REGULATORY IMPACT ANALYSIS:

PROTECTION OF STRATOSPHERIC OZONE

VOLUME I: REGULATORY IMPACT ANALYSIS DOCUMENT

PREPARED BY

STRATOSPHERIC PROTECTION PROGRAM
OFFICE OF PROGRAM DEVELOPMENT
OFFICE OF AIR AND RADIATION
U.S. ENVIRONMENTAL PROTECTION AGENCY

AUGUST 1, 1988

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PREFACE

This Regulatory Impact Analysis (RIA) document reflects comments received on the proposed regulation, "Protection of Stratospheric Ozone," Proposed Rule, 40 CFR Part 82, December 14, 1987, and on the draft RIA, and is the final RIA to accompany the Final Rule, which is to be completed by August 1, 1988.

This document is contained in three volumes, as follows:

- Volume I contains the RIA document itself;
- Volume II contains appendices to the RIA document; and
- Volume III, in ten parts, contains addenda to the RIA. Parts 1 through 9 are studies prepared by engineering contractors which examine current uses of chlorofluorocarbons and halons and possible methods and costs of reducing their use. Part 10 of this volume is a supplement to these addenda containing information on changes and additions to the data presented in the original nine parts.

Much of the analysis and modeling on which this document is based was prepared by ICF Incorporated. Contributing authors from ICF include: Michael Barth, Craig Ebert, Michael Gibbs, Kevin Hearle, Brian Hicks, and William McNaught. The data on CFC uses and substitutes was collected and analyzed by ICF Incorporated, Industrial Economics Corporation, Midwest Research Institute, and Radian Corporation.

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EXECUTIVE SUMMARY

Results in Brief

On September 16, 1987, the United States, along with 23 other nations and the European Economic Community, signed an international protocol (the "Montreal Protocol") calling for a freeze on the use of CFCs beginning in approximately mid-1989, a 20 percent reduction in their use beginning in mid-1993, and another 30 percent reduction in their use beginning in mid-1998. In addition, this protocol calls for a freeze on halon usage at 1986 levels beginning in approximately 1992. The protocol will only enter into force when eleven nations, constituting two-thirds of global consumption of the controlled substances (i.e., CFCs and halons), have ratified it. On April 5, 1988, the President signed the Montreal Protocol, which the United States Senate had approved on March 14, 1988. As of July 1988, 37 nations have signed and two have ratified the Protocol.

On December 14, 1987, the U.S. Environmental Protection Agency published proposed regulations for protecting stratospheric ozone.[1] Accompanying these proposed regulations was a preliminary Regulatory Impact Analysis (RIA) examining the probable effects of regulatory action. Its major conclusion was that under virtually all sets of assumptions examined the benefits of limiting future CFC and halon use far outweigh the increased costs which these regulations would impose on the economy.

Since the publication of the proposed regulations, EPA has received comments from numerous interested parties and conducted further analyses of the costs to the economy of responding to the regulation. This final RIA[2] reflects revisions to the preliminary RIA incorporating the information obtained from these public comments and additional analyses. This final RIA does not reflect the recent evidence contained in the Ozone Trends Panel Report on the increasing severity of ozone depletion.[3] The major conclusion of the preliminary RIA is unchanged -- under virtually all possible assumptions about ozone depletion and CFC use, the benefits of CFC and halon regulation far exceed the costs.

Purpose

Since 1974, there has been increasing scientific evidence that increased emissions of CFCs and halon compounds would deplete stratospheric ozone. These compounds, commonly used in many applications such as refrigeration, foam blowing, sterilization, and fire protection, have extremely long atmospheric lives, meaning that current levels of CFC and halon production could affect the welfare of the human population for a number of generations.

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[1] Federal Register, December 14, 1987, pages 47489-47523

[2] To distinguish it from the preliminary RIA, the remainder of the document refers to this version of the RIA as the "final RIA."

[3] U. S. National Aeronautics and Space Administration, Executive Summary of Ozone Trends Panel Report, March 15, 1988.

The best available scientific evidence suggests that if CFC and halon emissions continue to increase, significant stratospheric ozone depletion would result. Decreases in stratospheric ozone would result in increases in the penetration of biologically-damaging ultraviolet-B radiation (i.e., 290 to 320 nanometers) reaching the earth's surface.

Under the auspices of the United Nations Environment Programme (UNEP), 24 nations and the European Economic Community signed an international protocol on September 16, 1987, in Montreal, Canada, which addressed the ozone depletion problem. Assuming entry into force on January 1, 1989, the protocol calls for a freeze on CFC use at 1986 levels beginning on July 1, 1989; a 20 percent reduction from 1986 levels beginning on July 1, 1993; and a 50 percent reduction from 1986 levels beginning on July 1, 1998. The protocol also calls for a freeze on halon use at 1986 levels beginning approximately on January 1, 1992.

To implement the obligations of the United States under this protocol and under its own authority as set out in Section 157(b) of the Clean Air Act of 1977, the Environmental Protection Agency is promulgating regulations restricting the use of CFC and halon compounds. Executive Order 12291 requires that the costs and benefits of "major rules" such as these CFC and halon restrictions be evaluated in a Regulatory Impact Analysis (RIA). This document presents the results of this evaluation.

Methodology

This final RIA estimates the costs and benefits of the proposed regulations by considering their effect in the future relative to a projected baseline of effects which would occur in the absence of any regulation. In this baseline case, CFC/halon use is projected to grow through 2050, and then level off. These growth projections are based upon analyses of past CFC/halon growth patterns that appear to be closely correlated to growth rates in per capita GNP levels. CFC and halon use is assumed to level off in 2050.

Associated with this increased use of CFCs and halons are projections of decreases in stratospheric ozone that lead to increased ultraviolet radiation levels and global climate change. These projected levels of ozone depletion are based upon the representations of the chemical processes affecting the atmosphere, particularly the stratosphere. In the baseline case (i.e., no regulations), levels of stratospheric ozone are projected to decrease by 50 percent or more by the end of the 21st century.

This final RIA considers seven options for regulating CFC/halon use. They range from a simple freeze on CFC use without any controls on halon use, to an option comparable to the protocol reached in Montreal, to an option which expands the Montreal Protocol by imposing an 80 percent reduction in CFC usage. Still another option considers the costs and benefits of CFC/halon regulation by the United States alone in the absence of any regulatory actions in the rest of the world. Given the existence of the Montreal Protocol, this case is presented for comparison purposes only. Analysis of all options takes into account which nations participate. A summary description of each scenario is provided below:

- No Controls -- No controls on CFCs or halons occur. This is the baseline scenario against which the impacts of various control options are measured.

- CFC Freeze -- CFC use is held constant at 1986 levels starting in 1989.

- CFC 20% -- In addition to the CFC freeze in 1989, a 20% CFC reduction worldwide occurs in 1993.

- CFC 50% -- In addition to the CFC freeze in 1989 and the 20% reduction in 1993, a 50% CFC reduction occurs in 1998.

- CFC 80% -- In addition to the CFC freeze in 1989, the 20% reduction in 1993, and the 50% reduction in 1998, an 80% CFC reduction occurs in 2003.

- CFC 50%/Halon Freeze -- In addition to the freeze on CFC use in 1989, the 20% reduction in 1993, and the 50% reduction in 1998, halon use is held constant at 1986 levels starting in 1992. This case is intended to resemble the Montreal Protocol as closely as possible.

- CFC 50%/Halon Freeze/U.S. 80% -- Same as the CFC 50%/Halon Freeze case, except that the U.S. reduces to 80% of 1986 CFC levels in 2003.

- U.S. Only/CFC 50%/Halon Freeze -- Same as the CFC 50%/Halon Freeze case, except the U.S. is the only country in the world that participates.

The benefits of these regulations were estimated by assembling the best available scientific estimates on the effects of decreases in stratospheric ozone on human health and the environment. The major health benefits are due to avoiding ultraviolet radiation effects, which include increased numbers of skin cancers and cataracts. The value of reductions in skin cancer incidence was estimated by first estimating the additional numbers of skin cancers likely to occur due to decreased stratospheric ozone levels. Then the proportion of skin cancers that were fatal were estimated and multiplied by an estimated statistical value of human life. For the remaining nonfatal skin cancers and all cataracts, cases were valued by multiplying by an estimated social cost of treatment. Estimates of pain and suffering were not included in the valuation of the skin cancer cases; pain and suffering estimates were included for the cataract cases. In order to assess the potential effects of possible improvements in medical technology, additional analyses were performed to measure the sensitivity of estimated health benefits to decreased incidence rates of skin cancer.

The major environmental effects were more difficult to quantify due to a lack of scientific data on the likely magnitude of these effects. Although limited in scope, some studies of decreased crop yields (for soybeans) and fish harvests (for anchovies) associated with increased levels of ultraviolet radiation are available. The effects of ultraviolet radiation on yields in these studies were used to estimate the probable decreased productivity of specified agricultural and marine industries due to stratospheric ozone depletion. For the purposes of calculating benefits, values were assigned to increased crop and fish harvests using current market prices of each commodity.

Additionally, decreased stratospheric ozone can be expected to lead to increased tropospheric (ground-based) ozone (which can also reduce crop yields), and to more rapid deterioration of polymers. Also, CFCs and changes in the vertical distribution of ozone can increase global temperatures, resulting in a rising sea level. Although the benefits of reductions in ground-based ozone levels to humans is no doubt quite large due to avoided human health impacts, this final RIA quantitatively assesses only the impacts of these reductions on crop production levels. The benefits accruing to avoidance of faster deterioration of polymers were assessed by estimating the costs of adding light stabilizers to polymers to retard the absorption of ultraviolet radiation. The impacts of a rising sea level were valued by estimating potential impacts on major ports.

The costs attributable to reducing CFC and halon use through regulation were estimated by examining the costs of alternative technologies and materials for producing CFC-based and halon-based products. This final RIA examines a wide range of alternative approaches, including replacing CFCs and halons with less ozone-depleting chemicals, recycling or recovering CFCs and halons, or eliminating the CFC-based or halon-based product entirely.

Extensive engineering analyses were performed to estimate the costs of producing each CFC-based or halon-based product with the alternative technologies. These analyses included all variable costs, such as material, labor, energy, and operating expenses; capital costs, properly discounted for the expected useful life of the equipment; and nonrecurring costs, such as the costs of retooling, research and development or training. For the cost analysis, technologies were selected that minimized the increases in production costs required to achieve each level of reduction in CFC and halon use.

Two types of costs result from the reduced availability and higher prices of CFC-based and halon-based products induced by regulations. Social costs are the additional amount of resources required to produce an equivalent amount of goods and services for consumers. Regulation also transfers income from consumers of CFC-based and halon-based products, who now must pay higher prices, to other sectors of society. These transfer payments are not losses in welfare to society and are not counted as costs of regulation.

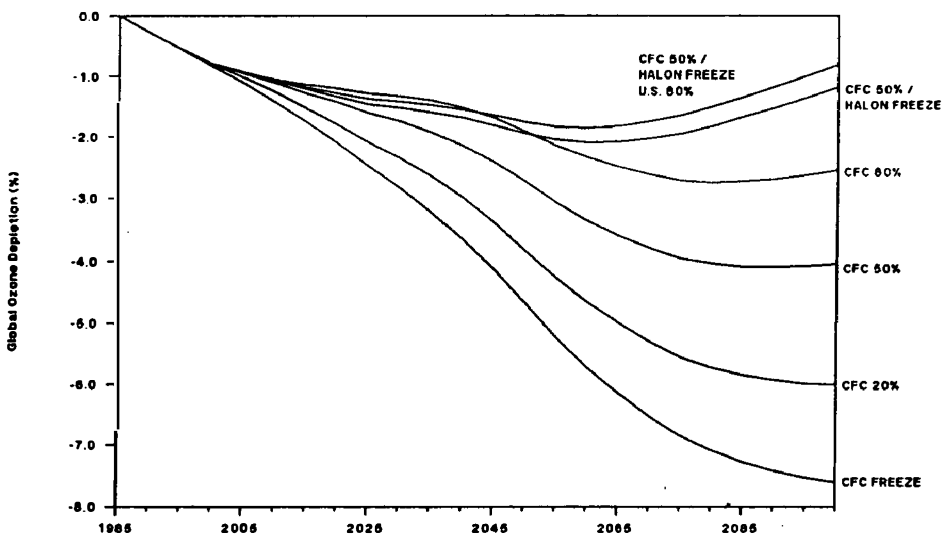
Results

Each of the options analyzed significantly reduces the depletion of stratospheric ozone. Exhibit ES-1(a) shows the pattern of these reductions over time for each alternative control option (except the U.S. Only/CFC 50%/Halon Freeze case); Exhibit ES-1(b) shows the U.S. Only/CFC 50%/Halon Freeze case along with the No Controls and CFC 50%/Halon Freeze cases. (Note that the scales differ in the two panels.) The least stringent control option reduces the ozone depletion percentage by the end of the 21st century from 50 percent to approximately 8 percent. In contrast, by 2100 the most stringent control option reduces the ozone depletion percentage to about 1 percent. In all cases except the "U.S. only" case, depletion estimates assume substantial levels of participation by other nations. (See Chapter 6 for additional information.)

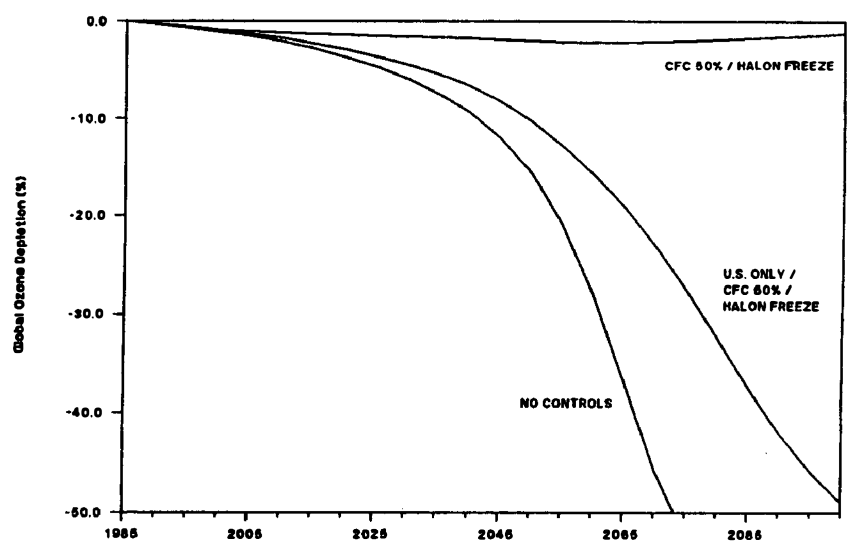
EXHIBIT ES-1

GLOBAL OZONE DEPLETION FOR ALTERNATIVE CONTROL OPTIONS CASES

(a)



(b)



In the baseline case, depletion of stratospheric ozone is estimated to cause nearly 178 million additional nonmelanoma skin cancers and over 890,000 additional melanoma skin cancers for persons born before the year 2075 in the U.S. Both types of skin cancers combined are estimated to result in about 3.7 million additional deaths for people born before the year 2075 in the U.S. (See Chapter 7 for additional information.)

Regulation of CFC and halon use reduces the additional incidence of skin cancers for people born before 2075 by about 55 million cases in the least stringent regulatory option and about 174 million cases avoided in the most stringent regulatory option. Deaths avoided range from 1.2 million to 3.7 million over the same range of options. The present value of benefits to United States citizens born before 2075 from avoiding these cancers ranges from $1.4 trillion to $3.5 trillion.

A second part of the human health benefits of CFC and halon regulation is the reduced incidence of cataracts. Of the 20 million additional cases of cataracts projected to occur among people born before 2075 in the U.S. due to ozone depletion, from 4.1 to 19.2 million cases are estimated to be avoided under the various CFC and halon regulatory options. The present value of the benefits in the U.S. of these avoided cases ranges from $1 to $3 billion.

The quantifiable environmental benefits in the U.S. due to CFC and halon regulation, although substantial, are small when compared to the value of the avoided cancer benefits:

- The estimated increased value of crops harvested due to decreased levels of damaging ultraviolet radiation ranges from $8.6 billion to $27.7 billion.

- The estimated increased value of fish harvested due to decreased levels of damaging ultraviolet radiation ranges from $2.4 billion to $6.7 billion.

- The estimated increased value of crops harvested due to decreased levels of tropospheric (ground-based) ozone ranges from $6.4 billion to $15.6 billion.

- The decreased costs in protecting polymer products from increased ultraviolet radiation ranges from $0.8 billion to $3.6 billion.

- The estimated benefits of avoiding costs due to a rise in the sea level range from $1.4 billion to $5.1 billion.

The basis for these environmental effects estimates is much less certain than the human health impacts; the actual environmental impacts could be significantly higher or lower. (See Chapter 8 for additional information.)

The costs of regulating CFCs and halons are more sensitive to the regulatory option selected than are the benefits. The costs of these regulations are expected to depend on the speed at which specific CFC-user industries and the economy as a whole can adopt techniques to reduce CFC and halon use and on the potential for these technologies to achieve the reductions required. For the least stringent case--a freeze on CFCs only--the present value of the costs for the United States are estimated to range from $7 to $19 billion through the year 2075. However, for the most stringent regulatory option--in which ultimately CFC usage is reduced 80 percent in the U.S. (50 percent in the rest of the world) and halon use is frozen at 1986 levels--the present value of costs range from $24 to $65 billion through the year 2075.

The level of transfer payments generated by CFC regulation is significant, particularly in the initial years of regulation. The present value of these transfer payments is estimated to range from $1.9 to $7.3 billion through the year 2000. If allocated quotas were the regulatory option chosen, these transfer payments would accrue to CFC producers and their presence could provide an incentive for producers to delay the introduction of chemical substitutes. Using pessimistic assumptions about the speed with which industries adopt CFC conservation techniques, a one year delay in the introduction of these substitutes is estimated to increase transfer payments by $2.7 billion. Using the same pessimistic assumptions, a two year delay increases transfer payments by over $10 billion and makes it difficult to achieve the mandated reduction to 80 percent of 1986 usage levels scheduled to occur in 1993. Using moderate assumptions about industries' responsiveness to CFC conservation, a one year delay in the introduction of CFC substitutes has little effect, but a two year delay increases transfer payments by $1.3 billion. Using optimistic assumptions about industries' responsiveness to CFC conservation, delays in the introduction of CFC substitutes has little impact because the price of these substitutes usually exceeds the cost of alternative conservation measures. (See Chapter 9 for additional information.)

A major uncertainty in performing the cost analysis is the speed at which the new technologies would be adopted by CFC user industries. A series of alternative cost simulations was performed to assess the impact on costs if certain key industries implement technologies to reduce CFC use widely and quickly. The key industries identified in these analyses are: the mobile air conditioner servicing industry, the solvent industry, the hospital industry, the mobile air conditioner manufacturing industry, and the aerosol industry. Even if all other industries implemented CFC reduction measures slowly and with reduced effectiveness, the rapid and effective implementation of reduction measures by these key industries reduces the present value of social costs incurred by society through the year 2000 from $2.9 billion to $1.1 billion.

Because the costs of regulation are incurred immediately while the benefits of reduced ozone depletion accrue over hundreds of years, it is difficult to determine an appropriate time period for conducting the cost-benefit comparisons. Exhibit ES-2 compares the benefits accruing to persons born prior to 2075 to the costs incurred prior to 2075. If the benefits exceed the costs of regulation for this comparison, then social welfare is increased because additional benefits from actions taken prior to 2075 continue to accrue in years following 2075 and benefits of stratospheric ozone regulation continue to increase while costs are relatively constant after 2075. As Exhibit ES-2 shows, the present value of benefits through the year 2075 far exceeds the costs imposed by the regulatory options. Of particular note is that not all costs and benefits have been quantified. These unquantifiable costs and benefits are also itemized in Exhibit ES-2. In any evaluation of the relative merits of various

EXHIBIT ES-2

COMPARISON OF COSTS AND BENEFITS THROUGH 2075 BY SCENARIO (billions of 1985 dollars)[a]

	Health and Environmental Benefits [b]	Costs	Net Benefits (Minus Costs)	Net Incremental Benefits (Minus Costs) [c]
No Controls	--	--	--	--
CFC Freeze	3,314	7	3,307	3,307
CFC 20%	3,396	12	3,384	77
CFC 50%	3,488	13	3,475	91
CFC 80%	3,553	22	3,531	56
CFC 50%/Halon Freeze	3,575	21	3,554	23
CFC 50%/Halon Freeze/ U.S. 80%	3,589	24	3,565	11
U.S. Only CFC 50%/Halon Freeze	1,373	21	1,352	1,352 [d]

Costs and Benefits That Have Not Been Quantified

Costs

- Transition costs, such as temporary layoffs while new capital equipment is installed
- Administrative costs
- Costs of unknown environmental hazards due to use of chemicals replacing CFCs

Health Benefits

- Increase in actinic keratosis from UV radiation
- Changes to the human immune system
- Tropospheric ozone impacts on the pulmonary system
- Pain and suffering from skin cancer

Environmental Benefits

- Temperature rise
- Beach erosion
- Loss of coastal wetlands
- Additional sea level rise impacts due to Antarctic ice discharge, Greenland ice discharge, and Antarctic meltwater
- UV radiation impacts on recreational fishing, the overall marine ecosystem, other crops, forests, and other plant species, and materials currently in use
- Tropospheric ozone impacts on other crops, forests, other plant species, and man-made materials

a/ All dollar values reflect the difference between the No Controls scenario and the specified alternative scenario, unless otherwise indicated. Valuation of the health and environmental benefits applies only to people born before 2075, costs are estimated through 2075. In all scenarios, benefits through 2165 for people born from 2075 to 2165 exceed the costs of control from 2075 to 2165. Estimates assume a 2 percent discount rate. Costs are for the "Case 2" cost assumptions which assumes controls are adopted expeditiously

b/ Assumes $3 million for the value of human life (unit mortality risk reduction). Estimated benefits would be higher if larger values for human life had been assumed.

c/ Change in net incremental benefits from the indicated scenario to the scenario listed above it, e g , "CFC Freeze" minus "No Controls," unless otherwise indicated.

d/ Compared to No Controls Case.

policy options, all costs and benefits, whether they have been quantified or not, should be recognized.

As a final stage of the analysis, a series of sensitivity runs were performed to test whether large changes in the assumptions used to estimate either costs or benefits would alter the recommendations of the RIA. Among the many assumptions altered during the sensitivity runs were:

- the rate of growth in baseline CFC use;
- the value of unit mortality risk reductions;
- the discount rate;
- the participation of other nations in the Montreal Protocol;
- the rate of growth of other trace gases affecting stratospheric ozone;
- the rate of incidence of skin cancer in the population; and
- the rate of improvement in medical technology.

The results were most sensitive to the choice of the social discount rate. However, even when this value was increased from its original value of two percent to a higher estimate of six percent, benefits due to cancer deaths avoided still exceeded social costs incurred by about 12:1 for the CFC 50%/Halon Freeze case. (See Chapter 10 for additional information.)

A review of the approaches for implementing various regulatory options considered the use of auctioned rights, regulatory fees, allocated quotas, engineering controls/bans, and hybrid combinations of these approaches. Regulatory fees and engineering controls/bans, used alone, do not ensure that regulatory goals will be satisfied. Auctioned rights create substantial uncertainties in their early years of operation. Allocated quotas, therefore, appear to offer the most straightforward approach to implementing the CFC and halon regulations, although they raise equity concerns because of the potentially large transfers to producers they create which could also result in the delay in the introduction of new chemical substitutes. Adding a regulatory fee to the allocated quota system would remove the economic incentive for delay. In addition, the analysis indicates that if delays in the adoption of CFC-conserving technologies are likely, command-and-control engineering requirements, in conjunction with allocated quotas, could significantly reduce costs faced by business in the next 15 years. (See Chapter 11 for additional information.)

CHAPTER 1

INTRODUCTION AND ORGANIZATION

Concern about stratospheric ozone depletion led Congress, as part of its 1977 amendments to the Clean Air Act, to include Part B on stratospheric ozone protection. Under the Authority granted by that Act, EPA has promulgated a regulation on August 1, 1988. As part of the process of promulgating a regulation, EPA prepared a regulatory impact analysis that evaluates the consequences of various options for limiting ozone-depleting chemicals. This chapter presents the basic logic and organization of this Regulatory Impact Analysis (RIA) which examines the regulatory options that could be used to reduce future emissions of chlorofluorocarbons (CFCs) and halons under Part B of the Clean Air Act.

This RIA is divided into three volumes. Volume I is the main report; Volume II contains the appendices supporting the analysis and findings of Volume I; and Volume III contains further documentation, primarily on costs of technical options to limit ozone depleting substances. The organization of each of these volumes is discussed in turn, after a brief review of the history of this document.

1.1 HISTORY OF THIS REGULATORY IMPACT ANALYSIS

In December 1987, EPA proposed a regulation to protect the stratospheric ozone layer. Accompanying that proposed rule was a draft RIA, the precursor to this document. Based on the proposed rule and draft RIA, the EPA received some 497 comments, many referring specifically to the RIA. A summary of these comments and responses to them is contained in the Background Information Document (EPA, 1988). The present document is the final RIA to accompany the final rule on protecting stratospheric ozone (see Appendix B). It reflects considerable analysis motivated by comments on the December 1987 RIA. In particular, major changes between the December 1987 RIA and the present version include the following:

- Revision of the estimates of baseline use and emissions of ozone-modifying chemicals (Chapter 4). These revisions incorporated data on 1986 production, import and export levels received by the EPA in response to their data request (Federal Register, pages 47486-47488, December 14, 1987). Also, assumptions about the growth in baseline use between 1987 and 1992 were increased based upon observations that growth in production in 1986 and 1987 were higher than expected.

- Extensive revision to the analysis of the costs of achieving reductions in use (Chapter 9). Data on the costs of options for reducing use were updated to incorporate: (1) information received from public comments; (2) information received through continuing contacts with industry officials; and (3) emerging technologies unknown at the time of the preparation of the draft RIA. The cost analysis includes new scenarios which describe the important effects that technical progress can have on costs.

- Revision of the discussion of regulatory options (Chapter 11). This section was revised to include information received from public comments about the effects of each regulatory alternative.

- Addition of a copy of the proposed rule (Federal Register, pages 47489-47523, December 14, 1987) and the final rule to Appendix B.

- Revision of the regulatory flexibility analysis (Appendix L). This analysis was revised to incorporate all changes included in the overall analysis of costs of control. The analysis also was revised to reflect additional information received through public comments about the effects of the proposed rule on the various foam-blowing industries.

- Revision of the administrative burden analysis (Appendix M). This analysis was revised to incorporate additional information gained from industry officials about the administrative costs of recordkeeping and reporting. The analysis also incorporates additional information on the costs to EPA of administering the proposed rule and its alternatives based, in part, on its experience in processing the 1986 data received in reference to its December 14 rule (§ 40 Part 82.20).

- Additional sensitivity analysis. Based on comments received, additional sensitivity analyses were performed. For example, a set of analyses examines the potential implications of improvements in medical technology on the incidence of skin cancer.

1.2 ORGANIZATION OF VOLUME I

Volume I analyzes the regulatory options to limit CFCs and other ozone-depleting substances. It is divided into eleven chapters that analyze various aspects of the options.

Following this introductory chapter, Chapter 2 lays the scientific basis for concern about stratospheric ozone depletion and for preventing stratospheric change. This chapter is not intended to provide a detailed scientific analysis related to ozone depletion. The primary scientific basis for this RIA is contained in the risk assessment on stratospheric protection published by EPA in December 1987. This assessment has been reviewed by the Environmental Protection Agency's Science Advisory Board and is available from EPA. Similarly, assessments on atmospheric science by the World Meteorological Organization (1986) and NASA (1986) are also used extensively in evaluating issues related to atmospheric ozone. Readers wishing a detailed presentation of the science should consult these source documents. Most recently, the Ozone Trends Panel convened by NASA has summarized at length the latest scientific findings on the Antarctic ozone hole and recent trends in ozone depletion (see NASA (1988)). Because this information has only recently become available, preventing its full consideration by EPA as part of this rulemaking, it has not been incorporated in this final RIA.

Chapter 3 lays the legal basis for regulating emissions that could affect the stratosphere. Chapters 4 through 10 evaluate alternatives to protect the stratosphere by analyzing factors that could result in ozone depletion and its effects. Various control levels (i.e., chemical coverage and stringency) are evaluated in terms of their costs and effects

Chapter 4 lays out the baseline production for CFCs, halons and other relevant trace gases that would occur if there is no regulation. This chapter considers not just ozone-depleters but concentrations of trace gases that also influence stratospheric ozone. Some of these gases increase ozone levels, while others could contribute to depletion. All are greenhouse gases. These scenarios of future growth in trace gases are inputs into the atmospheric models.

Chapter 5 lays out the chemical stringency and coverage options that could be used to reduce emissions over time, specifying four control level options that could be undertaken. These control level options cover a range of stringency both weaker and stronger than that contained in the protocol concluded in Montreal under the auspices of the United Nations Environment Programme (UNEP). Also considered is the effect of unilateral U.S. action, of U.S. action more stringent than the international protocol, and of exclusion of halons from control.

Chapter 6 outlines the potential atmospheric response to the baseline scenario and to the various control level options. This response is projected using a statistical representation of a one-dimensional atmospheric model.

Chapter 7 presents estimates of the health and environmental impacts of projected atmospheric change, including effects on skin cancers, cataracts, sea level, crop production, aquatics, tropospheric ozone, and polymers. This chapter examines these impacts both for the baseline and control level options.

Chapter 8 presents the economic value of avoiding the damages projected in Chapter 7, attaching dollar values to those impacts where quantitative estimates are possible. (Note that not all effects have been quantitatively estimated and that not all effects can be valued in dollar terms.)

Chapter 9 presents estimates of the costs that would be associated with each control level option. In this chapter, a range of cost estimates are presented. At one extreme, a "Case 1" scenario assumes that the CFC reduction potential of these technologies is reduced and that industries delay their adoption. At the other extreme, a "Case 2" cost estimate assumes that CFC-conserving technology is rapidly adopted and is relatively successful at reducing CFC use.

Chapter 10 integrates the costs and benefits of alternative control level options so that the net benefit of each can be assessed. Sensitivity analyses are included that examine the dependency of this analysis on various assumptions about emissions, atmospheric response, physical effects, economic valuation assumptions, and advances in medical technology.

Together Chapters 4-10 analyze the benefits and costs of different control level options. The analysis of costs varies based on assumptions about the penetration and availability of options to limit CFC and halon use. The method of implementation of these options could also affect costs. Chapter 11 has been devoted to the regulatory alternatives that could be used to implement any of the control level options.

Chapter 11 focuses on evaluating five regulatory options: allocated quotas: production quotas allocated to producers and importers; auctioned rights: rights auctioned to any interested party; fees that would be used to provide incentives to reduce demand; engineering regulations such as technology standards for industrial processes and bans on products; and hybrid systems such as the combination of allocated quotas with some engineering controls/bans or with regulatory fees. Chapter 11 examines how these options differ by qualitatively assessing such issues as costs, administrative burden, equity, legal certainty, enforcement, and impacts on small businesses. It draws on the cost analysis presented in Volume 1 and two additional studies on administrative burdens and regulatory flexibility, both of which are contained in Volume II.

Throughout these chapters, assumptions critical to understanding the analysis are presented. However, in order to allow the document to be read by a large audience of interested parties, detailed explanations of methodologies and assumptions are relegated to Volume II and Volume III.

1.3 ORGANIZATION OF VOLUME II

Volume II includes 13 appendices. Appendix A presents the Executive Summary of EPA's risk assessment. Appendix B presents EPA's Stratospheric Ozone Protection Plan, which was published in the Federal Register on January 10, 1986, as well as copies of the proposed and final rule for Protection of Stratospheric Ozone, the latter being the subject of this RIA. Appendix C presents an analysis of how CFC regulations can lead to technological rechanneling, thereby altering the demand for CFCs in both nations participating and not participating in the international protocol to protect ozone. Appendix D discusses factors affecting the use of CFCs specific to developing nations. Appendix E presents details of the human health effects modeling, while Appendix F focuses on the environmental effects. Appendix G discusses the value ascribed to preventing premature deaths now and in the future. Appendix H discusses issues related to specifying a base discount rate and sensitivity rates which are used to analyze the time flow of costs and benefits. Appendix I lays out in detail the framework and method for estimating control costs. Appendix J specifies the sequence of technical control options that would be taken to implement the protocol control level. Appendix K discusses issues related to international trade. Appendix L analyzes actions under the Regulatory Flexibility Act. Appendix M presents an Administrative Burdens Analysis.

1.4 ORGANIZATION OF VOLUME III

The addenda focus on detailed uses of CFCs and the costs of undertaking controls. The addenda are presented in nine parts: (1) rigid foam; (2) flexible foam; (3) automobile air conditioning; (4) refrigeration and other air conditioning; (5) miscellaneous uses (such as aerosols and food freezing); (6) sterilants; (7) solvents; (8) civilian uses of halons; and (9) military uses of halons. In each area, the use area is reviewed, and control options are discussed (broadly defined to include both technology controls, substitutes, etc.). For each control option, costs and penetration rates for three time periods are presented. This body of work forms the documentation of the database used in the cost modeling discussed in Appendix I. A supplement to the nine volumes of addenda presents changes and additions to the information on control options contained therein.

REFERENCES

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CHAPTER 2

THE SCIENTIFIC BASIS FOR CONCERN ABOUT THE STRATOSPHERE

2.1 ULTRAVIOLET RADIATION

The process of nuclear fusion in the sun provides energy transferred by photons to the earth. These photons have both wavelengths and energy levels. As shown in Exhibit 2-1, wavelengths less than 400 nanometers (nm) are "ultraviolet radiation" (UV-R). Wavelengths below 290 nm are "UV-C" radiation, wavelengths from 290 to 320 nm are "UV-B" radiation, and wavelengths from 320 to 400 nm are "UV-A" radiation.

Much of the ultraviolet energy that strikes the earth's atmosphere does not reach the planet's surface, but is absorbed by ozone (O_3) molecules in the stratosphere (Exhibit 2-2). As Exhibit 2-2 demonstrates, stratospheric ozone absorbs lower wavelengths most effectively. In fact, no UV-C radiation reaches the earth's surface. Stratospheric ozone partially absorbs UV-B radiation, and does not absorb any UV-A radiation.

This selective absorption of ultraviolet radiation by the earth's ozone layer has allowed life to develop on earth. Exposure to low UV-C and UV-B radiation has been shown to be deadly to many organisms, and it is doubtful that life in its current form could have evolved without the protective screening by the ozone layer.

For many biological targets, the probability of photon absorption increases with decreasing wavelength, especially for UV-B and UV-C. The relative effectiveness of UV-R in producing a biological effect is therefore greater at lower wavelengths. For example, Exhibit 2-3 shows experimental data on the relative effectiveness of UV-R wavelengths in damaging DNA, e.g., radiation at 300 nm is about 2.5 orders of magnitude more damaging than radiation at 320 nm.

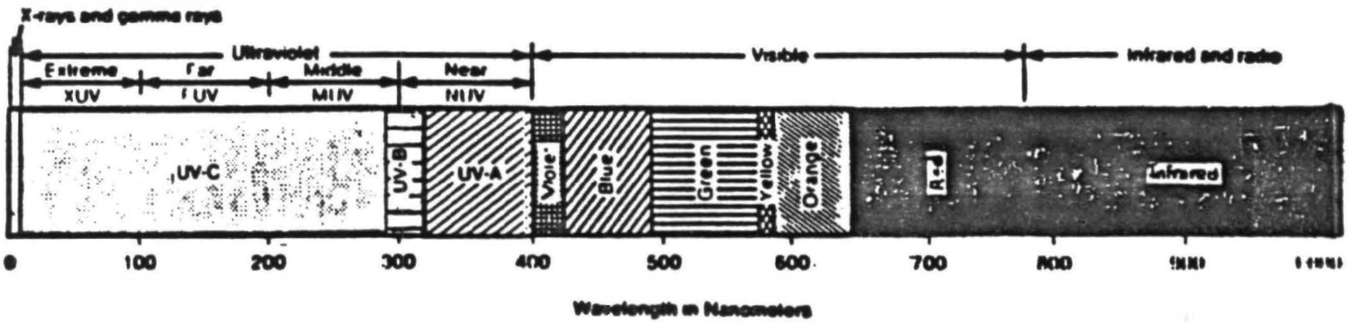
Current levels of UV-R are responsible for significant damages to human health, welfare, and the environment. Molecular, cellular, animal, and epidemiological evidence supports this conclusion. Examples of current UV-B effects include skin cancer and damage to outdoor polymers. Exhibit 2-4 shows that current U.S. incidence of nonmelanoma skin cancer cases is over 500,000 per year, and incidence of melanoma skin cancer is 25,000 cases per year. In addition, large sums of money are spent to prevent polymer degradation due to ambient levels of UV-R. A $72 million per year plastic stabilizer market has developed (Hattery, McGinniss, and Taussig, 1985).

2.2 CONCERN ABOUT STRATOSPHERIC OZONE DEPLETION

The creation of ozone has a simple basis: solar radiation breaks stratospheric oxygen (O_2) molecules into single oxygen atoms (O). Ozone is then naturally created by the reaction of O and O_2. If this were the only process occurring, it would ultimately lead to increasing concentrations of ozone. In reality, a series of reactions also destroys ozone. In particular, ozone (O_3) reacts with odd oxygen atoms (O) to form O_2 molecules. This natural

EXHIBIT 2-1

THE ELECTROMAGNETIC SPECTRUM

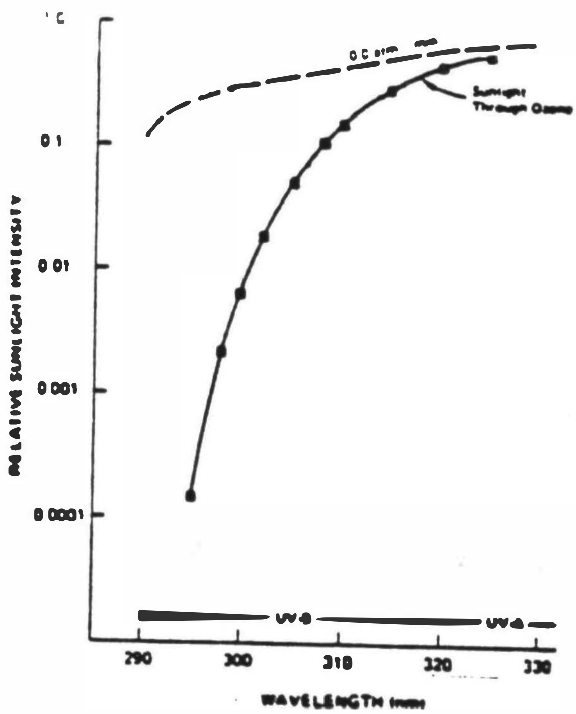


Ultraviolet radiation (UV-R) is defined as electromagnetic energy with wavelengths less than 400 nanometers (nm). UV-R is further divided into UV-C (less than 290 nm), UV-B (290 nm to 320 nm), and UV-A (320 nm to 400 nm).

Source: Adapted from Scotto, J., (1986), "Nonmelanoma Skin Cancer - UV-B Effects" in J.G. Titus (ed.), <u>Effects of Changes in Stratospheric Ozone and Global Climate</u>. <u>Volume II: Stratospheric Ozone</u>, U.S. Environmental Protection Agency, Washington, D.C., p. 34.

EXHIBIT 2-2

THE OZONE LAYER SCREENS HARMFUL UV-R

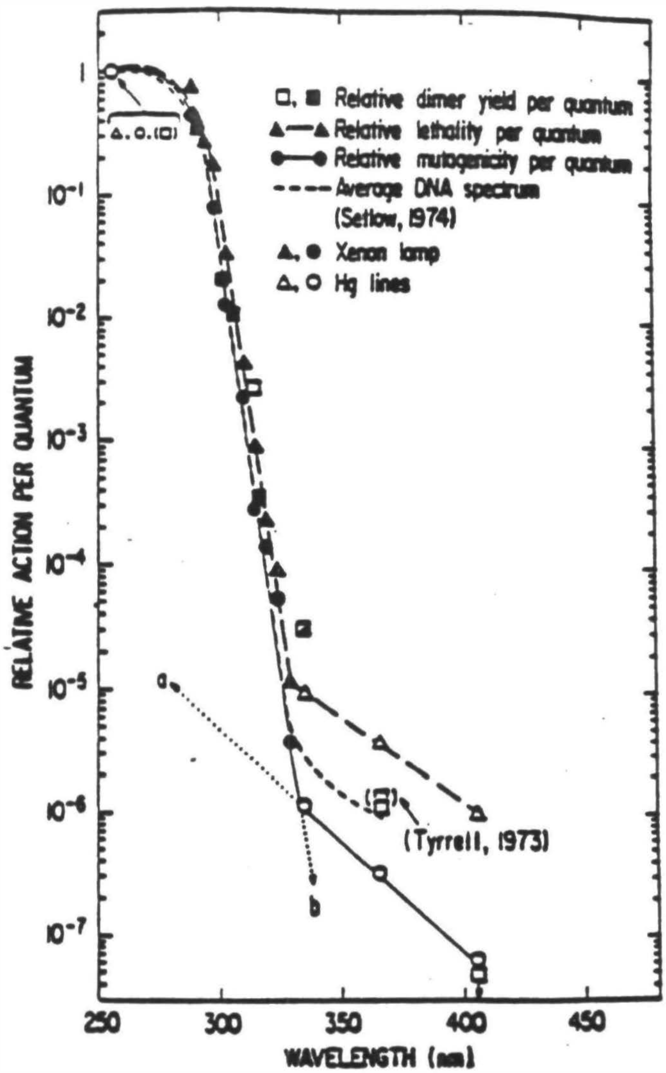


The upper line shows that significant amounts of UV-C and UV-B reach the top of the earth's atmosphere. The lower line, which represents the UV-R that reaches the earth's surface, demonstrates that the ozone layer effectively screens these harmful wavelengths.

Source: Adapted from National Academy of Sciences, (1982), Causes and Effects of Stratospheric Ozone Reduction, National Academy Press, Washington, D.C., p. 40.

EXHIBIT 2-3

UV-R DAMAGE TO DNA:
RELATIVE EFFECTIVENESS BY WAVELENGTH



The relative effectiveness of wavelengths in inducing damage constitutes an action spectrum. The action spectrum for DNA damage is shown above. Note that radiation at 300 nm is 2.5 orders of magnitude more effective at inducing DNA damage as radiation at 320 nm.

Source: Peak, M.J., J.G. Peak, M.P. Moerhing, and R.B. Webb (1984), "Ultraviolet Action Spectra for DNA Dimer Induction, Lethality, and Mutagenesis in Enscherichia coli with Emphasis on the UVB Region," Photochemistry and Photobiology, 40, 613-620.

EXHIBIT 2-4

DAMAGES IN U.S. AT CURRENT LEVELS OF UV-R

Non-melanoma skin cancer incidence:	>500,000 per year
Melanoma skin cancer incidence:	25,000 per year
UV-stabilizers for outdoor materials:	$72 million per year

Sources: Non-melanoma skin cancer incidence is based on rates in Scotto, Fears, and Fraumeni (1981). Melanoma incidence is based on rates in Scotto and Fears (1987). Methodology used to calculate total incidence is presented in EPA (1987). UV stabilizer estimates are reported in Hattery, G.R., V.D. McGinniss, and P.R. Taussig (1985).

cycle of creation and destruction (which includes many other species and interactions) leads to an "equilibrium" level of ozone, which if it were brought to ground level pressure could be 3 mm wide.

