. It is a weakness of the Protocol that it does not include emissions from existing sources of equipment that leak ODSs into the atmosphere. The only incentives for recycling under the Protocol arise because recycling makes it possible to continue using existing equipment for longer thereby slowing the pace of the switch-over to ODS substitutes. The strongest incentives for recycling operate through the market. If producers increase their demand for recycled materials in response to rising prices for newly produced ODS materials or their substitutes as the restrictions on controlled substances become effective, then markets for recycled materials will be stimulated. Whether the markets will flourish depends on the availability and cost-effectiveness of the requisite recycling technology. However, the recycling market can be weakened by uncertainty about future costs and availability of substitutes and by inadequate policy pressure on the prices of ODS chemicals. In these circumstances, special fiscal incentives for recycling could help to achieve a faster rate of reduction in the emissions of ODS chemicals.

Furthermore, in responding to this sense of urgency, we should be aware that an inadequate or delayed response to worsening stratospheric ozone depletion may make it increasingly necessary to take measures to contain the adverse impacts of ozone depletion on human health and to deal with rising agricultural and ecological risks.

S.22 **TECHNOLOGICAL OPTIMISM.** The case for accelerating the phase-out schedules is supported by the evidence for technological optimism in the development of substitutes for ODS chemicals. Certainly, the progress of the substitution process has been more rapid than expected. There is specific evidence that what were seen, not so long ago, as big and difficult problems have been successfully dealt with much more quickly and at lower cost than expected. That is not to say that the process of ODS substitution has been or will be easy or simple to realise. It is vitally important that appropriate incentives are in place to motivate and guide the actions of the key players. Market forces have played a major role in this process as industry has had to respond to the commercial implications of the regulatory regime set out in the Montreal Protocol and to the changes in the behaviour of consumers associated with their growing awareness of the ozone depletion problem. These forces have driven the changes in commercial reality that have led industry to accelerate its research and development, investment and marketing efforts in pursuit of competitive advantage in a changing marketplace. However, it is recognised that sustaining the pace of achievement may become more challenging as the substitution process proceeds. For example, representations have been made to the Committee to the effect that difficulties are expected in substituting for methyl chloroform (1,1,1-trichloroethane) in metal cleaning applications, especially in view of its diversified uses by large numbers of small enterprises which do not necessarily have the incentives or the capacity to respond actively to the regulatory regime. Other challenges for the phase-out of ODS chemicals include (a) the costs of capital equipment re-tooling, redesigning, retro-fitting and some early scrapping of air conditioning equipment; and (b) rigid foams for which non-toxic substitutes may not be readily available.

S.23 **EVIDENCE OF DYNAMISM.** The dynamism which has characterised the responses of the key actors provides convincing evidence of their commitment to accelerating the ODS substitution process. The Second Meeting of the Parties (London, June 1990) agreed (1) to accelerate the then existing phase-out schedules (2) to extend the scope of the Protocol to additional ODS chemicals and (3) to establish new incentives for non-Party countries to accede to the Protocol. Individual governments continue to press for more rapid phase-out schedules. The Parties established The Interim Multilateral Ozone Fund to facilitate the technology transfer to eligible developing countries through the provision of finance, technical assistance and information services. Several of these developing countries have made impressive progess with the implementation of the ODS substitution process.

Industry continues to respond dynamically to the challenge of developing and marketing ODS substitutes, in reducing their own use of ODS chemicals, and in making technology transfer a reality.

S.24 **REDUCING UNCERTAINTY.** At present, there are major uncertainties with respect to the ODS substitution process that are being faced by the developing countries. These include the costs of compliance and the extent to which their incremental costs will be covered by the Interim Multilateral Ozone Fund. Uncertainty cannot be eliminated. However, there can be substantial benefits from reducing uncertainty where it is possible to do so at acceptable cost. These uncertainties could be reduced by pushing forward the programme of country studies and resolving the outstanding issues regarding the modus operandi of the funding mechanism. The operating procedures of the Interim Multilateral Ozone Fund need to be well-defined, widely known and widely accepted. Delays in realising an adequately staffed and funded Secretariat are reflected in the small number investment projects currently under consideration and the lack of any disbursement of funds as of October 1991. Their effects also extend to delays in the delivery of the mandated technical assistance and information services. Progress in expediting these matters was made during the Third Meeting of the Parties (Nairobi; June 1991) but much remains to be done. As this process evolves, it is fundamental to its success that the Parties sustain confidence in the efficacy and equity of the operating procedures of the Interim Multilateral Ozone Fund.

S.25 **SUBSTITUTION COST PROFILES.** The incremental cost to individual countries of the substitution process for controlled substances varies with respect to (1) their end-uses of ODSs; (2) the extent to which ODSs are imported or produced domestically; (3) the extent to which a country exports these chemicals, or products containing or requiring them in their production processes; and (4) the size of their ODS-related markets relative to the size of their respective domestic economies. As the cost of substitution varies by end-use (eg foams; refrigeration; aerosols; fire suppression), differing structures of end-uses and sources of supply can significantly affect the incremental cost of ODS substitution. Countries which produce ODSs tend to have higher substitution costs than those which rely on imports. Export-oriented countries tend to address the substitution process more aggressively than those which focus on their domestic markets; the need for export-oriented countries to foster their competitiveness in world markets drives forward the substitution process with the costs usually being subsumed in market prices.

S.26 **THE ROLE OF INFORMATION.** The work of the Committee has made it clear that information is a key resource in the ODS substitution process, not least through reducing uncertainty. It is information on the extent of ozone-depletion and the contingent damage costs that motivates the ODS substitution process, and it is information on alternative technologies and processes that makes substitution possible. Furthermore, the effectiveness of the Interim Multilateral Ozone Fund will be built on efficient information flows; it requires a flow of information to the developing countries on what is available and a return flow on the incremental costs of the substitution process as essential inputs into decisions on the financing of technology transfer. Information, in the form of data reporting is essential to ensure compliance with the Protocol. It is critical to the success of the Protocol that the resources necessary are available to ensure that these information flows are generated, managed and disseminated efficiently.