Since the early 1970s, researchers have theorized that the natural destruction of ozone can be enhanced by other anthropogenically-produced compounds that could participate in catalytic reactions that destroy ozone. Of particular concern are chlorine, bromine, and nitrogen, which are believed to have the potential to reach the stratosphere in sufficient quantities to cause significant depletion of stratospheric ozone. Exhibit 2-5 shows the basic outline of these chlorine, bromine, and nitrogen cycles.

Natural sources of chlorine, bromine, and nitrogen contribute a small and stable amount of these species to the stratosphere. Researchers hypothesize, however, that man's activities may lead to rapidly increasing amounts of these molecules in the stratosphere. The scientific focus on this issue began in the early 1970s with analysis of nitrogen compounds from supersonic transport aircraft, the exhaust of emissions from the proposed space shuttle, and emissions of nitrous oxide from fertilizer applications.

In 1974, Molina and Rowland first outlined the potential effects of chlorofluorocarbons (CFCs) on the stratospheric ozone layer. They hypothesized that CFCs, a class of industrial chemicals valued for their stability, would accumulate in the lower atmosphere and eventually be transported to the stratosphere, where they would be photodissociated by the sun's high-energy UV-R and yield chlorine atoms, which would participate in catalytic reactions that destroy ozone.

Since 1974 there have been substantial improvements in the ability of researchers to evaluate the effects of CFCs on stratospheric ozone. Significant advances have enabled researchers to measure more accurately the rates of important chemical reactions affecting ozone that occur in the atmosphere and simulate these reactions affecting ozone in mathematical models. Comparisons of the calculated profiles of ozone and other atmospheric constituents with field measurements have allowed further refinements of atmospheric models. One-dimensional atmospheric models have been developed which can simulate both chemical reactions and vertical transport of compounds. Since 1974, the results of these models have been relatively consistent (Exhibit 2-6). For the "standard case" of constant emissions of CFC-11 and CFC-12 only, the Lawrence Livermore National Laboratory one-dimensional model has projected a mean depletion of 12.4 percent, plus or minus 3.8 percent (one standard deviation). No excursion was more than 8 percent from the mean and none ever went "positive."

Recent concern about potential stratospheric ozone depletion has been intensified by several developments. First, researchers recognized that total worldwide CFC emissions, which had remained relatively constant after the U.S. and others abandoned their use in aerosol sprays, were beginning to rise due to continued growth in non-aerosol uses such as air conditioning, refrigeration, and foam blowing. In addition, growing use of other chlorine-containing compounds, such as CFC-113 used in electronics as a solvent, was adding to the chlorine burden in the stratosphere.

EXHIBIT 2-5

CHEMICAL CYCLES THAT AFFECT THE CREATION AND DESTRUCTION OF OZONE

1. Chlorine cycle:

$$Cl + O_3 \longrightarrow ClO + O_2$$
$$O + ClO \longrightarrow Cl + O_2$$
$$\text{Net} \quad O + O_3 \longrightarrow 2O_2$$

2. Bromine cycle:

$$Br + O_3 \longrightarrow BrO + O_2$$
$$BrO + O \longrightarrow Br + O_2$$
$$\text{Net} \quad O + O_3 \longrightarrow 2O_2$$

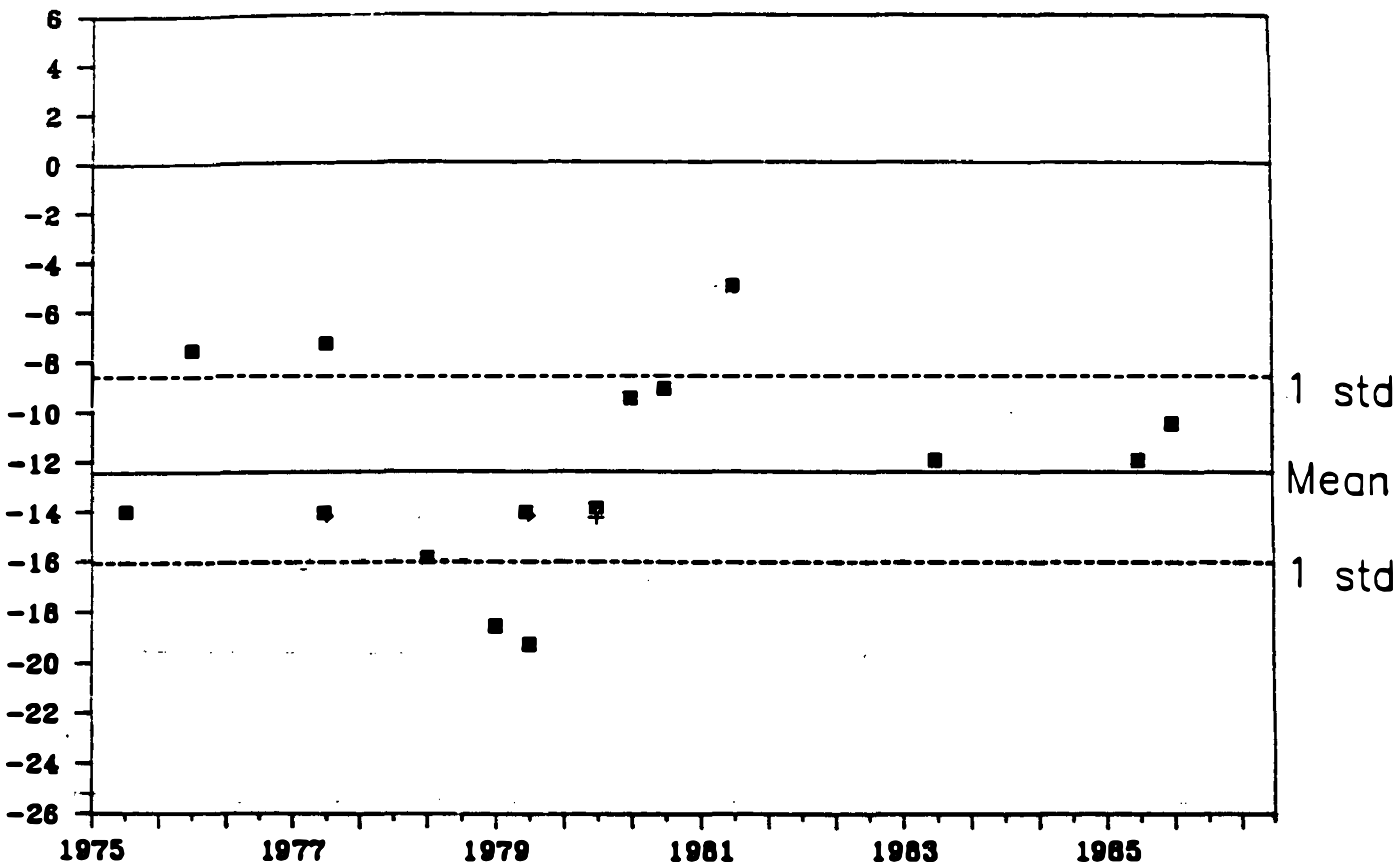
3. Nitrogen cycle:

$$NO + O_3 \longrightarrow NO_2 + O_2$$
$$NO_2 + O \longrightarrow NO + O_2$$
$$\text{Net} \quad O + O_3 \longrightarrow 2O_2$$

Chlorine, bromine, and nitrogen act as catalysts, converting ozone molecules into oxygen molecules, but emerging ready to eliminate another O_3 molecule after the two reactions.

EXHIBIT 2-6

HISTORY OF MODEL PREDICTIONS OF OZONE DEPLETION



The one-dimensional model of the Lawrence Livermore National Laboratory has been used to project ozone depletion and has shown consistent results over the last 12 years. For the standard case of constant CFC-11 and CFC-12 emissions at 1974 levels, mean projected depletion is 12.4 percent, with a standard deviation of 3.8 percent.

Source: Calculated from reported results of LLNL model. Data for 1975 to 1981 from Wuebbles (1983). Data for 1983 to 1985 taken from Figure 13-37 of WMO (1986).

The unexpected finding of the British Antarctic Survey in 1985 that concentrations of ozone above Antarctica were rapidly decreasing during the Spring also intensified concern. This depletion had not been predicted by atmospheric models, and considerable debate followed on the fundamental mechanism responsible for this "ozone hole". Nonetheless, the losses of ozone in Antarctica raise the possibility that atmospheric models might be underpredicting the effects of CFCs on ozone. Preliminary data from satellites and ground-based monitoring stations also raise the possibility that worldwide depletion of ozone has occurred in the last decade beyond what current models have predicted. The EPA risk assessment (EPA 1987) stated that data on the Antarctic ozone hole or the possible global depletion need additional scientific analysis before being used for policy decisions. Additional analysis is underway in the scientific community which may lead to further revision of the models used in this RIA. At this time, these data, as contained in the Ozone Trends Panel Report are not used as a basis for decisionmaking.[1]

2.3 THE STRATOSPHERE AND GLOBAL CLIMATE

In addition to its role in absorbing UV-R, the stratosphere is an important determinant of global climate. The vertical distribution of ozone, projected to change due to CFC emissions, plays a role in establishing the earth's radiative balance. Stratospheric water vapor also affects its radiative balance. While the current concentration of stratospheric water vapor is low, increases in methane, which by increasing ozone could partially offset losses in ozone from CFCs, would also increase water vapor concentrations. Some recent evidence suggests that water vapor may play a role in decreasing ozone in the stratosphere. The vertical distribution of ozone in the stratosphere may also have a role in controlling climatic circulation patterns, but the exact implications for weather and climate circulation patterns are uncertain. Projected changes in the stratosphere will alter vertical distribution and alter global temperatures.

2.4 HEALTH AND ENVIRONMENTAL EFFECTS OF STRATOSPHERIC MODIFICATION

Major reviews of scientific issues related to changes in stratospheric ozone have been conducted over the years by the National Academy of Sciences, the National Aeronautics and Space Administration, and the World Meteorological Organization. In its recently completed risk assessment, the U.S. Environmental Protection Agency also reviewed scientific work on the health and environmental effects of stratospheric change. Its report, Assessing the Risks of Trace Gases That Can Modify the Stratosphere, was reviewed by the Agency's Science Advisory Board and provides the scientific basis for developing regulations to protect the stratosphere. The Summary Findings of the risk assessment are listed below.

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[1] Most recently, the Ozone Trends Panel (NASA, 1988) reported larger than previously expected losses in global ozone levels over the past 17 years and clearly identified a link between CFCs and the Antarctic ozone hole. It is premature to modify the methods employed here to reflect these recent findings. The cause of the Antarctic ozone hole and the apparent ozone depletion over the past decade reported by the Ozone Trends Panel, although reasons for concern, are not yet well enough understood to use as a basis for modifying the models used in this assessment.

SUMMARY FINDINGS

1. Considerable research has taken place since 1974 when the theory linking chlorine from chlorofluorocarbons (CFCs) and depletion of ozone was first developed. While uncertainties remain, the evidence to date continues to support the original theory that CFCs have the potential to decrease stratospheric ozone.

2. Atmospheric measurements show that the chemical composition of the atmosphere -- including gases that affect ozone -- has been changing. Recently measured annual rates of growth in global atmospheric concentrations of trace gases that influence ozone include: CFC-11: 5 percent; CFC-12: 5 percent; CFC-113: 10 percent; carbon tetrachloride: 1 percent; methyl chloroform: 7 percent; nitrous oxide: 0.2 percent; carbon monoxide: 1 to 2 percent; carbon dioxide: 0.5 percent; and methane: 1 percent. More limited measurements of halon 1211 show recent annual increases of 23 percent in atmospheric concentrations.

3. CFCs, halons, methyl chloroform, and carbon tetrachloride release chlorine or bromine into the stratosphere where they act as catalysts to reduce the net amount of ozone. In contrast, carbon dioxide and methane either add to the total column of ozone or slow the rate of depletion. The effect of increases in nitrous oxide varies depending on the relative level of chlorine.

4. CFCs, methyl chloroform, carbon tetrachloride, and halons are industrially produced. Emissions of methane, carbon dioxide, and nitrous oxide occur from both human activity and the natural biosphere. Because all these gases (with the exception of methane and methyl chloroform) remain in the atmosphere for many decades to over a century, emissions today will influence ozone levels for more than a century. Also, as a result of these long lifetimes, concentrations of these gases will rise for more than a century, even if emissions remain at constant levels. For example, to stabilize concentrations of CFC-11 or -12 would require a reduction in current global emissions of about 85 percent.

5. In order to assess risks, scenarios of atmospheric change were evaluated using models. For CFCs, methyl chloroform, carbon tetrachloride, and halons, demand for goods that contain or are manufactured with these chemicals (e.g., refrigerators, computers, automobile air conditioners) and the historic relationship between economic activity and the use of these chemicals were analyzed. These analyses indicate that in the absence of regulation, the use and emissions of these compounds are expected to increase in the future. However, for purposes of analyzing risks, six "what-if" scenarios were adopted that cover a greater range of future production of ozone-depleting substance than is likely to occur.

6. Atmospheric chemistry models were used to assess the potential effects of possible future changes in atmospheric concentrations of trace gases. These models attempt to simulate processes that influence the creation and destruction of ozone. While the models replicate many of the characteristics of the atmosphere accurately, they are inconsistent with

measured values of other constituents, thus lowering our confidence in their ability to predict future ozone changes accurately.

7. Based on the results from these models, the cause of future changes in ozone will be highly dependent on future emissions of trace gases. One-dimensional models project that if the use of chlorine and bromine containing substances remains constant globally, and other trace gas concentrations continue to grow, total column ozone levels would at first decrease slightly, and then would subsequently increase. If the use of CFCs continues to grow at past rates and other gases also increase at recent rates, substantial total column ozone depletion would occur by the middle of the next century. If the use of CFCs stays at current levels and the growth in the concentrations of other trace gases slows over time, model results indicate total column ozone depletion will also occur.

8. In all scenarios examined, substantial changes are expected in the vertical distribution of ozone. Ozone decreases are generally expected at higher altitudes in all scenarios in which CFC concentrations increase. Ozone increases are expected at lower altitudes in some scenarios examined due to increases in methane concentrations. Such changes may have important climatic effects.

9. Two-dimensional (2-D) models provide information on possible changes in ozone by season and by latitude. Results from 2-D models suggest that global average depletion could be higher than estimates from a one-dimensional (1-D) model for the same scenario. Moreover, the 2-D model results suggest that average annual ozone depletion above the global average would occur at higher latitudes (above 40 degrees), while depletion over tropics is predicted to be lower than the global average; and depletion would be greater in the spring than the annual average. Uncertainties in the representation of the transport of chemical species used in 2-D models introduces uncertainty in the magnitude of the latitudinal gradient of ozone depletion, but all 2-D models project a gradient.

10. Measurements of ozone concentrations are another valuable tool for assessing the risks of ozone modification. Based on analysis of data for over a decade from a global network of ground-based monitoring stations, ozone concentrations have decreased at mid-latitudes in the upper and lower stratosphere and increased in the troposphere. According to studies using ground-based instruments, there appears to have been no statistically significant change in column ozone between 1970 and 1983. High altitude, lower stratospheric, and total column trends are roughly consistent with current two-dimensional model predictions.

11. Recent evidence indicates that since the late 1970s substantial decreases in ozone (up to 50 percent) have occurred over and near Antarctica during its springtime. These losses have been verified by different measurement techniques, and different theories have been suggested to explain the cause of the seasonal loss in ozone. Insufficient data exist to state whether chlorine and bromine are responsible for the observed depletion, or whether some other factor is the cause (e.g., dynamics or changes in solar flux that alters NOx). Furthermore, even if man-made chemicals are the cause of the phenomenon, stratospheric conditions surrounding Antarctica are different from the stratospheric conditions for the rest of the world, so that it

cannot be assumed that similar depletion would occur elsewhere. Models did not predict the Antarctic ozone depletion, however. Consequently, the change in Antarctica suggests that ozone abundance is sensitive to yet unknown natural or anthropogenic factors not yet incorporated in current models.

12. Preliminary data from Nimbus-7 suggest a decrease in global ozone concentrations (4-6 percent) may have occurred during the past several years. These data have not yet been published and require additional review and verification. If verified, further analysis would be required to determine if chlorine is responsible for the reported decrease in ozone levels, or whether the decrease is due to other factors or reflects short-term natural variations.[2]

13. Decreases in total column ozone would increase the penetration of ultraviolet-B (UV-B) radiation (i.e., 290-320 nanometers) reaching the earth's surface.

14. Exposure to UV-B radiation has been implicated by laboratory and epidemiologic studies as a cause of two common types of skin cancers (squamous cell and basal cell). It is estimated that there are more than 400,000 new cases of these skin cancers each year. While uncertainty exists concerning the appropriate action spectrum (i.e., the relative biological effectiveness of different wavelengths of ultraviolet radiation), a range of relationships was developed that allows increased incidence of these skins cancers to be estimated for future ozone depletion (these cancers are also referred to as nonmelanoma skin cancers).

15. Studies predict that for every 1 percent increase in UV-B radiation (which corresponds to less than a 1 percent decrease in ozone because the amount of increase in UV-B radiation, depending on the action spectrum, is greater than rather than proportional to ozone depletion), nonmelanoma skin cancer cases would increase by about 1 to 3 percent. The mortality for these forms of cancer has been estimated at approximately 1 percent of total cases based on limited available information.

16. Malignant melanoma is a less common form of skin cancer. There are currently approximately 25,000 cases per year and 5,000 deaths. The relationship between cutaneous malignant melanoma and UV-B radiation is a complex one. Laboratory experiments have not succeeded in transforming melanocytes with UV-B radiation. However, recent epidemiological studies, including large case control studies, suggest that UV-B radiation plays an important role in causing melanoma. Uncertainties in action spectrum, dose measurement, and other factors necessitates the use of a range of dose-response estimates. Taking into account such uncertainties, recent studies predict that for each 1 percent change in UV-B intensity, the incidence of melanoma could increase from 0.5 to 1 percent.

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[2] The Ozone Trends Panel (NASA, 1988) report concluded that significant instrument drift resulted in their inability to verify these losses which are substantially greater than other ground-based and satellite measurements.

17. Studies have demonstrated that UV-B radiation can suppress the immune response system in animals and possibly humans. While UV-B-induced immune suppression has been linked to chronic reinfection with herpes simplex virus and leishmaniasis in animals, its possible impact on other diseases and its impact on humans has not been studied.

18. Increases in exposure to UV-B radiation are likely to increase the incidence of cataracts and could adversely affect the retina.

19. While studies generally show adverse impacts on plants from increased UV-B exposure, difficulties in experimental design, the limited number of species and cultivars tested, and the complex interactions between plants and their environments prevent firm conclusions from being made for the purpose of quantifying risks. Field studies on soybeans suggest that yield reductions could occur in some cultivars of soybeans, while evidence from laboratory studies suggest that two out of three cultivars are sensitive to UV-B.

20. Laboratory studies with numerous other crop species also show many to be adversely affected by UV-B. Increased UV-B has been shown to alter the balance of competition between plants. While the magnitude of this change cannot be presently estimated, the implications of UV-altered, competitive balance for crops and weeds and for nonagricultural areas such as forests,' grasslands, and desert may be far reaching.

21. Aquatic organisms, particularly phytoplankton, zooplankton, and the larvae of many fishes, appear to be susceptible to harm from increased exposure to UV-B radiation because they spend at least part of their time at or near surface waters. However, additional research is needed to better understand the ability of these organisms to mitigate adverse effects and any possible implications of changes in community composition as more susceptible organisms decrease in numbers. The implications of possible effects on the aquatic food chain requires additional study.

22. Research has only recently been initiated into the effects of UV-B on the formation of tropospheric ozone (an air pollutant with negative health and plant effects). An initial chamber and model study shows that tropospheric ozone levels could increase, resulting in additional urban areas being in non-compliance with National Ambient Air Quality Standards. The increase in UV-B would also produce ozone peaks closer to urban centers, exposing larger populations to unhealthy concentrations of tropospheric ozone. The same study also predicts substantial increase in hydrogen peroxide, an acid rain precursor. However, because only one study has been done, the results must be treated with caution. Additional theoretical and empirical work will be needed to verify these projections.

23. Research indicates that increased exposure to UV-B would likely cause accelerated weathering of polymers, necessitating polymer reformulation or the use of stabilizers in some products, and possibly curtailing use of certain polymers in some areas.

24. The National Academy of Sciences (NAS) has recommended that 1.5°C to 4.5°C represents a reasonable range of uncertainty about the temperature sensitivity of the Earth to a doubling of CO2 or an increase in other trace gases of the equivalent radiative forcing. While some of the trace gases

discussed above deplete ozone and others result in higher ozone levels, all, on net, would increase the radiative forcing of the Earth and would contribute to global warming.

25. Using the middle of the NAS range for the Earth's temperature sensitivity and a wide range of future trace gas growth (e.g., from a phase-down of CFCs by 80 percent from current levels by 2010 to a 5 percent annual increase through 2050; CO2 doubling by 2060; N20 increasing at 0.2 percent; CH4 increasing by 0.017 ppm/year through 2100), equilibrium temperatures can be expected to rise from 4°C to 11.6°C by 2075. Of this amount, depending on the scenario, CFCs and changes in ozone would be responsible for approximately 15-25% of the projected climate change.

26. In most situations, inadequate information exists to quantify the risks related to climate change. Studies predict that sea level could rise by 10-20 centimeters by 2025, and by 55-190 centimeters by 2075. Such increases could damage wetlands, erode coastlines, and increase damage from storms. Changes in hydrology, along with warmer temperatures, could affect forests and agriculture. However, lack of information about the regional nature of climatic change makes quantification of risks difficult. A study suggests that rising temperatures could adversely affect human health if acclimatization lags.

27. To perform the computations necessary to evaluate the risks associated with stratospheric modification, an integrating model was developed to evaluate the joint implications of scenarios or estimates for: (1) potential future use of CFCs and change in other trace gases; (2) ozone change as a consequence of trace gas emissions; (3) changes in UV-B radiation associated with ozone change; and (4) changes in skin cancer cases and cataracts associated with changes in UV-B radiation. Potential impacts of stratospheric modification that could not be quantified were not addressed by the integrating model. On a global basis, the risks of ozone depletion may be greatest for plants, aquatic systems and the immune system, even though knowledge to assess these efforts is much less certain than for skin cancers.

28. Uncertainty about future risks is partly driven by the rate at which CFC and halon use and other trace gases grow or decline. For this reason, a wide range of "what-if" scenarios of potential CFC and halon use and growth in trace gas concentration was evaluated. To reflect the large uncertainties, the scenarios range from an 80 percent global phase-down in the use of CFCs by 2010 to an average annual growth in use of 5 percent per year from 1985 to 2050. For ozone-modifying gases other than CFCs, scenarios were based on recently measured trends, with uncertainties being evaluated by considering a range of future emissions and concentrations.

29. Across the wide range of "what-if" scenarios considered, ozone change by 2075 could vary from as high as over 50 percent ozone depletion to increased abundance of ozone of approximately 3 percent. This range of ozone change implies a change in the number of skin cancer cases among people alive today and born through 2075 ranging from an increase of over 200 million to a decrease on the order of 6.5 million. The overwhelming majority (over 95 percent) of the increases and decreases in skin cancer cases estimated for this wide range of scenarios is associated with basal and squamous cell

cancers (i.e., nonmelanoma skin cancer). Mortality impacts are estimated to be on the order of 1.5 to 2.0 percent of the changes in total cases, and a large percentage of the estimated impacts are associated with people born in the future. The statistical uncertainty of these estimates is on the order of plus and minus 50 percent. Additional uncertainties exist, some of which cannot be quantified. The greatest single uncertainty about future risks is driven by the rate at which CFC and halon use grows or declines. This uncertainty is reflected in the assessment by examining a wide range of "what if" scenarios of future use.

2.5 SUMMARY

The stratosphere plays an important role in protecting human health, welfare and the environment. The stratospheric ozone layer acts as a protective shield against harmful ultraviolet radiation. In addition, the stratosphere influences global climate. Increased emissions of CFCs and other trace gases are projected to deplete stratospheric ozone and contribute to global climate change.

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CHAPTER 3

LEGAL BASIS FOR REGULATION AND REGULATORY IMPACT ASSESSMENT

Concern about protecting stratospheric ozone began in 1974 soon after Molina and Rowland published their paper theorizing depletion from chlorofluorocarbons (CFCs). In the U.S., voluntary action by consumers and manufacturers soon resulted in significant reductions in CFC use. In 1978, the Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) banned the use of CFCs in non-essential aerosol propellants. Congress strengthened EPA's regulatory authority in the 1977 amendments to the Clean Air Act. In 1980, EPA issued an Advance Notice of Proposed Rulemaking (ANPR) that stated that it was evaluating further restrictions on CFC use.

In 1986 EPA published its Stratospheric Ozone Protection Plan, which superseded its 1980 ANPR and outlined a program of further research and decisionmaking. The plan called for research and analysis to narrow scientific uncertainties, and proposed that the Agency evaluate domestic regulations concurrently with ongoing international efforts to develop a CFC control protocol to protect stratospheric ozone. In 1987, EPA published a proposed rule for protecting stratospheric ozone. This rule would constitute the implementation by the United States of its obligations under the Montreal Protocol. (Appendix B contains copies of both the Stratospheric Ozone Protection Plan and the proposed rule.)

3.1 DOMESTIC AND INTERNATIONAL REGULATORY HISTORY PRIOR TO THE 1977 CLEAN AIR ACT REVISIONS

In 1974, aerosol propellants accounted for approximately half of CFC use in the United States. By 1980, this use had fallen to five percent of previous totals in the U.S. (Exhibit 3-1). A number of events -- economic forces, environmental concern, and regulations -- contributed to the reduction of the use of CFCs (Kavanaugh, et al., 1986).

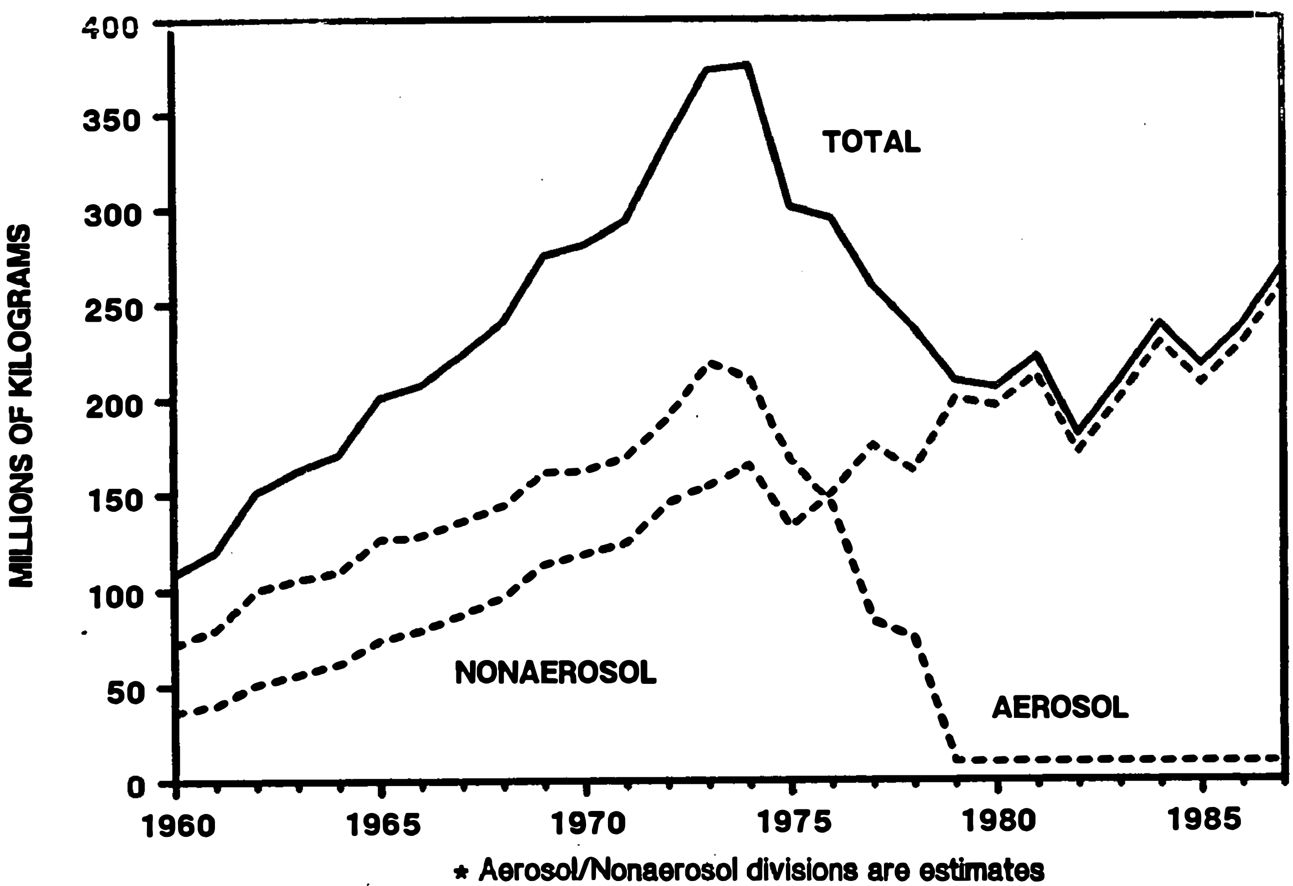
The initial impetus away from CFC use in aerosols was the environmental concern of consumers and producers. Consumers, alerted by news reports and television, sought other products. Taking advantage of such environmental concern, producers of non-CFC propelled aerosols and of alternative delivery systems, such as pumps and hydrocarbon propelled sprays, advertised that their products did not contain CFCs. The overall effect of these activities was a reduction in sales of personal care aerosols.

Governmental restrictions on CFCs were first discussed in Congressional hearings in December 1974. In 1976, EPA, the FDA, and the Consumer Product Safety Commission (CPSC) began to evaluate regulations restricting CFC use in aerosols.

The ban on CFC use in non-essential aerosol propellants was promulgated in 1978 (43 FR 11301; March 17, 1978). The FDA acted pursuant to its authority under the Federal Food, Drug and Cosmetic Act to ban most CFC use in food, drug, and cosmetic aerosol devices. EPA, acting under the Toxic Substances Control Act, banned non-essential CFC use in all aerosols. The CPSC issued regulations

EXHIBIT 3-1

CFC-11 AND CFC-12 PRODUCTION IN THE UNITED STATES*



*Production of CFC-11 and CFC-12 in the United States increased rapidly throughout the 1960s and early 1970s. Production reached a maximum of 376.4 mill kg in 1974, with 56 percent used in aerosol sprays. Non-essential use of CFCs in aerosol sprays was banned in 1978, and aerosol use today accounts for only 5 percent of total CFC-11 and CFC-12 production.

EXHIBIT 3-1

CFC-11 AND CFC-12 PRODUCTION IN THE UNITED STATES*
(Continued)

Sources:

(a) Total CFC-11 and CFC-12 production from 1960 to 1985 from United States International Trade Commission, Synthetic Organic Chemicals, USITC, Washington, DC, annual series.

(b) Total CFC-11 and CFC-12 production in 1985 and 1986 from United States International Trade Commission, "Preliminary Report on U.S. Production of Selected Synthetic Organic Chemicals (Including Synthetic Plastics and Resin Materials), USITC, Washington, D.C., March 31, 1987, and February 26, 1988.

(c) Aerosol share of production is estimated for three periods: (i) estimates for 1960-69 assume that in 1960, aerosol share for CFC-11 was 81 percent, declining smoothly to 54 percent in 1970. For CFC-12, aerosol share assumed to be constant at 60 percent; (ii) estimates for 1970-78 from Wolf, K.A., Regulating Chlorofluorocarbon Emissions: Effects on Chemical Production, N/1483-EPA, The RAND Corporation, Santa Monica, CA; and (iii) estimates for 1979 to 1986 assume that aerosol use in essential applications has remained constant at the level reported for 1985 by Hammitt, J.K., et al., (1986), Product Uses and Market Trends for Potential Ozone-Depleting Substances, R-3386-EPA, The RAND Corporation, Santa Monica, CA.

(d) Non-aerosol use equals total production minus aerosol use.

requiring that exempted aerosol products bear a warning label that they contained CFCs, which may deplete ozone.

Reductions in aerosol propellant use of CFCs by the U.S. and other nations caused world CFC use to remain approximately constant from 1974 through the early 1980s. Belgium, Canada, Norway and Sweden banned CFC use in aerosol sprays. Member nations of the European Economic Community (EEC) adopted measures to reduce CFC use in aerosols by 30 percent from 1976 levels. Exhibit 3-2 shows an estimate of the cumulative CFC-11 and CFC-12 emission reductions achieved by the U.S. and EEC due to reductions in CFC aerosol use.

In addition to reducing aerosol use, EEC nations agreed not to increase their CFC production capacity, and adopted engineering codes of practice to discourage unnecessary CFC emissions from other applications. Restrictions adopted by other nations include the Netherlands, which requires a warning label on CFC-propelled products; Portugal, which banned CFC production and established CFC import quotas; Brazil, which implemented a production capacity cap; Australia, which reduced CFC use in aerosols by 66 percent; and Japan, which also reduced CFC aerosol use and discourages increases in production capacity of CFC-11 and CFC-12. In the last few years, however, total world use has increased (Exhibit 3-3).

One measure of the relative effectiveness of CFC restrictions is the per capita use of CFCs. Exhibit 3-4 shows that per capita use of CFC-11 and CFC-12 in the U.S. is now roughly equivalent with that in the EEC, and is still higher than Japan. When CFC-113 is included, however, the differences between Japan and the U.S. are dramatically reduced (Exhibit 3-5).

Because CFC emissions from all nations mix uniformly in the global atmosphere, it is important to review international efforts to reduce CFC use. Concerted international efforts began in 1981 under the auspices of the United Nations Environment Programme (UNEP). At the 1981 Montevideo Senior Level Meeting on Environmental Law, this subject was recommended as a priority for future work within UNEP. On the basis of this recommendation, the UNEP Governing Council established the Ad Hoc Working Group of Legal and Technical Experts, which in 1982 began negotiating a global framework for a convention to protect the ozone layer.

3.2 EPA AUTHORITY UNDER THE CLEAN AIR ACT

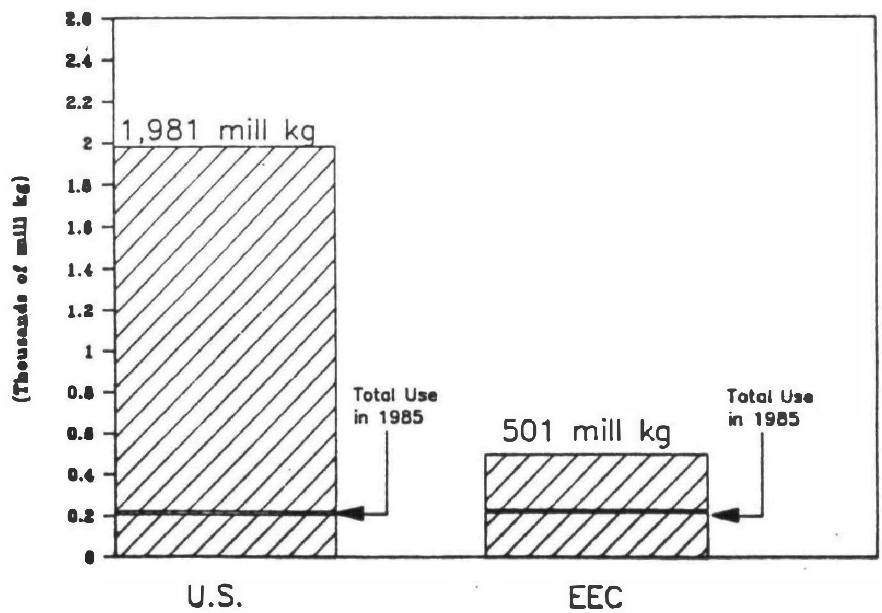
3.2.1 Domestic Regulations

In 1977, Congress strengthened EPA's authority to regulate and to protect the stratosphere. Part B of the Clean Air Act (Section 157(b)) requires that:

> ... the Administrator (of EPA) shall propose regulations for the control of any substance, practice, process, or activity (or any combination thereof) which in his judgment may reasonably be anticipated to affect the stratosphere, especially ozone in the stratosphere, if such effect in the stratosphere may reasonably be anticipated to endanger public health or welfare. Such regulations shall take into account the feasibility and costs of achieving such control.

EXHIBIT 3-2

CUMULATIVE REDUCTIONS IN CFC-11 AND CFC-12 EMISSIONS DUE TO AEROSOL REDUCTIONS IN THE U.S. AND EEC



Cumulative reductions in use of CFC-11 and CFC-12 in the U.S. and EEC due to reductions in aerosol use. For purposes of illustration, assumes that in absence of environmental concerns, CFC use would have remained constant at peak levels: 1974 level in U.S. and 1976 level in EEC.

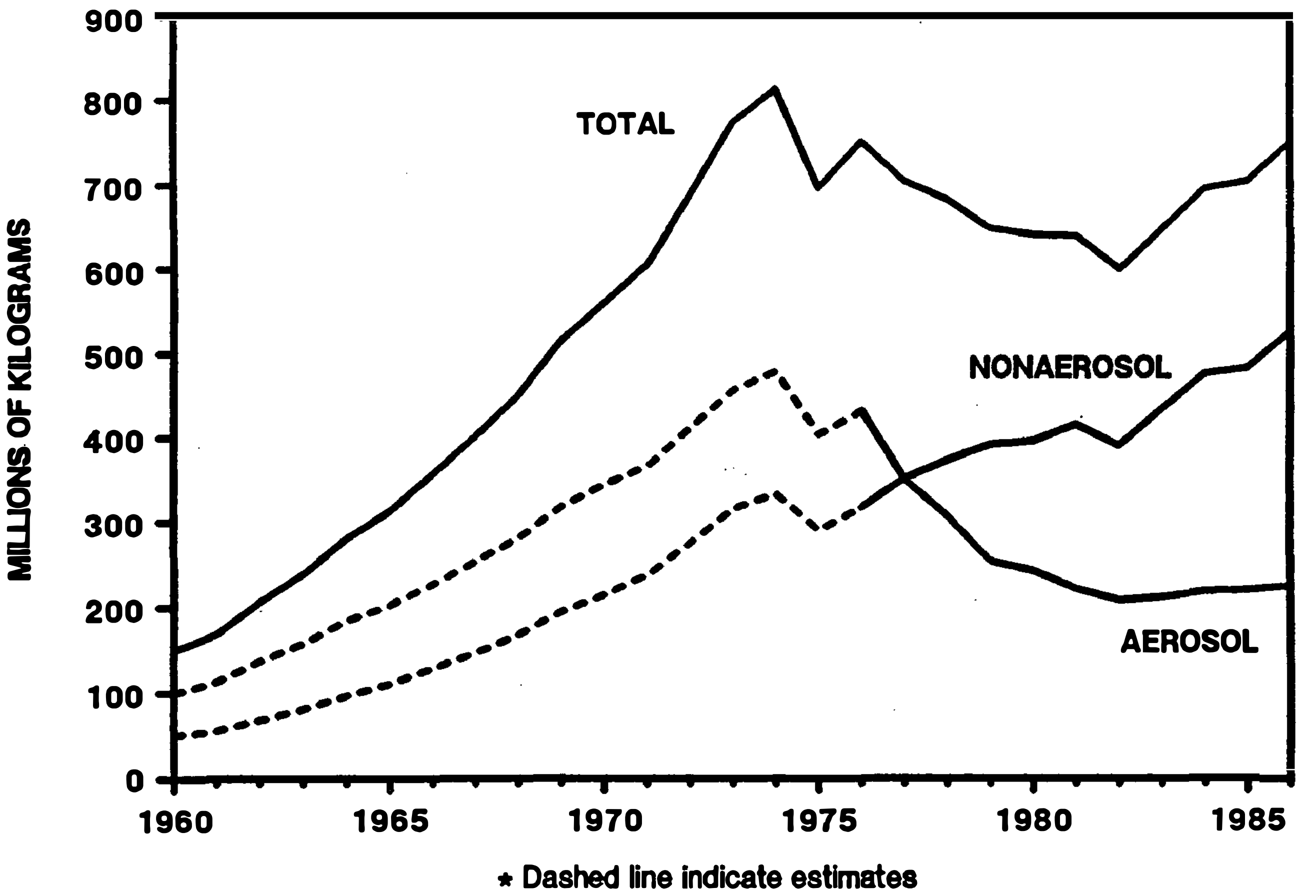
Sources:

(a) U.S. historical use of CFC-11 and CFC-12 from 1974 to 1977 for aerosol propellants based on total production and aerosol shares reported in Wolf, K.A., (1980), Regulating Chlorofluorocarbon Emissions: Effects on Chemical Production, N/1483-EPA, The RAND Corporation, Santa Monica, CA. Aerosol use from 1978 to 1985 assumed to be constant at level reported by Hammitt, J.K., et al., (1986), Product Uses and Market Trends for Potential Ozone-Depleting Substances, R-3386-EPA, The RAND Corporation, Santa Monica, CA. Total production of CFC-11 and CFC-12 in 1985 from USITC, "Preliminary Report on U.S. Production of Selected Synthetic Organic Chemicals (Including Synthetic Plastics and Resin Materials), Preliminary Totals, 1986", USITC, Washington, DC., March 31, 1987.

(b) EEC historical aerosol use from EEC (1985), "Chlorofluorocarbons in the Environment: Updating the Situation," Communication from the Commission to the Council. 1985 total sales of CFC-11 and CFC-12 from EFCTC (1986), "CFC Production and Use Statistics for the EEC," paper submitted to UNEP Chlorofluorocarbon Workshop, 1986.

EXHIBIT 3-3

CFC-11 AND CFC-12 PRODUCTION IN THE DEVELOPED WORLD (CMA REPORTING COMPANIES)

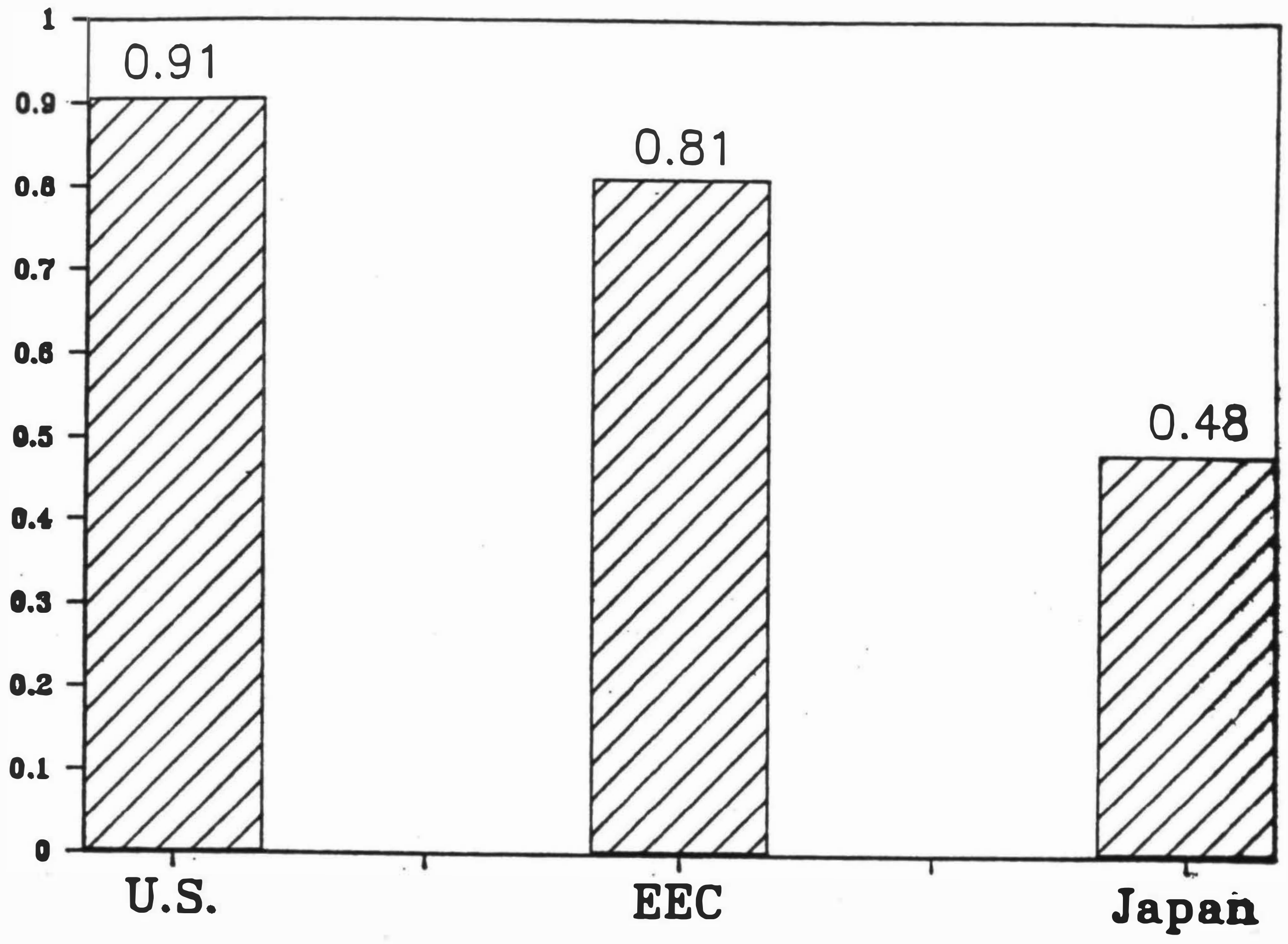


The Chemical Manufacturers Association collects CFC-11 and CFC-12 production data from all producers in the non-communist developed world. The data show that CFC-11 and CFC-12 production increased rapidly throughout the 1960s and 1970s. Production reached a maximum of 812.5 mill kg in 1974, with 59 percent used in aerosol sprays. Aerosol use fell from 1974 to 1982 following announcement of the CFC-ozone hypothesis, while non-aerosol use has continued to increase. Current production, 703.1 mill kg, is 85 percent of the 1974 level.

Source: Chemical Manufacturers Association (CMA), (1987), Production, Sales, and Calculated Release of CFC-11 and CFC-12 Through 1986, CMA, Washington, D.C. Estimates for the aerosol share of total production from 1960 to 1975 are based on the 1976 share reported in the CMA schedule.

EXHIBIT 3-4

PER CAPITA USE OF CFC-11 AND CFC-12
IN THE U.S., EEC, AND JAPAN
(kg/capita)

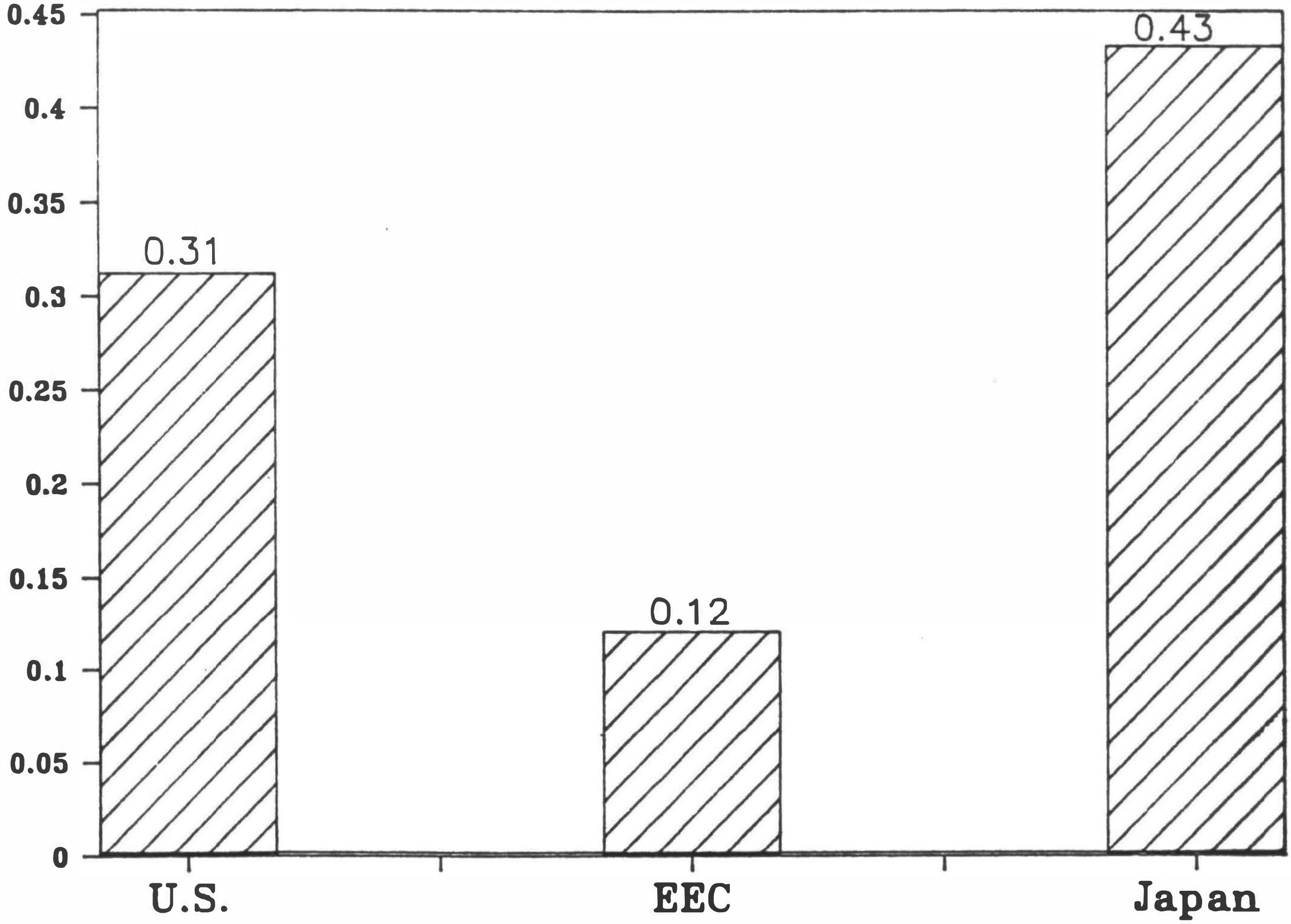


Per capita use of CFC-11 and CFC-12 is roughly equivalent in the U.S. and EEC. Japanese per capita use is significantly lower.

Sources: See sources for Exhibit 3-5.

EXHIBIT 3-5

PER CAPITA USE OF CFC-113
IN THE U.S., EEC, AND JAPAN
(kg/capita)



Per capita use of CFC-113 is higher in Japan than in the U.S. or EEC.

Sources: See following page.

EXHIBIT 3-5 (Continued)

PER CAPITA USE OF CFC-113
IN THE U.S., EEC, AND JAPAN
(kg/capita)

Per Capita Use of CFCs in U S , EEC, and Japan

	Population (mill)	CFC-11	CFC-12	CFC-11 and -12 Net Use	CFC-11 and -12 Per Cap (kg/cap)	CFC-113	CFC-113 Per Cap (kg/cap)	Total CFC Use (kg/cap)
U S	234 49 a/	79 73 b/	136 94 b/	212 34 e/	0 906	73 20 g/	0.312	1.218
EEC	269 01 a/	126.40 c/	91.30 c/	217.70	0 809	32 50 c/	0.121	0 930
Japan	119 25 a/	27.80 d/	34.70 d/	57.50 f/	0 482	51.53 h/	0.432	0 914

a/ 1983 population estimates from The World Bank (1966), "The World Bank Atlas, 1986," Washington, D.C.

b/ CFC-11 and CFC-12 1985 production from USITC, "Preliminary Report on U.S. Production of Selected Synthetic Organic Chemicals (Including Synthetic Plastics and Resin Materials). Preliminary Totals, 1986," March 31, 1987.

c/ 1984 sales within EEC of CFC-11, CFC-12, and CFC-113 from Bevington, C.F.P. (1986), "Projections of Production Capacity, Production and Use of CFCs in the Context of EEC Regulations," paper submitted for UNEP Chlorofluorocarbon Workshop, April 1986.

d/ 1985 production of CFC-11 and CFC-12 from Kurosawa, K., and K. Imazeki (1986), "Topic 2: Projections of the Production, Use and Trade of CFCs in Japan in the next Five to Ten Years," Paper submitted to UNEP Chlorofluorocarbon Workshop, April 1986.

e/ Net domestic use of CFC-11 and CFC-12. Import and export data from Weigel, C.M., and R.M. Whitfield (1986), "Reply to the RAND Corporation's Response to DRI's review of RAND's working draft, 'Projected Use, Emissions and Banks of Potential Ozone Depleting Substances," DRI. Total CFC Imports in 1985 reported to be 7.08 mill kg. Exports of "fluorinated hydrocarbons" reported to be 13.418 mill kg. CFC-11 and CFC-12 assumed to be 85 percent of this total (11.406 mill kg) mid-range of Weigel/Whitfield estimate.

f/ CFC-11 and CFC-12 production minus estimated exports reported in Kurosawa and Imazeki (see note d) of 2.7 mill kg for CFC-11 and 2.3 mill kg for CFC-12.

g/ U S. CFC-113 production in 1985 estimated by Hammitt, J.K., et al. (1986), "Product Use end Market Trends for Potential Ozone Depleting Substances," R-3386-EPA, The RAND Corporation, Santa Monica, CA. Does not exclude substantial exports.

h/ 1985 Japanese CFC-113 production reported by I. Araki of MITI Basic Industries Bureau Chemical Products Division summarized in State Dept. cable ref. Tokyo 1525; State 21900. Does not include substantial imports.

It is important to consider the key provisions of this section:

1. "may reasonably be anticipated". The law does not require a finding that harm has occurred. Rather, it requires the Administrator to act if there is a reasonable probability that the stratosphere will be affected, and that the effects would endanger health or welfare.

2. "any substance, practice, process, or activity". The scope of the Agency's authority is broad.

3. "affect the stratosphere". The law is concerned with all effects in the stratosphere. While the main focus is on stratospheric ozone, the law also grants authority for EPA to act on other stratospheric concerns such as stratospherically-induced climate change.

3.2.2 1980 Advanced Notice of Proposed Rulemaking (ANPR)

In 1980, EPA issued an Advance Notice of Proposed Rulemaking (ANPR), "Ozone-Depleting Chlorofluorocarbons: Proposed Production/Restriction" (45 FR 66726; October 7, 1980) which called for limits on non-aerosol uses of CFCs. The Agency announced its objective to freeze current emissions of ozone-modifying compounds. It considered two approaches to achieve this goal: mandated engineering controls and market-based controls.

In 1984, the Natural Resources Defense Council sued the Agency in District Court, arguing that the ANPR constituted a finding of a reasonable threat to the stratosphere, which required the Agency promptly either to issue regulations or formally withdraw the ANPR. In 1985, EPA and NRDC were joined by the Alliance for Responsible CFC Policy, Inc. in filing a joint settlement motion calling for a proposed regulatory decision by May 1, 1987 and a final decision by November 1, 1987. This consent decree was extended in 1987 with deadlines set for December 1, 1987, and August 1, 1988, for proposal and final action, respectively.

3.2.3 Stratospheric Ozone Protection Plan

The Agency announced its Stratospheric Ozone Protection Plan in 1986 (51 FR 1257; January 10, 1986), which reviewed past EPA activities, called for an expanded program of research and analysis, and established a framework for the development of domestic and international regulations to protect the stratosphere. The program plan called for further research in several areas:

SCIENTIFIC ASSESSMENTS

The scientific community completed several major reviews of atmospheric science issues. A major review coordinated by the World Meteorological Organization (WMO), the National Aeronautics and Space Administration (NASA), the United Nations Environment Programme (UNEP), and several other national and international scientific organizations, was published in 1986. A companion report was published by NASA in 1986. Other scientific issues, particularly regarding the effects of ozone depletion on human health and the environment, were reviewed by UNEP's Coordinating Committee on the Ozone Layer, whose panel of scientific and technical experts released its findings in 1986. Issues related to climate change were evaluated in a report prepared by WMO in Villach, Austria in October 1985.

KEY AREAS OF EPA ANALYSIS

The program plan called for a series of domestic and international workshops and conferences aimed at improving understanding of all aspects of stratospheric protection. In March and May 1986, workshops were held which focused on analysis of future supply and demand for CFCs, and possible technical controls to reduce their use and emissions. In July and September 1986, workshops were held which covered the analysis of potential strategies to protect stratospheric ozone. In June 1986 an international conference discussed the health and environmental effects of stratospheric ozone depletion and global climate change (U.S. EPA, 1986).

3.2.4 EPA's Risk Assessment

In December 1986, EPA submitted a draft risk assessment to the Science Advisory Board (SAB). The document reviewed the scientific understanding of all aspects of stratospheric protection. The Executive Summary of that risk assessment was again reviewed in January 1987. The Executive Summary, the body of the assessment, and supporting appendices were further revised and reviewed by SAB panel members and published in October 1987. The SAB closure letter stated that the final document "had adequately responded to the subcommittees advice on all major scientific issues" (Nelson 1988). The risk assessment, Assessing the Risks of Trace Gases that Can Modify the Stratosphere, serves as the scientific basis for future Agency decisionmaking, including this Regulatory Impact Analysis.

3.2.5 International Negotiations

Section 156 of the Clean Air Act calls for international cooperation to protect the stratosphere:

> The President shall undertake to enter into international agreements to foster cooperative research which complements studies and research authorized by this part, and to develop standards and regulations which protect the stratosphere consistent with the regulations applicable within the United States.

Since 1981, international negotiations to protect the stratosphere have been conducted under the auspices of UNEP. In 1985, the negotiations resulted in the adoption of the Vienna Convention for Protection of the Ozone Layer. The Convention was ratified by the U.S. Senate in July 1985 and signed by the President in September 1985. The Convention has now been signed by 28 parties, 11 of which have completed their formal ratification or acceptance. While it sets no specific targets for CFC restrictions, the Convention establishes a framework for further international negotiations to develop such limits, and requires member nations to submit CFC production and use data to UNEP.

While early negotiations on a Protocol to limit CFCs had failed, nations had agreed in 1985 that prior to the resumption of negotiations scheduled for

December 1986, a series of workshops were to be held to discuss technical issues. These workshops were companions to domestic workshops that focused on future supply and demand for CFCs, technical control options, control strategies, and the health and environmental effects of ozone modification.

When negotiations resumed in December 1986 and February 1987, initial agreement was reached that CFC use should at least be frozen at or near current levels of production. Disagreement continued over the necessity for further limitations.

In April 1987, another round of negotiations was held in Geneva, Switzerland. A working draft protocol text emerged from this session calling for a CFC production freeze, 20% cutback in three years, followed by a possible further 30% cutback in two years. Disagreement remained over several significant issues relating to stringency, timing, and special provisions for developing countries.

In September 1987 in Montreal, Canada, a final Diplomatic Conference was held that concluded protocol negotiations. The major provisions of the protocol include:

- Reductions in CFC Use. The use of CFC-11, -12, -113, -114 and -115 is to be frozen at 1986 levels starting in approximately mid-1989, reduced to 80 percent of 1986 levels in 1993, and reduced to 50 percent of 1986 levels in 1998. The reduction from 80 percent to 50 percent will take place unless the parties vote otherwise.

- Reduction in Halon Use. The use of Halon 1211, 1301 and 2402 is to be frozen at 1986 levels starting in approximately 1992.

- Assessment and Review. Beginning in 1990, and at least every four years thereafter, the Parties will assess the control measure in light of the current data available. Based on these assessments the Parties may adjust the control levels and substances covered by the Protocol.

- Trade. Each Party shall ban the import of the controlled substances (bulk CFCs and halons) from any state not party to the Protocol beginning one year after entry into force. Additionally, the Parties shall develop a list of products that contain the controlled substances which will be subject to the same trade restrictions. The feasibility of restricting trade in products manufactured with the controlled substances shall also be assessed.

- Developing Countries. Developing countries with low levels of use per capita are permitted to delay their compliance with the protocol for up to 10 years. The Parties also agree to assist developing countries to make expeditious use of environmentally-safe alternative substances and technologies.

3.2.6 The Proposed Rule

On December 14, 1987, EPA announced in the Federal Register its intention to limit the production and consumption of CFCs and halons. The proposed limitations corresponded to those set out in the Montreal Protocol and were to be implemented only if the United States ratified the Protocol and following entry into force. In a separate notice, EPA also required all firms producing, importing or exporting CFCs or halons to report on the extent of these activities during 1986.

EPA conducted a public hearing on this proposed rulemaking on January 7, and 8, 1988, at which 27 persons presented statements. In addition, EPA received written comments on the proposed rulemaking from 497 individuals, corporations, and public agencies. Summaries and responses to these comments are available in the Background Information Document accompanying this final RIA. As noted in Chapter 1, many of the revisions made in this RIA respond to comments received on the proposed rulemaking.

3.3 NEED FOR A REGULATORY IMPACT ANALYSIS

Executive Order 12291 requires that the costs and benefits of "major rules" be evaluated in a Regulatory Impact Analysis:

> "A 'major rule' means any regulation that is likely to result in:
>
> (1) An annual effect on the economy of $100 million or more;
>
> (2) A major increase in costs or prices for consumers, individual industries, Federal, State, or local government agencies, or geographic regions; or
>
> (3) Significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of United States-based enterprises to compete with foreign-based enterprises in domestic or export markets."

Under these definitions, a rule is considered major if it meets at least one of these three conditions. Condition (1) is probably met by the proposed rule. Because options of the stringency under consideration are likely to result in a total cost to the economy of $100 million or more per year, this RIA is being prepared.

REFERENCES

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National Aeronautics and Space Administration (NASA) (1986), Present State of Knowledge of the Upper Atmosphere: An Assessment Report. Processes That Control Ozone and Other Climatically Important Trace Gases, NASA Reference Publication 1162, NASA, Washington, D.C.

Nelson, Norton (Chairman of the Executive Committee of the Science Advisory Board), letter to Mr. Lee Thomas (EPA Administrator), January 29, 1988.

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World Meteorological Organization (WMO) (1985), Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts, WMO - No. 661, WMO, Geneva, Switzerland.

World Meteorological Organization (WMO) (1986), Atmospheric Ozone 1985. Assessment of Our Understanding of the Processes Controlling Its Present Distribution and Change, WMO Global Ozone Research and Monitoring Project - Report No. 16, WMO, Geneva, Switzerland.

CHAPTER 4

BASELINE USE AND EMISSIONS OF GASES THAT CAN INFLUENCE THE STRATOSPHERE

This chapter summarizes estimates of the potential use and emissions of ozone-modifying compounds that may be expected in the absence of regulatory intervention. These estimates are referred to as the baseline, which is used for estimating (in the absence of future regulation) levels of ozone depletion, and the associated impacts on human health, welfare, and the environment. This baseline is also used for estimating the costs of foregoing the use of ozone-depleting compounds.

Because ozone depletion is a global phenomenon, influenced by worldwide emissions, the analysis must assess the global use and emissions of ozone-modifying compounds. The analysis in this final RIA divides the world into the following six regions for purposes of specifying baseline compound use:[1]

- United States (U.S.);
- USSR and Eastern Bloc;
- Other Developed Countries;
- People's Republic of China (China) and India;
- Developing Countries with 1985 compound use of 0.1 to 0.2 kilograms per capita (Group I Developing Countries)[2]; and
- Other Developing Countries (Group II Developing Countries).

The potential control of seven compounds of concern is the primary focus of this RIA. These seven compounds are CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, Halon 1211, and Halon 1301.[3] Therefore, most of the discussion in this chapter addresses the estimation of the baseline use and emissions of these seven chemicals. Other compounds such as HCFC-22, carbon tetrachloride, and methyl chloroform have been identified as potential ozone depleters but are not currently under consideration for control because they have low ozone-depletion potential, low emissions, or short atmospheric lifetimes. Because the future use and emissions of these compounds influence ozone depletion, baseline assumptions for these compounds are also presented.

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[1] Areas included in each region are: Other Developed Countries: Canada, Western Europe, Japan, Australia, and New Zealand; Group I Developing Countries: Algeria, Argentina, Liberia, Malaysia, Mexico, Panama, South Korea, Taiwan, Tunisia, and Turkey; Group II Developing Countries: countries in Central Asia, Africa, Middle East, Latin America, South America, and South and East Asia not included in the other five regions.

[2] Dupont (1987) identified the Group I Developing countries as having 0.1 to 0.2 kg per capita CFC use (Algeria, Argentina, Liberia, Malaysia, Mexico, Panama, South Korea, Taiwan, Tunisia, and Turkey). For purposes of this analysis, these countries are assumed to have 0.2 kg per capita use of combined CFC-11 and CFC-12.

[3] The Montreal Protocol also includes Halon 2402. However, due to lack of data this compound is not analyzed in this RIA.

For purposes of this analysis, the baseline level is defined in terms of compound use (as opposed to compound production). In the U.S., production is approximately equal to use, because imports and exports of these compounds are approximately equal (as well as relatively small).[4] For other regions, use and production may differ significantly. Developing countries, for example, are net importers of CFCs, so that use exceeds production; other developed countries are net exporters of CFCs, so that production exceeds use.

Each compound is used in a variety of ways, referred to as end uses. Total use within each region must be identified in terms of its end uses for purposes of identifying the level of CFC or halon releases anticipated over time. Each end use has a rate at which its chemical compounds are released to the atmosphere, which may vary from "prompt" (e.g., CFCs in aerosols are released immediately upon use), to being retained within products for many years (e.g., CFCs are contained or "banked" in rigid foam for many decades).

Of note is that three additional trace gases are important determinants of ozone depletion: carbon dioxide (CO2); methane (CH4); and nitrous oxide (N2O). These gases are considered to be key "greenhouse gases" that may warm the Earth's climate in the coming decades. Because the rising atmospheric concentrations of these gases are expected to counter somewhat the potential ozone depletion caused by the compounds of concern (which are also greenhouse gases), the baseline assumptions regarding the future concentrations of these gases are important. In addition to countering ozone depletion, the increasing concentrations of these three trace gases are expected to cause changes in climate which themselves will have significant impacts. These potential climate change impacts induced by these trace gases are not the focus of this RIA. Climate change impacts are discussed in EPA (1987a).

This chapter is organized as follows:

- Section 4.1 describes each compound and its use(s) for each of the regions examined;
- Section 4.2 describes the assumptions that were used to estimate each region's compound use in 1986;
- Section 4.3 describes the methods used to project future compound use in each region; and
- Section 4.4 presents the projections of other trace gas concentrations.

4.1 CHARACTERISTICS OF COMPOUND USE

Each of the seven compounds of concern is discussed in turn. The major uses of each compound are first described briefly, then data are presented on the distribution of the compound's use across its defined end uses for the U.S. and the rest of the world. Finally, release rates are presented for each end use.

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[4] Industry data reported to EPA indicates that U.S. exports may have increased in 1987. This analysis adjusts use to account for these recent data.

4.1.1 CFC-11

CFC-11 currently is used in the following ways throughout the world:

- aerosol propellant;
- blowing agent for flexible foam;
- blowing agent for rigid polyurethane foam;
- refrigeration; and
- miscellaneous uses.

As noted below, non-essential aerosol propellant uses of CFC-11 have been banned in the United States.

The U.S. is estimated to have approximately 20 percent of global CFC-11 use while the EEC's use is about 35 percent. The USSR and East Bloc countries are estimated to have about seven percent of global use. The developing nations are estimated to account for roughly 25 percent of non-U.S. use, or about 20 percent of the world total.[5]

Exhibit 4-1 presents the distribution of CFC-11 use in the U.S. (in percent) for each of up to 10 different use categories (the distributions for the other six compounds of concern are also shown in the exhibit). These end use data were derived from the information available from Volume III.[6] As shown in the exhibit, CFC-11 is used primarily in rigid polyurethane foam. Aerosol propellant use is small because non-essential aerosol propellant applications have been banned. (Certain uses are still allowed, however, including medical uses and uses in which the CFC is an active ingredient -- for example, as a foaming agent in children's party products that leave colored strings of foam sticking to the wall.)

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[5] This estimate for developing countries is consistent with the available data that indicate that the EEC exports a significant share of its CFC-11 and CFC-12 production to areas outside the EEC (over one-third, see EFCTC (1985)). Additionally, a significant portion of the developing nation use is probably concentrated in Group I countries and large developing nations (see Appendix D). Nevertheless, data on the use of CFC-11 (as well as the other compounds of concern) in developing nations is very uncertain. Some "use" may actually occur as products containing or made with CFCs are used in developing nations. However, the global and U.S. values are considered reliable.

[6] Volume III presents detailed data on the use of CFCs and halons in each of 74 applications. The 10 use categories in Exhibit 4-2 are aggregations of the detailed use categories presented in Volume III. These estimates are similar to previously published estimates, e.g., in Hammitt (1986). Of note is that the distributions of use shown in the exhibit are for the known uses of the compounds. A significant portion of CFC-11 and CFC-12 use in the U.S. cannot be allocated to individual uses based on available data. The implications of the inability to identify 100 percent of the use of CFC-11 and CFC-12 for the evaluation of costs is described in Chapter 9.

EXHIBIT 4-1

ESTIMATED U.S. 1985 END USE BY COMPOUND
(Percent of Total Allocated Use)

	Aerosol	Flexible Foam	Rigid Polyurethane Foam	Rigid Nonurethane Foam	Fast Release b/ Refrigeration	Medium Release b/ Refrigeration	Slow Release b/ Refrigeration	Solvent	Fire Extinguishing	Miscellaneous
CFC-11	5.7	23.6	62.4	--	8.3	--	--	--	--	0.0
CFC-12	5.2	--	8.9	7.1	52.7	6.7	3.3	--	--	16 1
CFC-113	--	--	--	--	--	--	--	100	--	--
CFC-114	--	--	--	76.2	23.8	--	--	--	--	--
CFC-115	--	--	--	--	--	100	--	--	--	--
Halon 1211	--	--	--	--	--	-- a/	-- a/	--	100	--
Halon 1301	--	--	--	--	--	-- a/	-- a/	--	100	--

a/ These may be minor uses.

b/ Includes air conditioning categories.

Source: Derived from data presented in Volume III

Exhibit 4-2 shows the end use distributions for CFC-11 use outside the U.S. For purposes of emission release rates, all the regions outside the U.S. are assumed to have the end use allocations shown in the exhibit. These end use estimates were calculated by subtracting the U.S. estimates from end use estimates reported in CMA (1986). As expected, the end use distribution for CFC-11 outside the U.S. differs significantly from the distribution for the U.S. because of the U.S. aerosol ban. Although actual end use distributions may, in fact, vary among the non-U.S. regions, the impact of this variation is not likely to be significant in terms of estimated atmospheric concentrations and ozone depletion.

Finally, Exhibit 4-3 shows the manner in which releases occur from all of the end uses that are examined (as shown above in Exhibits 4-1 and 4-2, CFC-11 is used in only a subset of all the end uses examined). The exhibit is constructed to show cumulative releases that occur following the year of initial compound use. For instance, for rigid polyurethane foam releases, the total amount of chemical that is released within six years of its initial use is 31.7 percent. A final cumulative release rate of "1.000" indicates that all compound use eventually is emitted into the atmosphere. Note that aerosol propellant and some foam applications have immediate releases and hence the "1.0" release rate for year 1.

Also note that there are several release rates that describe the refrigeration end use. Several types of refrigeration uses have been identified with varying release characteristics. These types have been grouped into three categories: fast, medium, and slow release. A "fast" release implies an approximate 10 percent annual release of the compound remaining in use, with a total venting after 4 years. A "medium" release implies an approximate 10 percent annual release with a total venting occurring on average after 17 years. Finally, a "slow" release implies an approximate 1.5 percent annual release, with a total venting after 17 years. Mobile Air Conditioning and Centrifugal Chillers end uses have been identified as fast releasers. Hermetically-sealed units (such as Home Refrigerators) are assumed to be slow releasers.[7]

4.1.2 CFC-12

CFC-12 has the following principal end uses:

- aerosol propellant;
- blowing agent for rigid nonurethane foam;
- blowing agent for rigid polyurethane foam;
- refrigeration; and
- miscellaneous uses.

We note the following significant factors regarding the use of CFC-12:

- U.S. use is approximately 30 percent of world use.

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[7] The following are the three refrigeration release types and some of the uses that are assumed to have similar release characteristics: Fast Release -- Mobile Air Conditioning, Centrifugal Chillers; Medium Release -- Retail Food, Cold Storage; Slow Release -- Vending Machines, Water Coolers, Ice Machines, Freezers, Refrigerators, Dehumidifiers.

EXHIBIT 4-2

ESTIMATED NON-U.S. 1985 END USE BY COMPOUND
(Percent of Total Allocated Use)

	Aerosol	Flexible Foam	Rigid Polyurethane Foam	Rigid Nonurethane Foam	Fast Release b/ Refrigeration	Medium Release b/ Refrigeration	Slow Release b/ Refrigeration	Solvent	Fire Extinguishing	Miscellaneous
CFC-11	38.9	18.1	27.3	--	8.2	--	--	--	--	7.5
CFC-12	46.6	--	7.6	4.4	13.6	18.6	9.2	--	--	0.0
CFC-113	--	--	--	--	--	--	--	100	--	--
CFC-114	--	--	--	76.2	23.8	--	--	--	--	--
CFC-115	--	--	--	--	--	100	--	--	--	--
Halon 1211	--	--	--	--	--	-- a/	-- a/	--	100	--
Halon 1301	--	--	--	--	--	-- a/	-- a/	--	100	--

a/ These may be minor uses.

b/ Includes air conditioning categories.

Sources: Derived from CMA (1986) and data presented in Volume III.

EXHIBIT 4-3

CUMULATIVE FRACTION RELEASED BY YEAR OF EMISSION AND END USE

Year of Initial Use	a/ Aerosol	a/ Flexible Foam	a/ Rigid Polyurethane Foam	a/ Rigid Nonurethane Foam	a/ Fast Release Refrigeration	a/ Medium Release Refrigeration	b/ Slow Release Refrigeration	a/ Solvent	c/ U.S. Halon 1211 Fire Extinguishing	c/ ROW Halon 1211 Fire Extinguishing	c/ U S Halon 1301 Fire Extinguishing	c/ ROW Halon 1301 Fire Extinguishing
1	1.0	1.0	0 141	1.0	0 190	0 190	0.094	0.85	0.062	0 029	0 111	0 167
2			0.179		0.271	0 271	0 107		0.085	0 069	0 140	0 198
3			0.216		0 344	0 344	0.121		0.108	0 108	0 169	0 228
4			0 251		1.000	0 410	0 134		0.130	0 144	0 197	0 257
5			0 285			0 469	0.147		0.151	0 180	0 224	0 285
6			0.317			0.522	0 160		0.172	0 214	0 249	0 312
7			0.348			0.570	0 172		0.192	0 246	0 275	0 338
8			0.377			0.613	0.185		0.212	0 277	0 299	0.363
9			0.405			0.651	0.197		0.232	0 307	0 322	0 387
10			0.432			0.686	0.209		0.250	0 335	0 345	0.410
11			0 458			0.718	0.221		0.269	0 362	0 367	0.432
12			0 482			0.746	0.233		0.287	0 388	0 388	0 454
13			0 505			0.771	0.244		0.304	0 413	0 408	0.474
14			0 528			0.794	0.255		0.321	0.437	0 428	0 494
15			0 549			0.815	0.267		0.337	0 460	0 447	0 513
16			0 569			0.833	0 278		0.353	0.482	0 465	0.531
17			0 589			1.000	1 000		0 369	0.503	0 483	0 549
18			0 607						0.384	0 523	0 500	0.566
19			0.625						0 399	0 542	0 517	0.582
20			1.000						0.693	0 945	0 533	0.598
25									0.727	0.938	0 665	0.779
30									0.866	0 979	0 717	0 817
35											0 760	0.849
40											0 853	0.944

a/ Release assumptions derived from estimates in Quinn (1986).

b/ Release assumptions derived from estimates in Gamlen (1986).

c/ Release assumptions derived from estimates from IEc (1987).

- U.S. CFC-12 aerosol use is a small proportion of total U.S. CFC-12 use because of the ban on aerosol uses in the U.S. (Exhibit 4-1). The percent of CFC-12 use in aerosols outside the U.S. is estimated to be about 47 percent (Exhibit 4-2).

- The largest proportion, almost 53 percent, of U.S. CFC-12 use is assigned to the fast release refrigeration group. This allocation reflects widespread use of CFC-12 in mobile (i.e., automobile) air conditioning. End use allocations for "fast" release refrigeration outside the U.S. are much smaller (14 percent).

4.1.3 CFC-113

CFC-113 is used almost exclusively in rapidly-growing solvent applications, including Vaporized Degreasing, Cold Cleaning, Conveyorized Degreasing, and some specialty Dry Cleaning applications. CFC-113 is an attractive solvent because it is non-flammable and has few toxic side-effects. CFC-113 global and non-U.S. estimates are considered to be more uncertain than the CFC-11 and CFC-12 estimates because the CMA does not report data on CFC-113 production and use.

We note the following significant factors regarding the use of CFC-12:

- U.S. use accounts for nearly 40 percent of global use.

- Exhibit 4-3 shows that 85 percent of CFC-113 use in solvents is released in one year with no additional releases thereafter. This implies that only 85 percent of the solvent use is ever released to the atmosphere, reflecting the estimated 15 percent of annual production that is buried or reacted (Quinn 1986).

4.1.4 CFC-114

In the U.S. CFC-114 is used primarily as a blowing agent for nonurethane foam. CFC-114 is also used as a refrigerant in Centrifugal Chiller applications.

End use shares for U.S. CFC-114 use are based on data reported in Volume III (see Exhibit 4-1). Because detailed data on CFC-114 are not available for areas outside the U.S., the U.S. end use share estimates are adopted for regions outside of the U.S. (see Exhibit 4-2). CFC-114 represents only a minor source of total CFC use. The data used to describe the production, use, and emissions of CFC-114 contain significant uncertainty.

4.1.5 CFC-115

In the U.S. virtually all of CFC-115 is used as a refrigerant in combination with HCFC-22 in Retail Food and Cold Storage applications. Therefore, the "medium" release refrigeration category is used to estimate CFC-115 emissions (see Exhibit 4-3). Because detailed data on CFC-115 are not available for areas outside the U.S., the U.S. end use share estimates are adopted for other regions (see Exhibit 4-1 and 4-2). Like CFC-114, CFC-115 constitutes only a minor portion of total CFC use, and the production, use, and emissions data for CFC-115 contain significant uncertainty.

4.1.6 Halon 1211

Halon 1211 is used almost exclusively for portable fire extinguishing applications in both the U.S. and other regions.

Exhibit 4-3 shows the slow release characteristics of Halon 1211, reflecting emissions from the sealed canisters that hold the compound. The last year of the release table does not equal "1.000", indicating that some portion of Halon 1211 use is never released into the atmosphere. This portion represents recovery from existing systems and destruction of the chemical during fires. Halon 1211 release rates for the U.S. differ from release rates for the non-U.S. or "Rest of World" (ROW) regions, reflecting alternative assumptions about halon recovery when units are disposed and about discharge testing (see IEc 1987).

Halon 1211 has only recently been identified as an important ozone-depleting compound. Therefore, data on its current use is somewhat sketchy. The estimates of Halon 1211 use and emissions are very uncertain.[8]

4.1.7 Halon 1301

Halon 1301 is used exclusively for total flooding fire extinguishing systems. Because it is held in permanent fixed systems, Halon 1301 has a longer release period than Halon 1211 (Exhibit 4-3). In addition, Halon 1301 release rates estimated for the U.S. differ from release rates for other regions (see IEc 1987).

4.2 1986 COMPOUND USE ESTIMATES

To estimate baseline compound use over the period from 1986 through 2050, we first estimate the pattern of compound use in 1986 and then project these estimates through 2100. Global estimates of 1986 compound use are based on published estimates of compound use. U.S. compound data are compiled from industry reports submitted in response to the final rule requiring the reporting of all production, import, or export of potentially controlled substances. (Federal Register, December 14, 1987.) In this analysis, these data are referred to as EPA (1988). This information is considered confidential business information and cannot be published. Therefore in the discussion of this section we describe the methodology used to construct 1986 compound use estimates but do not present data describing the results of this methodology.

4.2.1 CFC-11 and CFC-12

CFC-11 and CFC-12 use is estimated from data provided by the U.S., Chemical Manufacturer's Association (CMA), and country reports. The methods and sources for the CFC-11 and CFC-12 estimates in this analysis are as follows:

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[8] Of note is that the impacts of Halon 1211 and Halon 1301 on stratospheric ozone are more uncertain than the impacts of the CFCs. The atmospheric characteristics of the halons have not been studied as extensively.

- United States - Production, export, and import information for 1986 use is provided by EPA (1988). Compound use for the U.S. is estimated by adding imports and subtracting exports from production data. In addition, industry reports on production and export levels for 1987 are incorporated in this analysis (EPA 1988).

- Other Developed - EEC production is estimated from U.S. industry sources. Production is adjusted to reflect imports and exports based on 1985 data presented in EFCTC (1986). Estimates for Japan are from Kurosawa and Imazeki (1986). Estimates for Australia are from UNEP (1986). Estimates for all remaining countries in the Other Developed Region[9] are calculated by multiplying estimated use per capita by each country's population. Estimates of per capita use are taken from DuPont (1987). Population estimates are from The World Bank (1987).

- USSR and East Bloc - The USSR estimates were obtained by EPA during recent international negotiations held in Montreal on substances that deplete the ozone layer. The estimated use in East Bloc countries is assumed to be 40 percent of USSR compound use.

- China and India - Estimated use for China is presented in Zhijia (1986). India use estimates are discussed in Appendix K.

- Developing I Countries - Group I developing countries use estimates from DuPont (1987) and are derived using the same procedure described for the remaining countries in the Other Developed Region.[10]

- Developing II Countries - Group II developing countries use is calculated by subtracting the sum of estimated use in each other region for each compound from a global estimate. Global estimates are estimated based on CMA (1986) and Hammitt (1986).

4.2.2 CFC-113

The 1986 use of CFC-113 is estimated by combining estimates of regional and global use as well as assumptions about the share of CFC-113 used in regions where no direct estimates are available. The methods and sources for estimated CFC-113, use are as follows:

- United States - U.S. 1986 production, export, and import information is provided by EPA (1988). In addition, industry reports on production and export levels for 1987 are incorporated in this analysis (EPA 1988).

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[9] These developed countries are Bahrain; Norway; Venezuela; Austria; Finland; Israel; Kuwait; Singapore; Switzerland; and UAE. For purposes of this analysis it was assumed that 40 percent of the combined CFC-11 and CFC-12 use in these countries is CFC-11.

[10] Group I developing countries are those countries in which CFC use is currently between 0.1 and 0 2 kilograms per capita, and is likely to reach the 0.3 kilogram per capita limit established in the Protocol prior to 1999. All other countries are included in Group II.

- Other Developed - EEC production is estimated from U.S. industry sources. Production is adjusted to reflect imports and exports based on data presented in EFCTC (1986). The estimate for Japan is based on a State Department cable from Araki (1986). Australia use estimates are from UNEP (1986). Other developed countries are assumed to have the same average share of non-U.S. use as reflected in CFC-11 and CFC-12 use.

- Remaining Regions - Estimates for all other regions are developed according to each region's share of the non-U.S. use of CFC-11 and CFC-12. Global estimates are estimated based on Hammitt (1986).

4.2.3 CFC-114 and CFC-115

The 1986 use of CFC-114 and CFC-115 is estimated by combining estimates of U.S. and global use as well as assumptions about the shares of CFC-114 and CFC-115 in regions where no direct estimates are available. The methods and sources for CFC-114 and CFC-115 are as follows:

- United States - U.S. 1986 production, export, and import information is provided by EPA (1988). In addition, 1987 industry estimates for production and exports have been reported and are incorporated in this analysis (EPA 1988).

- Remaining regions - Non-U.S. CFC-114 and CFC-115 use is allocated according to the non-U.S. share of CFC-11 and CFC-12 use. Global estimates are based on industry estimates provided to EPA.

4.2.4 Halon 1211 and Halon 1301

The 1986 use of Halon 1211 and Halon 1301 is estimated by combining estimates of U.S. and global use as well as assumptions about the shares of halons in regions where no direct estimates are available. The methods and sources for Halon 1211 and Halon 1301 are as follows:

- United States - U.S. 1986 Halon 1211 and Halon 1301 production, export, and import information is provided by EPA (1988).

- Remaining Regions - Non-U.S. halon use is allocated according to the non-U.S. share of CFC-11 and CFC-12 use. Global estimates are based on IEc (1987).

4.2.5 Other Ozone Depleting Compounds

Three other substances -- HCFC-22, methyl chloroform, and carbon tetrachloride -- are potentially ozone depleting compounds, but are not currently being considered for regulatory action. Estimates of the use and emissions of these compounds are necessary to project future trends in stratospheric ozone.

Estimates of HCFC-22 use for 1986 in the U.S. are based on ITC (1987). The global estimates for HCFC-22 are calculated assuming that the U.S. share of world production is approximately 56 percent (WMO, 1986). All HCFC-22 estimates are adjusted to account for compound use in polymer manufacturing because HCFC-22 is not subsequently emitted from this use.

Methyl chloroform use estimates for 1986 are provided by ITC (1987) for the U.S. World estimates are based on assumptions for other developed (Prinn 1983) and East Bloc nations (Hammitt 1986).

Carbon tetrachloride is the primary precursor chemical in the production of CFC-11 and CFC-12 (Hammitt 1986). Therefore, carbon tetrachloride use is estimated to vary directly with the use of CFC-11 and CFC-12.[11]

4.3 PROJECTIONS OF FUTURE COMPOUND USE[12]

Ozone-modifying compounds are assumed to grow in the future primarily because of their strong historical correlation with economic growth. Quinn (1986) found that historical growth in CFC use generally exceeded growth in per capita national income. Gibbs (1986) found similar results. In addition, studies on lesser developed countries discussed in Appendix D suggest that future economic growth and compound use growth may be of comparable magnitudes. Therefore, projections of economic growth imply growth of the compounds of concern.

The degree to which compound use is correlated with GNP varies with the maturity of the products and technologies that use the compounds. For instance, a mature product market in the developed world (such as refrigeration) is expected to grow at rates comparable to population growth rates. Developing products and technologies (such as new solvent uses) are expected to grow more rapidly than GNP. In addition, new products not yet introduced may create new demand for these ozone-depleting substances.

4.3.1 Previous Projections

Several previous studies project U.S. and global production of CFCs, including: Camm (1986), Hammitt (1986), Nordhaus and Yohe (1986), and Gibbs (1986). All these studies link compound growth to economic projections. Some of the factors these authors have identified as critical in determining chemical use in the future are: development of chemical markets in developing countries; development of chemical markets in the USSR and East Bloc countries; development of new products that use ozone-depleting compounds; development of new products that will replace products that use ozone-depleting compounds; and the manner in which the relationship between chemical use and income will change as income rises.

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[11] Hammitt (1986) reports that approximately 1.12 kg and 1.27 kg of carbon tetrachloride are needed to produce every kilogram of CFC-11 and CFC-12 respectively. Hammitt estimates that 2.7 percent of this carbon tetrachloride use is eventually emitted.

[12] These projections of future use are similar to the scenarios presented in EPA (1987). Several updates have been incorporated based on data received during the recent Montreal negotiations.