S.27 **TRANSITIONAL CHEMICALS.** Accelerating the phase-out of the controlled substances would raise the demand for transitional chemicals. Consortia of international chemical companies are conducting unified risk assessments of the myriad of chemicals presently being considered as potential substitutes for CFCs. It is essential that the search for zero ozone depleting replacements for CFCs should not foreclose intermediate steps that would help to alleviate the problem. Uncertainty surrounding the regulatory fate of the so-called "transitional chemicals" (ie the HCFCs) could delay or preclude their production and adoption, with the perverse consequence that CFCs with much greater ozone-depleting and global warming potentials would continue to be used. One of the major challenges for the negotiators in revising the Protocol will be to allow a sufficient window for transitional chemicals to supplant CFCs in the near term, which would allow investments in their supply to be recovered, without opening the door for unacceptable environmental damage caused by indefinite or excessive reliance on such chemicals. Whilst it is technically feasible to meet these conditions, it is not clear how to translate them into a workable regulatory framework. One of the chief difficulties is that percentage cut-backs in their use, applied to each individual country, would not constitute a reasonable control scheme because the market for these chemicals is only in an early stage of development.

S.28 **UNIFIED RISK ASSESSMENT.** It has become clear that the evaluation of substitute chemicals and technologies must have regard to technical criteria other than their respective ozone-depleting potentials (ODP). The major examples of other relevant criteria are their respective implications for climate change, molecular stability, toxicity and flammability. The use of multiple criteria complicates the evaluation process in that it makes additional testing necessary and tends to produce mixed results in performance testing. The ranking of the possible ODS substitutes are likely to differ across the criteria. Hence, uniquely dominant substitute are likely to be exceptions. Thus the choice of substitutes for specific ODS uses is likely to depend on specific factors rather than to be generic solutions.

V. RECOMMENDATIONS INCLUDING RESPONSES TO DECISION III/12 OF THE PARTIES

S.29 The Economic Options Committee makes the following recommendations and responses to the issues set out in Decision III/12 of the Parties to the Montreal Protocol based on the 1992 Economic Panel Report, other materials available to it, and its own deliberations.

S.30 **With regard to whether the phase-out schedules of the ozone-depleting substances subject to the Montreal Protocol should be accelerated, our response is as follows.**

As set out in paragraph S.20 above, there is an economic case for accelerating the ODS phase-out schedules. We cannot determine the optimal reductions in these schedules analytically given the uncertainties attached to the available scientific and economic information. However, it is our judgment, based on our reading of the available evidence, that the phase-out schedules could be accelerated by three years without incurring a diminishing level of net economic benefits; more rapid accelerations would be expected to encounter steeper rises in substitution costs with the implication that net benefit levels, though still large, might be diminished. Although, the information available to us will not support the estimation of meaningful quantitative changes in the level of net benefits associated with changes in the regulatory regime, it is our judgment that a three year acceleration is close to the margin of acceptability. Whilst recognising that methyl chloroform (1,1,1-trichloroethane) is a more recently controlled chemical under the Protocol, and currently has a lengthier phase-out schedule, there is evidence from the 1992 Report of the Solvents Technical Options Committee that its phase-out could be accelerated to conform with those of the other controlled chemicals.

S.31 **With regard to whether the 10 year grace period for the phase-out schedules of the developing countries should be reduced, our response is as follows.**

A shorter grace period would reduce the incentives to build-up stocks, production capacity and/or use of ODS chemicals in the interim before the phase-out schedules become effective for the developing countries which might raise the economic cost of the eventual phase-out.

The Government of Mexico has announced the goal of phasing out the controlled substances on the same schedule as the developed countries. The other developing countries are also invited to consider this strategy and to make further study about the possible benefits and whether they really need the grace period.

There is evidence from the country studies that the total costs of compliance, subject to market structure and trade policy, could be lower than under the existing phase-out schedules. Furthermore, the incremental costs associated with the ODS substitution process would remain eligible for funding through the Interim Multilateral Ozone Fund. Therefore, even if these costs were to be somewhat higher, which is not expected, the cost would be paid by the Fund.

Whilst the available information is insufficient to determine analytically by how much developing countries could reduce the phase-out schedule, it is our judgment that it would be economically worthwhile to reduce it by 2 to 5 years.

S.32 **We recommend that the Parties should make all practicable effort to sustain mutual confidence in the efficacy and equity of the Interim Multilateral Ozone Fund in meeting the incremental costs to the developing countries.**

The establishment of the Fund is indicative of the spirit of global partnership that is necessary to underpin initiatives to manage global environmental risks. The uncertainties faced by the developing countries in the ODS substitution process can be best contained if confidence in the capacity of the Fund to prevent the cost from becoming excessive relative to national resources. Mutual confidence depends on good faith negotiating, the acceptability of the modus operandi of the Fund, and the adequacy of the Fund's resources to meet the legitimate demands placed upon it.

S.33 **We recommend that the Parties should set interim targets for ODS substitution in their national ozone strategies that are consistent with the phase-out schedules of the Montreal Protocol.**

The setting of interim targets in national ozone strategies would create a framework for policy action and establish pressures for early and sustained action on ODS substitution. In their absence, there is the risk that some national implementation programmes could be adversely affected by a lack of motivation and direction, especially during the grace period allowed for developing countries.

S.34 **We recommend that the resources of the Interim Multilateral Ozone Fund, and that of its successors, should be determined on a "rolling plan" basis that is consistent with the interim targets established in the national implementation programmes of the Parties.**

The uncertainties associated with the ODS substitution process are too great to make possible realistic estimates of the total incremental costs to be financed by the Fund over the phase-out periods for the developing countries. Substitution requirements and costs are both changing significantly over time. The way to deal with this problem is to reassess funding requirements at appropriate intervals based on information available at the time. The timing of these reassessments should correspond to the phasing of the recommended interim targets for national implementation programmes so that decisions on the overall resource requirements of the Fund might relate to the latest estimates of the cost of the next tranche of the substitution process.

S.35 **We recommend that the funding of incremental costs should be used only to subsidise economically efficient ODS substitution.**

Funding should be granted only to the extent that would be warranted by an economic cost efficient substitution strategy. In particular, project funding should be based on resource, not financial, costs estimates. This implies that a country that insisted on pursuing an industrial strategy which was not consistent with cost efficient substitution would be granted financial aid only to the extent that would be sanctioned by a cost efficient strategy. Furthermore, in the light of the points made about recycling in paragraph S.21 above, The IMOF could legitimately finance a range of market based recyling activities as part of a cost efficient strategy. Apart from technical assistance in setting up the recovery facilities and in instituting the appropriate fiscal incentives, funding for the transfer of recovery technology could be a substantial part of such financing.