In addition, several reports have explored production and use of CFCs for specific countries, including: Sheffield (1986), EFCTC (1985), Bevington (1986), Kurosawa (1986), and Hedenstrom (1986).[13] These studies focus on growth of aerosol and non-aerosol markets. Aerosol markets generally are projected to remain constant or grow slowly. This is important because historically (in the 1970s) global reductions in aerosol markets offset rapid growth in non-aerosol applications. This indicates that future growth of CFCs will be driven by non-aerosol applications.

EPA (1987) presents a synthesis of these projections, and presents a range of scenarios for policy testing. These scenarios form the basis for the projections used in this RIA.

4.3.2 Uncertainties Inherent in Long Term Projections

Use of the seven compounds is projected from 1986 to 2050. For modeling purposes use is held constant after 2050. It is important to note that these projections are subject to great uncertainty. Uncertainty derives from various sources, including:

- The long period of the forecast. The lifetimes of the most damaging ozone-modifying compounds are generally longer than 75 years. In addition, a significant lag period exists between tropospheric compound emissions and stratospheric ozone damage. Therefore, once they are emitted, damage to the ozone layer (and subsequent effects) will occur for more than 100 years. To evaluate potential damages properly in these future years, chemical use and emissions must be projected for these extended periods. Projections for such long periods are necessarily speculative.

- The poor quality and incomplete data that are available (especially from developing nations). The seven compounds are used in a wide variety of end uses. Aggregating end use data (bottom up approach) is subject to inaccuracies (Hammitt (1986) could not account for 31 percent of U.S. CFC-12 use for 1985), while the production information (top down approach) is considered reliable. Developing country data are particularly poor because many of these countries lack a centralized trade center that would track the products that use the examined compounds. The combination of these factors leads to large uncertainties about production and use data for the recent years. Since projections for this analysis are based on applying annual growth rates to base year compound use, uncertainty in the base year creates uncertainty in all succeeding years.

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[13] These projections were presented in the 1986 UNEP meeting in Rome and are summarized in UNEP (1986).

- Uncertainty inherent when projecting estimates that depend on forecasted rates of economic growth. Compound projections based on economic projections not only include the uncertainty of the economic projection, but also the uncertainty of how closely the intensity of use for the products that use these compounds are linked to economic growth.

In addition, chemical use and economic relationships are based on a limited historical record. In the future, GNP will exceed the historical ranges where these relationships were developed. Therefore, even existing linkages between compound use and economic growth are uncertain for use projections.

4.3.3 Baseline Compound Use Projections

Projections of growth rates in use for the ten compounds examined are made for the six regions from 1986 to 2050.[14] These projections are developed by applying annual growth rates to the base year of use (1986). CFC and halon use is assumed to level off in the year 2050 for modeling purposes. Hence, projections are presented here only through that year. End use shares and release rates for all regions are assumed constant over time.

The projections used in this final RIA differ from those used in an earlier draft (EPA 1987b). The growth rates used in that earlier draft had been based upon analyses of long-term trends in CFC use (EPA 1987a). Exhibit 4-4 compares the growth rates assumed in the earlier version of the RIA to the growth rates reported by the U.S. International Trade Commission for two major CFC compounds. The previously assumed growth rate (2.5 percent) substantially underestimated growth from 1986 to 1987. Therefore, the rates assumed in this final RIA incorporate higher projected growth in CFC use through the year 1992. For the year 1987, actual data on CFC use in the United States is utilized. These 1987 data are taken from reports made by producers to the EPA and are confidential business information but are generally similar to the data reported to the ITC.[15]

Projections for the seven compounds of concern are discussed in turn. The regional annual growth rates used to construct the projections are displayed in Exhibit 4-5. Exhibit 4-6 presents the global growth rates over selected years.

CFC-11 PROJECTED USE

In EPA's risk assessment (EPA 1987), a series of future growth rates for global CFC use were used for policy testing. The estimate of 2.5 percent per year was the middle of a wide range of potential rates of growth, recognizing

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[14] U.S. estimates are based on 1987 use data. Therefore, growth rate projections are made for the U.S. from 1987 through 2050.

[15] Estimates of U.S. use for 1987 have been adjusted to reflect increases in exports of most controlled substances. The ITC growth rates presented in Exhibit 4-4 do not adjust for trade and are therefore overestimates of the growth in use.

EXHIBIT 4-4

COMPARISON OF ASSUMED U.S. CFC-11 AND CFC-12 GROWTHS IN AN EARLIER VERSION OF THIS RIA WITH ACTUAL GROWTH IN PRODUCTION

	Growth Rate Assumed EPA (1987b)[a/]	ITC Estimated Growth Rates[b/]	
		1985-1986	1986-1987
CFC-11	2.5	14.5	11.0
CFC-12	2.5	6.8	14.3

a/ Growth Rates assumed from 1986 to 2000. Rates correspond to those presented in Exhibit 4-5 in EPA (1987b).

b/ "Report on U.S. Production of Selected Synthetic Organic Chemicals," U.S. International Trade Commission, 1988. Growth rates for CFC-113, CFC-114, CFC-115 are not reported.

EXHIBIT 4-5

PROJECTED GROWTH RATES FOR COMPOUNDS BY REGION
(ANNUAL PERCENT)

		1986-1992	1992-2000	2000-2050	2050-2100
CFC-11, CFC-12, CFC-114, AND CFC-115					
	UNITED STATES	3.75[a/]	2 50	2 50	0 00
	USSR & EAST BLOC	6 56[b/]	2 50	2.50	0 00
	OTHER DEVELOPED	3.75	2 50	2 50	0 00
	CHINA & INDIA	15 00	10 00	2 50	0 00
	DEVELOPING (GROUP I)	7.50	5.00	2.50	0.00
	DEVELOPING (GROUP II)	1.50	1.00	2.50	0.00
CFC-113[c/]	UNITED STATES	5.63[a/]	3.75	2.50	0.00
	USSR & EAST BLOC	9.83	3.75	2.50	0.00
	OTHER DEVELOPED	5.63	3.75	2.50	0 00
	CHINA & INDIA	22 50	15.00	2 50	0.00
	DEVELOPING (GROUP I)	11.25	7 50	2.50	0.00
	DEVELOPING (GROUP II)	2.25	1 50	2.50	0.00
HALON 1211	UNITED STATES	8 69	3.85	2.75	0.00
	USSR & EAST BLOC	11.95	3 58	2.99	0.00
	OTHER DEVELOPED	9.21	4.60	2.99	0.00
	CHINA & INDIA	20.74	12.21	2.99	0 00
	DEVELOPING (GROUP I)	13.00	7.51	2.99	0 00
	DEVELOPING (GROUP II)	6.91	3.15	2.99	0.00
HALON 1301	UNITED STATES	2.61	-2.46	3.12	0.00
	USSR & EAST BLOC	5.94	-2 51	3.20	0.00
	OTHER DEVELOPED	3.34	-2.49	3.20	0.00
	CHINA & INDIA	14.25	-4.60	3.20	0.00
	DEVELOPING (GROUP I)	6.93	-0.11	3.20	0.00
	DEVELOPING (GROUP II)	1.16	-3.84	3.20	0.00

a/ Growth rates from 1987 through 1992 Growth rates from 1986 to 1987 are reported to EPA as confidential business information and are not shown

b/ The USSR and East Bloc grow at eight percent annually until 1990 to reflect chemical plants that will be completed that year. From 1990 through 1992 use grows at 3.75 percent.

c/ CFC-113 growth rates are assumed to be 1.5 times other growth rates from 1986 through 2000.

EXHIBIT 4-6

PROJECTED GLOBAL GROWTH RATES FOR CONTROLLED COMPOUNDS a/

	Projected Global Growth Rate			
	1986-1992	1992-2000	2000-2050	2050-2100
CFC-11	4.34	2.71	2.50	0.00
CFC-12	5.32	3.06	2.50	0.00
CFC-113	7.03	4.09	2.50	0.00
CFC-114	4.95	2.79	2.50	0.00
CFC-115	3.20	2.73	2.50	0.00
Halon 1211	9.77	4.80	2.93	0.00
Halon 1301	3.46	-2.20	3.16	0.00

a/ Average annual rates computed using data cited in Exhibit 4-5.

that, as described above, the future rates of CFC use over the long term are very uncertain. However, as discussed above, recent ITC reports and data reported to the EPA indicate more rapid rates of growth in CFC usage in 1986 and 1987. Consequently, these projections for the U.S. assume a more rapid growth rate, 3.75 percent in the short-term (through 1992). The middle growth assumption of the Risk Assessment -- 2.5 percent annual growth -- is used for years after 1992 (see Exhibit 4-5).

Other regions are also assumed to have accelerated growth rates in the short term. Other developed countries are assumed to have growth rates that are identical to the U.S. No data for growth in other developed countries are available for 1987. Available data do indicate growth in other developed countries was less than the U.S. from 1985 to 1986. However, analysis of past trends in nonaerosol CFC usage shows this use in other developed countries to be even more sensitive to economic growth than in the U.S. Also, the latest projections of income growth in 1987 for these countries (Wharton, 1987) indicate that their growth probably slightly exceeded that of the U.S. Therefore, it is reasonable to presume that their CFC usage rates would also be growing at least as rapidly as those in the U.S. for these countries.

The rates of growth for the USSR and Eastern Bloc, China and India, and the developing countries are primarily based upon information received during the Montreal negotiations. In particular, the USSR announced its plans for 8.0 percent annual growth through 1990 (see Exhibit 4-5). The Protocol incorporates provisions allowing for this growth. Following 1990, baseline annual growth in the USSR and Eastern Bloc is assumed to equal the rate of growth for other developed countries.

The rate of future growth in developing countries is particularly uncertain. The developing countries that are experiencing rapid economic growth will likely have larger than average CFC use growth (see Appendix D). Therefore, for the period 1986 to 2000 the annual rate of CFC growth in Group I Developing Countries is assumed to be 7.5 percent. China and India are assumed to grow about four times as fast as the United States. Therefore, 15 percent annual growth is assumed for this region. Growth from 1992 through 2000 is assumed to be 10 percent annually (four times the projected U.S. growth rate for that time period). The annual rate of growth in Group II Developing Countries is assumed to be 1.5 percent from 1986 to 1992 and 1.0 percent from 1992 through 2000 based on the assumption that these countries are experiencing slow economic growth.

As shown in Exhibit 4-5 all regions are assumed to grow at 2.5 percent per year from 2000 to 2050. The growth rates for each region are applied to the estimates of 1986 use to project regional use in all years through 2050. Regional projections are then summed to estimate global use through 2050. Global growth rates are presented by compound in Exhibit 4-6.

CFC-12 PROJECTED USE

The annual average regional growth rates for CFC-11 use were also applied to regional CFC-12 use (see Exhibit 4-5). Because the regional distribution of use for CFC-12 is different from the regional distribution of use for CFC-11, the implied global annual growth rates differ between CFC-11 and CFC-12 (Exhibit 4-6).

CFC-113 PROJECTED USE

CFC-113 use is expected to grow more rapidly than CFC-11 and CFC-12 use because of its application in making electronic components (see EPA 1987). For purposes of EPA's risk assessment, it was assumed that the annual CFC-113 growth would be 1.5 times the CFC-11 and CFC-12 growth in the period 1986 to 2000, and would be equal to CFC-11 and CFC-12 growth for the period 2000 to 2050. This assumption of a 50 percent higher growth rate for CFC-113 through the year 2000 was retained in the baseline scenario examined here. As shown in Exhibit 4-5, the assumed rates of growth in the U.S. for CFC-113 are 5.63 percent for the period 1987 to 1992 and 3.75 percent for the period 1993 to 2000. Global growth rates for CFC-113 are presented in Exhibit 4-6. Following 2000, the 2.5 percent annual rate is used for all regions.

CFC-114 AND CFC-115 PROJECTED USE

Global and regional use of CFC-114 and CFC-115 is assumed to grow at the same rates as those used for CFC-11 and CFC-12 (see Exhibit 4-5). Global growth rates differ from CFC-11 and CFC-12 because U.S share of global use is different in 1986 for each compound. Global growth rates for CFC-114 and CFC-115 are presented in Exhibit 4-6. Because of limited information available for these compounds, these projections are uncertain.

HALON 1211 AND HALON 1301 PROJECTED USE

IEc (1987) presents projected estimates of U.S. and global Halon 1211 and Halon 1301 use through the year 2050. This analysis assumes that these rates are applied to U.S. and global 1986 halon estimates. U.S. rates are presented in Exhibit 4-5; global rates are presented in Exhibit 4-6. Regional halon use is estimated by assuming non-U.S. use is allocated in any given year by the average share of non-U.S. CFC-11 and CFC-12 use. The implied regional growth rates from these use estimates are presented in Exhibit 4-5.

The global growth rates for Halon 1211 are relatively large in the short-term: approximately 10 percent through 1992, and about five percent from 1992 to 2000. From 2000 to 2050 the growth rates are about three percent. The projected growth rates for Halon 1301 are smaller and include a period of decline from 1992 to 2000. This period of decline in sales of newly-produced Halon 1301 is caused by increased recovery of the chemical from retiring systems. The recovered halon reduces the levels of new halon required to be produced. Over the long term (2000 through 2050) the increase in demand is estimated to exceed the increased levels of recovery that are achieved, so that production increases.

The growth rates in Exhibit 4-5 are applied to 1986 estimates to produce scenarios of future halon use. Note that no estimates are made at this time for Halon 2402 (also covered by the Protocol) for which information is not currently available.

PROJECTIONS OF OTHER OZONE DEPLETING COMPOUNDS

Exhibit 4-7 presents the global growth rates for HCFC-22, methyl chloroform, and carbon tetrachloride. Growth rates for these compounds are based on CFC-11 and CFC-12 growth rates.

As described above, these scenarios of future use for these compounds are subject to considerable uncertainty. As presented in EPA (1987a) and Chapter 10, alternative assumptions reflecting these uncertainties must be evaluated.

4.3.4 Results

Exhibit 4-8 shows the global weighted CFC and halon use and emissions from 1986 to 2075. Total weighted CFC use grows from about one billion kilograms in 1986 to over seven billion kilograms in 2050. CFC and halon use are assumed constant after 2050. Emissions lag use because in some uses these chemicals are not released to the atmosphere immediately. Also, in some instances, they are destroyed during use, e.g., Halon 1301 is destroyed when used to extinguish fires.

4.3.5 Alternative Growth Projections

To present sensitivities of all results to changes in usage rates, an alternative usage scenario is developed. This scenario, labelled the Slower Growth Scenario, assumes a lower rate of growth in compound use from 1986 to 1992. In the following chapters, the baseline use scenario described above is referred to as the Middle Growth Scenario.

The Slower Growth Scenario assumes that growth rates for 1986 to 1992 equal the rates assumed for 1992 through 2000 in the Middle Growth Scenario.[16] All other growth rates are identical to those of the Middle Growth Scenario. This results in approximately 34 percent less global weighted use in 1992. The cost and health and environmental implications of reduced baseline use of CFCs and halons are presented in Chapter 10.

4.3.6 Technological Rechanneling

The projections discussed above are based on the assumption that no regulatory intervention takes place. In such a situation, the future use and emissions of CFCs and halons will be driven by GNP and population growth, product maturation and saturation, and technological change. Of particular importance is technological change, which has several key influences: (1) existing products that require CFCs and halons will improve, so that CFCs and halons will be used less intensively; (2) existing products that require CFCs and halons may become obsolete; and (3) new products that require CFCs and halons will be developed.

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[16] One exception to this is that USSR and East Bloc projections remain identical through the year 1990 for both compound use projection scenarios.

EXHIBIT 4-7

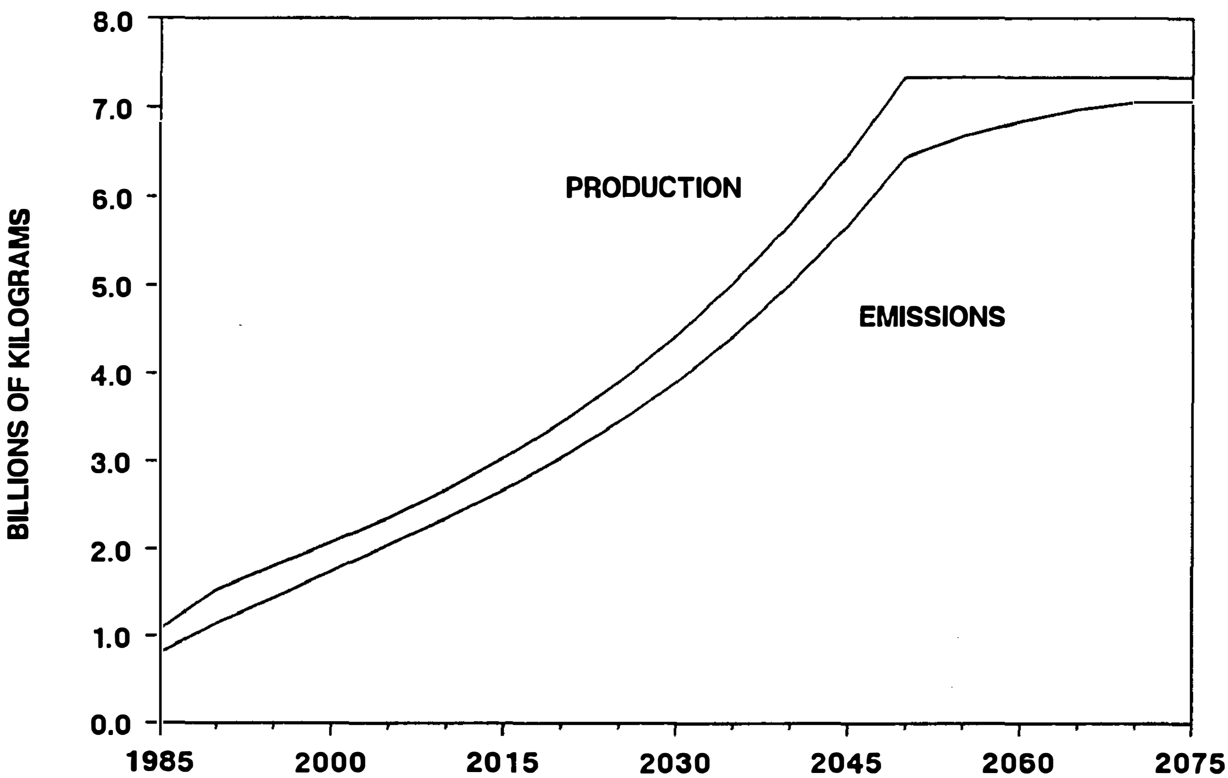
PROJECTED GLOBAL GROWTH RATES FOR POTENTIALLY OZONE DEPLETING COMPOUNDS WHICH ARE NOT CONTROLLED[a/]

	Projected Global Growth Rate			
	1986-1992	1992-2000	2000-2050	2050-2100
HCFC-22	4.37	2.74	2.50	0.00
Methyl chloroform	4.70	2.78	2.50	0.00
Carbon tetrachloride	4.90	2.91	2.50	0.00

a/ Based upon average growth rates for CFC-11 and CFC-12 cited in Exhibit 4-5.

EXHIBIT 4-8

WEIGHTED GLOBAL PRODUCTION AND EMISSIONS
(Billions of Kilograms)



Historically, the development of new products that require CFCs has been an important factor fueling the continued growth of CFC use. Because CFCs have attractive properties, and because people are familiar with the characteristics of CFCs, a steady stream of research investments has been made to develop new products and improve old ones. It is likely that in the absence of regulatory interventions that new products could continue to develop.

Once regulations are contemplated or required, however, the investments required to create new uses for CFCs and improve existing products will slow and likely stop, reducing the expected future use of the compounds. Individuals will move away from the familiar CFC compounds and toward alternative solutions that may be more or less costly than using CFCs. Of note is the possibility that alternative methods that do not require CFCs may be less costly or preferred to using CFCs. Appendix C describes this phenomenon as "technological rechanneling," where individuals continue to exploit a technology (such as CFCs) even though alternatives may be preferred. Channeling occurs due to limited information and other factors (see Appendix C).

The key factor to assess is that once regulations are contemplated, the baseline levels of use described above will not be realized because individuals will "rechannel" their research and development investment resources away from CFCs and into other approaches. Consequently, new products that require CFCs will not develop, and total use will be less. The magnitude and sign of the costs associated with this rechanneling cannot be assessed easily, nor can the magnitude of the impact that rechanneling will have on the level of CFC use. Appendix C describes a range of assumptions used to assess this phenomenon, and the next chapter presents the baseline assumptions which assume that the level of rechanneling varies with the stringency of the proposed regulations.

4.4 OTHER TRACE GASES

Three other trace gases that have an important impact on ozone depletion are:

- Carbon dioxide (CO_2);
- Methane (CH_4); and
- Nitrous oxide (N_2O).

Future stratospheric ozone levels appear to be especially sensitive to future trends in CH_4 concentrations. Methane and carbon dioxide act to offset potentially some or all of the ozone depletion from CFCs and halons. Nitrous oxide could either increase or decrease ozone levels depending on its level relative to CFC levels. The sources, sinks, and projections of concentrations of these influential trace gases are discussed in EPA (1987a). Here we present the middle case from that study.

Exhibit 4-9 presents projections for the concentrations of the three trace gases from 1985 through 2165. The implied annual growth rate for CO_2 is approximately 0.7 percent over the 180 year period (NAS 1984). Concentrations grow at 5.9 ppm annually after 2100. Obviously, such growth is unlikely if society becomes concerned with the greenhouse effects. CH_4 grows at 0.017 ppm for the 180 years of the analysis (EPA 1987a). N_2O concentrations are assumed to grow at a 0.2 percent rate from 1985 concentration values for the entire period of analysis (EPA 1987a).

EXHIBIT 4-9

GROWTH OF TRACE GAS CONCENTRATIONS OVER TIME

Year	CO2 (PPM)	CH4 (PPM)	N2O (PPB)
1985	350.2	1.8	303.1
2000	366.0	2.0	312.3
2025	422.0	2.4	328.3
2050	508.0	2.9	345.1
2075	625.0	3.3	362.8
2100	772.0	3.7	381.4
2165	1,154.2	4.8	434.3

Source: EPA (1987a).

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CHAPTER 5

STRINGENCY AND COVERAGE OPTIONS

This chapter presents the stringency and coverage options (i.e., the control levels) currently being considered for domestic action. These control level options define the extent of reductions in chemical use that may be required. The options do not define the regulatory means by which the reductions are achieved (see Chapter 11). To a large extent, the stringency and coverage alternatives can be defined and evaluated without consideration of the specifics of the regulatory mechanisms used to implement the requirements.

The remainder of this chapter is organized as follows:

- Section 5.1 identifies the chemical coverage options considered;
- Section 5.2 presents the control stringency options;
- Section 5.3 defines the country participation assumptions; and
- Section 5.4 presents the options selected for analysis.

5.1 CHEMICAL COVERAGE OPTIONS

As described in Chapter 4, the following eleven compounds are currently identified as potential ozone-depleters: CFC-11; CFC-12; HCFC-22; CFC-113; CFC-114; CFC-115; carbon tetrachloride (CCl4); methyl chloroform (CH3CCL3); Halon 1211; Halon 1301; and Halon 2402. Chapter 4 presents the baseline use assumptions for all compounds except Halon 2402. Halon 2402, which is not produced in the U.S., is not addressed here due to a lack of data on this compound at this time.

Any chlorinated or brominated substance that survives long enough to reach the stratosphere could contribute to ozone depletion. However, the lifetimes of methyl chloroform and HCFC-22 are shorter than those of the other ozone-depleters because they contain hydrogen, and therefore break down by combining with the hydroxyl (OH) radical in the lower atmosphere. Consequently, the ozone depletion potential per pound is much lower for methyl chloroform and HCFC-22 compared to the other gases (see Exhibit 5-1).

In addition, their shorter lifetimes have another important implication for assessing risks. In the event that ozone depletion occurs, the recovery time and the level of control needed to arrest an increase in the chlorine contribution to the stratosphere would be much shorter. For example, to stabilize CFC-11 concentrations would require an 80% reduction in emissions. To stabilize methyl chloroform concentrations would take about a 15% reduction. Thus, if an unexpected ozone depletion problem develops, it is both easier to arrest and rollback depletion for short-lived substances than for long-lived ozone-depleters. As a consequence of these characteristics, and because of their capability to displace CFC-11, -12, and -113, substances with shorter

EXHIBIT 5-1

CHARACTERISTICS OF VARIOUS OZONE-DEPLETING COMPOUNDS

	Ozone Depletion Potential Weight (Mass Basis) a/	Lifetime (years) d/	1985 U.S. Production (Metric Tons) Unweighted	Weighted
CFC-11	1.0	64	79,700	79,700
CFC-12	1.0	108	136,900	136,900
CFC-113	0.8	88	68,500	54,800
CFC-114	1.0	185	4,000	4,000
CFC-115	0.6	380	4,500	2,700
Halon 1211	3.0 b/	25	2,800	8,400
Halon 1301	10.0 b/	110	3,500	35,000
HCFC-22	0.05	22	99,200	4,960
Methyl Chloroform	0.1 c/	10	190,955	19,096

a/ Measured relative to CFC-11, which is set to 1.0. The values for all compounds, except HCFC-22 and Methyl Chloroform, were adopted in the Montreal Protocol.

b/ Preliminary estimates with large uncertainties.

c/ Range 0.06-0.15.

d/ Some uncertainty exists for these estimates.

lifetimes are considered part of the solution to potential ozone depletion problems.[1]

Thus, the following two chemical coverage options are being considered for purposes of preventing potential stratospheric ozone modification:

- Fully-halogenated CFCs: CFC-11, CFC-12, CFC-113, CFC-114, and CFC-115; and

- Fully-halogenated compounds: CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, Halon 1301, Halon 1211, and Halon 2402.

The difference between these two options is the inclusion of the halon compounds.

In evaluating these options it is assumed that the fully-halogenated CFCs would be controlled as a group, and that the halons would also be controlled as a group (if covered) but would be controlled separately from the CFCs. As discussed in Chapter 4 above, the halon uses (primarily as fire extinguishants) are significantly different from the CFC applications. In addition, the ozone depletion potentials of halons are more uncertain (although clearly higher than CFCs) and are dependent on the level of chlorine in the atmosphere. Consequently, tradeoffs with CFCs could not assume a linear or fixed ratio. (Tradeoffs between these brominated compounds, however, may make sense.)

5.2 STRINGENCY OPTIONS

The following stringency options are considered for control of the fully-halogenated CFCs. Each option is evaluated in terms of total ozone depletion potential. Individual substances are weighted with the requirement for control applied against all CFCs based on their ozone depletion potential (e.g., 1.25 kilograms of CFC-113 would be equal to 1.00 kilograms of CFC-11 in terms of meeting a control limit):

- No Controls (Baseline Case);

- Freeze use (in terms of ozone depletion potential) at 1986 levels starting in 1989;

- 20 percent: Freeze use at 1986 levels starting in 1989; and reduce use by 20 percent starting in 1993;

- 50 percent: Freeze use at 1986 levels starting in 1989; reduce use by 20 percent in 1993; and reduce use by 50 percent in 1998; and

- 80 percent: Freeze use at 1986 levels in 1989; reduce use by 20 percent in 1993; reduce use by 50 percent in 1998; and reduce use by 80 percent in 2003.

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[1] Carbon tetrachloride is not currently considered for control because it is used primarily as a chemical intermediate, and its emissions are small.

Exhibit 5-2 shows graphically the expected use of CFC-11 for these five stringency options if it were controlled separately (in reality, controls will likely be applied against the pool of CFCs so CFC-11 use could be higher or lower depending on whether it was more or less expensive to control than other CFCs). CFC-11 use in the No Controls scenario grows at a 3.75 percent annual rate from 1987 to 1992 and a 2.5 percent annual rate from 1992 to 2050, after which use remains constant. Each of the four other lines in the exhibit reflects CFC-11 use assuming 100 percent participation worldwide in a global control protocol. As noted below, however, it may be unlikely that 100 percent participation will be achieved.

The stringency for halons in the Montreal Protocol is for a freeze at current (e.g., 1986) levels of production. This is the only stringency option considered for halons at this time.

5.3 PARTICIPATION ASSUMPTIONS

It is unlikely that all nations of the world will participate in the international protocol to protect stratospheric ozone through reductions in the use and emissions of ozone-depleting compounds. For purposes of assessing the impact of alternative U.S. domestic requirements, assumptions regarding potential participation internationally are required. In particular, the influence of alternative U.S. actions on participation abroad should be assessed.

For purposes of this analysis, it is assumed that the U.S. will participate, and that 100 percent compliance will be achieved in the U.S. Although this 100 percent compliance figure may seem high for most engineering-related requirements, it is probably reasonable for a market-based regulatory approach (such as production and import rights) where few producers and importers are involved. Therefore, the 100 percent compliance rate for the U.S. is used.

It is expected that many of the nations of the world will participate in and comply with the international protocol. Exhibit 5-3 lists the nations that have signed the Montreal Protocol. As shown in the exhibit, 37 nations plus the EEC have signed the Protocol. Virtually all industrialized nations have indicated an intention to sign the protocol.

It is estimated that the nations who have signed the Protocol or have been involved in the protocol development process account for a large majority of global CFC production. However, a significant portion of this production (e.g., one-third of production in the EEC) is exported, some portion possibly to nations that have not been involved to date. Also, many CFC-related products (such as automobiles) are exported. Therefore, the effective global participation in the protocol may be expected to be less than 100 percent, and possibly considerably less, depending on the effectiveness of trade provisions in the protocol.

EXHIBIT 5-2

ILLUSTRATIVE USE OF CFC-11 UNDER
FIVE STRINGENCY OPTIONS

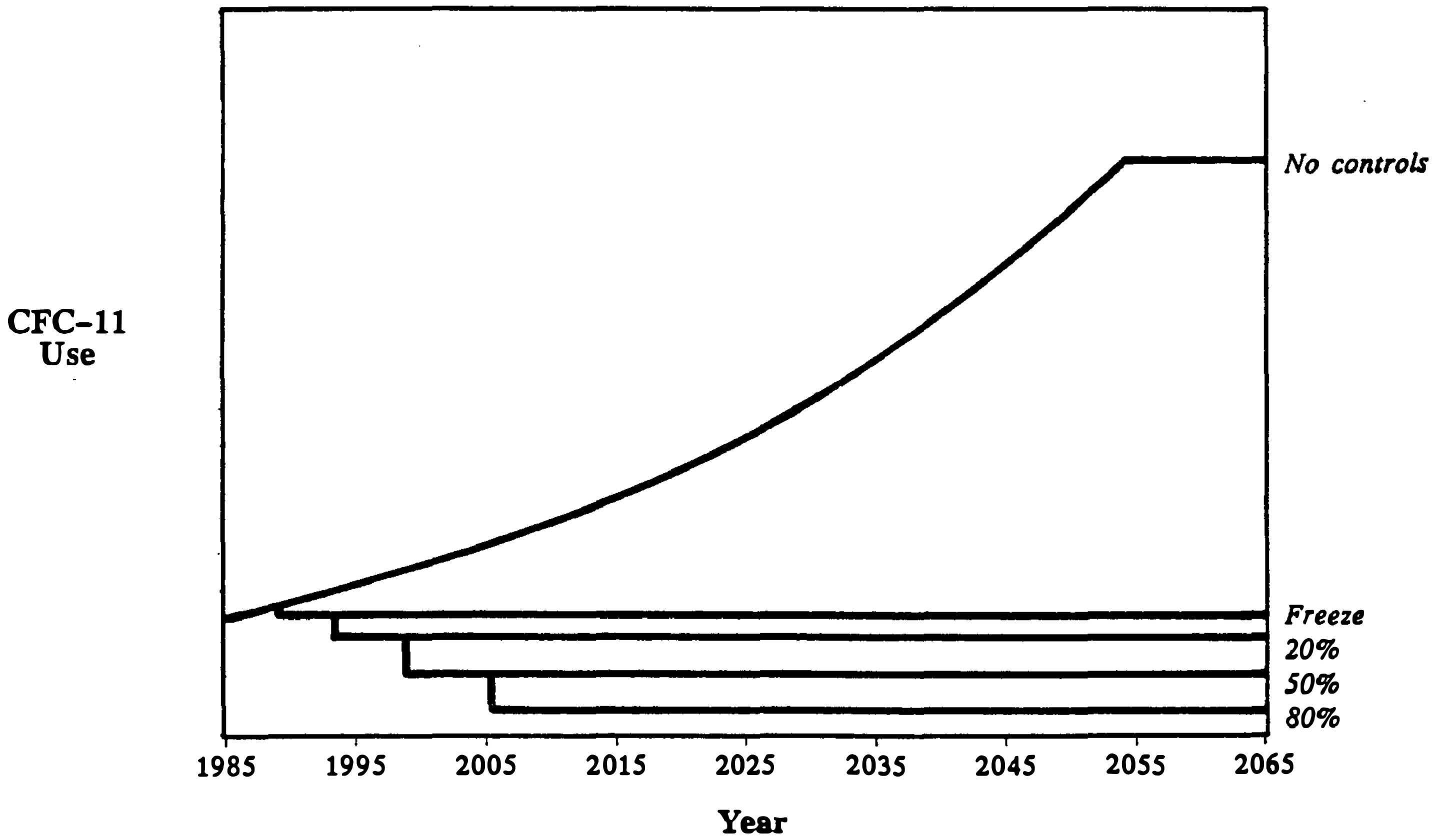

EXHIBIT 5-3

NATIONS THAT HAVE SIGNED THE PROTOCOL

Argentina
Australia
Belgium
Byelorussian Soviet Socialist Republic
Canada
Chile
Denmark
Egypt
European Economic Community
Finland
France
Germany
Ghana
Greece
Indonesia
Israel
Italy
Japan
Kenya
Luxembourg
Maldives
Mexico
Morocco
Netherlands
New Zealand
Norway
Panama
Portugal
Senegal
Spain
Sweden
Switzerland
Togo
Ukranian Soviet Socialist Republic
Union of Soviet Socialist Republics
United Kingdom
United States
Venezuela

Source: U.S. EPA.

For purposes of analysis it is assumed that, among other developed nations, 94 percent participation may be expected. (Sensitivity analysis was performed with 75 percent and 100 percent.) Among developing nations, participation may be lower, and is assumed to be 65 percent. (Sensitivity analysis was performed using 40 percent and 100 percent.) Because few developing nations have been involved in the protocol process to date an additional sensitivity analysis was performed assuming participation only by nations who are already signatories to the protocol. It is further assumed for purposes of analysis that those nations who participate achieve 100 percent compliance.

For nations that do not participate in the protocol, their continued use of CFCs is assumed to follow the modified path of demand defined in Appendix C.[2] The adoption of "rechanneled" technologies in developing countries will be strongly influenced by: (1) technology transfer from developed countries; and (2) the ability to sell products in developed countries (see Appendix D for a description of the factors affecting CFC use in developing nations). If new technologies are not adopted in the non-participating developing nations, then their CFC use may approach their baseline use in the absence of global restrictions. However, transnational corporations (TNCs) or protocol trade restrictions may cause non-participating nations to modify their CFC use. Therefore, a range of values must be assessed. It is important to note that the participation rates and the reduced growth rates assumed here for analysis purposes are based on qualitative assessments of the relevant forces influencing future use of CFCs. Alternative hypotheses are plausible.

Exhibit 5-4 illustrates graphically how the protocol participation rates are used in the analysis, and how the growth in CFC use is reduced for non-participants. As shown in Exhibit 5-4(a), the total baseline use is divided between participants and non-participants. The participants are analyzed assuming that they achieve the reductions (e.g., 50 percent) set forth by the protocol (see Exhibit 5-4(b)). The non-participants would experience reduced growth (as shown in Exhibit 5-4(c)).

5.4 SELECTED POLICY OPTIONS FOR CONTROLS ON POTENTIAL OZONE DEPLETERS

Exhibit 5-5 shows the control level options selected for analysis in future chapters of this final RIA. These cases reflect varying coverage and stringency assumptions. The stringency varies from no controls to an 80 percent reduction, and two sets of compound coverage are analyzed.

Each coverage option is assumed to be applied globally, unless indicated otherwise. Similarly, with two exceptions, each stringency option is assumed to be applied globally. However, for cases 7 and 8 in Exhibit 5-5, it is assumed that other parties implement less stringent requirements.

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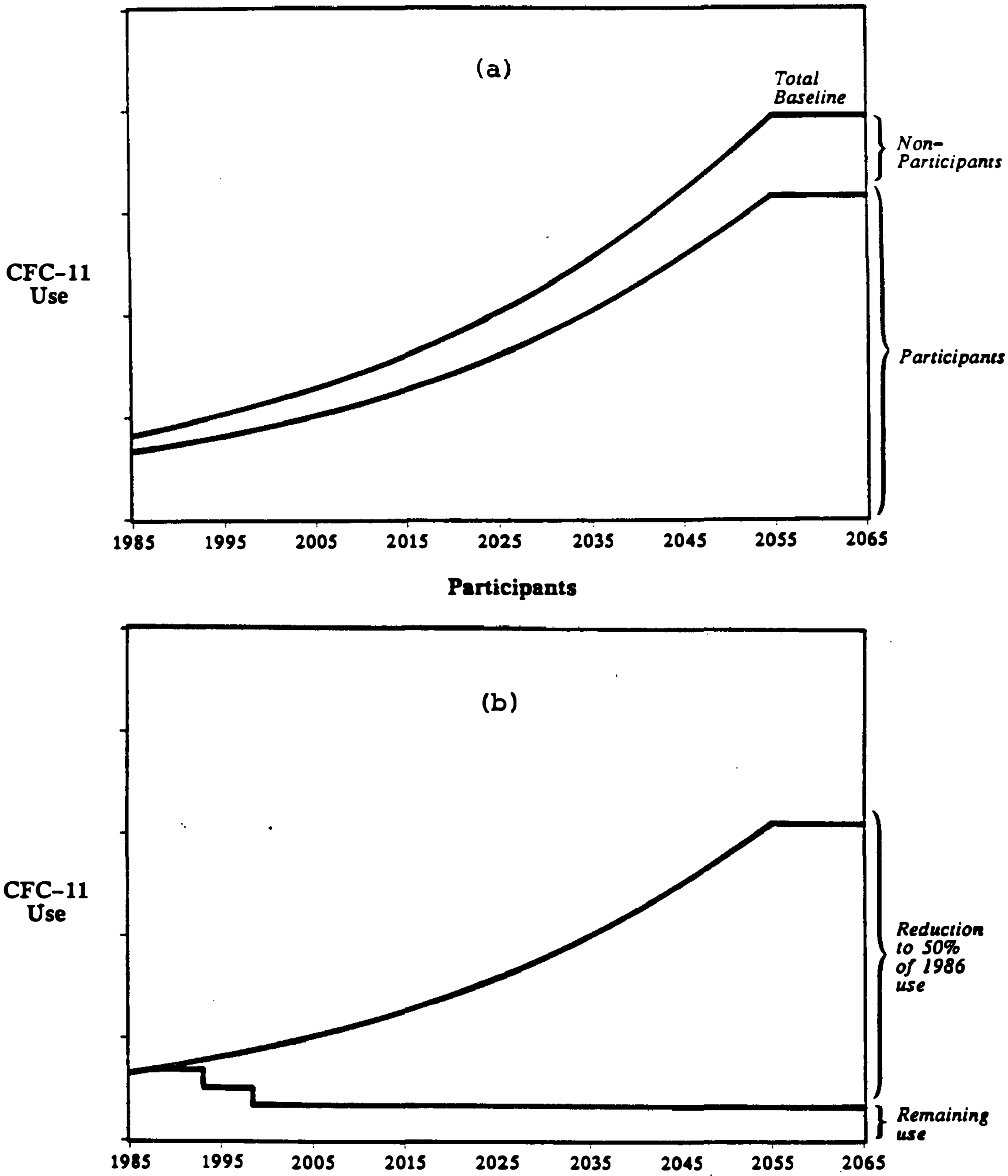
[2] As described in Appendix C, the discussion and implementation of regulations will influence people's investments in research and development, resulting in a "rechanneling" of technology away from CFC-related products. This rechanneling results in less CFC use than would be expected in the absence of any restrictions on CFCs.

EXHIBIT 5-4

ILLUSTRATION OF PARTICIPATION RATES



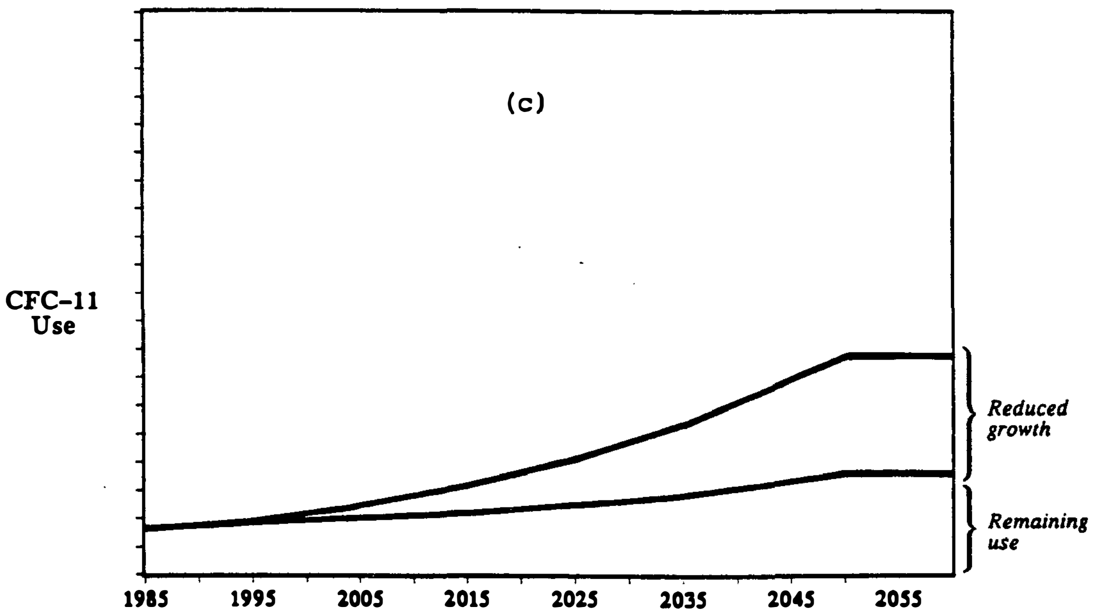
(a) Total Baseline use is divided into participants and non-participants according to the participation rate (in this case 80%).

(b) The participants reduce use according to the requirements of the protocol (e.g., to 50% of 1986 use).

EXHIBIT 5-4

ILLUSTRATION OF PARTICIPATION RATES
(Continued)

Non-Participants



(c) The non-participants experience reduced rates of growth due to the technological changes induced by reductions undertaken by the participants.

EXHIBIT 5-5

CONTROL OPTIONS ANALYZED a/

	U.S. Requirements b/		Non-U.S. Reductions			
					Participation and Reduced Growth	
Case	Fully-Hal. CFCs	Halons	Fully-Hal. CFCs	Halons	Non-U S. Developed c/	Developing
1	No Controls		No Controls		--	--
2	Freeze	--	Freeze	--	94% participation and 1/2 growth	65% participation and 3/4 growth
3	20%	--	20%	--	94% participation and 1/2 growth	65% participation and 5/8 growth
4	50%	--	50%	--	94% participation and 3/8 growth	65% participation and 1/2 growth
5	80%	--	80%	--	94% participation and 3/8 growth	65% participation and 1/2 growth
6	50%	Freeze	50%	Freeze	94% participation and 3/8 growth	65% participation and 1/2 growth
7	80%	Freeze	50%	Freeze	94% participation and 3/8 growth	65% participation and 1/2 growth
8	50%	Freeze	--	--	0% participation and full growth	0% participation and full growth

a/ The control options analyzed reflect a variety of coverage and stringency cases. The stringency ranges from a freeze to an 80 percent reduction. The coverage includes all the fully-halogenated CFCs, and as an option includes the halon compounds (cases 6-8).

b/ U.S. participation is assumed to always be 100%; reductions in U.S. growth are equal to the assumptions on reduced growth for the other (non-U.S.) developed countries. In Case 8, the reductions in U.S. growth are equal to the U.S reductions in Case 6.

c/ Prior to the Montreal Protocol it was estimated that developed countries other than the U.S would achieve a participation rate of 80 percent (excluding the U.S.S.R. and other Eastern Bloc countries). With the signing of the Protocol by the USSR, it is estimated that participation among non-U.S. developed countries could be about 94 percent based on 1986 CFC production levels.

A summary description of each scenario is provided below:

- No Controls -- No controls on CFCs or halons occur. This is the baseline scenario from which the impacts of various control options are measured.

- CFC Freeze -- CFC use is held constant at 1986 levels starting in 1989.

- CFC 20% -- In addition to the CFC freeze in 1989, a 20% CFC reduction worldwide occurs in 1993.

- CFC 50% -- In addition to the CFC freeze in 1989 and the 20% reduction in 1993, a 50% CFC reduction occurs in 1998.

- CFC 80% -- In addition to the CFC freeze in 1989, the 20% reduction in 1993, and the 50% reduction in 1998, an 80% CFC reduction occurs in 2003.

- CFC 50%/Halon Freeze -- In addition to the freeze on CFC use in 1989, the 20% reduction in 1993, and the 50% reduction in 1998, halon use is held constant at 1986 levels starting in 1992. This case is intended to resemble as closely as possible the Montreal Protocol.[3]

- CFC 50%/Halon Freeze/U.S. 80% -- Same as the CFC 50%/Halon Freeze case, except that the U.S. reduces to 80% of 1986 CFC levels in 2003.

- U.S. Only/CFC 50%/Halon Freeze -- Same as the CFC 50%/Halon Freeze case, except the U.S. is the only country in the world that participates.

Throughout this report each scenario is referenced by the underlined title listed above.

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[3] Assuming entry into force on January 1, 1989, the Montreal Protocol specifies that the CFC freeze would begin on July 1, 1989, the 20% CFC reduction on July 1, 1993, and the 50% reduction on July 1, 1998. For purposes of analysis in this study, the effective dates were analyzed on a calendar year basis with a six month delay. This adjustment has been made for all of the alternative control scenarios; it has less than a 0.5 percent impact on the estimated costs and benefits presented in later chapters.

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U.S. Environmental Protection Agency (1987), Assessing the Risks of Trace Gases That Can Modify the Stratosphere, U.S. Environmental Protection Agency, Washington, D.C. This is a revised version of: U.S. Environmental Protection Agency (1986), An Assessment of the Risks of Stratospheric Modification, U.S. EPA, Washington, D.C.

CHAPTER 6

ANALYSIS OF ATMOSPHERIC RESPONSE

This chapter presents estimates of the atmospheric response to perturbations due to emissions of ozone-depleting compounds. The cases being analyzed are presented in Exhibit 5-5 in Chapter 5. The global ozone depletion associated with each of these cases is presented below. These ozone depletion estimates are used in subsequent chapters to assess the potential risks that ozone depletion may pose to human health and the environment. The potential impacts of the emissions associated with each of the cases on global climate is also evaluated.

There is currently some uncertainty surrounding the potential impacts of CFC emissions on stratospheric ozone. Historically, many models have been developed and used to assess the potential impact of various emissions and concentrations on stratospheric ozone. Over time the results of these models have varied, but always have projected depletion in the event of increasing chlorine. A recent UNEP-sponsored model intercomparison workshop concluded that the major 1-dimensional models currently produce about the same results. The simplified model used in this assessment was found to produce ozone depletion estimates that are within the range of the estimates of the more complex models, although slightly on the low side (i.e., underestimating ozone depletion) in some cases (UNEP 1987).

The largest uncertainties related to current atmospheric models are driven by recent empirical findings on ozone itself. The identification of the Antarctic ozone hole, and the inability of current theories and models to predict or account for the hole, reduce the level of confidence that can be placed in the current model estimates. Nevertheless, because the atmosphere in the Antarctic is very different from the atmosphere over most of the rest of the globe, it is premature to alter the current models until a better understanding of the hole is achieved.

Additionally, preliminary global ozone trends based on both satellite and ground-based estimates indicate that a reduction of <u>global</u> ozone appears to be occurring at rates faster than those predicted by the models. This is possibly a second indication that the current models <u>underestimate</u> the response of stratospheric ozone to perturbations. However, changes to the atmospheric models to reflect recent ozone trends analyses have not yet been undertaken. Therefore, the analysis presented throughout this report, but especially in the following chapters on effects, does not reflect the information.

One mechanism that could lead to the current models being incorrect is the existence of chemical reactions whereby gaseous species interact on particles (such as particulates). These reactions (referred to as "heterogeneous" chemistry because they occur at the interface between two phases, such as gas-liquid or gas-solid) are not included in the current atmospheric models used to assess ozone depletion. Considerable investigation is required before the implications of this reaction mechanism for estimates of ozone depletion can be assessed. One preliminary study shows that heterogeneous chemistry could significantly increase the sensitivity of stratospheric ozone to perturbations from chlorine-containing compounds such as CFCs. Another possibility is that Antarctic depletion itself could have an impact on global ozone.

The remainder of this chapter is organized as follows:

- Section 6.1 presents estimates of global ozone depletion for the baseline case of no controls. The uncertainty in this estimate associated with the understanding of the atmospheric chemistry currently included in the model is also presented.

- Section 6.2 presents estimates of global ozone depletion for the control cases defined in Chapter 5. These estimates form the basis for the analyses presented in Chapters 7-10.

- Section 6.3 presents an estimate of ozone depletion with alternative assumptions for growth of greenhouse gases. (Not carried forward to effects chapters.)

- Section 6.4 presents estimates of global warming associated with the eight cases defined in Chapter 5.

6.1 BASELINE CASE GLOBAL OZONE DEPLETION

This section presents estimates of global ozone depletion for the No Controls Case using the baseline CFC, halon and trace gas assumptions defined above in Chapter 4. A statistical representation of a 1-dimensional model is used to relate emissions and concentrations to ozone depletion.[1]

Exhibit 6-1 displays estimates of ozone depletion over time for the No Controls Case.[2] As shown in the exhibit, the horizontal axis is time (1985 to 2100) and the vertical axis is the level of global ozone depletion simulated to occur. Note that ozone depletion is identified as negative, so that increasing levels of ozone depletion are depicted as downward-sloping curves. Note also that in Exhibit 6-1 the ozone depletion beyond 50 percent is not shown. Throughout this analysis (including the impacts assessments in subsequent chapters) ozone depletion is truncated at 50 percent. Although the model used to evaluate ozone depletion indicates levels in excess of 50 percent, the data used to develop the parameterized model do not allow it to be carried beyond this point. This truncation at 50 percent results in an underestimate of ozone depletion and impacts over the long term in the No Controls Case.

The No Controls Case shows average column ozone depletion of 2 percent by the year 2010 from 1985 levels; depletion that may have occurred prior to 1985 is ignored. Note that depletion continues to get worse after 2050 when

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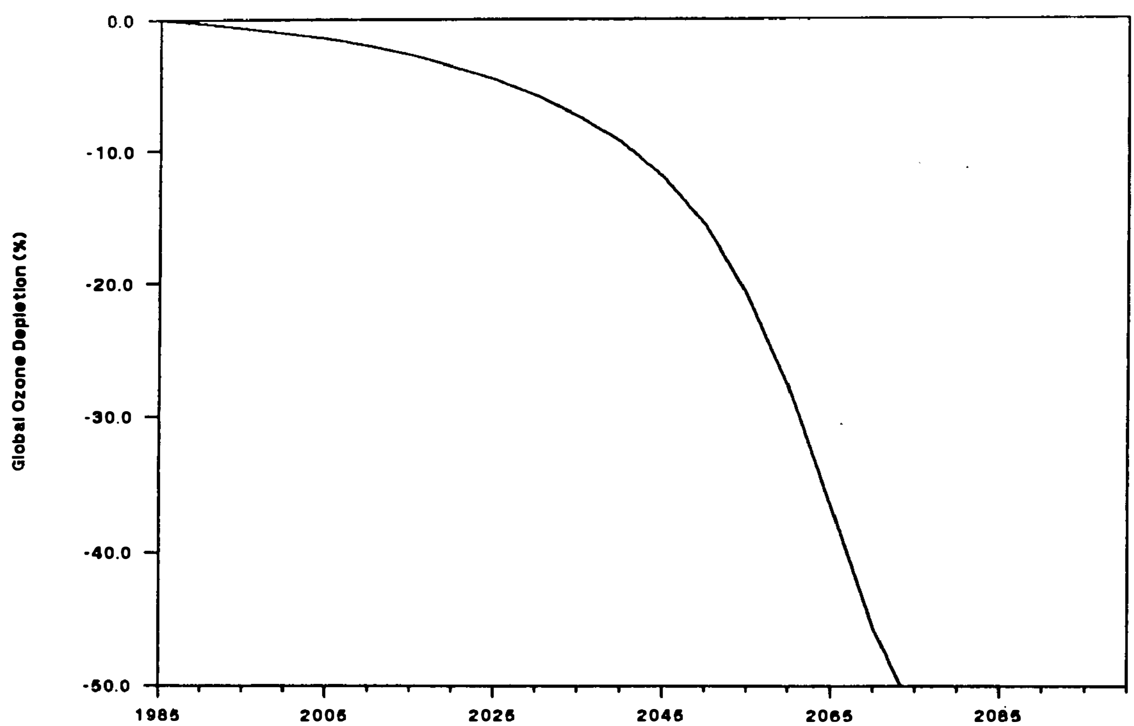
[1] The model used to evaluate ozone depletion is described in EPA's recent risk assessment of stratospheric modification (EPA 1987). The statistical model is presented in Connell (1986).

[2] Recall that in this no controls case CFC/Halon use is assumed to grow through 2050, and then remain constant. As described below, ozone depletion continues to get worse after 2050 even though CFC use has leveled out.

EXHIBIT 6-1

GLOBAL OZONE DEPLETION FOR THE NO CONTROLS CASE



Ozone depletion is estimated for the no controls case defined in Chapter 5. The baseline CFC, halon, and trace gas assumptions are defined in Chapter 4. Note that ozone depletion is truncated at 50 percent. This truncation results in an underestimate of ozone depletion over the long term in this No Controls Case. See text.

Source: Estimates based on the statistical method developed by Connell (1986).

CFC/halon use is assumed arbitrarily to level out. The depletion continues because the concentrations of chlorine and bromine in the stratosphere do not reach steady state by 2050, and the concentrations continue to increase with constant emissions. To prevent continued depletion beyond 2050 (or at any point in the time horizon examined) CFC/halon emissions would have to be reduced significantly in order to prevent chlorine and bromine concentrations from continuing to grow.

6.2 GLOBAL OZONE DEPLETION FOR THE CONTROL CASES

Exhibit 6-2 displays the estimates of global ozone depletion for the No Controls Case, and the CFC 50%/Halon Freeze Case. As shown in the exhibit, the more stringent policy results in less ozone depletion. With No Controls ozone depletion reaches 50 percent by 2075, at which point it is arbitrarily constrained in this analysis. The CFC 50%/Halon Freeze Case leads to ozone depletion of only about 2.0 percent in the same time frame.

Ozone depletion estimates are presented in Exhibit 6-3 for the alternative control option cases (except the U.S. Only/CFC 50%/Halon Freeze case). These cases include:

- CFC Freeze;
- CFC 20%;
- CFC 50%;
- CFC 80%;
- CFC 50%/Halon Freeze; and
- CFC 50%/Halon Freeze/U.S. 80%.

As expected, the more stringent policies result in less ozone depletion over time. By 2100, the CFC Freeze leads to depletion of almost 8 percent. The CFC 80% Case reduces depletion to about 2.5 percent by 2100.

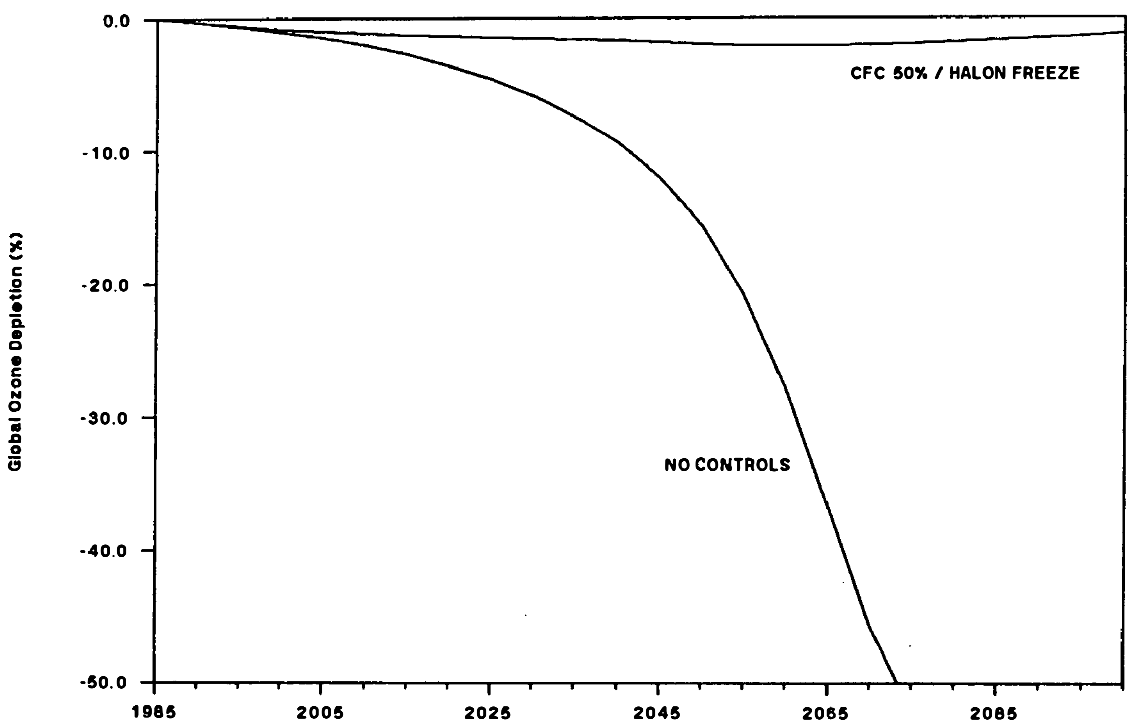
The final two cases shown in Exhibit 6-3 show even less ozone depletion, which is to be expected as the CFC 50%/Halon Freeze case and the CFC 50%/Halon Freeze/U.S. 80% case incorporate a freeze on halon production. The CFC 50%/Halon Freeze case leads to depletion of 1.0 percent in 2100, and the CFC 50%/Halon Freeze/U.S. 80% case to depletion of 0.8 percent.

Finally, Exhibit 6-4 presents the No Controls Case, CFC 50%/Halon Freeze Case, and U.S. Only/CFC 50%/Halon Freeze Case. While the CFC 50%/Halon Freeze case shows a marked decrease in depletion from the No Controls case, the U.S. Only/CFC 50%/Halon Freeze case shows a large increase over the CFC 50%/Halon Freeze case. This is a result of having only the U.S. participate in the control policy (U.S. Only/CFC 50%/Halon Freeze case) as opposed to the policy being globally implemented (CFC 50%/Halon Freeze case).

Exhibit 6-5 summarizes the results of the control cases in tabular form. For each case the estimated ozone depletion for the years 2000, 2025, 2050, 2075, and 2100 are listed. As shown in the exhibit, the more stringent the

EXHIBIT 6-2

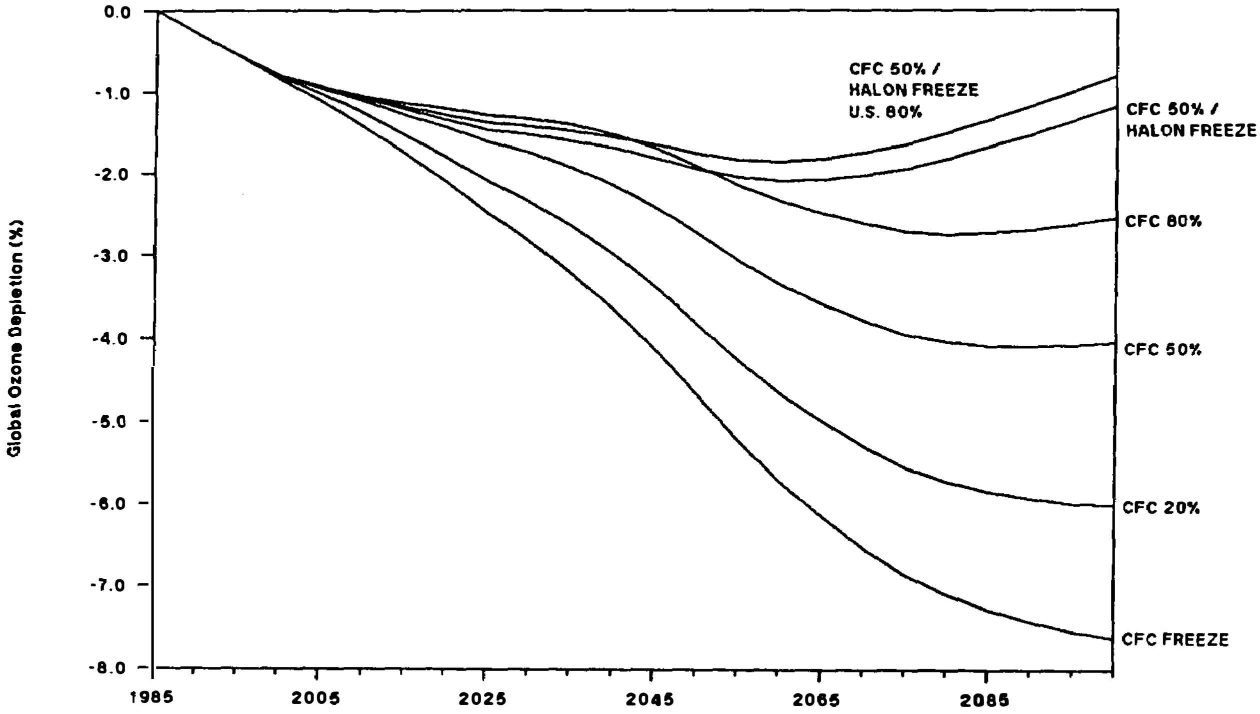
GLOBAL OZONE DEPLETION ESTIMATES FOR THE NO CONTROLS CASE AND CFC 50%/HALON FREEZE CASE (Percent)



Source: Estimates based on the statistical method developed by Connell (1986).

EXHIBIT 6-3

GLOBAL OZONE DEPLETION ESTIMATES FOR ALTERNATIVE CONTROL OPTIONS CASES[a]

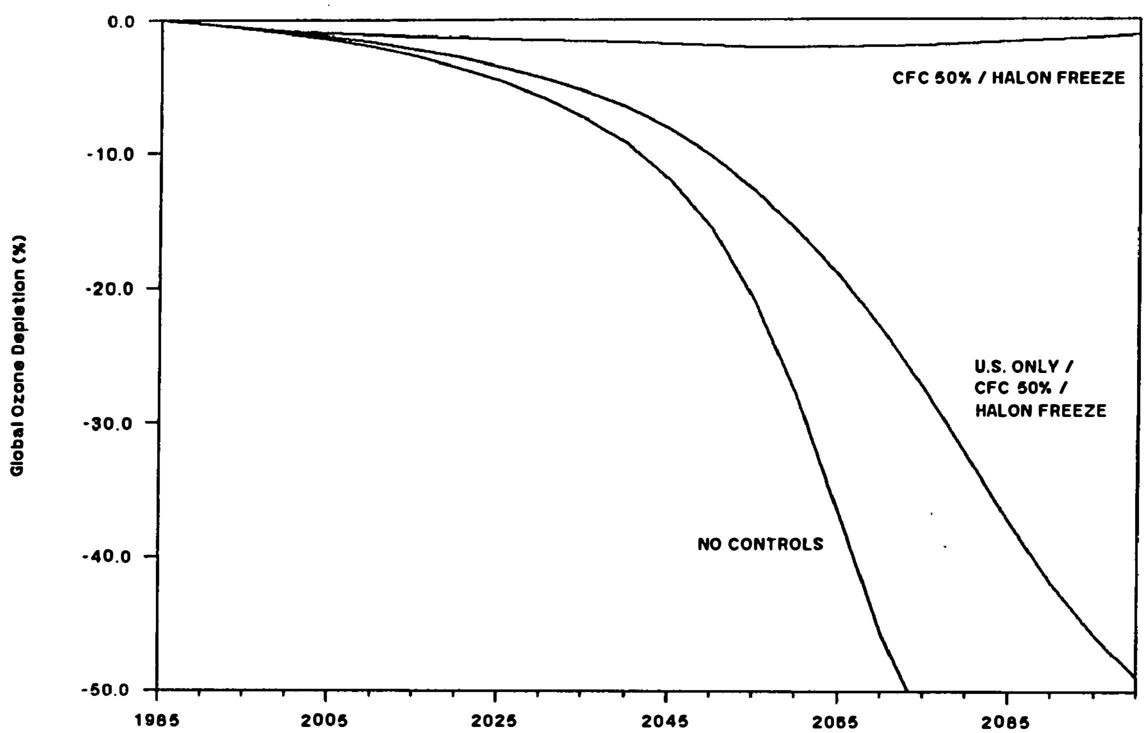


a/ All alternative cases except the U.S. Only case.

Source: Estimates based on the statistical method developed by Connell (1986).

EXHIBIT 6-4

GLOBAL OZONE DEPLETION ESTIMATES FOR THE NO CONTROLS, CFC 50%/HALON FREEZE, AND U.S. ONLY CASES



Source: Estimates based on the statistical method developed by Connell (1986).

EXHIBIT 6-5

SUMMARY OF OZONE DEPLETION ESTIMATED FOR THE 8 CONTROL CASES
(Ozone Depletion Reported in Percent)

Case a/	2000	2025	2050	2075	2100
1. No controls	1.0	4.6	15.7	50.0 b/	50.0 b/
2. CFC Freeze	0.8	2.5	4.7	6.9	7.6
3. CFC 20%	0.8	2.1	3.8	5.6	6.0
4. CFC 50%	0.8	1.6	2.7	4.0	4.0
5. CFC 80%	0.8	1.3	1.9	2.7	2.6
6. CFC 50%/Halon Freeze	0.8	1.5	1.9	1.9	1.2
7. CFC 50%/Halon Freeze/ U.S. 80%	0.8	1.4	1.8	1.6	0.8
8. U.S. Only/CFC 50%/Halon Freeze	0.9	3.5	10.3	27.4	49.0

a/ Cases are defined in Chapter 5.

b/ Global ozone depletion arbitrarily constrained at 50 percent in this analysis.

control policy, the less ozone depletion occurs. Interesting to note is that in the later years (2075-2100) a freeze on halons becomes increasingly important in keeping ozone depletion to a minimum.

6.3 GLOBAL DEPLETION WITH ALTERNATIVE GREENHOUSE GAS GROWTH

As described in EPA (1987) there is uncertainty surrounding the potential rates of growth of the atmospheric concentrations of CO_2, N_2O, and CH_4. The potential level of future ozone depletion is sensitive to these growth rates, particularly the rates for CH_4. Exhibit 6-6 displays estimates of ozone depletion for the CFC 50%/Halon Freeze case with the following trace gas concentration sensitivity assumptions:

- <u>Low Trace Gas</u>:

  -- CO_2: NAS 25th percentile growth estimate;
  -- N_2O: 0.15 percent per year; and
  -- CH_4: 0.01275 ppm/year (75 percent of the baseline assumption of 0.017 ppm/year).

- <u>High Trace Gas</u>:

  -- CO_2: NAS 75th percentile growth estimate;
  -- N_2O: 0.25 percent per year; and
  -- CH_4: 1.0 percent per year compounded annually.

As shown in the exhibit, by 2100 the ozone depletion estimates vary by several percentage points due to these alternative trace gas assumptions.

Also shown in the exhibit is an estimate of ozone depletion for the CFC 50%/Halon Freeze case in which equilibrium global warming is limited to 2.0 degrees C by 2075. This case is undertaken to reflect the potential implications of nations undertaking policies to prevent significant global warming. In order to perform this simulation, the trace gas concentration growth rates were reduced to 10 percent of their baseline assumption values after the year 2000. When the equilibrium global warming is limited to 2.0 degrees C by 2075 in this manner, the resulting ozone depletion estimates are much higher than the other sensitivities, indicating that reducing the growth in concentrations for purposes of preventing global warming may have important implications for ozone depletion.

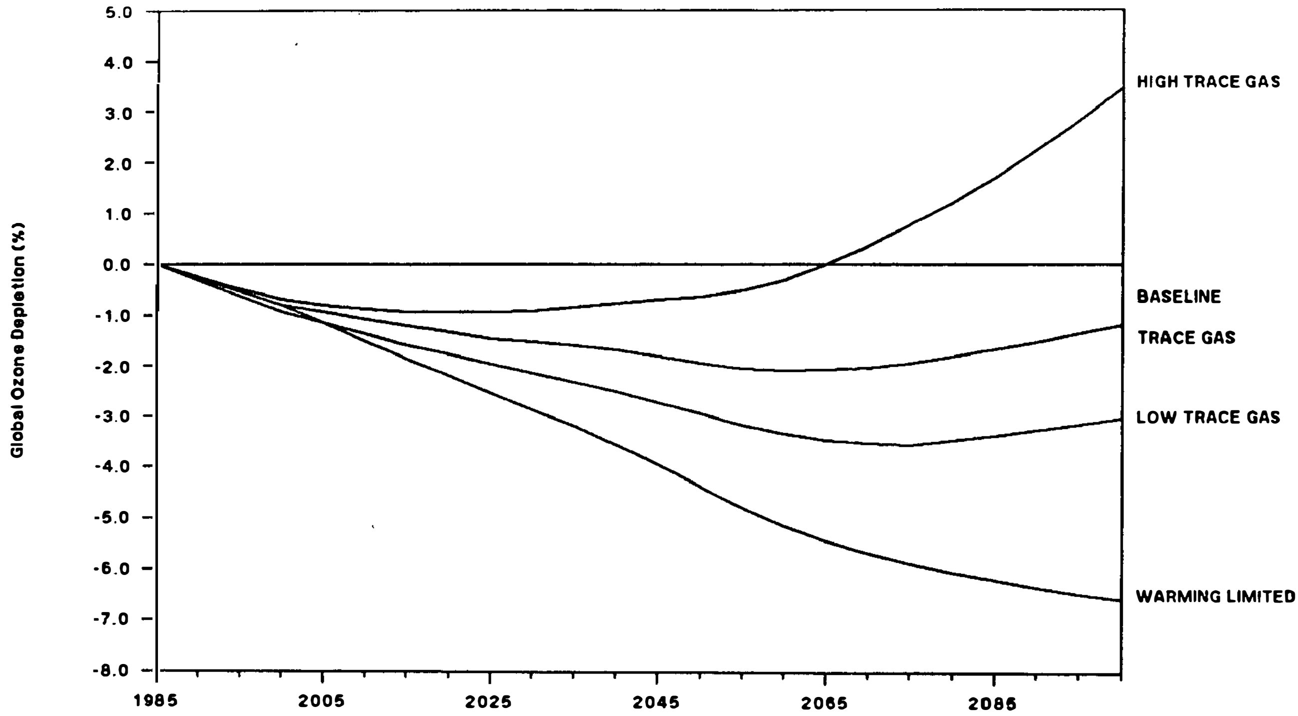
6.4 ESTIMATES OF GLOBAL WARMING

As presented in EPA's risk assessment (EPA 1987), CFCs may also contribute to global warming through the "Greenhouse Effect." Exhibit 6-7 summarizes estimates of equilibrium global warming from 1985 to 2075 associated with each of the 8 control level cases, assuming a climate sensitivity of 3 degrees C for doubled CO_2.

As shown in the exhibit, global warming may reach 6.0 degrees C in the No Controls Case for equilibrium conditions in 2075. The warming is less for the other cases, but remains fairly substantial because the carbon dioxide (CO_2),

EXHIBIT 6-6

GLOBAL OZONE DEPLETION ESTIMATES FOR THE CFC 50%/HALON FREEZE CASE FOR ALTERNATIVE TRACE GAS CONCENTRATION ASSUMPTIONS



Source: Ozone depletion estimates are based on the statistical method developed by Connell (1986). Global warming estimated based on a statistical representation of a 1-dimensional model of the ocean and atmosphere, see Hoffman, et al (1986) and assuming a climate sensitivity of 3 degrees C for doubled CO2.

EXHIBIT 6-7

ESTIMATES OF EQUILIBRIUM GLOBAL WARMING BY 2075
(Degrees Centigrade)

Case a/	Climate Sensitivity 3.0 Degrees C b/	CFC/Halon Contribution (%) c/
1. No controls	6.0	37%
2. CFC Freeze	4.6	17%
3. CFC 20%	4.5	14%
4. CFC 50%	4.4	10%
5. CFC 80%	4.2	7%
6. CFC 50%/Halon Freeze	4.4	9%
7. CFC 50%/Halon Freeze/U.S. 80%	4.3	9%
8. U.S. Only/CFC 50%/Halon Freeze	5.6	32%

a/ See Chapter 5 for the case definitions.

b/ A range of climate sensitivity can be used from 1.5 to 4.5 degrees C based on NAS (1979) although recent climate model developments indicate that 4.0 degrees C is the most likely estimate. Estimates of equilibrium warming for 1.5°C and 4.5°C can be made simply by multiplying the values by 50 percent and by 150 percent. See EPA (1987).

c/ Estimate of the contribution to estimated global warming from CFC-11, CFC-12, and Halon-1301. The contributions of other controlled substances to global warming have not yet been evaluated and are therefore not included in the global warming computation.

Source: Estimates based on a statistical representation of a 1-dimensional model of the ocean and atmosphere, see Hoffman, *et al*. (1986).

methane (CH_4), and nitrous oxide (N_2O) concentrations are assumed to increase in all the cases (see Chapter 4 for a summary of the trace gas concentration assumptions). Also shown in the exhibit is the contribution of CFC-11, CFC-12 and Halon-1301 to the estimated warming.[3] The contribution of these compounds ranges from under 7.0 percent to over 35 percent. CFC-11 and CFC-12 account for the majority of this contribution, with Halon-1301 accounting for 0.5 percent or less in all cases.

Also of note is that the global warming estimate (as well as the ozone depletion estimates) are sensitive to the baseline growth assumptions for the compounds of concern. Sensitivity analyses that vary the baseline growth assumptions are presented in Chapter 10.

Exhibit 6-8 compares the contributions of CFC-11 and CFC-12 to the contributions of other major greenhouse gases. The exhibit illustrates the significant decrease in projected global warming through 2075 attributable to the control of CFCs through the Montreal Protocol.

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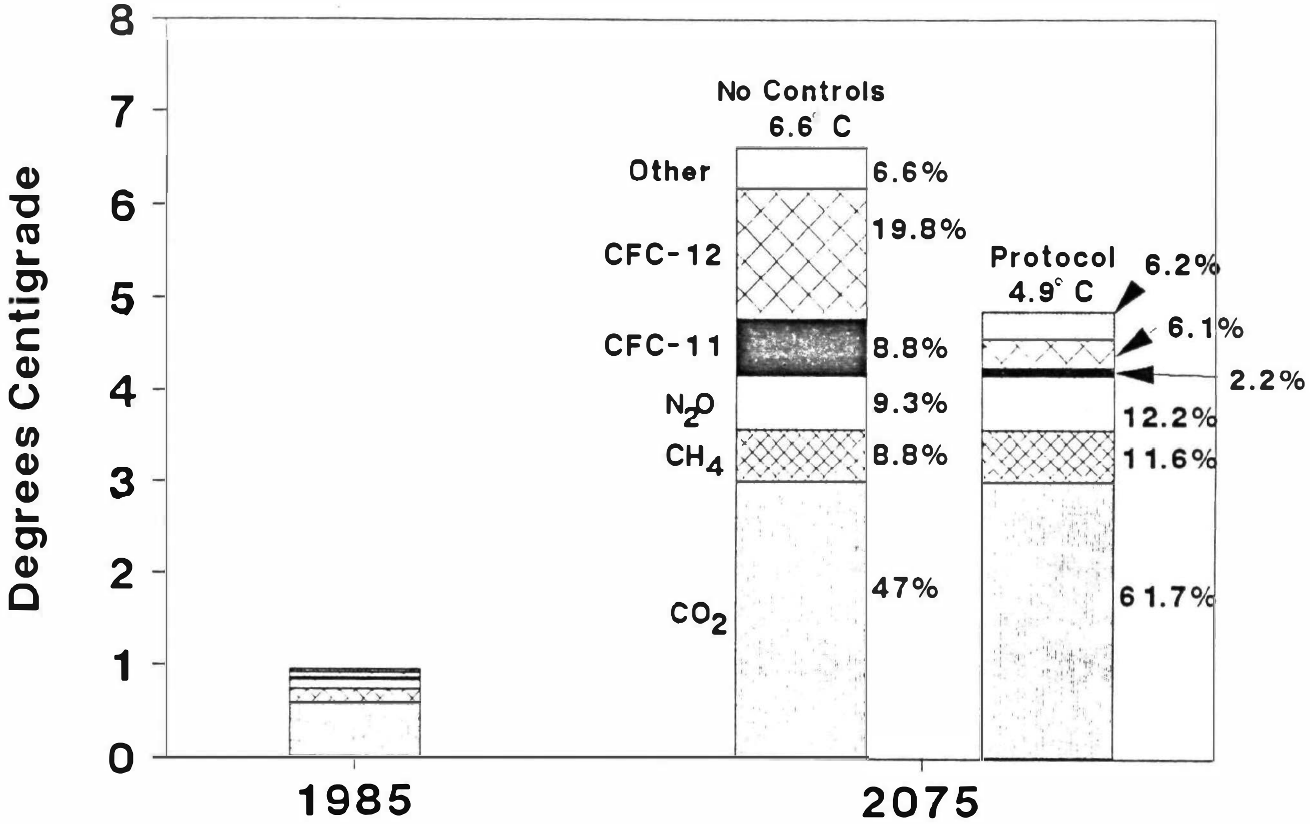
[3] The other controlled compounds (CFC-113, CFC-114, CFC-115, and Halon 1211) are not included in the global warming calculation.

EXHIBIT 6-8

GLOBAL WARMING CONTRIBUTIONS OF VARIOUS GASES FOR THE NO CONTROLS AND CFC 50%/HALON FREEZE CASE: 2075 a/



Note: a/ Equilibrium global warming relative to 1985, computed by modified GISS parameterized radiative-convective model. No controls case assumes CFC growth of 2.7%/yr; protocol case simulates 50% phased reduction with 94% participation by developed nations and 65% by developing nations. Both scenarios assume CO2 concentrations increase at 0.7%/yr; N2O concentrations at 0.2%/yr; and CH4 concentrations at 17 ppb/yr. Assumes temperature sensitivity of 3° for doubled CO2.

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CHAPTER 7

ESTIMATES OF PHYSICAL HEALTH AND ENVIRONMENTAL EFFECTS

This chapter discusses the types of physical effects that can occur due to stratospheric ozone depletion. These physical effects are divided into health and environmental (non-health) impacts. The analysis of each physical effect begins with a brief description of the physical effect, followed by a summary of the scientific evidence indicating the potential severity of the problem. Estimates of the physical magnitude of the effects are presented for the baseline (i.e., no controls) case and the alternative cases. These scenarios are described in detail in Chapter 4 (for the baseline) and Chapter 5 (for the alternative control level scenarios).

This chapter is only intended to provide an overview of the health and non-health impacts that could result from stratospheric ozone depletion. For greater detail, see EPA's risk assessment (EPA 1987) and Appendix E for more information on the health impacts and Appendix F for more detail on the environmental impacts.

7.1 HEALTH IMPACTS

This section of the chapter discusses the potential health impacts from stratospheric ozone depletion. These impacts include:

- Nonmelanoma skin cancer, specifically basal and squamous cell carcinoma;
- Cutaneous malignant melanoma;
- Cataracts; and
- Changes to the immune system.

Actinic keratosis, the most common form of UV-B-induced skin damage, is not considered in this chapter (see Appendix E for further discussion).

7.1.1 Nonmelanoma Skin Cancer

As a result of ozone depletion, the amount of potentially-damaging UV radiation reaching the earth's surface is likely to increase. The cumulative increase in lifetime exposure to UV radiation that individuals would experience could increase the incidence of nonmelanoma cancers, specifically basal and squamous cell carcinoma.

To estimate changes in the incidence of nonmelanoma skin cancer as a function of the changes in exposure, the following equation has been used:

$$\text{Fractional change in incidence} = (\text{Fractional change in exposure}+1)^{b} - 1.$$

where the fractional change in exposure is defined as the change in UV flux reaching the earth's surface and "b" is the dose-response coefficient. This dose-response coefficient is often referred to as the "biological amplification factor" or BAF; it equals the percent change in incidence associated with a one percent change in exposure. The estimates of the BAF used in this analysis are taken from EPA's risk assessment (1987), and are summarized in Exhibit 7-1 for white males and females (non-whites are assumed not to be affected).

The number of additional nonmelanoma cases that would result from the dose-response coefficients shown in Exhibit 7-1 is a function of the size of the U.S. population exposed to the higher UV levels. This population is described in terms of (1) the total population over time, specifically (a) all people born by 2075 as defined by three cohorts -- people alive today, people born from 1986-2029, and people born from 2030-2074, and (b) all people born through 2165; (2) the fraction of the total population that resides in each of three regions within the U.S. (the regions vary by latitude); and (3) the fraction of the population in each region that is white, non-white, male, female, and in each of nine age groups. Exhibit 7-2 shows the additional number of nonmelanoma cases that occur in people born by 2075 in the No Controls case and the alternative scenarios by type of nonmelanoma. In Exhibit 7-3 the number of nonmelanoma cases that occur in people born by 2075 is shown for each of the three population cohorts; this exhibit indicates that the vast majority of cases occur in people not yet born. Exhibit 7-4 shows the additional number of nonmelanoma cases that occur in all people by 2165.

The increase in incidence in nonmelanoma skin cancer is expected to cause an increase in mortality as well. Based on the information available on mortality rates (one percent of all cases), basal cases resulting in death have been assigned a fraction of 0.0031, and the squamous cases resulting in death have been assigned a fraction of approximately 0.0375. These fractions have been multiplied in Exhibit 7-5 by the estimated additional cases of nonmelanoma skin cancer in Exhibit 7-2 to determine additional mortality due to nonmelanoma skin cancer for people born before 2075. Exhibit 7-6 shows the additional mortality among people born before 2075 by the three population cohorts; most of the additional deaths occur in later generations. Exhibit 7-7 shows the total increase in mortality from nonmelanoma by 2165 (including people born from 2075-2165).

7.1.2 Cutaneous Malignant Melanoma

The increase in UV radiation from ozone depletion can also cause an increase in the incidence and mortality of melanoma skin cancer. The dose/response equation used for melanoma is similar in form to the equation used for nonmelanoma:

$$\text{Fractional change in incidence} = (\text{Fractional change in exposure} + 1)^{b} - 1$$

where the fractional change in exposure is defined as the change in UV flux reaching the earth's surface and "b" is the dose-response coefficient. This dose-response coefficient is often referred to as the "biological amplification factor" or BAF; it equals the percent change in incidence associated with a one percent change in exposure. The estimates of the BAF used in this analysis are taken from EPA's risk assessment (1987), and are summarized in Exhibit 7-8 for whites by location on the body (non-whites are assumed not to be affected).

EXHIBIT 7-1

DOSE-RESPONSE COEFFICIENTS: NONMELANOMA SKIN CANCER
(Whites Only)

	DNA-Damage Action Spectrum			Erythema Action Spectrum		
	Low [a]	Middle	High [b]	Low [a]	Middle	High [b]
Squamous						
Male	1.42	2.03	2.64	1.54	2.21	2.88
Female	1.47	2.22	2.98	1.57	2.42	3.26
Basal						
Male	0.932	1.29	1.65	1.02	1.41	1.80
Female	0.316	0.739	1.16	0.346	0.809	1.27

a/ Middle minus one standard error.

b/ Middle plus one standard error.

Source: EPA (1987).

EXHIBIT 7-2

ADDITIONAL CASES OF NONMELANOMA SKIN CANCER IN THE U.S. FOR PEOPLE BORN BY 2075 BY TYPE OF NONMELANOMA[a/]
(Whites Only)

Scenario	Ozone Depletion by 2075 (%)	Basal	Squamous	Total
No Controls	50.0[b/]	91,465,100	86,533,000	177,998,100
Freeze	6.8	10,683,900	6,656,900	17,340,800
CFC 20%	5.5	8,488,000	5,215,400	13,703,400
CFC 50%	3.9	5,968,700	3,603,600	9,575,000
CFC 80%	2.7	4,147,900	2,470,900	6,618,800
CFC 50%/Halon Freeze	1.9	3,220,600	1,883,300	5,103,900
CFC 50%/Halon Freeze/U.S. 80%	1.6	2,785,900	1,618,600	4,404,500
U.S. Only/CFC 50%/ Halon Freeze	27.1	65,005,300	58,031,300	123,036,600

a/ Skin cancer is already a serious problem; in the absence of any ozone depletion, 122.9 million cases of basal cancers would occur and 37.0 million cases of squamous cancers would occur among people born before 2075.

b/ Global ozone depletion is arbitrarily constrained at 50 percent in this analysis.

EXHIBIT 7-3

ADDITIONAL CASES OF NONMELANOMA SKIN CANCER BY COHORT
(Whites only)

Scenarios	People Alive Today	People Born 1986-2029	People Born 2029-2074	Total
No Controls	3,513,900	42,457,800	132,026,400	177,998,100
CFC Freeze	1,508,100	5,756,800	10,075,900	17,340,800
CFC 20%	1,294,700	4,649,900	7,758,800	13,703,400
CFC 50%	1,050,500	3,360,800	5,163,700	9,575,000
CFC 80%	886,900	2,425,200	3,306,700	6,618,800
CFC 50%/Halon Freeze	937,700	2,237,100	1,929,100	5,103,900
CFC 50%/Halon Freeze U.S. 80%	899,200	2,015,700	1,489,600	4,404,500
U.S. Only/CFC 50%/ Halon Freeze	2,412,300	23,493,700	97,130,600	123,036,600

EXHIBIT 7-4

**ADDITIONAL CASES OF NONMELANOMA SKIN CANCER IN U.S.
BY 2165 BY TYPE OF NONMELANOMA
(Whites Only)**

Scenario	Basal	Squamous	Total
No Control	129,763,400	119,790,400	249,553,800
Freeze	14,041,100	8,402,000	22,443,100
CFC 20%	10,988,200	6,491,200	17,479,400
CFC 50%	7,518,100	4,380,700	11,898,800
CFC 80%	5,015,200	2,898,100	7,913,300
CFC 50%/Halon Freeze	3,410,500	1,975,500	5,386,000
CFC 50%/Halon Freeze/ U.S. 80%	2,815,700	1,633,200	4,448,900
U.S. Only/ CFC 50%/ Halon Freeze	101,814,700	89,391,600	191,206,300

EXHIBIT 7-5

ADDITIONAL MORTALITY FROM NONMELANOMA SKIN CANCER IN U.S. AMONG PEOPLE BORN BEFORE 2075 BY TYPE OF NONMELANOMA[a/]
(Whites Only)

Scenario	Ozone Depletion by 2075 (%)	Basal	Squamous	Total
No Controls	50.0[b/]	283,600	3,245,100	3,528,700
Freeze	6.8	33,200	249,600	282,800
CFC 20%	5.5	26,300	195,600	221,900
CFC 50%	3.9	18,500	135,200	153,700
CFC 80%	2.7	12,900	92,600	105,500
CFC 50%/Halon Freeze	1.9	10,000	70,600	80,600
CFC 50%/Halon Freeze/U.S. 80%	1.6	8,600	60,500	69,300
U.S. Only/CFC 50%/Halon Freeze	27.1	201,500	2,176,200	2,377,700

a/ Nonmelanoma skin cancer deaths among people born before 2075 assuming no ozone depletion is estimated at 1.77 million.

b/ Global ozone depletion is arbitrarily constrained at 50 percent in this analysis.