S.36 **We recommend that any outstanding issues regarding the modus operandi of the Interim Multilateral Ozone Fund should be resolved with a sense of urgency consistent with the case for accelerating the ODS phase-out schedules.**

The information, technical assistance and financial services of the Fund to the developing countries are essential to the ODS substitution process. The delays in settling operational procedures and in delivering these services is a source of uncertainty which can only hinder the implementation of the Protocol. We recommend, in particular, that the funding of ODS substitution initiatives in developing countries should not be impeded solely on the grounds that a national implementation strategy is not yet in place. Allowance must be made for projects that would be robust under any feasible strategy. An extension of this exception, would be to specify the basic components of "generic" strategies (eg projects with recognised low ODS abatement costs and perhaps a simple, supportive policy such as a tax on CFCs) that might be funded in the absence of a specially designed national implementation strategies.

S.37 **We recommend that high priority be given to the full implementation of the information clearing-house role of the UNEP Industry and Environment Office.**

We regard information as a key resource in the ODS substitution process. The Committee encountered evidence of a high level of unmet demand for the information that is expected to be delivered by the UNEP Industry and Environment Office (IEO) under its June 1991 mandate from the Executive Committee of the Interim Multilateral Ozone Fund. There are opportunities for collaborative efforts in generating information exchange through the IEO clearing-house, and demand for an authoritative on-line computer information service. Face-to-face meetings of people actively, or prospectively, involved in the ODS substitution process are particularly important to catalyse technology transfer in local areas and to generate information flows back to the clearing-house for wider dissemination. We welcome the impetus given to these important activities by the UNEP Industry and Environment Office and recommend that high priority is given to adequately resource and progress its information services.

S.38 **We recommend the early resolution of the regulatory uncertainty that exists with respect to transitional chemicals.**

Regulatory uncertainty can impede the commercialisation of ODS substitutes. Economic analysis cannot prescribe a "best" outcome; equity concerns, political acceptability and administrative efficiency must all bear upon the shaping of a workable agreement.

S.39 **We recommend that the Parties should seek the commitment of those carrying out unified risk assessments of potential ODS substitutes, involving multiple criteria, to ensure direct comparability between the reported results.**

Decisions by end-users on the most appropriate ODS substitutes will need to take into account the full range of the performance testing results for each substance. It is important that the reported test data are based on a common set of criteria and measurements so as to facilitate the decision process. Such decisions may depend on highly specific factors which makes it necessary to have close regard to the respective performance mixes of each potential substitute with respect to the multiple criteria used in the evaluation process.

S.40 **We recommend that a standing technical and economic advisory panel should be kept on call to review projects submitted for funding to the Interim Multilateral Ozone Fund and the Global Environmental Facility.**

The continuous involvement of a small number of technical and economic experts would facilitate the accumulation of expertise of direct relevance to the work of the Parties. The proposed panel would have the contacts in academia, government and with consultants to influence research work on the most appropriate issues. The chairsa and vice-chairs of the Technical and Economic Assessment could form the first committee.

ANNEX A
CONTROLLED AND TRANSITIONAL SUBSTANCES LISTED IN THE MONTREAL PROTOCOL

1. **Substances Controlled under the Original Montreal Protocol, adopted in September 1987**

Substance	Chemical Formula	Ozone Depletion Potential
GROUP I		
CFC-11	$CFCl_3$	1.0
CFC-12	CF_2Cl_2	1.0
CFC-113	$C_2F_3Cl_3$	0.8
CFC-114	$C_2F_4Cl_2$	1.0
CFC-115	C_2F_5Cl	0.6
GROUP II		
CF_2BrCl	halon 1211	3.0
CF_3Br	halon 1301	10.0
$C_2F_4Br_2$	halon 2402	6.0

2. **Substances controlled under the Amended Montreal Protocol, adopted in June 1990**

Substance	Chemical Formula	Ozone Depletion Potential
GROUP I		
CFC-13	CF_3Cl	1.0
CFC-111	C_2FCl_5	1.0
CFC-112	$C_2F_2Cl_4$	1.0
CFC-211	C_3FCl_7	1.0
CFC-212	$C_3F_2Cl_6$	1.0
CFC-213	$C_3F_3Cl_5$	1.0
CFC-214	$C_3F_4Cl_4$	1.0
CFC-215	$C_3F_5Cl_3$	1.0
CFC-216	$C_3F_6Cl_2$	1.0
CFC-217	C_3F_7Cl	0.6
GROUP II		
carbon tetrachloride	CCl_4	1.1
GROUP II		
1,1,1-trichloroethane (methyl chloroform)	$C_2H_3Cl_3$*	0.1

* This formula does not refer to 1,1,2-trichloroethane

3. **Transitional Substances listed in the Amended Montreal Protocol, adopted in June 1990**

Substance	Chemical Formula
HCFC-21	$CHFCl_2$
HCFC-22	CHF_2Cl
HCFC-31	CH_2FCl
HCFC-121	C_2HFCl_4
HCFC-122	$C_2HF_2Cl_3$
HCFC-123	$C_2HF_3Cl_2$
HCFC-124	C_2HF_4Cl
HCFC-131	$C_2H_2FCl_3$
HCFC-132	$C_2H_2F_2Cl_2$
HCFC-133	$C_2H_2F_3Cl$
HCFC-141	$C_2H_3FCl_2$
HCFC-142	$C_2H_3F_2Cl$
HCFC-151	C_2H_4FCl
HCFC-221	C_3HFCl_6
HCFC-222	$C_3HF_2Cl_5$
HCFC-223	$C_3HF_3Cl_4$
HCFC-224	$C_3HF_4Cl_3$
HCFC-225	$C_3HF_5Cl_2$
HCFC-226	C_3HF_6Cl
HCFC-231	$C_3H_2FCl_5$
HCFC-232	$C_3H_2F_2Cl_4$
HCFC-233	$C_3H_2F_3Cl_3$
HCFC-234	$C_3H_2F_4Cl_2$
HCFC-235	$C_3H_2F_5Cl$
HCFC-241	$C_3H_3FCl_4$
HCFC-242	$C_3H_3F_2Cl_3$
HCFC-243	$C_3H_3F_3Cl_2$
HCFC-244	$C_3H_3F_4Cl$
HCFC-251	$C_3H_4FCl_3$
HCFC-252	$C_3H_4F_2Cl_2$
HCFC-253	$C_3H_4F_3Cl$
HCFC-261	$C_3H_5FCl_2$
HCFC-262	$C_3H_5F_2Cl$
HCFC-271	C_3H_6FCl

ANNEX B

CFC, 1,1,1-TRICHLOROETHANE, AND HALON NOMENCLATURE

CFC Nomenclature

Chemical manufacturers and consumers have developed an "industry code" for naming halogenated compounds. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) use a three number code which identifies the composition. The code is defined as follows:

(H)CFC-xyz

where: x is the number of carbon atoms in the compound minus 1 (if x=0, then it is omitted from the code);

y is the number of hydrogen atoms in the compound plus 1; and,

z is the number of fluorine atoms.

For example, the formula for trichlorotrifluoroethane is CCl_2FCClF_2. Applying the naming convention to the formula, the code becomes:

$X = 2 - 1 = 1$ No. of carbon atoms = 2
$Y = 0 + 1 = 1$ No. of hydrogen atoms = 0
$Z = 3$ No. of fluorine atoms = 3

Thus, this compound is labeled CFC-113.

1,1,1-Trichloroethane Nomenclature

1,1,1-trichloroethane is also known by several other names including methyl chloroform and "trike." The use of "methyl chloroform" is somewhat confusing because it implies that the product contains chloroform, which is not the case. The use of "trike" is also confusing because it has also been used for trichloroethylene.

Halon Nomenclature

The halon terminology is a convenient means to reference halogenated hydrocarbon fire extinguishants. Halogenated hydrocarbons are acyclic saturated hydrocarbons in which one or more of the hydrogen atoms have been replaced by atoms from the halogen series; fluorine, chlorine, bromine, iodine. The first digit of the halon numbering system represents the number of carbon atoms in the molecule; the second digit, the number of fluorine atoms; the third digit, the number of chlorine atoms; the fourth digit, the number of bromine atoms; and the fifth digit, the number of iodine atoms. Trailing zeros are not expressed. Valence requirements not accounted for are assumed to be hydrogen atoms.

Thus

the number of hydrogen atoms = double the number of carbon atoms + 2 - the total number of halogen atoms

Example: Bromotrifluoromethane - CF_3Br - halon 1301

Here there are 1 carbon atom, 3 fluorines, 0 chlorines and 1 bromine, hence halon 1301

the number of hydrogen atoms is double the number of carbon atoms ($2x1=2$) plus 2 minus the number of halogen atoms ($3+1=4$) so $2+2-4=0$ - there are no hydrogen atoms.

Overlapping CFC and Halon Nomenclature

CFCs, HCFCs, and carbon tetrachloride can be labeled as halons. Chemicals are only listed under the halon nomenclature if they contain chlorine and/or bromine and have been historically considered as halons or if they contain chlorine and/or bromine and are candidates to replace halons controlled by the Montreal Protocol. See Table 1.

Table 1

Chemical/Compound	CFC Nomenclature	Halon Nomenclature
$CFCl_3$	CFC-11	halon 113 [1]
CF_2Cl_2	CFC-12	halon 122 [1]
$C_2F_3Cl_3$	CFC-113	
$C_2F_4Cl_2$	CFC-114	
C_2F_5Cl	CFC-115	
CF_3Cl	CFC-13	
C_2FCl_5	CFC-111	
$C_2F_2Cl_4$	CFC-112	
C_3FCl_7	CFC-211	
$C_3F_2Cl_6$	CFC-212	
$C_3F_3Cl_5$	CFC-213	
$C_3F_4Cl_4$	CFC-214	
$C_3F_5Cl_3$	CFC-215	
$C_3F_6Cl_2$	CFC-216	
C_3F_7Cl	CFC-217	
CHF_2Br	HBFC-22B1	halon 1201 [2]
CF_2BrCl	CBFC-12B1	halon 1211 [1]
CF_3Br	BFC-13B1	halon 1301 [1]
$C_2F_4Br_2$	BFC-114B2	halon 2402 [1]
CCl_4	Carbon Tetrachloride	halon 104 [1]
$CHFCl_2$	HCFC-21	
CHF_2Cl	HCFC-22	halon 121 [1]
CH_2FCl	HCFC-31	
C_2HFCl_4	HCFC-121	
$C_2HF_2Cl_3$	HCFC-122	
$C_2HF_3Cl_2$	HCFC-123	halon 232 [2]
C_2HF_4Cl	HCFC-124	halon 241 [2]
C_2HF_5	HFC-125	halon 25 [2]
C_2HF_4Br	HBFC-124B1	halon 2401 [2]

[1] Chemicals containing chlorine and/or bromine that have been historically listed as "halon."

[2] Chemicals containing chlorine and/or bromine that are candidates to replace controlled halons.

Table 1 (Continued)

Chemical/Compound	CFC Nomenclature	Halon Nomenclature
$C_2H_2FCl_3$	HCFC-131	
$C_2H_2F_2Cl$	HCFC-132	
$C_2H_2F_3Cl$	HCFC-133	
$C_2H_3FCl_2$	HCFC-141	
$C_2H_3F_2Cl$	HCFC-142	
C_2H_4FCl	HCFC-151	
C_3HFCl_6	HCFC-221	
$C_3HF_2Cl_5$	HCFC-222	
$C_3HF_3Cl_4$	HCFC-223	
$C_3HF_4Cl_3$	HCFC-224	
$C_3HF_5Cl_2$	HCFC-225	
C_3HF_6Cl	HCFC-226	
$C_3H_2FCl_5$	HCFC-231	
$C_3H_2F_2Cl_4$	HCFC-232	
$C_3H_2F_3Cl_3$	HCFC-233	
$C_3H_2F_4Cl_2$	HCFC-234	
$C_3H_2F_5Cl$	HCFC-235	
$C_3H_3FCl_4$	HCFC-241	
$C_3H_3F_2Cl_3$	HCFC-242	
$C_3H_3F_3Cl_2$	HCFC-243	
$C_3H_3F_4Cl$	HCFC-244	
$C_3H_4FCl_3$	HCFC-251	
$C_3H_4F_2Cl_2$	HCFC-252	
$C_3H_4F_3Cl$	HCFC-253	
$C_3H_5FCl_2$	HCFC-261	
$C_3H_5F_2Cl$	HCFC-262	
C_3H_6FCl	HCFC-271	
$C_2H_3Cl_3$	1,1,1-trichloroethane	