EXHIBIT 7-6

ADDITIONAL MORTALITY FROM NONMELANOMA SKIN CANCER BY COHORT
(Whites only)

Scenarios	People Alive Today	People Born 1986-2029	People Born 2029-2074	Total
No Controls	60,000	798,100	2,670,600	3,528,700
CFC Freeze	24,800	93,700	164,200	282,800
CFC 20%	21,200	75,400	125,300	221,900
CFC 50%	17,100	54,100	82,500	153,700
CFC 80%	14,300	38,800	52,400	105,500
CFC 50%/Halon Freeze	15,200	35,500	29,900	80,600
CFC 50%/Halon Freeze/ U.S. 80%	14,500	31,800	23,000	69,300
U.S. Only/CFC 50%/ Halon Freeze	40,400	423,800	1,913,500	2,377,700

EXHIBIT 7-7

ADDITIONAL MORTALITY FROM NONMELANOMA SKIN CANCER IN U.S. BY 2165 BY TYPE OF NONMELANOMA (Whites Only)

Scenario	Basal	Squamous	Total
No Control	402,300	4,492,100	4,894,400
Freeze	43,500	315,100	358,600
CFC 20%	34,100	243,400	277,500
CFC 50%	23,300	164,300	187,600
CFC 80%	15,500	108,700	124,200
CFC 50%/Halon Freeze	10,600	74,100	84,700
CFC 50%/Halon Freeze/ U.S. 80%	8,700	61,200	69,900
U.S. Only/ CFC 50%/ Halon Freeze	315,600	3,352,200	3,667,800

EXHIBIT 7-8

DOSE-RESPONSE COEFFICIENTS:
MELANOMA SKIN CANCER INCIDENCE
(Whites Only)

	Low a/	Middle	High b/
Face, Head and Neck			
Male	0.398	0.512	0.624
Female	0.477	0.611	0.744
Trunk and Lower Extremities			
Male	0.200	0.310	0.420
Female	0.268	0.412	0.553

a/ Middle minus one standard error.

b/ Middle plus one standard error.

Source: Derived from: Scotto and Fears, "The Association of Solar Ultraviolet and Skin Melanoma Incidence Among Caucasians in the United States," Cancer Investigation, (1987).

The number of additional cases of melanoma resulting from the dose-response relationships in Exhibit 7-8 can be determined by applying these dose-response coefficients to the population estimates discussed above for a specified increase in UV radiation. The results of this procedure lead to the additional melanoma cases listed in Exhibit 7-9 for people born before 2075 for the baseline and alternative control level scenarios. The additional melanoma cases for people born before 2075 are shown in Exhibit 7-10 by the three population cohorts; the large majority of cases occur in later generations. Exhibit 7-11 summarizes the additional melanoma cases that occur by 2165 (including people born from 2075-2165).

The increase in incidence of melanoma is also expected to lead to an increase in mortality. The extent to which mortality will increase has been calculated from estimates developed by Pitcher (1986). These dose-response coefficients are summarized in Exhibit 7-12; the number of additional deaths resulting from melanoma among people born before 2075 are summarized in Exhibit 7-13 for the baseline and alternative control level scenarios. The number of additional deaths from melanoma are summarized in Exhibit 7-14 for the three population cohorts; this exhibit indicates that most deaths from melanoma will occur in people not yet born. Exhibit 7-15 summarizes the number of additional deaths that occur by 2165 among the U.S. population (including people born from 2075-2165).

7.1.3 Cataracts

Several epidemiological studies have identified a correlation between the prevalence of various types of cataracts in humans and the flux of sunlight or ultraviolet radiation reaching the earth's surface. Hiller, Sperduto, and Ederer (1983) developed a multivariate logistic risk function that describes the correlation found between the prevalence of senile cataracts and the flux of UV-B and other risk factors. Based on the Hiller study, the change in the prevalence of cataract for each 1.0 percent change in UV-B is estimated to be approximately 0.5 percent. This estimated relationship between UV-B and cataract prevalence varies with age, as shown in Exhibit 7-16. This exhibit displays the expected percent increase in cataract prevalence due to increases in UV-B for persons of different ages.

To evaluate the impact of ozone depletion on cataract incidence, a model developed from the Hiller (1983) study was used to relate increases in prevalence to changes in lifetime UV radiation exposure. The dose-response coefficients resulting from this approach are provided in Exhibit 7-17. These values were then used to estimate the increase in cataract incidence for the baseline and alternative control level scenarios. These estimates are provided in Exhibit 7-18 for people born before 2075. Exhibit 7-19 summarizes the increase in cataract incidence among people born before 2075 by each of the three population cohorts; this exhibit indicates that the majority of cases will occur in people not yet born. Exhibit 7-20 indicates all cataract cases that occur by 2165 (including cases that occur in people born from 2075-2165).

EXHIBIT 7-9

ADDITIONAL CASES OF MELANOMA SKIN CANCER IN U.S. FOR PEOPLE BORN BEFORE 2075[a/] (Whites Only)

Scenarios	Ozone Depletion by 2075 (%)	Total Cases
No Controls	50.0[b/]	893,300
Freeze	6.8	139,700
CFC 20%	5.5	112,400
CFC 50%	3.9	80,400
CFC 80%	2.7	56,900
CFC 50%/Halon Freeze	1.9	45,900
CFC 50%/Halon Freeze/U.S.	1.6	40,200
U.S. Only/CFC 50%/ Halon Freeze	27.1	647,400

a/ Melanoma is already a serious problem in the U.S.; in the absence of ozone depletion 4.2 million cases would be expected for people born before 2075.

b/ Global ozone depletion is arbitrarily constrained at 50 percent in this analysis.

EXHIBIT 7-10

ADDITIONAL CASES OF MELANOMA SKIN CANCER BY COHORT
(Whites only)

Scenarios	People Alive Today	People Born 1986-2029	People Born 2029-2074	Total
No Controls	21,800	222,200	649,300	893,300
CFC Freeze	10,400	45,300	84,000	139,700
CFC 20%	9,100	37,200	66,100	112,400
CFC 50%	7,500	27,500	45,400	80,400
CFC 80%	6,500	20,400	30,000	56,900
CFC 50%/Halon Freeze	6,900	19,700	19,300	45,900
CFC 50%/Halon Freeze/ U.S. 80%	6,600	18,000	15,600	40,200
U.S. Only/CFC 50%/ Halon Freeze	15,700	136,900	494,800	647,400

EXHIBIT 7-11

ADDITIONAL CASES OF MELANOMA SKIN CANCER BY 2165 IN U.S.
(Whites Only)

Scenarios	Total
No Controls	1,442,700
Freeze	207,500
CFC 20%	163,500
CFC 50%	112,600
CFC 80%	75,200
CFC 50%/Halon Freeze	50,000
CFC 50%/Halon Freeze/U.S. 80%	40,900
U.S. Only/CFC 50%/Halon Freeze	1,181,900

EXHIBIT 7-12

DOSE-RESPONSE COEFFICIENTS:
MELANOMA SKIN CANCER MORTALITY
(Whites Only)

	DNA-Damage Action Spectrum			Erythema Action Spectrum		
	Low a/	Middle	High b/	Low a/	Middle	High b/
Male	0.39	0.42	0.46	0.42	0.46	0.50
Female	0.25	0.29	0.33	0.28	0.32	0.36

a/ Middle estimate minus one standard error.

b/ Middle estimate plus one standard error.

Source: Pitcher, H.M., "Examination of the Empirical Relationship Between Melanoma Death Rates in the United States 1950-1979 and Satellite-Based Estimates of Exposure to Ultraviolet Radiation." U.S. EPA, Washington, D.C., March 17, 1987, draft.

EXHIBIT 7-13

ADDITIONAL MORTALITY FROM MELANOMA SKIN CANCER IN U.S. AMONG PEOPLE BORN BEFORE 2075[a/]
(Whites Only)

Scenarios	Ozone Depletion by 2075 (%)	Total
No Controls	50.0[b/]	211,300
Freeze	6.8	33,600
CFC 20%	5.5	27,000
CFC 50%	3.9	19,300
CFC 80%	2.7	13,500
CFC 50%/Halon Freeze	1.9	10,800
CFC 50%/Halon Freeze/U.S. 80%	1.6	9,300
U.S. Only/CFC 50%/Halon Freeze	27.4	156,900

a/ In the absence of ozone depletion, melanoma mortality would be expected to be 1.2 million for people born before 2075.

b/ Global ozone depletion is arbitrarily constrained at 50 percent in this analysis.

EXHIBIT 7-14

ADDITIONAL MORTALITY FROM MELANOMA SKIN CANCER BY COHORT (Whites only)

Scenarios	People Alive Today	People Born 1986-2029	People Born 2029-2074	Total
No Controls	6,000	57,600	147,700	211,300
CFC Freeze	2,800	11,100	19,700	33,600
CFC 20%	2,400	9,100	15,500	27,000
CFC 50%	2,000	6,700	10,600	19,300
CFC 80%	1,700	4,900	6,900	13,500
CFC 50%/Halon Freeze	1,800	4,700	4,300	10,800
CFC 50%/Halon Freeze/ U.S. 80%	1,700	4,200	3,400	9,300
U.S. Only/CFC 50%/ Halon Freeze	4,300	35,700	116,900	156,900

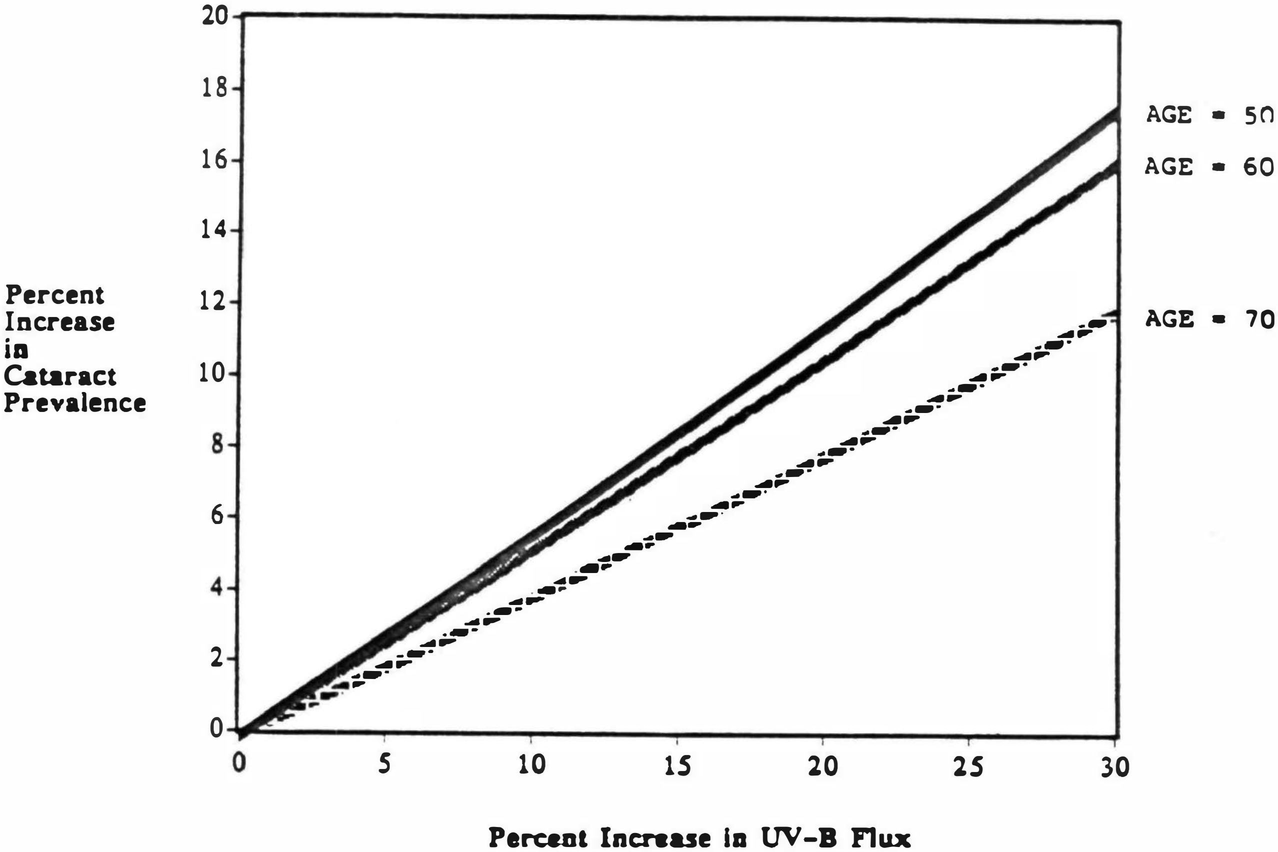
EXHIBIT 7-15

ADDITIONAL MORTALITY FROM MELANOMA SKIN CANCER IN U.S. BY 2165 (Whites Only)

Scenarios	Total
No Controls	310,000
Freeze	46,300
CFC 20%	36,600
CFC 50%	25,300
CFC 80%	17,000
CFC 50%/Halon Freeze	11,500
CFC 50%/Halon Freeze/U.S. 80%	9,500
U.S. Only/CFC 50%/Halon Freeze	252,900

EXHIBIT 7-16

ESTIMATED RELATIONSHIP BETWEEN RISK OF CATARACT AND UV-B FLUX



Increased UV-B flux (measured with an RB-meter) is associated with increased prevalence of cataract. The percent change in prevalence varies by age.

Source: Developed from data presented in R. Hiller, R. Sperduto, and F. Ederer, "Epidemiologic Associations with Cataract in the 1971-1972 National Health and Nutrition Examination Survey," American Journal of Epidemiology, Vol. 118, No. 2, pp. 239-249, 1983.

EXHIBIT 7-17

DOSE-RESPONSE COEFFICIENTS -- CATARACTS

Low a/	Middle	High b/
0.127	0.225	0.296

a/ Middle minus one standard error.

b/ Middle plus one standard error.

Source: Derived from data presented in: Hiller, Sperduto, and Ederer, "Epidemiologic Associations with Cataract in 1971-1972 National Health and Nutrition Examination Survey," American Journal of Epidemiology, Vol. 118, No. 2, pp. 239-249, 1983.

EXHIBIT 7-18

ADDITIONAL CATARACT CASES IN U.S. AMONG PEOPLE BORN BEFORE 2075[a]

Scenarios	Ozone Depletion by 2075 (%)	Total Cases
No Controls	50.0[b]	19,962,800
Freeze	6.8	3,178,000
CFC 20%	5.5	2,531,200
CFC 50%	3.9	1,774,100
CFC 80%	2.7	1,214,300
CFC 50%/Halon Freeze	1.9	876,100
CFC 50%/Halon Freeze/U.S. 80%	1.6	740,600
U.S. Only/CFC 50%/Halon Freeze	27.1	15,824,100

a/ Cataracts are already a serious problem in the U.S.; in the absence of ozone depletion 182 million cases would be expected for people born before 2075.

b/ Global ozone depletion is arbitrarily constrained at 50 percent in this analysis.

EXHIBIT 7-19

ADDITIONAL CATARACT CASES AMONG PEOPLE BORN BEFORE 2075 BY COHORT

Scenarios	People Alive Today	People Born 1986-2029	People Born 2029-2074	Total
No Controls	1,023,100	7,084,900	11,854,800	19,962,800
CFC Freeze	398,700	1,141,400	1,637,900	3,178,000
CFC 20%	338,800	922,100	1,270,300	2,531,200
CFC 50%	268,100	662,200	843,800	1,774,100
CFC 80%	218,600	468,300	527,400	1,214,300
CFC 50%/Halon Freeze	231,200	398,100	246,800	876,100
CFC 50%/Halon Freeze U.S. 80%	219,600	335,100	170,000	740,600
U.S. Only/CFC 50%/ Halon Freeze	686,200	4,670,300	10,467,600	15,824,100

EXHIBIT 7-20

ADDITIONAL CATARACT CASES IN U.S. BY 2165

Scenarios	Total Cases
No Controls	25,131,600
Freeze	3,888,500
CFC 20%	3,060,400
CFC 50%	2,097,600
CFC 80%	1,383,100
CFC 50%/Halon Freeze	888,800
CFC 50%/Halon Freeze/U.S. 80%	742,000
U.S. Only/CFC 50%/Halon Freeze	21,023,700

7.1.4 Changes to the Immune System

The increases in solar radiation brought about by depletion of the ozone layer could have a detrimental effect on the immune system of both humans and animals. In particular, UV radiation reduces the ability of the immune system to respond adequately to antigens. This UV radiation-induced immunosuppression can reduce the host's ability to fight the development of tumors. It can also affect the host's ability to respond to infectious diseases that enter through the skin, possibly including such diseases as the parasite Leishmania sp. and the Herpes simplex virus.

Although there are no experimental data that have specifically documented the precise nature of UV radiation-induced immunosuppression, based on research to date a number of hypotheses seem reasonable: (1) All populations, black and white, may be at risk; (2) Individuals who are already immunosuppressed, such as transplant patients, could be at greater risk than the rest of the population due to additive effects; and (3) In developing countries, particularly those exposed to higher UV-B levels near the Equator, parasitic infections of the skin could be exacerbated.

Insufficient information exists to estimate the effects of UV radiation on human immune systems. Although the extent of immunosuppression cannot be quantified, some evidence suggests that immunosuppression could be induced with much lower doses of UV radiation than those required for carcinogenesis. This may mean that exposure to low doses of UV radiation, even doses that do not cause a sunburn, may decrease the ability of the human immune system to provide an effective defense against neoplastic skin cells or skin infections.

7.2 ENVIRONMENTAL IMPACTS

This section of the chapter discusses the environmental (non-health) impacts that could occur due to stratospheric ozone depletion. These impacts include:

- Risks to marine organisms;
- Risks to crops;
- Increased concentrations of tropospheric (ground-based) ozone;
- Degradation of polymers; and
- Impacts due to sea level rise.

7.2.1 Risks to Marine Organisms

The increased levels of ultraviolet radiation that result from stratospheric ozone depletion pose a hazard to various marine organisms. Higher UV radiation levels have been shown to cause decreases in fecundity, growth, survival, and other functions in a variety of marine organisms, including fish larvae and juveniles, shrimp larvae, crab larvae, copepods, and plants essential to the aquatic food chain (EPA, 1987). These impacts occur mainly in organisms located near the surface of the water since they tend to be most directly exposed to the increased UV radiation levels. Although it has also been hypothesized that these effects would likely cause a change in species composition as organisms more resistant to the increase in UV radiation predominated, it is not known what the long-term effects of these impacts on the ecosystem might be.

The extent to which increased UV radiation levels may affect aquatic organisms depends on several variables, including the degree to which UV radiation penetrates the water, the amount of vertical mixing that occurs, and the seasonal abundance and vertical distributions of the organisms. UV-B penetration has been measured to depths of more than twenty feet in clear waters and more than five feet in unclear water. However, the scientific evidence currently available is generally insufficient to allow estimates to be made of the amount of damage to expect in the natural environment for a given increase in UV radiation.

In one study by Hunter, Kaupp, and Taylor (1982), analyses were conducted on anchovy larvae to estimate the potential effects of increased UV radiation on anchovy populations. The anchovy losses were estimated for three different models of mixing within the surface waters of the ocean -- static, mixing within the top ten meters, and mixing within the top fifteen meters. The results of this study are summarized in Exhibit 7-21.

To develop a rough estimate of the effects on aquatic organisms likely to result due to increases in UV radiation, the dose-response relationship estimated by Hunter, et. al. (1982) for anchovy larvae with vertical mixing occurring within the top ten meters has been assumed to apply to the adult anchovy population in the natural environment. This dose-response relationship is used as a measure of potential impacts on all major commercial aquatic organisms in the natural environment because it is the most reliable quantitative information available on the magnitude of these impacts.

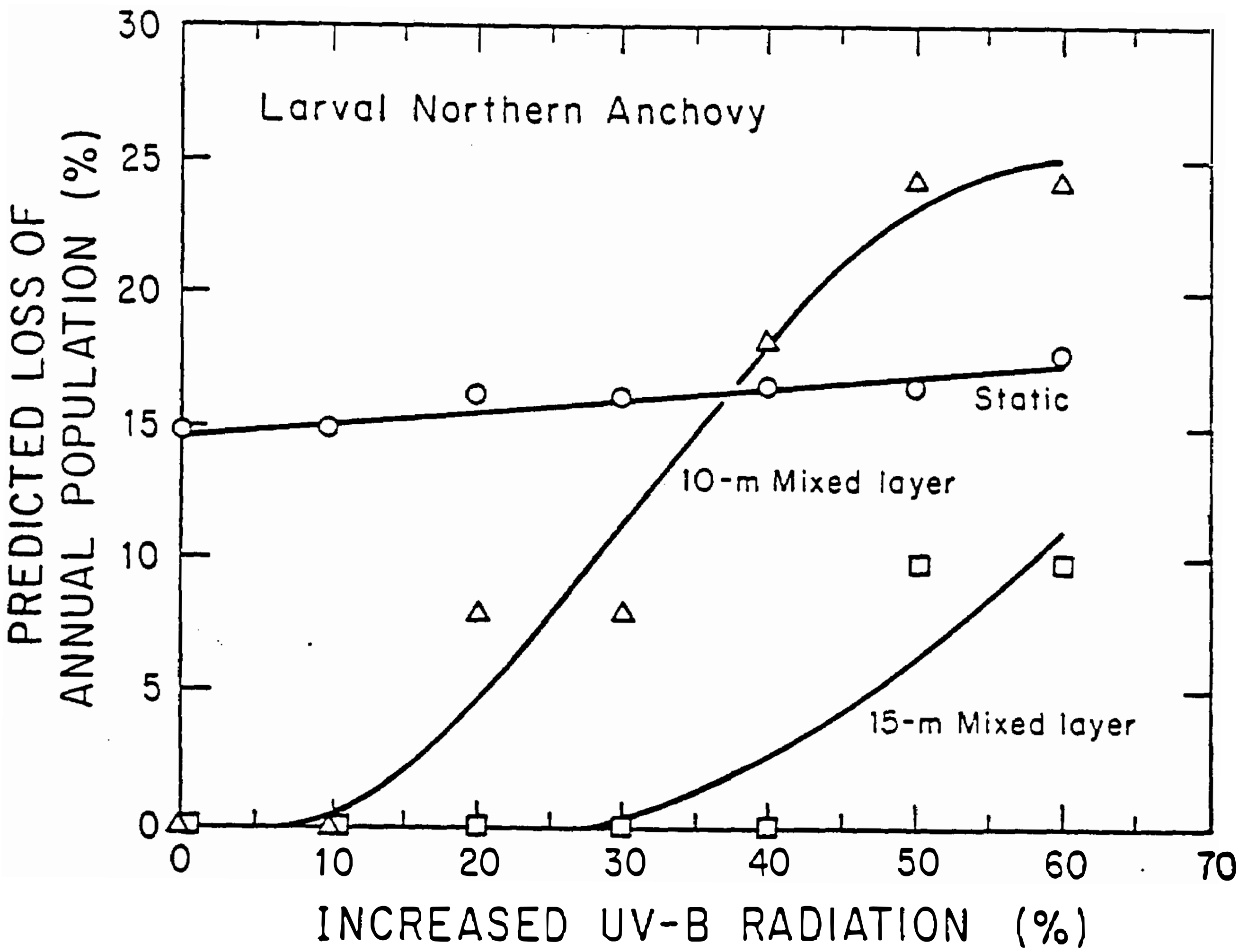
Increased UV radiation levels were assumed to affect harvest levels for the major commercial fish species, including fin fish and shell fish. Average harvest levels for the 1981-1985 period were used to represent average annual harvest levels through 2075 for these species. Then, the physical impacts on these commercial fishes were estimated by using the dose-response relationship for anchovy larvae indicated in Exhibit 7-21 for mixing within the top ten meters of the ocean to represent the decrease in harvest levels that would occur due to increased UV radiation. (This relationship, of course, is very uncertain and in reality, ozone depletion could result in greater or smaller losses.) These physical effects are summarized in Exhibit 7-22 for the baseline and alternative scenarios. For each scenario, the estimated increase in UV radiation by 2075 is shown, along with the decline in fish populations estimated to occur due to the indicated UV radiation increase. Clearly, this approach to damage estimation is highly extrapolative. Actual impacts will be species specific and could be greater or lower.

7.2.2 Risks to Crops

The increases in ultraviolet radiation that would occur due to stratospheric ozone depletion have the potential to affect agricultural crops and other

EXHIBIT 7-21

Effect of Increased Levels of Solar UV-B Radiation on the Predicted Loss of Larval Northern Anchovy from Annual Populations, Considering the Dose/Dose-Rate Threshold and Three Vertical Mixing Models



Based on data of Hunter, Kaupp, and Taylor 1982.

EXHIBIT 7-22

DECLINE IN COMMERCIAL FISH HARVESTS DUE TO INCREASED UV RADIATION

Scenario	UV Radiation Increase by 2075 (%)	Harvest Decrease by 2075 (%) [a]
No Controls	156.7[b]	>25.0
Freeze	15.1	2.5
CFC 20%	11.9	0.9
CFC 50%	8.2	0.0
CFC 80%	5.8	0.0
CFC 50%/Halon Freeze	4.0	0.0
CFC 50%/Halon Freeze/U.S. 80%	3.5	0.0
U.S. Only/CFC 50%/Halon Freeze	82.8[b]	>25.0

a/ These estimates are very uncertain; actual changes could be significantly higher or lower.

b/ UV radiation increases above 60 percent were assumed not to have any additional effects on harvest levels; this assumption was made to avoid extrapolating beyond the range analyzed by Hunter, Kaupp, and Taylor (1982).

Source: Based on Hunter, Kaupp, and Taylor (1982).

terrestrial ecosystems. For example, in a number of studies on a variety of different crops (and different varieties of the same crop), UV-B radiation has been shown to adversely affect crop yield and quality. In most instances, the available information does not indicate the extent to which crops may be affected; that is, the studies that have been conducted provide some qualitative indication of the adverse impacts that could occur, but insufficient data are available to develop crop-specific quantitative dose-response relationships required to estimate the amount of damage that may occur.

To develop estimates of the amount of damage that may occur, studies by Teramura on soybean cultivars, which are the most extensively studied crop, have been used.[1] Teramura's studies have been conducted for a period of several years under field conditions that allow for determination of a dose-response relationship between UV-B radiation and soybean yield. Teramura has analyzed the potential impacts for stratospheric ozone depletion estimates of up to 25 percent. Although there has been some variation in results, the general relationship considering a sample of tolerant and sensitive cultivars has been a 0.3 percent decline in soybean yield for each one percent decrease in stratospheric ozone. Since Teramura has only examined the possible relationship for ozone depletion estimates up to 25 percent, the maximum decline in soybean yield is limited to 7.5 percent to avoid extrapolating outside the range of the analyses.

To determine the magnitude of UV impacts on agricultural crops, average production levels from 1980 to 1983 for the major agricultural crops in the U.S. were used to represent annual crop production levels through 2075. Then, using the dose-response relationship developed from Teramura's work for soybeans as a reasonable estimate for UV impacts on the major agricultural crops, declines in crop production levels were estimated from the average 1980-83 production levels. The estimates of the crop production declines are presented for the baseline and alternative scenarios in Exhibit 7-23. The amount of the yield decrease is shown for 2075, along with the amount of stratospheric ozone depletion estimated by that date. Clearly, this approach to damage estimation is highly extrapolative; actual impacts will be crop-specific and could be significantly greater or lower.

7.2.3 Impacts Due To Tropospheric Ozone

Tropospheric (ground-based) ozone, commonly known as smog, is an air pollutant formed near the earth's surface as a result of photochemical reactions involving ultraviolet radiation, hydrocarbons, nitrogen oxides, oxygen, and sunlight. Because ultraviolet radiation is one of the factors that can affect the development of tropospheric ozone, depletion of stratospheric ozone, which leads to increased UV radiation, can cause increases in the amount of tropospheric ozone.

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[1] For example, see Teramura, A.H. and N.S. Murali, "Intraspecific Differences in Growth and Yield of Soybean Exposed to Ultraviolet-B Radiation Under Greenhouse and Field Conditions," in Env. Exp. Bot., in press, 1986.

EXHIBIT 7-23

DECLINE IN U.S. AGRICULTURAL CROP PRODUCTION LEVELS DUE TO OZONE DEPLETION

Scenario	Ozone Depletion by 2075 (%)	Decline in Production Levels by 2075 (%) a/
No Controls	50.0 b/	>7.50
Freeze	6.8	2.1
CFC 20%	5.5	1.7
CFC 50%	3.9	1.2
CFC 80%	2.7	0.8
CFC 50%/Halon Freeze	1.9	0.6
CFC 50%/Halon Freeze/U.S. 80%	1.6	0.5
U.S. Only/CFC 50%/Halon Freeze	27.1	7.5

a/ These estimates are highly uncertain; actual impacts could be significantly higher or lower.

b/ Global ozone depletion is arbitrarily constrained at 50 percent in this analysis.

Source: Based on Teramura (1987).

The extent to which increased UV radiation levels may increase the concentration of tropospheric ozone has been examined by Whitten (1986). In this analysis, the potential relationship between UV radiation and smog levels were estimated from studies conducted in three cities--Nashville, Tennessee; Philadelphia, Pennsylvania; and Los Angeles, California. These three cities were chosen to represent the variability in atmospheric conditions that could be encountered in the U.S.--Nashville is nearly in compliance with the 0.12 ppm Federal ozone standard; Philadelphia is moderately out of compliance (a 30-50 percent reduction in organic precursors would be required to come into compliance); and Los Angeles has one of the most severe smog problems in the U.S. The increase in tropospheric ozone for each one percent increase in UV radiation is based on the average results from these three areas.[2] Exhibit 7-24 indicates the percentage change in tropospheric ozone levels by 2075 for the baseline and alternative scenarios, along with the estimated increase in UV radiation.

At high concentrations, tropospheric ozone has been shown to adversely affect human health, agricultural crops, forests, and materials:

- The human health impacts include alterations in pulmonary function, respiratory and non-respiratory symptoms (such as chest tightness, throat dryness, difficulty in deep breathing, coughing, wheezing, etc.), effects on work performance, aggravation of preexisting respiratory diseases, morphological effects (such as lung damage), alterations in the host defense system (e.g., increased susceptibility to respiratory infection), and extrapulmonary effects (such as effects on the liver, central nervous system, blood enzymes, etc.).

- Agricultural crops and forests experience reduced growth and declines in yield.

- Materials degrade more quickly, particularly elastomers, textile fibers and dyes, and certain types of paints.

In this chapter, however, only the potential impacts on agricultural crops are quantified since insufficient information exists to quantify the impacts on human health, forests, and materials. That is, the available evidence on the last three areas indicates that damage does occur, but the state of the research is too limited to define specific dose-response relationships for different levels of tropospheric ozone. Nevertheless, these impacts are not inconsequential. In fact, the primary National Ambient Air Quality Standard (NAAQS) for ozone is determined based on human health considerations; the importance of these unquantifiable impacts should not be underestimated.

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[2] The dose-response relationship between UV radiation and tropospheric ozone levels may be linear or non-linear depending on the interplay between several factors, including local conditions, temperature, etc.

EXHIBIT 7-24

INCREASES IN TROPOSPHERIC OZONE DUE TO STRATOSPHERIC OZONE DEPLETION

Scenario	Increase in UV Radiation by 2075 (%)	Increase in Tropospheric Ozone by 2075 (%) a/
No Controls	156.7	>30.9
Freeze	15.1	5.7
CFC 20%	11.9	4.6
CFC 50%	8.2	3.2
CFC 80%	5.8	2.3
CFC 50%/Halon Freeze	4.0	1.6
CFC 50%/Halon Freeze/U.S. 80%	3.5	1.4
U.S. Only/CFC 50%/Halon Freeze	82.8	24.5

a/ These estimates are highly uncertain; actual impacts could be significantly higher or lower.

Source: Based on Whitten (1986).

The impacts on agricultural production due to tropospheric ozone increases were quantified by Rowe and Adams (1987) using the National Crop Loss Assessment Network (NCLAN). NCLAN was developed to assist EPA in the development of alternative NAAQS for ozone and is designed to evaluate the impacts that occur due to changes in tropospheric ozone.

To measure the magnitude of potential changes in agricultural output, Rowe and Adams (1987) used average 1980-83 data on the quantity of agricultural crop production to establish a baseline from which all changes were measured. 980 -- is summarized in Exhibit 7-25. Declines in agricultural output were then estimated on an annual basis; these declines are indicated by state for the major agricultural crops in Exhibit 7-26 for a tropospheric ozone increase of 25 percent. The three cities on which these estimates are based -- Nashville, Philadelphia, and Los Angeles -- do not constitute a representative sample for ground-based ozone levels throughout the U.S.; therefore, actual changes could vary significantly from these estimates.

7.2.4 Degradation of Polymers

Many polymers have a tendency to absorb UV radiation due to various impurities that are present in their formulations. The UV radiation tends to degrade polymers by affecting their mechanical and optical properties, e.g., reductions in tensile strength and impact strength, chalking, cracking, loss of transparency or color, yellowing, etc. Many of these UV radiation impacts currently affect polymeric materials causing manufacturers to take steps, such as the addition of light stabilizers, to reduce the amount of damage that can occur.

The extent to which polymers would require additional protection due to increases in UV radiation depends on the degree of outdoor exposure the polymer receives. However, there is insufficient information on the wide variety of applications for polymers to determine precisely which polymers would require additional protection from UV radiation. In a study by Andrady (1986), major applications where sunlight exposure was expected included polyvinyl chloride (PVC), polyester, polycarbonate, and acrylics, plus several other applications where exposure may occur on an intermittent basis.

To determine the impact of increased UV radiation on polymers, it has been assumed that polymer manufacturers would increase the amount of light stabilizer in the polymer to counteract the effects of the higher UV radiation levels. This alteration in the manufacturing process is assumed to be sufficient to prevent any additional UV-related impacts. (In this analysis, any impacts to polymeric materials currently in use have not been considered; these impacts to in-place products could be substantial.) The amount of increased stabilizer that would be required is a function of the increase in UV radiation due to stratospheric ozone depletion. The relationship between stratospheric ozone depletion and the need for increases in light stabilizers was estimated by Andrady (1986). This relationship is summarized in Exhibit 7-27.

EXHIBIT 7-25

1980 CROP PRODUCTION QUANTITIES USED IN NCLAN a/

Commodity	1980 Prices ($/unit) b/	1980 Quantities (million units)
Cotton	366.72	17.45
Corn	3.25	7,339.85
Soybeans	7.74	1,778.07
Wheat	3.71	2,633.94
Sorghum	3.00	700.88
Rice	12.79	164.78
Barley	2.91	335.50
Oats	1.93	472.91
Silage	19.46	91.24
Hay	70.90	141.58
Soybean Meal	0.11	46,180.80
Soybean Oil	0.24	10,755.81

a/ Average values from 1980-1983 were actually used in this analysis. Documentation for these average values was not publicly available in time for this study, so only 1980 data is shown here.

b/ Units are as follows: 500 pound bales for cotton; bushels for corn, soybeans, wheat, barley, oats, and surghum; hundred weight for rice; tons for hay and silage; pounds for soybean meal and oil.

Source: Adams (1984).

EXHIBIT 7-26

DECLINES IN CROP YIELD ASSUMING A 25 PERCENT INCREASE IN TROPOSPHERIC OZONE

STATE	CORN	SOYBEANS	COTTON	SPRING WHEAT	WINTER WHEAT	GRAIN SORGHUM	BARLEY
ALABAMA	.990	.958	.947	.000	.971	.993	.000
ARIZONA	.977	.000	.840	.974	.957	.967	.996
ARKANSAS	.984	.952	.933	.000	.969	.978	.000
CALIFORNIA	.976	.000	.837	.973	.958	.987	.996
COLORADO	.978	.000	.000	.975	.951	.987	.996
CONNECTICUT	.964	.000	.000	.000	.000	.000	.000
DELAWARE	.994	.954	.000	.000	.964	.000	.999
FLORIDA	.996	.974	.971	.000	.000	.000	.000
GEORGIA	.960	.962	.952	.000	.973	.993	.000
IDAHO	.985	.000	.000	.981	.951	.000	.997
ILLINOIS	.988	.955	.000	.000	.973	.992	.998
INDIANA	.986	945	.000	.000	.979	.990	.000
IOWA	.992	.961	.000	.000	.975	.994	.000
KANSAS	.985	.953	.000	.000	.975	.992	.999
KENTUCKY	.990	.957	.000	.000	.976	.993	.999
LOUISIANA	.989	.944	.939	.000	.973	.992	.000
MAINE	.994	.000	.000	.000	.000	.000	.000
MARYLAND	.986	.951	.000	.000	.973	.000	.998
MASSACHUSETTS	988	.000	.000	.000	.000	.000	.000
MICHIGAN	993	951	.000	.000	.975	.000	.999
MINNESOTA	.994	.963	.000	.991	.975	.000	.999
MISSISSIPPI	.986	.953	.938	.000	.966	.992	.000
MISSOURI	.986	.985	.940	.000	.967	.992	.000
MONTANA	.986	.000	.000	.982	.951	.000	.998
NEBRASKA	.989	.954	.000	.000	.970	.992	.999
NEVADA	.978	.000	.846	.975	.957	.000	.996
NEW HAMPSHIRE	.991	.000	.000	.000	.000	.000	.000
NEW JERSEY	.982	950	.000	.000	.974	.000	.997
NEW MEXICO	.985	.000	.880	.000	.962	.990	.997
NEW YORK	.991	.957	.000	.000	.974	.000	.998
NORTH CAROLINA	.982	.950	.924	.000	.962	.990	.996
NORTH DAKOTA	.994	954	.000	.992	.973	.000	993
OHIO	988	943	.000	.000	.978	.000	998
OKLAHOMA	.988	.956	.973	.000	.985	.992	.998
OREGON	.996	.000	.000	.993	.981	.000	.999
PENNSYLVANIA	.986	.939	.000	.000	.966	.990	.998
RHODE ISLAND	.978	000	.000	.000	.000	.000	.000
SOUTH CAROLINA	.980	.945	.919	.000	.954	.989	.996
SOUTH DAKOTA	.991	.956	.000	.988	.973	.994	.998
TENNESSEE	987	.950	.938	.000	.966	.991	998
TEXAS	.992	966	.978	.000	.978	.993	999
UTAH	.975	000	.000	.972	.940	.000	995
VERMONT	.988	.000	.000	.000	.000	.000	.000
VIRGINIA	.972	.924	.884	.000	.953	.985	.994
WASHINGTON	.998	.000	.000	.996	.984	.000	.999
WEST VIRGINIA	.987	.000	.000	.000	.969	.000	.998
WISCONSIN	.986	.963	.000	.991	.970	.000	.999
WYOMING	983	000	.000	.979	.951	.000	997

Source: Adams (1984)

EXHIBIT 7-27

INCREASE IN STABILIZER FOR RANGES OF OZONE DEPLETION

Ozone Depletion (percent)	Stabilizer Increase (%)		
	Low	Middle	High
0-5	1.0	3.0	5.0
5-10	1.0	5.0	9.0
10-20	3.0	20.5	38.0

Source: Derived from Horst (1986), p. 6-10.

7.2.5 Impacts Due To Sea Level Rise

Increased concentrations of CFCs are one of the factors expected to contribute to global warming, of which one impact is the rise in the level of the seas. As global warming occurs, sea level rise is likely due to three basic mechanisms: the warming and resulting expansion of the upper layers of the ocean, the melting of alpine glaciers, and the melting and disintegration of polar ice sheets in Greenland and Antarctica. Increases in the level of the sea will flood coastal wetlands and lowlands, accelerate coastal erosion, exacerbate coastal flooding, and increase the salinity of estuaries and aquifers.

Using a model originally developed by Lacis (1981) that evaluates the expected change in average global air temperature due to trace gas concentrations, sensitivity to greenhouse-gas forcings, and heat diffusion into the oceans, the change in global sea level was estimated. This change was evaluated for the effects of thermal expansion, alpine meltwater, and Greenland meltwater. The impact of these factors on sea level rise are provided in Exhibit 7-28 for the baseline and alternative control level scenarios. Note that the sea level rise estimates shown in Exhibit 7-28 do not evaluate the potential changes due to Antarctic ice discharge, Antarctic meltwater, or Greenland ice discharge. Antarctic ice discharge is not sensitive to rates of change of temperatures in the model used, and Antarctic meltwater and Greenland ice discharge were not considered.

EXHIBIT 7-28

CHANGES IN SEA LEVEL RISE DUE TO STRATOSPHERIC OZONE DEPLETION

Scenario	Decrease In Stratospheric Ozone by 2075 (%)	Sea Level Rise by 2075 (cm)
No Controls	50.0[a]	99.6
Freeze	6.8	89.6
CFC 20%	5.5	88.5
CFC 50%	3.9	87.1
CFC 80%	2.7	85.9
CFC 50%/Halon Freeze	1.9	87.0
CFC 50%/Halon Freeze/U.S. 80%	1.6	86.6
U.S. Only/CFC 50%/Halon Freeze	27.1	95.0

a/ Global ozone depletion is arbitrarily constrained at 50 percent in this analysis.

Source: Based on Lacis (1981).

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CHAPTER 8

VALUING THE HEALTH AND ENVIRONMENTAL EFFECTS

Chapter 7 presented estimates on the physical magnitude of the health and environmental effects that could result due to stratospheric ozone depletion. In this chapter these health and environmental effects are valued to estimate the economic impact associated with these effects. This valuation is designed to represent the benefits to society for avoiding these effects. Estimates of the value of each benefit are provided for the baseline scenario (as described in Chapter 4) and alternative control level scenarios (as described in Chapter 5).

This chapter is only intended to summarize the results of the valuation of the benefits. For greater detail on the methods used to value the health effects see Appendix E; for the environmental effects, see Appendix F.

8.1 VALUE OF PREVENTING HEALTH IMPACTS

This section of the chapter discusses the value of avoiding the health impacts due to stratospheric ozone depletion. These impacts include:

- Higher incidence and mortality of nonmelanoma skin cancer;
- Higher incidence and mortality of melanoma skin cancer; and
- Higher incidence of cataracts.

There are other health impacts associated with stratospheric ozone depletion that are not valued here because the extent of the impacts are unknown. These impacts include possible harmful effects on the immune system, including less resistance to infections, a higher incidence of skin damage from actinic keratosis due to UV radiation effects, and effects due to increased levels of tropospheric ozone (primarily impacts on the pulmonary system).

8.1.1 Nonmelanoma Skin Cancer

Increased UV radiation from stratospheric ozone depletion can lead to a higher incidence of nonmelanoma skin cancer, specifically basal and squamous cell carcinoma. An increase in the number of nonmelanoma skin cancer cases is also expected to cause an increase in the number of deaths from this type of cancer.