ANNEX C

PROVISIONAL LIST OF CFC AND 1,1,1-TRICHLOROETHANE TRADE, TRADEMARK AND COMPANY NAMES

There are currently more than 15 manufacturers of CFC in the U.S., Europe and Asia, plus an unknown number of manufacturers in the USSR, China, and Eastern Europe. As each has a different name for their product, Tables 1 and 2 provisionally list the producers, product names/trademarks, and CFC content for CFCs.

Suppliers use trade names in several different ways. All of ICI's Arklone™ products are 113-based, the suffix referring to the composition. Arklone™ P and P-SM are pure 113, while Arklone™ E, L, A, F, etc. are blended with other solvents, such as methylene chloride, isopropanol, ethanol, etc. However, Dupont uses the tradename Freon™ to describe its full line of CFCs, including CFC used as refrigerants and in other applications (for example Freon™-11 and Freon™-12). The Dupont 113-based systems have a prefix T (e.g., Freon™ TF, TMC, TP, TE, etc.).

An entry against a company for a particular product does not imply that the company concerned manufactures that product. Some companies, while manufacturing only a limited range of CFCs, buy in other products in order to be able to offer their customers a complete range of CFCs.

Tables 3 and 4 list the producers of 1,1,1-trichloroethane, their trade names, and the 1,1,1-trichloroethane content of their products.

In the case of halons, although trade names could be used, the equipment labelling requirements would also require the identification of the particular halon contained in the equipment.

N.B. The provisional information provided in this Annex is extremely complex, and subject to revision. Any additions or amendments should be communicated to the Technology and Economic Assessment Panel Co-Chairs;

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Dr Stephen O Andersen, U.S.EPA Fax +1 202 260 6344

Table 1. Provisional list of CFC Trade Names/Trademarks

Company/Country	CFC-113	CFC-11	CFC-12	CFC-13	CFC-114	CFC-115	CFC-500[1]	CFC-502[2]
ICI/UK	Arklone	Arcton 11	Arcton 12	Arcton 12	Arcton 114	Arcton 115	-	Arcton 502
Dupont/US	Freon	Freon 11	Freon 12	Freon 13	Freon 114	Freon 115	Freon 500	Freon 502
Elf AtoChem France[3]	Forane 113 Isotron 113 Racon 113	Forane 11 Isotron 11 Racon 11	Forane 12 Isotron 12 Racon 12	Forane 13 Isotron 13 Racon 13	Forane 114 Isotron 114 Racon 114	Forane 115 Isotron 115 Racon 115	Forane 500 Isotron 500 Racon 500	Forane 502 Isotron 502 Racon 502
Hoechst Germany	Frigen 113 Dional 113 Frigen TR 113	Frigen 11 Dional 11	Frigen 12	Frigen 13	Frigen 114	Frigen 115	Frigen 500	Frigen 502
Solvay-Kali Chemie Germany	Kaltron 113	Kaltron 11	Kaltron 12	-	Kaltron 114	Kaltron 115	-	Kaltron 502
Allied/US	Genesolv	Genetron 11	Genetron 12	Genetron 13	Genetron 114	Genetron 115	Genetron 500	Genetron 502
Montefluos (as of 1/1/92, Ausimont) Italy	Delifrene 113 Algofrene 113	Algofrene 11	Algofrene 12	-	Algofrene 114	Algofrene 115	-	Algofrene 502
Asahi Glass/Japan	Fronsolve	Asahifron 11	Asahifron 12	Asahifron 13	Asahifron 114	Asahifron 115	Asahifron 500	Asahifron 502
Daikin/Japan	Daiflon	Daiflon 11	Daiflon 12	Daiflon 13	Daiflon 114	Daiflon 115	Daiflon 500	Daiflon 502
Central Glass Japan	CG Triflon	-	-	-	-	-	-	-
Showa Denko Japan	Flon Showa Solvent	Flon Showa	Flon Showa	Flon Showa	Flon Showa	-	Flon Showa	Flon Showa
AKZO/Netherlands	-	FCC-11	FCC-12	FCC-13	-	-	-	-
Rhone-Poulenc UK	Isceon 113 Fluorisol	Isceon 11	Isceon 12	Isceon 13	Isceon 114	Isceon 115	Isceon 500	Isceon 502
Sicng/Greece	Flugene 113 Forane 113	Flugene 11 Forane 11	Flugene 12 Forane 12	n/a	n/a	n/a	n/a	n/a
Navin Fluorine Industries/India	Malfron 113	Malfron 11	Malfron 12	Malfron 13	Malfron 114	Malfron 115	-	Malfron 502
Shri Ram Fibres Ltd./India	Floron 113	Floron 11	Floron 12	-	-	-	-	-
Gujarat Fluoro-chemicals Ltd. India	-	Refron	Refron	-	-	-	-	-

All product names listed here are Registered Trademarks.

[1] CFC-500 is an azeotrope of 74% (by weight) CFC-12 and 26% HFC-152a. [2] CFC-502 is an azeotrope of 51% (by weight) CFC-115, and 49% HCFC-22.
[3] Forane should be the only remaining name for Elf Atochem in the future. n/a = not available.

Table 2. CFC-113 Content of Selected Products

Company	Product/Trademark	% CFC-113
Dupont	Freon TMS	94.05
	Freon TES	95.2
	Freon SMT	69
	Freon MCA	62.8
	Freon TA	88.9
	Freon TDF	99.9
	Freon TWD 602	91.5
	Freon TP35	65
	Freon TE35	65
	Freon TMC	50.5
	Freon TF	100
	Freon PCA	100
Asahi Glass Co., Ltd.	Fronsolve	100
	Fronsolve AE	96
	Fronsolve AP	65
	Fronsolve AM	50.5
	Fronsolve AES	96
	Fronsolve AMS	94
	Fronsolve AD-7	99.5
	Fronsolve AD-9	99.5
	Fronsolve AD-17	83
	Fronsolve AD-19	82
	Fronsolve UF-1	80
	Fronsolve UF-4	86
	Fronsolve UF-5	90
	Fronsolve AC	87.5
	Fronsolve AW	97
	Fronsolve E	96
	Fronsolve A	75
	Fronsolve B	65
Central Glass Co., Ltd.	CG Triflon	100
	CF Triflon E	96
	CG Triflon P	65
	CG Triflon M	50.5
	CG Triflon ES	95.5
	CG Triflon EE	92
	CG Triflon E35	65
	CG Triflon MES	93.3
	CG Triflon C1	98.7
	CG Triflon D1	99.5
	CG Triflon D3	99.4
	CG Triflon W1	91.2
	CG Triflon A	87.5
	CG Triflon FD	78
	CG Triflon CP	90
Showa Denko K.K.	Flon Showa FS-3	100
	Flon Showa FS-3E	96
	Flon Showa FS-3P	65
	Flon Showa FS-3M	50.5
	Flon Showa FS-3ES	96
	Flon Showa FS-3MS	50.5
	Flon Showa FS-3D	99.9
	Flon Showa FS-3W	91.5
	Flon Showa FS-3A	87.5

Table 3. Trade Names for 1,1,1-Trichloroethane

Manufacturer	Trade Name/Trademark
ICI	Genklene*
	Propaklone*
Dow	Chlorothene* (R) Industrial Solvent
	Chlorothene* (R) NU
	Chlorothene* (R) SM
	Chlorothene* (R) VG
	Chlorothene* (R) XL
	Chlorothene* (R) SL Solvent
	Dowclene (R) EC-CS
	Dowclene* (R) LS
	[1]Dowclene* (R) EC
	Prelete* (R) Defluxer Solvent
	Proact* (R) Solvent
	[2]Aerothene* (R) TT Solvent
	Aerothene* (R) TA Solvent
	Film Cleaning Grade
	S.E.M.I. Grade
	Methyl Chloroform, Low Stabilized - PW
	Methyl Chloroform, Low Stabilized
	Methyl Chloroform, Technical
AtoChem	Baltane*
	Mecloran*
Solvay	Solvethane*
PPG	Triethane*
Vulcan	1,1,1-Tri
Asahi Glass	Asahitriethane*
Toagosei	1,1,1-Tri
Kanto Denka Kogyo	Kanden Triethane*
London Chemical	Prelete*
Central Glass	1,1,1-Tri
Tosoh	Toyoclean*
Wacker	Wacker 3X1*

* Trademarks

[1] 75 percent 1,1,1-Trichloroethane and 25 percent perchloroethane.

[2] Aerosol Grade.

Table 4. 1,1,1-Trichloroethane Content of Selected Products

Manufacturer	Trade Name	1,1,1-Trichloroethane Content (%)
Asahi Chemical Industry Co., Ltd.	ETHANA NU	94
	ETHANA VG	94
	ETHANA AL	94
	ETHANA HT	94
	ETHANA RD	94
	ETHANA IRN	90
	ETHANA FXN	90
	ETHANA SL	94
	ETHANA TS	94
	ETHANA RS	84
	TAFCLEN (Dry cleaning solvent)	90
	AQUADRY 50	94
Asahi Glass Co., Ltd.	ASAHITRIETHANE	96
	ASAHITRIETHANE ALS	93
	ASAHITRIETHANE UT	96
	ASAHITRIETHANE LS	96
	ASAHITRIETHANE BS	92
	ASAHITRIETHANE V5	91
	ASAHITRIETHANE EC Grade	96
	SUNLOVELY (Dry cleaning solvent)	95
Central Glass Co., Ltd.	CG TRIETHANE N	97
	CG TRIETHANE NN	96
	CG TRIETHANE NNA	94
	CG TRIETHANE F	97
Dow Chemical	CHLOROETHENE* VG	96.6
	CHLOROTHENE* Industrial	97.5
	CHLOROTHENE* NU	96.8
	CHLOROTHENE* SM	96.6
	DOWCLENE* EC	72.4
	DOWCLENE* LS	96.5
	CHLOROTHENE* LM	93.8
	CHLOROTHENE* XL	95.0
	CHLOROTHENE* ST	96.1
	PROACT*	99.4
	PRELETE*	92.9
	PRELETE* S	92.0
	1,1,1-Trichloroethane S.E.M.I.	96.6
	Methyl Chloroform Low Stabilized PW	99.9
	1,1,1-Trichloroethane Film Cleaning Grade	99.9
	AEROTHENE* TT	96.1
	AEROTHENE* TA	70.1
	Methyl Chloroform FG	99.9
	Methyl Chloroform Technical grade	99.8

Table 4. 1,1,1-Trichloroethane Content of Selected Products (continued)

Manufacturer	Trade Name	1,1,1-Trichloroethane Content (%)
ICI PLC	GENKLENE LV	95.2
	GENKLENE N	95.4
	GENKLENE A	96.5
	GENKLENE P	99.7
	PROPAKLONE	89.6
	GENKLENE LVS	95.7
	GENKLENE LVX	90.7
	GENKLENE LVJ	95.2
	GENKLENE PT	99.9
Kanto Denka Kogyo Co., Ltd.	KANDEN TRIETHANE R	97
	KANDEN TRIETHANE H	97
	KANDEN TRIETHANE HA	94
	KANDEN TRIETHANE HAK	93
	KANDEN TRIETHANE E	98
	KANDEN TRIETHANE EP	97
	KANDEN TRIETHANE HB	94
	KANDEN TRIETHANE HC	94
	KANDEN TRIETHANE HF	94
	KANDEN TRIETHANE HG	94
	KANDEN TRIETHANE HS	99
	KANDEN TRIETHANE HT	97
	KANDEN TRIETHANE N	100
	KANDEN TRIETHANE ND	97
	KANDEN TRIETHANE SR	90
	KANDEN TRIETHANE SRA	91
	KANDEN TRIETHANE EL	97
	KANDEN TRIETHANE ELV	97
Toagosel Chemical Industry Co., Ltd.	Three One-R	96
	Three One-S	95
	Three One-A	95
	Three One-AH	95
	Three One-S(M)	95
	Three One-F	95
	Three One-TH	95
	Three One-HS	95
	Three One-EX	90
	Shine Pearl (Dry cleaning solvent)	94
Tosoh Corporation	Toyoclean EE	97
	Toyoclean T	97
	Toyoclean SE	84
	Toyoclean O	100
	Toyoclean HS	96
	Toyoclean IC	91
	Toyoclean NH	96
	Toyoclean AL	95
	Toyoclean ALS	91
	Toyoclean EM	96