Although there is a substantial amount of information evaluating the magnitude of the physical effects from nonmelanoma, there are no publicly available data sources to indicate the magnitude of the costs incurred by society for nonmelanoma. To determine the magnitude of these costs, a Skin Cancer Focus Group was organized to discuss the costs incurred by nonmelanoma patients. The Skin Cancer Focus Group comprised skin cancer specialists who were able to address the different types of treatment that various skin cancer patients would receive, including medical costs for treatment, recommended follow-up visits/treatments for the patient, the amount of time lost from work, and recommended preventive activities for the patient outside of the doctor's office or hospital. The objective of this procedure was to identify the primary components incurred by the individual and/or society for the "average" skin cancer case. These cost components include medical costs associated with treatment, the amount of work lost due to treatment, and costs due to preventative measures recommended for those people that have skin cancer. The costs of caregiving and chores performed by others, and pain and suffering incurred by skin cancer patients were not estimated by the Skin Cancer Focus Group. Therefore, the values of non-fatal health effects are likely to be underestimated.

The primary reasons that costs vary among different types of nonmelanoma cases are the size of the nonmelanoma and the likelihood of a recurrence once the nonmelanoma is treated. Based on the results from the Skin Cancer Focus Group (see Appendix E for additional discussion), the average costs across all types of nonmelanoma are estimated to be about $4000 for a basal cell carcinoma case and $7000 for a case of squamous cell carcinoma (it should be emphasized that the averages include a small number of serious cases and a number of less serious cases). Using these values to represent the average costs to society for nonmelanoma, the costs incurred for the additional nonmelanoma cases as a result of ozone depletion for all people born before 2075 are summarized in Exhibit 8-1. These costs represent the benefit to society for avoiding the increase in the number of nonmelanoma cases in people born before 2075. These costs are shown for a discount rate of two percent for the reference and alternative scenarios. For alternative results based on one and six percent discount rates, see Chapter 10.[1] Exhibit 8-2 summarizes the cost estimates for all additional nonmelanoma cases that occur by 2165 (including people born from 2075-2165).

The increase in the number of nonmelanoma cases will also lead to an increase in the number of deaths from nonmelanoma. This analysis generates two separate values for these mortality effects. Most cases use $3 million,[2] but a case is included which uses $12 million values for a unit mortality risk reduction. Furthermore, these values are assumed to grow in value at a rate equal to the annual rate of growth in GNP per capita (see Appendix G for an in-depth discussion of the valuations of mortality risk reductions used in this analysis). This analysis assumes that the total cost to society for these additional mortality risks is determined by multiplying these values for

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[1] Some analysts argue that values associated with human life should not be discounted. Results of a zero discount case are also shown in Chapter 10.

[2] As discussed in Appendix G, establishing a value of preventing risks to human life is context dependent. Presentation of $3 million dollars as the most commonly shown case should not be taken by readers as an indication that all analytical questions have been addressed to support this value rather than the higher values suggested by Viscusi and Ashford for non-voluntary risks.

EXHIBIT 8-1

VALUE OF ADDITIONAL CASES AVOIDED OF NONMELANOMA IN U.S. FOR PEOPLE BORN BEFORE 2075 (billions of 1985 dollars) a/

Scenario	Total Additional Cases by 2165	Total Cost (10^9 $)	Decrease From No Controls Scenario: Additional Cases Avoided	Decrease From No Controls Scenario: Value of Avoided Cases (10^9 $) b/
No Controls	177,998,100	76.90	-	-
CFC Freeze (Case 2)	17,408,000	10.40	160,657,300	66.50
CFC 20% (Case 3)	13,703,400	8.48	164,294,700	68.42
CFC 50% (Case 4)	9,575,000	6.27	168,423,100	70.63
CFC 80% (Case 5)	6,618,800	4.70	171,379,300	72.20
CFC 50%/ Halon Freeze (Case 6)	5,103,900	4.28	172,894,200	72.62
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	4,404,500	3.91	173,593,600	72.99
U.S. Only/CFC 50%/Halon Freeze (Case 8)	123,036,300	49.70	54,962,100	27.20

a/ Assumes a 2 percent discount rate.

b/ Value per case avoided based on results from the Skin Cancer Focus Group, July 23, 1987 (see Appendix E).

EXHIBIT 8-2

VALUE OF ADDITIONAL CASES AVOIDED FROM NONMELANOMA IN U.S. THAT OCCUR BY 2165 a/

Scenario	Total Additional Cases by 2165	Total Cost (10^9 $)	Decrease From No Controls Scenario: Additional Cases Avoided	Decrease From No Controls Scenario: Value of Avoided Cases (10^9 $) b/
No Controls	249,553,800	90.70	-	-
CFC Freeze (Case 2)	22,443,100	11.40	227,110,700	79.30
CFC 20% (Case 3)	17,479,400	9.20	232,074,400	81.50
CFC 50% (Case 4)	11,898,800	6.73	237,655,000	83.97
CFC 80% (Case 5)	7,913,300	4.96	241,640,500	85.74
CFC 50%/ Halon Freeze (Case 6)	5,386,000	4.34	244,167,800	86.36
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	4,448,900	3.93	245,104,900	86.77
U.S. Only/CFC 50%/Halon Freeze (Case 8)	191,206,300	62.70	58,347,500	28.00

a/ Assumes a 2 percent discount rate.

b/ Value per case avoided based on results from the Skin Cancer Focus Group, July 23, 1987 (see Appendix E).

mortality risk reduction by the aggregated population mortality risk. Exhibit 8-3 summarizes these estimates for people born before 2075 for the reference and alternative scenarios using a discount rate of two percent. For alternative results based on one and six percent discount rates, see Chapter 10. The aggregate population risk due to nonmelanoma is also shown for people born before 2075. Exhibit 8-4 summarizes these estimates for the aggregate population risk from nonmelanoma by 2165, including people born from 2075 to 2165.

8.1.2 Melanoma Skin Cancer

Increased UV radiation from stratospheric ozone depletion can also lead to a higher incidence of melanoma skin cancer, specifically cutaneous malignant melanoma. Any increase in the number of melanoma skin cancer cases is also expected to cause an increase in the number of deaths from this type of cancer.

Both nonmelanoma and melanoma are similar in that there are no publicly-available data sources to indicate the magnitude of the costs incurred by society. The Skin Cancer Focus Group discussed above was also used to determine the magnitude of these costs, including medical costs for treatment, recommended follow-up visits/treatments for the patient, the amount of time lost from work, and recommended preventive activities for the patient outside of the doctor's office or hospital. The objective of this procedure was to identify the primary components incurred by the individual and/or society for the "average" skin cancer case. A more in-depth discussion of the Skin Cancer Focus Group and the results obtained from it can be found in Appendix E.

Based on the information obtained from the Skin Cancer Focus Group, the cost of different melanoma cases were categorized according to the most likely location that the patient would receive treatment -- the doctor's office, on an outpatient basis, or in the hospital. Given these different types of cases, the average cost for a case of cutaneous malignant melanoma is assumed to be $15,000. Using this value to represent the average cost to society for melanoma, the costs incurred for the additional melanoma cases as a result of ozone depletion for people born before 2075 are summarized in Exhibit 8-5. These costs represent the benefit to society for avoiding the increase in the number of melanoma cases in people born before 2075. These costs are shown for a discount rate of two percent for the reference and alternative scenarios. The costs to society for all cases of melanoma that occur by 2165, including people born from 2075-2165, are shown in Exhibit 8-6. For alternative results based on one and six percent discount rates, see Chapter 10.

The increase in the number of melanoma cases will also lead to an increase in the number of deaths from this illness. This analysis generates two separate values for these mortality effects. Most cases use $3 million. A case using $12 million is included in Chapter 10. Furthermore, these values are assumed to grow in value at a rate equal to the annual rate of growth in GNP per capita (see Appendix G for an in-depth discussion of the valuations of mortality risk reductions used in this analysis). This analysis assumes that the total cost to society for these additional mortality risks is determined by multiplying these

EXHIBIT 8-3

VALUE OF ADDITIONAL DEATHS AVOIDED FROM NONMELANOMA IN U.S. FOR PEOPLE BORN BEFORE 2075 a/

Scenario	Total Additional Deaths by 2165	Total Cost (10^9 $)	Decrease From No Controls Scenario: Additional Deaths Avoided	Decrease From No Controls Scenario: Value of Avoided Deaths (10^9 $) b/
No Controls	3,528,700	3,340	-	-
CFC Freeze (Case 2)	282,800	341	3,245,900	2,999
CFC 20% (Case 3)	221,900	273	3,306,800	3,067
CFC 50% (Case 4)	153,700	197	3,375,000	3,143
CFC 80% (Case 5)	105,500	142	3,423,200	3,198
CFC 50%/ Halon Freeze (Case 6)	80,600	124	3,448,100	3,216
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	69,300	111	3,459,400	3,229
U.S. Only/CFC 50%/Halon Freeze (Case 8)	2,377,700	2,090	1,151,000	1,250

a/ Assumes a 2 percent discount rate and that the value of mortality risk reductions increases at the rate of increase in per capita income, i.e., an average 1.7 percent per year through 2075.

b/ Assumes $3 million value per unit mortality risk reduction. Those wishing to use a value of $12 million should multiply by 4.

EXHIBIT 8-4

VALUE OF ADDITIONAL DEATHS AVOIDED FROM NONMELANOMA IN U.S. THAT OCCUR BY 2165 a/

Scenario	Total Additional Deaths by 2165	Total Cost (10^9 $)	Decrease From No Controls Scenario: Additional Deaths Avoided	Decrease From No Controls Scenario: Value of Avoided Deaths (10^9 $) b/
No Controls	4,894,400	3,960	-	-
CFC Freeze (Case 2)	358,600	375	4,535,800	3,585
CFC 20% (Case 3)	227,500	299	4,666,900	3,661
CFC 50% (Case 4)	187,600	212	4,706,800	3,748
CFC 80% (Case 5)	124,200	151	4,770,200	3,809
CFC 50%/ Halon Freeze (Case 6)	84,700	126	4,809,700	3,834
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	69,900	112	4,824,500	3,848
U.S. Only/CFC 50%/Halon Freeze (Case 8)	3,667,800	2,660	1,226,600	1,300

a/ Assumes a 2 percent discount rate and that the value of mortality risk reductions increases at the rate of increase in per capita income, i.e., an average 1.7 percent per year through 2075.

b/ Assumes $3 million value per unit mortality risk reduction. Those wishing to use a value of $12 million should multiply by 4.

EXHIBIT 8-5

VALUE OF ADDITIONAL CASES AVOIDED OF MELANOMA IN U.S. FOR PEOPLE BORN BEFORE 2075 a/

			Decrease From No Controls Scenario	
Scenario	Total Additional Cases by 2165	Total Cost (10^9 $)	Additional Cases Avoided	Value of Avoided Cases (10^9 $) b/
No Controls	893,300	1.45	-	-
CFC Freeze (Case 2)	139,700	0.30	753,600	1.15
CFC 20% (Case 3)	112,400	0.24	780,900	1.21
CFC 50% (Case 4)	80,400	0.18	812,900	1.27
CFC 80% (Case 5)	56,900	0.14	836,400	1.31
CFC 50%/ Halon Freeze (Case 6)	45,900	0.13	847,400	1.32
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	40,200	0.12	853,100	1.33
U.S. Only/CFC 50%/Halon Freeze (Case 8)	647,400	0.99	245,900	0.46

a/ Assumes a 2 percent discount rate.

b/ Value per case avoided based on results from the Skin Cancer Focus Group, July 23, 1987 (see Appendix E).

EXHIBIT 8-6

VALUE OF ADDITIONAL CASES AVOIDED OF MELANOMA IN U.S. THAT OCCUR BY 2165 a/

Scenario	Total Additional Cases by 2165	Total Cost (10^9 $)	Decrease From No Controls Scenario: Additional Cases Avoided	Decrease From No Controls Scenario: Value of Avoided Cases (10^9 $) b/
No Controls	1,442,700	1.83	-	-
CFC Freeze (Case 2)	207,500	0.34	1,235,200	1.49
CFC 20% (Case 3)	163,500	0.28	1,279,200	1.55
CFC 50% (Case 4)	112,600	0.20	1,330,100	1.63
CFC 80% (Case 5)	75,200	0.15	1,367,500	1.68
CFC 50%/ Halon Freeze (Case 6)	50,000	0.13	1,392,700	1.70
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	40,900	0.12	1,401,800	1.71
U.S. Only/CFC 50%/Halon Freeze (Case 8)	1,181,900	1.35	260,800	0.48

a/ Assumes a 2 percent discount rate.

b/ Value per case avoided based on results from the Skin Cancer Focus Group, July 23, 1987 (see Appendix E).

values for mortality risk reduction by the aggregated population mortality risk. Exhibit 8-7 summarizes these estimates for people born before 2075 for the reference and alternative scenarios using a discount rate of two percent. Exhibit 8-8 summarizes the estimates which include risk reductions for people born between 2075 and 2165 for the reference and alternative scenarios using a discount rate of two percent. For alternative results based on one and six percent discount rates, see Chapter 10.

8.1.3 Cataracts

Increases in UV-B radiation due to stratospheric ozone depletion may increase the incidence of cataracts. An increase in the incidence rate would cause some individuals to be diagnosed with cataracts who would otherwise not have developed them and some individuals who would have incurred them later in life to develop them earlier in life.

The value of preventing an increase in the number of cataract cases has been developed from an analysis by Rowe, Neithercut, and Schulze (1987). In their study Rowe et. al. determined the social costs associated with cataract cases. These costs were defined as society's willingness to pay to avoid the cataracts, and included four major cost components: increased medical costs, increased work loss, increased costs for chores and caregiving, and other indirect social and economic costs. Rowe, et. al. (1987) obtained their data from a review of the literature, contacts with various health providers, and a survey of cataract patients. Based on their analysis, the average value assumed for a cataract case is $15,000.

Using an estimate of $15,000 per case, the value to society for avoiding the increase in cataracts in people born before 2075 is shown in Exhibit 8-9 for the reference and alternative scenarios. The value under each scenario is shown for a discount rate of two percent; the number of additional cataract cases that occur in people born before 2075 is also shown. The costs to society for all additional cataracts that occur by 2165, including cataracts that occur in people born from 2075-2165, are shown in Exhibit 8-10. For alternative results based on one and six percent discount rates, see Chapter 10.

8.2 VALUE OF PREVENTING ENVIRONMENTAL IMPACTS

This section of the chapter discusses the value of avoiding the environmental impacts due to stratospheric ozone depletion. These impacts include:

- Risks to aquatic life;
- Risks to crops;
- Increased concentrations of tropospheric (ground-based) ozone;
- Degradation of polymers; and
- Impacts due to sea level rise.

EXHIBIT 8-7

VALUE OF ADDITIONAL DEATHS AVOIDED FROM MELANOMA FOR PEOPLE BORN BEFORE 2075 a/

Scenario	Total Additional Deaths by 2165	Total Cost (10^9 $)	Decrease From No Controls Scenario: Additional Deaths Avoided	Decrease From No Controls Scenario: Value of Avoided Deaths (10^9 $) b/
No Controls	211,300	241	-	-
CFC Freeze (Case 2)	33,600	44	177,700	197
CFC 20% (Case 3)	27,000	36	184,300	205
CFC 50% (Case 4)	19,300	26	192,400	215
CFC 80% (Case 5)	13,500	20	197,800	221
CFC 50%/ Halon Freeze (Case 6)	10,800	17	200,500	224
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	9,300	16	202,000	225
U.S. Only/CFC 50%/Halon Freeze (Case 8)	156,900	167	54,400	74

a/ Assumes a 2 percent discount rate and that the value of mortality risk reductions increases at the rate of increase in per capita income, i.e., an average 1.7 percent per year through 2075.

b/ Assumes $3 million value per unit mortality risk reduction. Those wishing to use a value of $12 million should multiply by 4.

EXHIBIT 8-8

VALUE OF ADDITIONAL DEATHS AVOIDED FROM MELANOMA THAT OCCUR BY 2165 a/

Scenario	Total Additional Deaths by 2165	Total Cost (10^9 $)	Decrease From No Controls Scenario: Additional Deaths Avoided	Decrease From No Controls Scenario: Value of Avoided Deaths (10^9 $) b/
No Controls	310,000	290	-	-
CFC Freeze (Case 2)	46,300	51	263,700	239
CFC 20% (Case 3)	36,600	41	273,400	249
CFC 50% (Case 4)	25,300	29	284,700	261
CFC 80% (Case 5)	17,000	21	293,000	269
CFC 50%/ Halon Freeze (Case 6)	11,500	18	298,500	272
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	9,500	16	300,500	274
U.S. Only/CFC 50%/Halon Freeze (Case 8)	252,900	214	57,100	76

a/ Assumes a 2 percent discount rate and that the value of mortality risk reductions increases at the rate of increase in per capita income, i.e., an average 1.7 percent per year through 2075.

b/ Assumes $3 million value per unit mortality risk reduction. Those wishing to use a value of $12 million should multiply by 4.

EXHIBIT 8-9

VALUE OF AVOIDING AN INCREASE IN THE INCIDENCE OF CATARACTS IN U.S. IN PEOPLE BORN BEFORE 2075

			Decrease From No Controls Scenario	
Scenario	Total Additional Cases by 2165	Total Cost (10^9 $)	Additional Cases Avoided	Value of Avoided Cases (10^9 $) a/
No Controls	19,962,800	3.21	-	-
CFC Freeze (Case 2)	3,178,000	0.64	16,514,800	2.57
CFC 20% (Case 3)	2,531,200	0.52	17,161,600	2.69
CFC 50% (Case 4)	1,774,100	0.38	17,918,700	2.83
CFC 80% (Case 5)	1,214,300	0.29	18,478,500	2.92
CFC 50%/ Halon Freeze (Case 6)	876,100	0.26	18,816,700	2.95
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	740,600	0.23	18,952,200	2.98
U.S. Only/CFC 50%/Halon Freeze (Case 8)	15,824,100	2.33	3,868,700	0.88

a/ Value per case avoided based on Rowe, Neithercut, and Schulze (1987).

EXHIBIT 8-10

VALUE OF AVOIDING AN INCREASE IN THE INCIDENCE OF CATARACTS IN U.S. THROUGH 2165

			Decrease From No Controls Scenario	
Scenario	Total Additional Cases by 2165	Total Cost (10^9 $)	Additional Cases Avoided	Value of Avoided Cases (10^9 $) a/
No Controls	25,131,600	3.48	-	-
CFC Freeze (Case 2)	3,888,500	0.67	21,243,100	2.81
CFC 20% (Case 3)	3,060,400	0.55	22,071,200	2.93
CFC 50% (Case 4)	2,097,600	0.40	23,034,000	3.08
CFC 80% (Case 5)	1,383,100	0.30	23,748,500	3.18
CFC 50%/ Halon Freeze (Case 6)	888,800	0.26	24,242,800	3.22
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	742,000	0.23	24,389,600	3.25
U.S. Only/CFC 50%/Halon Freeze (Case 8)	21,023,700	2.61	4,107,900	0.87

a/ Value per case avoided based on Rowe, Neithercut, and Schulze (1987).

It is important to emphasize that this analysis focuses exclusively on the above environmental effects, all of which have anticipated, direct economic consequences. Damage to other aspects of the natural environment and to ecosystems are not estimated herein, although their long-term economic consequences could be highly significant, perhaps catastrophic. Therefore, these potential additional environmental consequences should be considered in interpreting the results of this analysis.

In this section the valuation procedures are discussed only briefly. For further detail, see Appendix F.

8.2.1 Risks to Aquatic Life

The potential risks to aquatic life were expressed in Chapter 7 as a decline in the commercial fish harvests. The commercial fish species evaluated were:

- Fin fish, including menhaden, Pacific trawlfish, anchovies, halibut, sea herring, jack mackerel, Atlantic mackerel, sablefish, and tuna.

- Shell fish, including clams, crabs, American lobster, spiny lobster, oysters, shrimp, scallops, and squid.

To determine the value associated with avoiding these declines, average commercial harvest levels and market values for these fish species from 1981-1985 were estimated from data available from the U.S. Department of Commerce. These average values were 5.9 million tons harvested with an average annual value of $3.65 billion, and were used to represent annual harvest levels and market values over the 1985-2075 period. For each scenario, the percentage decline in the amount harvested each year was estimated from these averages and valued based on the average market value, i.e., $3.65 billion, or about $620 per ton. The net present values of these annual impacts were calculated using a discount rate of two percent.

Sensitivity analyses were also conducted to capture some of the uncertainty by assuming that the impacts would range from one-half to twice the level estimated using the average annual values. The benefit estimates that result from this procedure are summarized in Exhibit 8-11. These estimates are quite speculative and could be higher or lower by significant margins.

8.2.2 Risks to Crops

The impacts on agricultural crops were valued by estimating the net present value of the forecasted yield declines due to increased UV radiation levels. Yield declines were estimated for the major grain crops: wheat, rye, rice, corn, oats, barley, sorghum, and soybeans. Potential impacts on other crops, including fruits and vegetables, forests, and other non-commercial species have not been evaluated.

The impacts on the major grain crops were valued by first estimating the value of the impacts on soybeans only. These impacts were analyzed by Rowe and

EXHIBIT 8-11

VALUATION OF IMPACTS ON FIN FISH AND SHELL FISH DUE TO INCREASED RADIATION (billions of 1985 dollars)

Scenario	Harvest Decline by 2075 (Percent)	Total Cost (10^9 $)			Decrease from No Controls-- Value of Avoided Impacts (10^9 $)		
		0.5	1.0	2.0	0.5	1.0	2.0
No Controls	>25.0	3.36	6.72	13.44	-	-	-
CFC Freeze (Case 2)	2.5	0.12	0.24	0.48	3.24	6.48	12.96
CFC 20% (Case 3)	0.9	0.02	0.04	0.08	3.34	6.68	13.36
CFC 50% (Case 4)	0.0	0.00	0.00	0.00	3.36	6.72	13.44
CFC 80% (Case 5)	0.0	0.00	0.00	0.00	3.36	6.72	13.44
CFC 50%/ Halon Freeze (Case 6)	0.0	0.00	0.00	0.00	3.36	6.72	13.44
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	0.0	0.00	0.00	0.00	3.36	6.72	13.44
U.S. Only/CFC 50%/Halon Freeze (Case 8)	>25.0	2.18	4.36	8.72	1.18	2.36	4.72

Source: Based on Hunter, Kaupp, and Taylor (1982).

Adams (1987) using the National Crop Loss Assessment Network (NCLAN), from which they developed the following relationship between soybean yield and economic damage:

$$D2 = 0.1068 * SOY - 0.00029 * SOY^2$$

where:

D2 = annual change in economic surplus, in billions of 1982 dollars, resulting from changes in soybean yield due to UV-B.

SOY = percent change in soybean yield due to UV-B, which was defined as 0.30 times the percentage decrease in stratospheric ozone.

The value of potential impacts on the major grain crops was then calculated by increasing the estimated impacts on soybeans by a factor of 3.85 to reflect the larger size of the market for all major grain crops compared to the size of the market for soybeans only. The factor of 3.85 was determined by using average annual crop production levels from 1981-1985 to represent average annual production levels for each crop, and the market value was estimated using the average market price for these crops during 1981-1985. This information was obtained from the U.S. Department of Agriculture; the average annual value of all soybean production was about $13 billion and the average annual value of all major grain crops was $50 billion (1985 dollars).

The net present value of these annual production declines was calculated for each scenario using a discount rate of two percent. Sensitivity analyses were also conducted by assuming that the impacts would range from one-half to twice the level estimated by the approach described above. The benefit estimates from this approach are summarized in Exhibit 8-12. These estimates are quite speculative and could be significantly higher or lower.

8.2.3 Increased Concentrations of Ground-based Ozone

The economic impact of tropospheric (ground-based) ozone on agricultural crops was determined from the National Crop Loss Assessment Network (NCLAN), which was developed to assist EPA in the evaluation of National Ambient Air Quality Standards (NAAQS) for ground-based ozone. In an analysis by Rowe and Adams (1987), the value of potential crop losses for soybeans, corn, wheat, cotton, rice, barley, sorghum, and forage was estimated using the following relationship between tropospheric ozone changes and economic damage:

$$D1 = -0.0678 * T - 0.000195 * T^2$$

where:

D1 = annual change in economic surplus, in billions of 1982 dollars, due to tropospheric ozone.

T = percent change in tropospheric ozone.

EXHIBIT 8-12

VALUATION OF IMPACTS ON MAJOR GRAIN CROPS DUE TO INCREASED RADIATION (billions of 1985 dollars)

Scenario	Harvest Decline by 2075 (Percent)	Total Cost (10^9 $)			Decrease from No Controls--Value of Avoided Impacts (10^9 $)		
		0.5	1.0	2.0	0.5	1.0	2.0
No Controls	>7.50	16.83	33.66	67.32	-	-	-
CFC Freeze (Case 2)	2.1	6.14	12.28	24.56	10.69	21.38	42.76
CFC 20% (Case 3)	1.7	5.16	10.32	20.64	11.68	23.34	46.68
CFC 50% (Case 4)	1.2	3.98	7.97	15.94	12.84	25.69	51.38
CFC 80% (Case 5)	0.8	3.16	6.31	12.62	13.68	27.35	54.70
CFC 50%/ Halon Freeze (Case 6)	0.6	3.18	6.35	12.70	13.66	27.31	54.62
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	0.5	2.48	5.97	11.94	13.84	27.69	55.38
U.S. Only/CFC 50%/Halon Freeze (Case 8)	>7.50	12.52	25.04	50.08	4.31	8.62	17.24

Source: Based on Rowe and Adams (1987).

This approach was used to generate a stream of annual impacts through 2075. The present value of these annual impacts was then calculated using a discount rate of two percent. Sensitivity analyses were also conducted by assuming that the impacts would range from one-half to twice the level estimated by the approach described above. A summary of the decreases in economic value for each scenario is provided in Exhibit 8-13. The estimated increase in tropospheric ozone by 2075 is also indicated. These estimates are quite speculative and could be significantly higher or lower.

8.2.4 Degradation of Polymers

The economic impact of UV radiation on polymers has been determined from work done by Horst (1986). Horst assumed that polymer manufacturers would increase the amount of light stabilizer in their products as a result of higher UV radiation levels. The amount of stabilizer was assumed to increase about one percent for each one percent decrease in stratospheric ozone, although this varied depending on amount of depletion and intensity of the UV radiation, among other factors. Also, the maximum change allowed due to manufacturing limitations was a 25 percent increase in stabilizer, which was estimated to lead to a 1.86 percent increase in the price of the polymer. Although the analysis by Horst was conducted on rigid PVC products only, these dose-response and price-response relationships were assumed to apply to acrylic and polyester applications as well (these products are also frequently exposed to UV radiation). The market size for all of these UV-sensitive materials was estimated to be 3.75 times larger than the market for rigid PVC products only.

For these polymer products, cost impacts through 2075 were calculated for each year using three basic steps:

- The size of the market for each polymer product was estimated.

- The amount of damage to polymer products (i.e., the amount of additional stabilizer required) due to increased UV radiation levels was assessed.

- The damage costs were determined based on the price-response relationship presented above.

The benefit estimates that result from this approach (i.e., the amount of damage that could be avoided if the amount of ozone depletion is reduced) are summarized in Exhibit 8-14 for the reference scenario and alternative scenarios. These damage estimates are shown for a discount rate of two percent. The amount of ozone depletion estimated to occur by 2075, from which the level of UV damage is determined, is also shown for each scenario.

8.2.5 Damages Due To Sea Level Rise

Sea level rise can cause loss of wetlands, higher storm surges, flooding, and beach erosion, among other factors In this section only the impacts on the major coastal ports have been valued. These impacts were valued using an analysis by Gibbs (1984) that evaluated the effects of a 0.75 to 2.2 meter rise

EXHIBIT 8-13

VALUATION OF IMPACTS ON MAJOR AGRICULTURAL CROPS DUE TO TROPOSPHERIC OZONE (billions of 1985 dollars)

Scenario	Tropospheric Ozone Increase by 2075 (Percent)	Total Cost (10^9 $)			Decrease from No Controls--Value of Avoided Impacts (10^9 $)		
		0.5	1.0	2.0	0.5	1.0	2.0
No Controls	>30.9	9.18	18.37	36.74	-	-	-
CFC Freeze (Case 2)	5.7	2.83	5.66	11.32	6.36	12.71	25.42
CFC 20% (Case 3)	4.6	3.38	4.75	9.50	6.81	13.62	27.24
CFC 50% (Case 4)	3.2	1.83	3.66	7.32	7.36	14.71	29.42
CFC 80% (Case 5)	2.3	1.45	2.90	5.80	7.74	15.47	30.94
CFC 50%/ Halon Freeze (Case 6)	1.6	1.46	2.92	5.84	7.72	15.45	30.90
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	1.4	1.37	2.74	5.48	7.82	15.63	31.26
U.S. Only/CFC 50%/Halon Freeze (Case 8)	24.5	5.97	11.94	23.88	3.22	6.43	12.86

Source: Based on Rowe and Adams (1987).

EXHIBIT 8-14

VALUATION OF IMPACTS ON POLYMERS DUE TO UV RADIATION INCREASES (billions of 1985 dollars)

Scenario	Stratospheric Ozone Decrease by 2075 (Percent)	Total Cost (10^9 $)			Decrease from No Controls--Value of Avoided Impacts (10^9 $)		
		0.5	1.0	2.0	0.5	1.0	2.0
No Controls	50.0[a]	2.57	5.14	10.28	-	-	-
CFC Freeze (Case 2)	6.8	1.24	2.49	4.98	1.18	2.65	4.74
CFC 20% (Case 3)	5.5	1.04	2.07	4.14	1.54	3.07	6.14
CFC 50% (Case 4)	3.9	0.89	1.78	3.56	1.68	3.36	6.72
CFC 80% (Case 5)	2.7	0.80	1.61	3.22	1.77	3.53	7.06
CFC 50%/ Halon Freeze (Case 6)	1.9	0.78	1.57	3.14	1.78	3.57	7.14
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	1.6	0.78	1.57	3.14	1.78	3.57	7.14
U.S. Only/CFC 50%/Halon Freeze (Case 8)	27.1	2.20	4.39	8.78	0.37	0.75	1.50

[a] Global ozone depletion is arbitrarily constrained at 50 percent in this analysis.

Source: Based on Horst (1986).

in sea level by 2075 on two coastal communities -- Charleston, South Carolina and Galveston, Texas. Gibbs analyzed impacts for two types of community responses -- damages if actions anticipating the rise in sea level were undertaken and damages if no anticipatory actions were undertaken.

The damage estimates developed by Gibbs for Charleston and Galveston were used to estimate a range of potential damages for all major coastal ports. Using the amount of tonnage shipped through each port each year as an approximate measure of the size of the port, the damage estimates developed by Gibbs were divided by the amount of tonnage shipped to represent the potential range of impacts due to sea level rise. For sea level rise of 98 cm, these cost estimates were $8 to $66 per ton shipped if anticipatory actions were taken and $16 to $181 per ton shipped if they were not. All costs are in 1985 dollars assuming a three percent discount rate. The primary reason for the variation in damages is the amount of protection a port has from severe storms -- costs are lower if the port is protected (like Galveston) or higher if the port is relatively unprotected (like Charleston).

These cost ranges were then used to determine potential impacts at all major coastal ports. These damage estimates are summarized in Exhibit 8-15 for the baseline scenario and alternative scenarios. The amount of sea level rise by 2075 is indicated for each scenario. Damage estimates are provided for anticipated and unanticipated responses. Low, medium, and high estimates are also provided -- the low estimates assume most ports will be relatively protected; the high estimates assume they will be relatively unprotected; and the medium estimates reflect a port-by-port assessment on whether the port appeared to be unprotected (hence higher damage estimates were assumed) or protected (hence lower damage estimates were assumed). Clearly, this is a crude estimating technique and real damages could be much higher or lower than indicated by these estimates. However, many sea level damage issues, such as flooding of coastal wetlands, beach erosion, increases in salinity in aquifers, among other factors, are not included here.

EXHIBIT 8-15

VALUATION OF IMPACTS OF SEA LEVEL RISE ON MAJOR COASTAL PORTS (billions of 1985 dollars) a/

Scenario	Sea Level Rise by 2075 (cm)	Anticipated			Unanticipated		
		Low	Medium	High	Low	Medium	High
No Controls	99.6	13.0	55.1	106.2	26.1	145.7	290.7
CFC Freeze (Case 2)	89.6	12.4	51.2	98.2	24.0	136.3	272.5
CFC 20% (Case 3)	88.5	12.4	50.8	97.3	23.7	135.2	270.5
CFC 50% (Case 4)	87.1	12.3	50.2	96.2	23.4	133.9	268.0
CFC 80% (Case 5)	85.9	12.2	49.7	95.3	23.2	132.8	265.8
CFC 50%/ Halon Freeze (Case 6)	87.0	12.3	50.2	96.2	23.4	133.8	267.8
CFC 50%/ Halon Freeze/ U.S. 80% (Case 7)	86.6	12.3	50.0	95.8	23.3	133.5	267.1
U.S. Only/CFC 50%/Halon Freeze (Case 8)	96.0	12.8	53.7	103.3	25.3	142.3	284.2

a/ All damage estimates were calculated assuming a three percent discount rate.

Source: Based on Gibbs (1984).

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CHAPTER 9

COSTS OF CONTROL

This chapter presents estimates of the costs that would be incurred if the use of CFCs and halons is regulated. A major objective of the chapter is the analysis of how user industries may respond to the reduced availability of CFCs. Because industry responses are uncertain, the chapter evaluates costs for a range of possible responses. In addition, the chapter estimates the costs of each of the stringency and coverage options described in Chapter 5. The costs presented in this chapter, when combined with the benefit estimates presented in Chapter 8, provide the basis for the cost-benefit comparisons presented in Chapter 10.

The chapter is organized as follows:

- Section 9.1 summarizes the approach used to estimate the costs of CFC regulation.

- Section 9.2 presents cost estimates for an initial scenario of industry responses. In this scenario, labeled Case 1, responses by industry start slowly, are implemented slowly, and achieve relatively small reductions in CFC use.

- Section 9.3 presents variations on the Case 1 scenario in which the responses (e.g., adoption of controls) of particular industries are evaluated, one industry at a time. Case 1 assumptions are relaxed on an industry-by-industry basis to analyze how the improved responses of individual industries can affect the costs of regulation.

- Section 9.4 then describes a second broad cost scenario, Case 2, in which industry responses start quickly, are implemented quickly, and achieve relatively large reductions in CFC use. This scenario includes all of the responses examined in Section 9.3 plus a similar set of responses in several other industries.

- Section 9.5 examines the sensitivity of the cost estimates to the development and introduction of long-term chemical substitutes for CFCs. Cost estimates are presented for a one-year delay in the initial availability of three important substitute chemicals -- FC-134a, HCFC-141b, and HCFC-123.

- Section 9.6 presents cost estimates for each of the stringency and coverage options described in Chapter 5.

- Section 9.7 discusses how costs might differ depending on the regulatory approaches used to restrict the domestic use of CFCs.

- Finally, Section 9.8 describes the major limitations to the cost estimates and Section 9.9 provides conclusions of the analysis.

9.1 APPROACH TO ESTIMATING COSTS

This section describes the analytical approach used to estimate the costs borne by society due to CFC and halon regulation. The economic theory underlying this approach is presented more fully in Appendix I. Section 9.1.1 describes the major types of costs resulting from regulation. Section 9.1.2 discusses the ways in which specific industry responses to reduce the use of CFCs are characterized in the analysis. Section 9.1.3 describes the methods used to estimate the size of these costs.

9.1.1 Types of Costs Considered[1]

The regulation of CFCs will restrict the supply of CFCs and possibly increase their price. Industries that use CFCs and consumers that buy CFC-based products can respond by:

- Switching from CFC-using products to other products; for example, replacing alternative materials for foam insulation produced with CFC-11 or CFC-12. This response reduces CFC use in direct proportion to the extent of the replacement -- if one-half of all foam insulation is replaced, CFC use in foam insulation decreases by one-half.

- Switching to production methods that use fewer CFCs per unit of output; for example, collecting and recycling CFCs when mobile air conditioners are serviced. As CFC prices rise in response to regulation, servicers of mobile air conditioners will have increased incentive to capture and reuse CFC-12 that otherwise would be discharged and replaced with new CFC-12 refrigerant.

- Switching from CFC-based production methods to ones using other chemicals; for example, using HCFC-22 in the production of packaging foams. After the U.S. Food and Drug Administration approved the use of HCFC-22 in food-contact packaging applications, foam manufacturers announced plans to eliminate completely the use of CFCs during foam production.

Each type of response may increase the amount of resources used to produce or consume the same amount of goods and services. A product switch may increase resources used because consumers must pay more for a different product than they were paying previously for the CFC-based product. A switch in production methods or the use of a substitute chemical similarly may increase the resources required to produce the same product. The manufacturer will, of course, pass as much of these increased production costs on to consumers as possible given market conditions.

For this RIA, the increase in resources necessary to produce the same amount of goods and services is termed a **social cost**. Other analyses often use the equivalent term real resource cost. Social costs measure the extent to which society as a whole is poorer due to regulation of CFCs.

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[1] The discussion of this section refers only to CFCs, although all points made apply equally to the regulation of halons.

Social costs can take different forms: capital costs (e.g., for purchasing equipment), labor, materials, energy, and one-time costs (e.g., product reformulations or research and development). For example, changing sterilization procedures for medical instruments might increase labor costs if workers must spend additional time preparing batches of medical equipment to minimize the number of times the sterilization chamber must be operated. Capital equipment costs could increase if stronger chambers are needed to protect workers against hazards of explosion due to reduced use of CFCs. Raw materials costs could increase if more expensive chemicals were substituted for CFCs. If less expensive materials are substituted, costs could decline.

The costs of CFC regulations are not all resource or social costs. For example, if a tax increases the price of a commodity, consumers pay more for the commodity, but more resources are not required to produce the product.[2] The tax only transfers money from consumers to the government. Similarly, if the supply of a commodity is restricted by government regulation or by a monopolist, consumers will have to pay more for the commodity but again no additional resources (machinery, labor, raw materials, etc.) will be needed to manufacture the commodity. If the price rises, it provides extra profit -- that is, money is transferred from consumers to producers, but no additional resources are used.

Economists distinguish such **transfer payments** from real resource or social costs. The distinction is important because if a regulation increases the social costs of production, society as a whole is poorer. However, a regulation that induces transfer payments but not resource costs makes someone in society poorer, but someone else richer by an equal amount. The society as a whole is neither poorer nor richer.

9.1.2 Characterizing CFC Reducing Technologies

The costs of CFC restrictions are estimated by identifying the costs of adjustments likely to be made by CFC users in response to the restrictions. As the availability of CFCs is reduced, industries and consumers will have increased incentive to conserve on the use of CFCs. As new methods of production which avoid using CFCs are discovered, social costs decrease.

To develop numerical estimates of social costs and transfer payments, data were gathered describing the production methods of each CFC-using industry. The major industries using CFCs are: mobile air conditioners; refrigeration; foam blowing; solvent cleaning; sterilization; and miscellaneous uses, which primarily include aerosols. Halons are primarily used in fire extinguishing applications. Using 1985 as the base period for the analysis, each of these industries was characterized according to its CFC consumption; CFC emissions; levels of output (e.g., metric tons of foam manufactured); and the stock of CFC-consuming equipment (e.g., number of mobile air conditioning units).[3]

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[2] For simplicity, this discussion assumes the tax does not decrease the amount of this commodity purchased by consumers.

[3] The engineering and other data gathered for this analysis are described in a series of technical addenda, found in Volume III of this RIA.

For this analysis, these industries were divided into 74 application categories that further differentiate the types of products made with CFCs. (A list of these applications is provided in Appendix I and each application is discussed in Volume III of this RIA.)

For each of these applications, it was necessary to characterize all possible responses to reduce the use of CFCs. For the 74 applications, nearly 900 possible responses were identified. Of these responses, about 350 were excluded from further analysis because of reasons relating to risk/toxicity, technical feasibility, and cost. For the remaining responses (approximately 550), estimates were prepared concerning the cost of the response and its possible reduction in annual CFC use.

Each response was characterized in terms of its capital costs; variable costs, such as materials, labor, and energy expenses; and nonrecurring costs, such as research and development. For example, one possible response to CFC regulation is the substitution of alternative materials for insulating foams that are manufactured with CFCs. Because these alternative materials may be less efficient insulators, additional costs were estimated to be incurred over the life of the alternative product. These costs were either the additional labor and materials costs necessary to install insulation of equivalent energy efficiency or the additional energy costs resulting from the use of less efficient insulation.

The potential implementation of response actions was estimated based on analyses of the expected availability of each alternative technology. Not all chemical substitutes, product substitutes, or process changes are available immediately; many require research and development before becoming commercially available. Therefore, the ability of any action to reduce CFC use was constrained based on estimates of:

- Starting Date: the time at which the action is first available to be adopted by at least one producer;

- Penetration Time: the time which the action would take to be evaluated by the entire industry and adopted by all producers for whom it would be cost effective given estimated CFC prices; and

- Reduction Potential: the amount by which CFC use can be reduced when all producers who wish to take the action have in fact adopted it.

Each of these factors is important. Some responses may be relatively easy to adopt but able to achieve only small reductions in CFC use. These types of responses are typically changes in existing production procedures. For example, CFC emissions can be controlled through the use of covers on the tanks used in solvent cleaning or through better production scheduling in running sterilization chambers. These types of responses often provide inexpensive short term methods to reduce CFC use but are limited in achieving the larger reductions in use which may be necessary in the longer term.

Some responses which have a larger potential reduction may face a greater number of obstacles to their adoption. An example is the use of a chemical substitute which is non-ozone depleting, but would require the installation of new machinery. Any requirement for a substantial modification or replacement of existing equipment can be expected to delay the date at which producers would begin to adopt the response action and slow the rate at which it would penetrate throughout the industry. Such obstacles could exist even if the response is cheaper than current production methods. For example, it could be less expensive in the long run to install new capital equipment to use existing alternative solvents. However, firms may prefer to depreciate their existing equipment and continue use of CFCs for some period before switching to the new chemical.

Alternatively, some responses with a large reduction potential take a substantial time to achieve their maximum use. For example, mobile air conditioners may be converted to use FC-134a. Despite this conversion, older cars with existing air conditioners could possibly continue the use of CFC-12 throughout their lifetime, which could extend 10 to 15 years.

Another obstacle which could impede the implementation of some responses are risks associated with the new technology. For example, helium air conditioning may be a good alternative to CFC-12 in mobile air conditioners, but that is not certain because the technology is new and untested. Until uncertainties about its use are resolved, helium air conditioning is unlikely to penetrate the market.

9.1.3 Methods Used to Estimate Costs

Based on the engineering data, the CFC or halon price increases necessary to trigger one or more of these responses were estimated. Trigger prices were estimated based on a calculation of the annual cost of each response as seen by industrial users of CFCs. Trigger prices were estimated using discounted cash flow analysis. This analysis: (1) specified the magnitude and timing of pre-tax capital and operating costs that would be incurred; (2) calculated after-tax cash flows to the industry (including reductions in taxes associated with depreciation of capital equipment); (3) discounted the stream of after-tax cash flows using the private cost of capital to compute a present value private cost; and (4) converted the present value private cost into an equivalent annual stream of costs, again using the private cost of capital as a discount rate. The resulting annualized costs were divided by the total kilogram reduction in CFC use that can be achieved to produce an annualized private cost per kilogram of CFC use avoided.[4]

Firms were assumed to choose the production technology that minimizes their production costs. As CFC prices rise in response to supply restrictions, firms were assumed to compare the costs of paying more for CFCs to the costs of available chemical substitutes, product substitutes, and process changes. Options with a trigger price less than or equal to the price increases were simulated to be undertaken, subject to technical constraints identified in the engineering analysis. Estimates of trigger prices were used to determine the order in which these responses to CFC regulation would be taken.