ANNEX D

NATIONAL LEGISLATION MORE STRINGENT THAN THE MONTREAL PROTOCOL

Article 2, paragraph 11 of the Montreal Protocol states that "notwithstanding the provisions contained in [this Article] ...Parties may take more stringent measures than those required by this Article and Articles 2A to 2E" ie the control measure Articles which provide for the phased elimination of the controlled substances.

Many Parties are implementing national policies more stringent than required by the Protocol. Such policies limit further the emissions of controlled substances which derive from production and consumption within the countries concerned, and so make an added contribution to global measures for the protection of the ozone layer. They may also be implemented so as;

1 to influence the Parties as a whole to adopt accelerated phaseouts of controlled substances,

2 to promote research and development of substitutes chemicals and alternative technologies,

3 to create a market for these new substances and technologies, and

4 to prove that faster phaseout is technically and economically feasible.

Measures additional to the Protocol's provisions can take many forms, including; quantitative limits on production and consumption; bans on the use of controlled substances in specific applications; measures to limit emissions of controlled substances or otherwise encourage good practice in leak minimisation, recovery and recycling; and direct participation, encouragement or subsidy of research, development or investment in replacement technologies.

It is not possible for this assessment to detail the advanced policies adopted by all Parties, due to lack of information and time, and the difficulty of quantifying the effects of different policy measures. However the following table gives some of the more significant examples, where such measures can be presented in comparison with the provisions of the Protocol itself. The table shows the dates by which intermediate reductions and subsequent phaseout of production and consumption of CFCs and halons are to be achieved under the national measures of different Parties. This list of examples is not exclusive.

EXAMPLES OF NATIONAL POLICIES MORE STRINGENT THAN THE MONTREAL PROTOCOL (Base 1986)

CFC PHASEOUT

	MP	EC[1]	Austria	Denmark	Finland	Germany	N'lands[2]	Norway	Sweden	Switz.	U.S.
100%	07/89				12/90				01/89		
85%							01/91			12/92	01/91
80%											01/92
50%	01/95	01/92			12/92	01/92	01/92	01/91	01/91		
15%	01/97	07/93									
10%			01/93								
5%							01/95			12/94	
0%	01/00	07/97[3]	01/95	01/97[4]	12/94	12/94[5]	01/97	01/95	01/95	12/95	

HALON PHASEOUT (Exemptions for essential use)

	MP	EC	Austria	Denmark	Finland	Germany	N'lands[6]	Norway	Sweden	Switz.	U.S.
100%	01/92						01/92				
50%	01/95						01/93				
0%	01/00		01/91[7]	01/00[8]	12/91	12/91[9]	01/95	01/95	01/98	12/91[10]	

CFC-113 SOLVENT PHASEOUT

	MP	EC	Austria	Denmark	Finland	Germany	N'lands[11]	Norway	Sweden	Switz.	U.S.
100%	07/89										
85%							01/91				01/91
80%											01/92
50%	01/95	01/92		01/92			01/92				
15%	01/97	07/95		07/95			07/95				
0%	01/00	07/97[3]	01/94[12]	01/96[13]	12/94	03/92[14]	07/97	07/91[15]	01/91[16]	01/93[17]	

NOTES FOR NATIONAL POLICIES MORE STRINGENT THAN THE MONTREAL PROTOCOL

1 The EC comprises Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain and the United Kingdom. Denmark, Germany and the Netherlands have more stringent phaseout schedules than the EC regulations and are listed separately here.

2 Phaseout for new (static) installations is 01/92; phaseout for new mobile installations is 01/94.

3 Exemptions for essential uses (if any - to be agreed).

4 After this date, only research, development and laboratory use is permitted until further notice. Earlier phaseout dates exist for open-celled polyurethane foams, electronic equipment degreasing, fabric cleaning, rigid polyurethane insulation and integral foam, and refrigeration.

5 For CFC in closed new refrigeration and air conditioning systems with less than 5 kg of refrigerant. Earlier phaseout dates include 12/91 for CFC in systems with more than 5 kg of refrigerant and 12/93 for CFC in closed new mobile refrigerating units and 12/99 for HCFC-22 in closed new refrigeration and air conditioning systems.

6 Phaseout of new uses (except essential uses) is 01/92; filling and refilling only with recycled halon is effective 01/95.

7 90-95% phaseout of halon by 1991. All systems sales and refill banned after 2000. Exemption to protect human life, irreplaceable cultural heritage objects, refills.

8 After this date, research, development and laboratory use is permitted until further notice. This exemption also applies to essential uses in aircraft, air traffic control centres and national defence. Earlier phaseout dates exist for emissions in connection with training and testing, for hand-held fire extinguishers and stationary fire extinguishing installations and refilling of these systems.

9 For halons produced through 12/91, uses are allowed until 12/93.

10 Sale of portable extinguishing systems banned from mid-1992; refill of halon portable extinguishers banned from 1991.

11 Use of CFC solvents only in systems with recovery is effective 01/93.

12 CFC-113 by permit only 01/92-12/93; banned after 01/94.

13 The phaseout date of 01/96 applies to uses in installations for fabric cleaning established before 01/92. Earlier phaseout dates exist for newer electronic equipment and fabric cleaning installations.

14 All manufacture will be banned; any substance in stock may be used up during a period of nine months.

15 All but one use banned; dry cleaning will be banned 12/94.

16 All but one use banned 01/91; exemptions for essential use only.

17 Exemptions granted for essential uses if no known substitutes and if measures are taken to minimise emissions.

ANNEX E
METHYL BROMIDE USES AND ALTERNATIVES

(Based on information provided to the U.S.EPA)

Introduction

Methyl bromide is a colorless, odorless, highly toxic gas used as a multi-purpose fumigant and in some chemical processes such as rubber processing.

Approximately 50 percent[1] of the methyl bromide present in the atmosphere is from man-made agricultural and industrial applications while the remainder is primarily from natural marine sources (CMR 1988a). Man-made sources include (CMR 1988):

- soil fumigation;
- space and structure fumigation;
- chemical processing and organic synthesis;
- grain and commodity fumigation.

Production and Use

Methyl bromide is used and/or produced in at least twelve countries including the United States, the United Kingdom, Germany, Israel, Yugoslavia, Bulgaria, Greece, Ireland, France, Japan, Australia, and the Netherlands (Producers 1988, CMR 1990, European 1991). Table 1 presents a list of manufacturers and/or distributors by country.

Methyl bromide is a broad spectrum pesticidal fumigant for insecticidal, fungicidal, acaricidal, nematicidal, rodenticidal, and herbicidal purposes. It is used as a pesticide on:

- crops (food, beverage (coffee and cocoa), forage-fodder, fiber, timber, ornamental, turf and tobacco);
- processing and storage facilities (food, feed, grain, and spice);
- textiles, fabrics, and fibers;
- bulk soil, manure and compost;
- seasoned and unseasoned forest products;
- structures and contents (residential, office, barns, greenhouses and mushroom houses);
- ships, trains, and truck cargo areas; and
- cadavers and caskets.

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[1] Alternatively, Ethyl Corporation estimated that in 1988, approximately 75 to 95 percent of methyl bromide emissions were from natural sources (CMR 1988a).

Methyl bromide is usually used in highly intensive farming situations by commercial growers. It is used to a lesser extent in chemical processes such as organic synthesis, and as an extraction solvent for vegetable oils. Methyl bromide is also used in ionization chambers, degreasing wool, extracting oils from nuts, seeds and flowers, fumigating crops before export, and in organic synthesis. In the past it has been used as a methylating substance in the production of rubber, as a refrigerant, and in fire extinguishers (Mulder 1979, ACGIH 1986). Table 2 presents information on U.S. methyl bromide consumption by use area.

The distribution of methyl bromide use in the United States is typical of other countries with intensive agricultural cropping.

The regulation of methyl bromide as a hazardous chemical varies among countries (Netherlands 1987, Osteen and Szmedra 1989, European 1991). In many countries methyl bromide use is allowed only for specific applications (product and pest) and/or expressly prohibited for specific uses. Many countries require that operators be trained and certified, that special application equipment is used, that gases are contained by tarps or containers for specified times, that products are degassed for specified time periods prior to marketing or reentering the area, and that chloropicrin is added as a warning tear gas.

Substitutes

There are a small number of pesticide substitutes for the soil, stored commodity and structure fumigation uses, most of which are fumigants. In some cases, more than one pest control strategy might be needed to replace methyl bromide. Pesticides are undergoing regulatory review and are subject to different restrictions depending on the country where they are used and on the markets where the food products are sold. Some crop/pest combination substitutes have not been identified. Table 3 lists some of the substitute fumigants.

TABLE 1. COMPANIES MANUFACTURING AND/OR DISTRIBUTING METHYL BROMIDE

COUNTRY	COMPANY	PRODUCT NAME
United States	Great Lakes Chemical Corporation	Trical, Brom-O-Sol
	Ethyl Corporation	Brom-O-Gas, Haltox, Meth-O-Gas, Terr-O-Gas ICO
United Kingdom	Great Lakes Chemical (Europe) Ltd. May & Baker Ltd. Bromine and Chem.	Methyl Bromide 98
Ireland	Rentokil	Methyl Bromide (cylinder)
	National Agrochemicals	Methyl Bromide (tin)
Israel	Dead Sea Bromide Ltd.	
Greece	Rhone-Poulenc Filocrops	Sobrom AX
Germany	Air Product GmbH Dr. Theodor Schuchardt & Co. ICC MCU Chemogas Helm	Methylbromid SU Methylbromide 98/2
Yugoslavia	Bromine Compounds	
Netherlands	Eurobrom Heek's	Methylbromide 100
France	Atochem	
Japan	Asahi Glass Co. Ltd. Dokai Chemical Industry Co. Ltd. Ichikawa Gosei Chemical Co. Ltd Nippon Chemicals Co. Ltd. Nippon Shokubai Kagaku Kogyo Co. Ltd. Teijin Chemicals Ltd.	
Italy	Farmatalia Carlo Erba Societa Azionaria Industria Bromo Italiano	
Spain	Derivados del Etilo S.A.	

Source: Producers 1988, European 1991.

Table 2. Distribution of Use of Methyl Bromide in the U.S. 1988

Use Area	Percent of Total
Soil Fumigant	55%
Space and Structure Fumigant	10%
Chemical Processes	10%
Grain and Commodity Fumigant	5%
Exports	20%

Source: CMR 1988

Table 3. Substitutes for Methyl Bromide *

Stored Product Fumigants	Soil Fumigants	Stored Product Pesticides
Carbon disulfide	Chloropicrin	Malathion
Ethylene oxide	Dichloropropene	Aluminum phosphide
Aluminium phosphide	Methyl Isothiocyanate	Magnesium phosphide
Magnesium phosphide		
Sulfuryl fluoride		
Dichlorvos (DDVP)		

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* There are also non-fumigant soil pesticides.

Source: Merwin 1991, Horton 1990, U.S.EPA 1992.

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ANNEX F
MEMBERSHIP OF THE TECHNOLOGY AND ECONOMIC ASSESMENT PANEL AND ITS OPTIONS COMMITTEES

TECHNOLOGY AND ECCONOMIC ASSESSMENT PANEL

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Steve Lee-Bapty - (United Kingdom) - Co-Chair

Jean Lupinacci - (United States) - Chair of Flexible and Rigid Foams Technical Options Committee

Major E Thomas Morehouse Jr. - (United States) - Co-Chair of Halons Technical Options Committee

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