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[4] Because this private annualized cost was computed on an after-tax basis, and CFC prices are observed in the economy on a before-tax basis, private annualized costs were divided by (1 - Tax Rate) so that CFC price increases and trigger prices would be comparable (i.e., each on a before-tax basis).

Next, the responses available to each industry were combined into compatible sets of options. To specify a set of compatible responses, the full list of possible responses was evaluated, and a subset of responses was chosen based on the responses most likely to be implemented. During this step, many of the possible responses described in Volume III were eliminated from the cost analysis.[5] For example, some applications may have two possible chemical substitutes, where only one would realistically be used. The resulting set of responses, totalling about 300 actions, includes only those considered technically feasible and internally consistent. Appendix J lists the options simulated to be undertaken in the analysis and the CFC reductions associated with each.

As a final step in the analysis, the responses simulated to be adopted across industries in a particular scenario were combined. Since the responses affect different CFC compounds, the reductions in CFC use were weighted to reflect the relative ozone-depletion potential of the various CFCs (e.g., under the regulation CFC-11 has an ozone-depletion potential of one, but CFC-113 has an ozone-depletion potential of 0.80). This combined list of response actions is sorted by trigger prices to determine the order in which each action would be taken. Given any required level of total weighted CFC reduction, the list defines the trigger price necessary to initiate all sufficient responses to achieve the reduction. This trigger price is the estimated CFC price change resulting from CFC regulation.

9.2 THE CASE 1 SCENARIO

This section presents estimates of the costs of CFC regulation for a scenario that characterizes the adoption of CFC conserving methods by U. S. industry. This section analyzes an initial case, labeled Case 1 for discussion purposes, in which industry responses to CFC regulation are characterized by slow starts, slow penetration rates, and small reductions. Later sections examine the implications of accelerated responses in five major CFC-using industries and the impacts of delays in the introduction of substitute chemicals.

In Case 1, industry responses start slowly, are implemented slowly, and achieve small reductions relative to the engineering data developed and displayed in Volume III of this RIA. These engineering data present best estimates of the potential implementation of response actions. All cost scenarios analyzed in this chapter are based on variations in these engineering estimates.

The analysis in this and the following sections concentrates on four principal effects of CFC regulation: increases in CFC and halon prices; social costs; transfer payments; and the reductions in CFC use in individual industrial sectors. As noted above, social costs capture the increased resources necessary to replace the use of CFCs. Transfer payments capture the increased prices paid by consumers for the remaining CFCs. Industry reductions are measured by comparing CFC use after regulation to the baseline use which was estimated to have occurred if CFC use had not been regulated.

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[5] About 250 of the 550 responses remaining after the initial screening were eliminated at this point.

The cost scenarios presented in this chapter reflect varying assumptions about the technical feasibility of possible industry responses. Industry responses that are included in some cost scenarios are excluded from others. However, response actions that are known to exist today (e.g., HCFC-22 in packaging foams) are included in all cost scenarios. Exhibit 9-1 lists the possible industry responses that are common to all cost scenarios. Not all of the responses shown are simulated; whether particular responses are implemented depends on the extent of the CFC price rise.

9.2.1 Description of Case 1 Scenario

Although difficult to quantify, delays in the development and adoption of any of the responses that reduce CFC use are possible. The nature of the research and development process, i.e., solving previously unsolved problems, emphasizes the uncertainty of predicting its completion. Furthermore, even when developed and commercially available, technologies may not be adopted by producers and consumers.

Therefore, to capture some of the likely "stickiness" present when converting from one set of manufacturing technologies to another, the initial cost scenario assumes that for many responses available to reduce CFC use:

- industries delay the start of many of their responses;
- the pace at which the use of these responses spreads through an industry is relatively slow compared to an "ideal" engineering response; and
- the maximum reduction of CFCs achieved is relatively small.

We label this cost scenario, Case 1. The basic rationale behind its development is that some of the industry hesitates to commit to specific action until CFC prices rise in response to regulation, not perceiving the effect that their joint inaction could have on raising prices. In this case, the effects on the economy of CFC regulation are magnified. The Case 1 scenario serves as a reference for comparison against which the impacts of faster implementation of these responses, as assumed in later cases, can be measured. It should not be viewed as the most likely option but as one against which others can be compared.

Exhibit 9-2 lists the assumptions made in Case 1 about starting dates, penetration times, and reduction potentials for selected methods of reducing CFC use. The exhibit shows reduction potentials for 1998. By that year, most of the responses are simulated to have reached their maximum level of implementation. Although each of the responses listed in this exhibit is available for use by its industry, whether it is actually implemented in any year is determined by the extent of the CFC price rise.[6] Before a response action is simulated to be undertaken, the price rise must equal or exceed the estimated trigger price of the action.

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[6] Appendix J provides a complete listing of all response actions simulated to be undertaken in some of the key years of the simulation.

EXHIBIT 9-1

MAJOR CONTROLS AVAILABLE IN ALL COST SCENARIOS

Application	Response Actions
Aerosols	Carbon Dioxide[a/] HCFC-22[a/]
Flexible PU Foam - Molded	Water-Blown Processes[a/] HCFC-141b[a/] HCFC-123[a/]
Flexible PU Foam - Slabstock	Modified Polyol Systems[a/] HCFC-141b[a/] HCFC-123
Mobile Air Conditioners	FC-134a[a/] Recovery at Service - Large Shops Recovery at Service - Medium Shops Recovery at Service - Small Shops Quality Engineering
Rigid Insulating Foams	Product Substitutes[a/] HCFC-141b HCFC-123 CFC-11/22 (in poured applications) FC-134a
Packaging Foams	HCFC-22[a/] Product Substitutes[a/]
Refrigeration	Shift to other currently available systems (e.g., HCFC-22 chillers)[a/] HCFC-123 FC-134a CFC-502 HCFC-22[a/]
Solvents	Terpenes and Aqueous Cleaning[a/] Reclaim Waste Solvent CFC-113 Azeotropes[a/] Improved Housekeeping Practices Methyl Chloroform Carbon Adsorption and Drying Tunnel (Conveyorized Vapor Degreasing)[a/] Petroleum (Cold Cleaning)[a/] Refrigerated Freeboard Chiller (Open Top Vapor Degreasing) CFC-113 Automatic Cover (Open Top Vapor Degreasing)

EXHIBIT 9-1 (continued)

MAJOR CONTROLS AVAILABLE IN ALL COST SCENARIOS

Application	Response Actions
	CFC-113 Automatic Hoist (Open Top Vapor Degreasing)
Sterilization	Nitrogen Purge then Pure Ethylene Oxide Acid-Water Scrubber and Condensation/Reclamation[a/] FC-134a/Ethylene Oxide Blend[a/] Contract Out[a/] Disposables (in Hospitals)[a/]

Note: a/ Reduction potential, implementation time, or starting date for these responses vary among different cost scenarios. All other responses listed here are available and remain the same in all cost scenarios. The chemical substitutes HCFC-123, FC-134a, and HCFC-141b are varied separately in Section 9.5.

EXHIBIT 9-2

CASE 1 ASSUMPTIONS ABOUT TECHNICAL FEASIBILITY OF CFC-CONSERVING TECHNOLOGIES

Sector/ Technology	Start Date a/	Penetration Time b/	Use-Specific Reduction Potential in 1998 c/
Mobile Air Conditioning			
Recovery at Service-Large Shops	1989	3	6.5%
Recovery at Service-Medium Shops	d/	d/	d/
Recovery at Service-Small Shops	d/	d/	d/
DME	d/	d/	d/
Solvents			
Terpenes and Aqueous Cleaning	1988	5	24%
CFC-113 Azeotropes	1989	4	7% e/
Housekeeping	1989	1	5-12% f/
HCFC-123	d/	d/	d/
Hospital Sterilization			
Disposables	1988	9	22%
Alternate Blends	1988	5	7%
Contracting Out	1988	9	4%
Steam Cleaning	d/	d/	d/
Refrigeration			
Recovery at Service	1988	5	3-11%
Recovery at Rework	1988	3	2%
FC-134a	1992	10-21 f/	5-53% f/
Foam Insulation			
Product Substitutes	1990	5-10 f/	20-40% f/
HCFC-123	1992	3	27-50% f/
HCFC-141b	1991	3	30-50% f/
Flexible Foam-Molded			
Water-Blown Processes	1988	3	41%
HCFC-141b	1991	9	18%
Flexible Foam-Slabstock			
HCFC-123	1992	9	26%
HCFC-141b	1991	9	18%
Foam Packaging			
Product Substitutes	1988	3-5 f/	10-51% f/
HCFC-22	1988	2	0-90% f/

EXHIBIT 9-2 (Continued)

CASE 1 ASSUMPTIONS ABOUT TECHNICAL FEASIBILITY OF CFC-CONSERVING TECHNOLOGIES

Sector/ Technology	Start Date a/	Penetration Time b/	Use-Specific Reduction Potential in 1998 c/
Aerosols			
Carbon Dioxide	1988	4	25%
HCFC-22 Blends	1988	2	25%

Notes:

a/ Year in which technology initially becomes available for commercial use.

b/ Years until maximum use of technology is achieved.

c/ Possible reduction in CFC use for the sector in 1998 for this control only. Some technologies can only control a small percentage of an application's use. Thus, a number smaller than 100% may not indicate low penetration but may indicate that the control can only eliminate a small percentage of the application's use.

d/ Case 1 assumes that no CFC reductions are possible through this technology.

e/ Azeotrope consists of 70 percent CFC-113. The reduction shown reflects the 30 percent reduction in CFC-113 achieved when using the azeotrope and the fraction of the solvent sector adopting the azeotropes.

f/ Ranges reflect differences in assumptions about technical feasibility across subsectors within this sector (e.g., in some subsectors the reductions are lower than others). Within particular subsectors, the reductions do not exceed 100 percent.

Other assumptions in addition to those about industry responses are needed to analyze costs of CFC regulation. For all the analyses presented in this chapter, it is assumed that:

- baseline use grows according to the middle growth assumptions described in Chapter 4;
- the rate of social discount is two percent[7]; and
- the rate of private discount is six percent.

The implications of alternative assumptions about baseline use and discount rates are presented in the sensitivity cases in Chapter 10. Additionally, for all analyses except those presented in Exhibit 9-15 below, it is assumed that the chemicals covered by regulation and the schedule of reductions imposed are those set out in the CFC 50%/Halon Freeze Option, the Protocol Option, described in Chapter 5.

Using these assumptions, Exhibit 9-3 displays the estimated price increases for CFCs and halons. The prices shown in this exhibit are weighted for the ozone depletion potential of each chemical as stipulated in the Montreal Protocol. Thus the estimated increase for CFC-11, which has an ozone depletion potential of 1, equals the values shown in the table, but the estimated increase for CFC-113, which has an ozone depletion potential of .8, would be 80 percent of the reported CFC increases. Prices are shown in 1985 constant dollars and thus do not reflect any inflation that might occur during the period.

The increase in CFC prices in 1989, the year the freeze is initially implemented, is estimated to exceed $6 per kilogram -- increasing the price of CFCs more than four-fold. The price increase remains high through 1990 and drops significantly in 1991 as many of the industry responses listed in Exhibit 9-2 begin to penetrate and achieve reductions in CFC use. The price increases again when a 20 percent reduction in CFC use is imposed in 1993. Over the longer term when CFC use is reduced to half its 1986 levels (1998 and beyond), the price of CFCs is estimated appears to depend on the cost of replacing CFC-12 with FC-134a in mobile air conditioning uses -- $5.48 per kilogram of CFC-12 replaced.

Exhibit 9-3 also shows the pattern of halon price increases. The price of halons increases slightly immediately upon the imposition of the freeze in 1992 and continues at this level through the year 2010. Over the longer term, the price is projected to increase by $2.75 per kilogram (weighted for ozone-depleting potential). This estimate assumes that replacement chemicals will be developed.

Exhibit 9-4 shows the estimated social costs and transfer payments for the Case 1 scenario. These estimates are for the United States only. No data on

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[7] The rate of social discount is the interest rate at which society translates a dollar amount into its present value. Thus, using a two percent discount rate, society would value $1.02 next year as equal to $1.00 today. The private rate of discount is the interest rate at which private citizens make the same translation. Appendix H provides a more complete description of these concepts.

EXHIBIT 9-3

PROJECTED CFC AND HALON PRICE INCREASES FOR CASE 1 COST SCENARIO a/ (in 1985 dollars)

	--- Increases in the Prices of ---	
	CFCs	Halons
1989	6.69	0.00
1990	5.32	0.00
1991	1.84	0.00
1992	1.60	0.49
1993	3.93	0.49
1994	3.77	0.49
1995	3.77	0.49
1996	3.77	0.49
1997	3.77	0.49
1998	5.48	0.49
1999	5.48	0.49
2000	5.48	0.49
2010	5.48	2.75
2025	5.48	2.75
2050	5.48	2.75

Note: a/ The stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993 and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed growth in baseline use is the Middle Growth Case described in Chapter 4. Price increases are cited on a standardized "ozone-depleting equivalent" basis per kilogram.

EXHIBIT 9-4

SOCIAL COST AND TRANSFER PAYMENT ESTIMATES FOR THE CASE 1 COST SCENARIO [a/]
(in millions of 1985 dollars)

	Social Costs[b/]	Transfer Payments[c/]
Annual Values		
1989	47	2,030
1990	36	1,610
1991	40	552
1992	59	500
1993	183	981
1995	232	908
1998	707	868
2000	707	891
2025	1,240	938
2050	1,880	969
2075	1,880	969
2100	1,880	969
2165	1,880	969
Present Values		
1989-2000	2,730	7,280
1989-2075	39,500	13,700
1989-2165	52,700	13,710

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs are discounted at a 2 percent rate of social discount.

c/ Transfer payments are discounted at a rate of 6 percent to reflect the opportunity cost of funds in the private sector.

possible industry responses in other countries were gathered for this analysis. Social costs and transfer payments are presented on an annual basis for 1989-2000 and for selected years thereafter. The present value of social costs and transfer payments are shown at the bottom of the exhibit for three time periods.The present value of social costs were calculated using an assumed social discount rate of 2 percent. For transfer payments a discount rate of 6 percent was used.

During the initial freeze on CFC use (1989-1992), annual transfer payments exceed annual social costs. Social costs are relatively low in these years because small reductions in CFC use are required to satisfy the freeze. Transfer payments are large, however, because (1) industry continues to use CFCs up to the amount allowed by the freeze (1986 levels), and (2) industry must pay more for the remaining CFCs they use. Exhibit 9-3 shows price increases of $6.69 and $5.32 in 1989 and 1990, a three- to four-fold increase in CFC prices.

After 1998, annual social costs begin to exceed transfer payments. The large increase in social costs results from the increasing levels of reductions required by regulation. Larger reductions are simulated because (1) baseline demand for products that would use CFCs is estimated to increase in the absence of regulation, and (2) the reductions required to meet the regulatory limits also increase. Thus, society must incur increasing amounts of capital and operating costs to achieve the required reductions. Annual social costs and transfer payments are constant after 2050 because, by assumption, CFC use in the absence of regulation is held fixed after that year.

For the three time periods, the results for social costs and transfer payments are divided into those incurred through the year 2000, through the year 2075, and through the year 2165. In all three cases, 1989 is the assumed beginning year. Through the year 2000, the present value of social costs are estimated to be $2.7 billion. Over longer time periods, the present value of social costs grows significantly--to nearly $40 billion by 2075. These results indicate that, even with the technical progress projected in the analysis, the regulation of CFCs forces society to commit additional resources to the production of goods currently produced with CFCs.[8]

In the short term, the present value of transfer payments is $7.3 billion. The increase in transfer payments over longer periods is much smaller, to $14 billion through 2075, with little change thereafter. Annual transfer payments are lower in the long term because fewer kilograms of CFCs are allowed to be produced after the 50 percent reduction limit is imposed in 1998.

The increase in CFC prices accompanying regulation induces each industrial sector to reduce its use of CFCs. Exhibit 9-5 displays the magnitude of these reductions. The reductions presented are relative to the level of use which would have occurred in the absence of regulation. Thus, the 2.17 percent reduction figure for mobile air conditioning in 1989 represents a 2.17 percent reduction from the amount of CFCs which would have been used in mobile air conditioning in 1989 if CFC prices had not increased.

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[8] Of course, technical options that were not included in the analysis may emerge in the future and reduce these costs substantially.

EXHIBIT 9-5

ESTIMATED REDUCTIONS IN CFC USE BY INDUSTRIAL SECTOR FOR THE CASE 1 COST SCENARIO a/

	1989	1993	1998
Total Reductions			
Mobile Air Conditioning	2.17%	8.50%	62.17%
Refrigeration	8.22%	23.02%	53.05%
Solvents	48.67%	62.32%	64.10%
Sterilization	20.80%	40.98%	93.07%
Flexible Foams	12.61%	25.82%	53.96%
Rigid Insulating Foams	7.44%	78.21%	95.95%
Rigid Packaging Foams	63.73%	88.66%	91.51%
Aerosols	40.00%	50.01%	50.01%
Other	5.49%	0.00%	22.84%

Notes: a/ Percentage reduction in CFC use relative to projected baseline use in each year. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4. The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992.

Reductions are not spread evenly among industries. In 1989, industries with many low cost alternatives to CFCs show the highest reductions. For example, the use of CFCs as solvents is reduced substantially by a switch by electronics users to aqueous and terpene cleaning. Thus, the actions of some of the large electronics firms that have announced CFC reduction programs lead to reductions in 1989. Similarly, the plans announced by the food packaging industry to switch to alternative chemicals lead to large reductions in CFC use. Other industries, such as mobile air conditioning and refrigeration, for which no "drop-in" chemical substitutes exist and which produce an essential service with few substitutes, experience small reductions.

Use of CFCs in various sectors decreases in 1993 and 1998 because more stringent reductions are imposed. Relative reductions across sectors also change. In 1993, rigid insulating foams start switching to the use of HCFC-141b and HCFC-123 as an alternative blowing agent and substantially reduce their use of CFC-11 and CFC-12. By 1998, both rigid foam sectors are estimated to have almost completely eliminated their use of fully halogenated CFCs by switching to alternative chemicals. Similar shifts to alternative chemicals (primarily FC-134a) by the refrigeration and mobile air conditioning sectors enables them to substantially decrease their use of CFCs by 1998.

9.3 EFFECTS OF IMPROVED RESPONSES IN INDIVIDUAL INDUSTRIES

Because of the importance of industries' responses to CFC regulation, analysis of the available responses in specific sectors is useful. For this purpose, this section identifies five key industries using CFCs and analyzes the implications of accelerated action in each. The five industries identified are:

- Mobile Air Conditioner Servicing (Case 1A)
- Solvents (Case 1B)
- Hospitals (Case 1C)
- Mobile Air Conditioner Manufacturing (Case 1D)
- Aerosols (Case 1E)

This section examines impacts of improved responses--earlier start dates, faster penetrations, and larger achieved reductions--in each of these sectors. A common reference for comparison of the improved responses is used: the Case 1 scenario. The analysis for each industry is presented in a separate subsection.

The analysis begins by describing in the text (in a boxed insert) the manner in which the start date, penetration time, and reduction potential varies from the Case 1 scenario. Then, an exhibit provides data on the effects of the altered assumptions on social costs, transfer payments, CFC price increases, and reductions by industry. The analysis of each industry is assigned a case designation (e.g., Case 1A for mobile air conditioner servicing), shown above.

Changes in the responses of halon users are not analyzed in the exhibits to follow. Because there are few responses available to reduce halon use and the stringency cases analyzed call for only a freeze on halon use, the remaining analyses concentrate on CFC markets only. In all these cases, halon prices are simulated to be identical to those displayed in Exhibit 9-3 and are not shown. The costs of achieving a freeze on halon use are, however, included in all social cost estimates.

9.3.1 Case 1A: Enhanced Recovery of CFCs in Mobile Air Conditioners

Mobile air conditioners, which cool the passenger compartments of automobiles, trucks, and buses, are the largest single use of CFCs in the United States, accounting for an estimated 19 percent of total CFC use. CFC-12 is used as a refrigerant agent to install the initial refrigerant charge in new motor vehicles and to replace the charge that is lost during vehicle operation and service.

Because most CFC use in mobile air conditioners goes to replace operating and servicing losses, recovery and recycling of CFCs from mobile air conditioners is an important method of conservation. When mobile air conditioners are serviced, either to repair the unit or to replace lost refrigerant, the remaining refrigerant charge often is vented into the atmosphere. Also, small cans of CFC refrigerant often are used to refill the refrigerant charge, sometimes leading to spillage and wastage of unused amounts in the cans.

Recovery and recycling equipment could be used to prevent the loss of CFC-12 when mobile air conditioners are serviced. With this equipment, the CFC refrigerant would be (1) withdrawn during servicing of the mobile air conditioners, (2) purified, and (3) returned to the mobile air conditioners or sold. Recovery and recycling both avoids the venting of the refrigerant charge and eliminates the need to use small cans during servicing.

In Case 1 above, it was assumed that these recovery responses occurred only in large automobile servicing centers, such as those servicing large fleets of automobiles. To perform the recovery, servicing centers would be required to purchase recovery equipment. In Case 1, only large shops were assumed to be able to afford or obtain access to the equipment. This limited response to recycling reduces the use of CFCs in mobile air conditioning by 6.5 percent when fully adopted by all such shops (after a three year penetration period.)

The box below shows, in contrast to Case 1, an alternative set of responses in which recovery and recycling equipment is available for use in all automobile service shops. The wider adoption of recovery equipment could eventually reduce the use of CFCs in mobile air conditioning by an estimated 32.7 percent.

The improved implementation of recovery and recycling equipment in Case 1A affects the opportunities for reducing CFC consumption from other possible responses to CFC regulation. As shown in the box below, FC-134a, a possible long-term chemical substitute for CFC-12 in mobile air conditioners, is simulated to be available to reduce a smaller portion of CFC use in Case 1A than in Case 1. The difference is accounted for by the larger reductions possible from recovery at service, which shrinks the reductions available for FC-134a in Case 1A.

Several steps would be required before the widespread implementation of recovery and recycling in mobile air conditioners could occur. In particular:

- Automobile manufacturers must allow continued warranty coverage of mobile air conditioners that are refilled with recycled CFC-12 refrigerant.

ASSUMED CHANGES IN START DATE, PENETRATION TIMES, AND REDUCTION POTENTIAL FOR THE MOBILE AIR CONDITIONER SERVICING CASE

	Start Date	Penetration Time	Use-Specific Reduction Potential in 1998
Case 1			
Recovery at Service - Large Shops	1989	3	6.5%
Recovery at Service - Medium Shops	a/	a/	a/
Recovery at Service - Small Shops	a/	a/	a/
Quality Engineering	1992	10	7.0%
FC-134a	1992	12	48.5%
		Total =	62.0%
Case 1A: MAC Servicing Case			
Recovery at Service - Large Shops	1989	3	6.5%
Recovery at Service - Medium Shops	1989	3	19.2%
Recovery at Service - Small Shops	1989	3	7.0%
Quality Engineering	1992	10	7.0%
FC-134a	1992	12	33.5%
		Total =	73.2%

a/ Case 1 assumes that no CFC reductions are possible through this technology.

- Mobile air conditioner servicemen must be trained to operate the recovery equipment.

- An industry testing program must be completed that determines the necessary purity of recycled refrigerant.

- CFC recovery equipment must be readily available and accepted by most mobile air conditioner service shops (including medium-sized and small shops), thus avoiding the use of CFC-12 to recharge mobile air conditioners and eliminating wastage of CFC-12 associated with the use of small recharge cans.

The availability of options to recycle CFC-12 from mobile air conditioners does not imply these actions would be taken in all cases. The cost of recycling equipment could make the use of this option prohibitively expensive for some shops that would use this equipment only sporadically. Thus, whether accelerated implementation occurs depends on how the recharging business evolves. If larger shops capture a larger portion of the business, or smaller shops can purchase lower priced equipment, then more rapid penetration is likely.

Exhibit 9-6 shows the results of accelerated action by the mobile air conditioner servicing sector in recycling CFCs. CFC prices are reduced by $2.20 in 1989 and $0.83 in 1990. Social costs are reduced slightly in the short term and by $3.4 billion through 2075. Transfer payments are reduced by $774 million through the year 2000.

The enhanced recovery of CFCs in mobile air conditioners increases the estimated reduction in CFC use in this sector from 2.17 percent to 8.56 percent in 1989. Because of this larger reduction, other industrial sectors are able to use more CFCs, i.e., must achieve much smaller reductions. Although not shown in Exhibit 9-6, increased reductions in CFC use due to enhanced recycling are even greater in later years, providing all other industrial sectors with greater access to CFCs.

9.3.2 Case 1B: Enhanced Conservation in Solvent Uses

Solvent cleaning uses various chemicals, including CFC-113, to remove contaminants from the surfaces of manufactured parts. Electronics components and metal parts account for most of the CFC-113 usage in solvent cleaning, although many other products and processes use CFC-113 for this purpose.

CFC-113 is used in different solvent cleaning processes. The major processes are:

- cold cleaning, in which electronic components or metal parts are immersed in, sprayed, or wiped with CFC-113 at or above room temperature; and

- vapor degreasing, a process that uses hot CFC-113 vapor.

Several alternatives to CFC-113 exist in both solvent processes.

In Case 1B, costs are evaluated for the improved implementation of three possible responses available for conserving CFCs in solvent uses:

- Substitution of a CFC-113 azeotrope for the pure CFC-113 currently used as a solvent. CFC-113 azeotropes are mixtures of CFC-113 with other compounds that are not ozone depleting. CFC-113 azeotropes are expected to cost the same as pure CFC-113 solvent and to be equally, and possibly more, effective as a solvent.

- Improved housekeeping procedures. Housekeeping practices, such as inventory control and careful handling of CFCs to prevent spillage, are expected to provide a low-cost means for solvent users to conserve on some CFC-113 consumption.

- Terpene- and aqueous-based cleaning. A major electronics manufacturer recently announced that terpene-based cleaning methods could replace up to one-third of the CFCs it uses in electronics manufacturing. Aqueous cleaning offers additional opportunities for replacing CFC-113 solvent cleaning.

EXHIBIT 9-6

ANALYSIS OF THE IMPACTS OF ENHANCED RECOVERY DURING THE SERVICING OF MOBILE AIR CONDITIONERS (CASE 1A) a/

	Case 1	Case 1A	Difference (Savings)
Social Costs b/			
1989-2000	2,730	2,580	(150)
1989-2075	39,500	36,100	(3,400)
Transfer Payments c/			
1989-2000	7,280	6,540	(740)
1989-2075	13,600	13,100	(500) d/
CFC Price Increases e/			
1989	6.69	4.49	(2.20)
1990	5.32	4.49	(0.83)
1991	1.84	1.84	0.00
1992	1.60	1.60	0.00
1993	3.93	3.93	0.00
1995	3.77	3.77	0.00
1998	5.48	5.48	0.00
2000	5.48	5.48	0.00

Notes a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992 The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ The model used for this analysis predicts that transfer payments during 2001-2075 will be slightly larger in Case 1A than those in Case 1 (i.e , 500 is less than 740). This anomalous result occurs because the model assumes all responses with trigger prices up to and equalling the reported CFC price increases are fully implemented, when full implementation is not required to achieve a given reduction in CFC use. During the 2001-2075 period, actual reductions in Case 1A slightly exceed those in Case 1 This induces a corresponding reduction in estimated transfer payments in Case 1A.

e/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

As shown in the box below, the response of the solvent sector to CFC regulation could be improved if greater reductions could be achieved from each of these response actions.[9] In addition, a potential CFC substitute, HCFC-123, could possibly be employed as a solvent.

ASSUMED CHANGES IN START DATE, PENETRATION TIMES, AND REDUCTION POTENTIAL FOR RESPONSES IN SOLVENT SECTOR

	Start Date	Penetration Time	Use-Specific Reduction Potential in 1998
Case 1			
Terpenes and Aqueous Cleaning	1988	5	24%
CFC-113 Azeotropes	1989	4	7% a/
Housekeeping	1989	1	6%
HCFC-123	b/	b/	b/
Carbon Adsorption and Drying Tunnel	1992	3	16%
Reclaim Waste Solvent	1988	2	2%
Methyl Chloroform	1988	2	7%
		Total =	62%
Case 1B: Solvent Case			
Terpenes and Aqueous Cleaning	1988	5	50%
CFC-113 Azeotropes	1989	4	10% a/
Housekeeping	1989	1	14%
HCFC-123	1992	10	2%
Carbon Adsorption and Drying Tunnel	1988	2	10%
Reclaim Waste Solvent	1988	2	1%
Methyl Chloroform	1988	2	3%
		Total =	85%

a/ Azeotrope consists of 70 percent CFC-113. The reduction shown reflects the 30 percent reduction of CFC-113 achieved when using the azeotrope and the fraction of the solvent sector adopting the azeotrope.

b/ Case 1 assumes that no CFC reductions are possible through this technology.

The improved implementation of these responses changes the simulated mix of reductions available from other response actions in the solvents sector. By increasing the reductions possible for terpenes and aqueous cleaning, CFC-113 azeotropes, and housekeeping practices, the reductions possible from other

[9] For purposes of illustration, the box shows Case 1 and Case 1B for one solvent application of CFC-113, Conveyorized Vapor Degreasing.

responses are lowered in Case 1B. These other responses, shown in the box below, are carbon adsorption, reclaiming waste solvent, and methyl chloroform (a possible chemical substitute).

To achieve the responses assumed in Case 1B:

- Firms within the solvents sector must shift 50 percent of solvent cleaning operations to aqueous cleaning or terpene-based solvents by 1992; achieving this shift requires: (1) terpene-based solvents must be available in commercial quantities; (2) use-specific technology must be developed for aqueous cleaning equipment; (3) capital equipment must be purchased for aqueous cleaning; and (4) cost-effective methods for complying with state and local regulations on aqueous cleaning waste disposal must be developed.

- CFC-113 azeotropes must be available in commercially useful quantities and adopted by 33 percent of the CFC-113 solvent sector.

- Solvent users must improve housekeeping practices by adopting identified operating procedures that minimize wasted solvent and achieve immediate reductions in CFC-113 emissions.

Exhibit 9-7 shows impacts on costs of enhanced solvent conservation of CFCs. The rise in CFC prices is reduced by $4.74 in 1989 and $3.48 in 1990. Smaller reductions in CFC prices persist through 1997.

In the short term, accelerated response by the solvent sector reduces social costs by over $400 million. The effect on transfer payments is even greater--these increased payments by consumers are reduced by $2.3 billion. The longer term impacts of larger reductions in the solvent sector are an additional reduction in transfer payments of about $380 million.

The reductions in CFC use in the solvent sector in 1989 provide additional time for the refrigeration, flexible foam, aerosol, and other sectors to make a transition out of CFCs. The decrease in the simulated reductions in 1989 in the aerosol sector--from 40 percent to 15 percent--is particularly large.

Thus, faster and larger responses in the solvent sector lower the costs of meeting CFC restrictions in the short term. CFC prices are substantially reduced in 1989 and 1990 and transfer payments decrease by over $2.3 billion. Over the longer term, when many other responses are available, particularly the use of FC-134a in mobile air conditioners, CFC conservation in the solvent sector has a lesser impact on social costs.

9.3.3 Case 1C: Enhanced Conservation in Hospital Sterilization Uses

Hospital sterilization is another important use of CFCs. CFC-12 is used in a gas mixture to sterilize surgical instruments and medical items. Gas sterilization involves placing the instruments and items into specially designed chambers and exposing them to a sterilant gas under pressure. In the gas mixture, ethylene oxide gas is the active ingredient, and CFC-12 is an inert ingredient that dilutes the mixture's flammability.

EXHIBIT 9-7

ANALYSIS OF THE IMPACTS OF ACCELERATED RESPONSES IN THE SOLVENT SECTOR (CASE 1B) a/

	Case 1	Case 1B	Difference (Savings)
Social Costs b/			
1989-2000	2,730	2,310	(420)
1989-2075	39,500	36,400	(3,100)
Transfer Payments c/			
1989-2000	7,280	4,960	(2,320)
1989-2075	13,600	10,900	(2,700)
CFC Price Increases d/			
1989	6.69	1.95	(4.74)
1990	5.32	1.84	(3.48)
1991	1.84	1.59	(0.25)
1992	1.60	1.55	(0.05)
1993	3.93	3.55	(0.38)
1995	3.77	3.55	(0.22)
1998	5.48	5.48	0.00
2000	5.48	5.48	0.00

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992 The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars

The four major methods of conserving CFC use in hospital sterilization considered in this analysis are:

- substitution of disposable medical items for those needing sterilization;
- use of steam cleaning instead of gas sterilization for equipment and instruments that are not heat- or moisture-sensitive;
- substitution of alternate blends such as a blend of ethylene oxide with carbon dioxide, which requires higher operating pressures; and
- use of centralized facilities ("Contract Out") in which pure ethylene oxide could be used as a sterilant.

The box below lists the assumptions used to analyze accelerated responses by the hospital sector in conserving CFCs. They involve modest use of steam cleaning; slightly greater use of centralized sterilization facilities; and faster penetration and increased use of disposable items and alternate blends.

ASSUMED CHANGES IN START DATE, PENETRATION TIMES, AND REDUCTION POTENTIAL FOR RESPONSES IN HOSPITAL SECTOR

	Start Date	Penetration Time	Use-Specific Reduction Potential in 1998
Case 1			
Disposables	1988	9	22%
Contract Out	1988	9	4%
Alternate Blends	1988	5	7%
Steam Cleaning	a/	a/	a/
FC-134a	1992	8	50%
		Total =	83%
Case 1C: Hospital Case			
Disposables	1988	4	35%
Contract Out	1988	9	5%
Alternate Blends	1988	3	35%
Steam Cleaning	1988	1	10%
FC-134a	1992	8	4%
		Total =	89%

a/ Case 1 assumes that no CFC reductions are possible through this technology.

Note that the acceleration of these responses lowers the simulated role of FC-134a in achieving CFC reductions in Case 1C.

The following steps are necessary for hospitals to implement the improved responses assumed in Case 1C:

- expanding the use of disposable medical equipment requires that more of these disposables must become commercially available at reasonable costs and the problems with waste disposal of these items be solved;

- shifting a portion of in-house sterilization to external contract facilities requires: (1) the development of off-site facilities (there is currently only one in U.S.); (2) analysis of financial costs and benefits of off-site sterilization; (3) acceptance by hospital administrators; and (4) overcoming a strong preference for in-house sterilization among central processing staff, surgeons and physicians, and other clinical staff;

- increasing the use of steam cleaning requires a review of instruments and medical items that are gas sterilized to determine those that can be steam sterilized; and

- using alternate blends requires solving technical problems (e.g., blends of ethylene oxide and carbon dioxide require better distribution lines and mixing technology).

Exhibit 9-8 compares the results of the Case 1 assumptions and altered assumptions of the responses for the hospital sector. Results are similar to those for the solvent sector. CFC prices are reduced substantially in 1989 and 1990, slightly from 1991 through 1997, and not at all after 1997. Social costs decrease by $300 million in the short term and by $1.6 billion in the long term. Transfer payments decrease by nearly $2 billion in both time periods. The increased reduction in sterilization uses allows four other sectors--refrigeration, solvents, flexible foams, and other uses--more time to achieve a transition away from CFCs.

9.3.4 Case 1D: Switch to DME in Mobile Air Conditioning Uses

As noted above, the largest single use of CFCs is in mobile air conditioners. An important short term response action by mobile air conditioner manufacturers would be to substitute a mixture of dimethyl ether (DME) and CFC-12 for the pure CFC-12 currently used. By replacing a portion of the CFC-12 with a non-ozone depleting compound, this action could eliminate about 20 percent of the amount of CFC-12 used in mobile air conditioning. DME mixtures may also be viable chemical substitutes in other refrigeration applications (e.g., commercial refrigeration).

In Case 1, the DME/CFC-12 mixture is assumed not to be a viable method for reducing CFC consumption. For Case 1D, this substitution could begin in 1989 and is assumed fully to penetrate the market over a period of three years. If viable, the DME mixture would be a "drop in" chemical substitute that could be used in existing mobile air conditioners. The major obstacle to substituting DME for some CFC-12 in mobile air conditioners uses is a decision by mobile air conditioner manufacturers to accept DME use under their equipment warranties. Studies on the toxicity and combustibility of using DME would also need to be completed.

EXHIBIT 9-8

ANALYSIS OF THE IMPACTS OF ACCELERATED RESPONSES IN THE HOSPITAL SECTOR (CASE 1C) a/

	Case 1	Case 1C	Difference (Savings)
Social Costs b/			
1989-2000	2,730	2,430	(300)
1989-2075	39,500	37,900	(1,600)
Transfer Payments c/			
1989-2000	7,280	5,300	(1,980)
1989-2075	13,600	11,700	(1,900) d/
CFC Price Increases e/			
1989	6.69	2.21	(4.48)
1990	5.32	1.95	(3.37)
1991	1.84	1.60	(0.24)
1992	1.60	1.59	(0.01)
1993	3.93	3.77	(0.16)
1995	3.77	3.55	(0.22)
1998	5.48	5.48	0.00
2000	5.48	5.48	0.00

Notes a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5 CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992 The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars

d/ The model used for this analysis predicts that transfer payments during 2001-2075 will be slightly larger in Case 1C than those in Case 1 (i e , 1,900 is less than 1,980) This anomalous result occurs because the model assumes all responses with trigger prices below or equal to the reported CFC price increases are fully implemented, when full implementation is not required to achieve a given reduction in CFC use. During the 2001-2075 period, actual reductions in Case 1C slightly exceed those in Case 1. This induces a corresponding reduction in estimated transfer payments in Case 1C.

e/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

ASSUMED CHANGES IN START DATE, PENETRATION TIMES, AND REDUCTION POTENTIAL FOR USE OF DME IN MOBILE AIR CONDITIONERS

	Start Date	Penetration Time	Use-Specific Reduction Potential in 1998
Case 1			
DME	a/	a/	a/
Case 1D: DME Case			
DME	1989	3	20%

a/ Case 1 assumes that no CFC reductions are possible through this technology.

Exhibit 9-9 shows the estimated impacts of the substitution of DME/CFC-12 for CFC-12 in mobile air conditioner uses. This substitution results in considerable decreases in social costs both in the short term and long term--$730 million and $6.1 billion, respectively. Transfer payments decrease by about $2.4 billion, with virtually all of this decrease occurring in the short term. CFC price increases are reduced sharply in 1989 and 1990 (by $4.48 and $3.48, respectively), and by lesser amounts through 1995. Thereafter, the DME substitution does not affect the price increase. The sectors benefitting from this DME substitution are the refrigeration, solvents, flexible foams, and other use sectors.

9.3.5 Case 1E: Switch to Chemical Substitutes in Aerosol Uses

The fifth, and final, industry-specific contrast to the Case 1 scenario relates to CFC use in aerosols. Although the use of CFCs in most aerosols was banned by the United States in 1978, some uses in which the CFC is an essential ingredient of the aerosol were exempted from the ban. Examples of existing exemptions are uses in mining, aircraft operations, military applications, and pesticides. Also, uses in which CFCs are claimed as active ingredients, such as a foaming agent in novelty items, are allowed.

Two types of alternate blowing agents for these aerosols could substitute for the CFC-11 and CFC-12 currently in use: (1) carbon dioxide or (2) a blend of HCFC-22 and either DME or CFC-142b. In Case 1, both these substitutions were assumed to occur, but eventually to replace only half of the current CFC usage in aerosols. In Case 1E, it is assumed that these substitutions could eventually eliminate all usage of CFC-11 and CFC-12 in aerosols.[10]

[10] Note that the reductions from the two responses are additive.

EXHIBIT 9-9

ANALYSIS OF THE IMPACTS OF THE USE OF DME IN MOBILE AIR CONDITIONERS (CASE 1D) a/

	Case 1	Case 1D	Difference (Savings)
Social Costs b/			
1989-2000	2,730	2,000	(730)
1989-2075	39,500	33,400	(6,100)
Transfer Payments c/			
1989-2000	7,280	4,850	(2,430) d/
1989-2075	13,600	11,400	(2,200) d/
CFC Price Increases e/			
1989	6.69	2.21	(4.48)
1990	5.32	1.84	(3.48)
1991	1.84	0.88	(0.96)
1992	1.60	1.54	(0.06)
1993	3.93	2.92	(1.01)
1995	3.77	3.50	(0.27)
1998	5.48	5.48	0.00
2000	5.48	5.48	0.00

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5 CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992 The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ The model used for this analysis predicts that transfer payments during 2001-2075 will be slightly larger in Case 1D than those in Case 1 (i.e., 2,200 is less than 2,430). This anomalous result occurs because the model assumes all responses with trigger prices below or equal to the reported CFC price increases are fully implemented, when full implementation is not required to achieve a given reduction in CFC use. During the 2001-2075 period, actual reductions in Case 1D slightly exceed those in Case 1. This induces a corresponding reduction in estimated transfer payments in Case 1D.

e/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

ASSUMED CHANGES IN START DATE, PENETRATION TIMES, AND REDUCTION POTENTIAL FOR USE OF CHEMICAL SUBSTITUTES IN AEROSOLS

	Start Date	Penetration Time	Use-Specific Reduction Potential in 1998
Case 1			
Carbon Dioxide	1988	4	25%
HCFC-22 Blends	1988	2	25%
			Total = 50%
Case 1E: Aerosol Case			
Carbon Dioxide	1988	4	50%
HCFC-22 Blends	1988	4 a/	50%
			Total = 100%

a/ 25 percent reduction assumed in two years and 50 percent reduction assumed after four years.

Achieving this reduction in CFC use in aerosols would require several actions:

- a finding that HCFC-22 blends are not toxic in areas of substantial human exposure (e.g., the use of CFC-11 as an insecticide propellant);
- an agreement between EPA and the Department of Defense to replace essential military uses of aerosols with alternate blends;
- a review of those aerosol uses exempted from the 1978 ban to determine whether these exemptions should be continued;
- the development of higher pressure cans to utilize the HCFC-22 blends; and
- the refinement of spray can technology so that the use of carbon dioxide produces a uniform spray.

Exhibit 9-10 shows the results for Case 1E. Price decreases again occur primarily in 1989 and 1990. Social costs decrease by $260 million over 1989-2000 and by $2.5 billion over the long term. Transfer payments decline by about $1.2 billion. The accelerated implementation of chemical substitutes in the aerosols sector lowers the size of the reductions in the solvents and flexible foams sectors.

EXHIBIT 9-10

ANALYSIS OF THE IMPACTS OF THE USE OF CHEMICAL SUBSTITUTES IN THE AEROSOL SECTOR (CASE 1E) a/

	Case 1	Case 1E	Difference (Savings)
Social Costs b/			
1989-2000	2,730	2,470	(260)
1989-2075	39,500	37,000	(2,500)
Transfer Payments c/			
1989-2000	7,280	6,120	(1,160)
1989-2075	13,600	12,600	(1,000) d/
CFC Price Increases e/			
1989	6.69	5.32	(1.37)
1990	5.32	2.21	(3.11)
1991	1.84	1.84	(0.00)
1992	1.60	1.59	(0.01)
1993	3.93	3.70	(0.23)
1995	3.77	3.55	(0.22)
1998	5.48	5.48	0.00
2000	5.48	5.48	0.00

Notes a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5 CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ The model used for this analysis predicts that transfer payments during 2001-2075 will be slightly larger with trigger prices below or equal to the reported CFC price increases than those in Case 1 (i.e., 1,000 is less than 1,160). This anomalous result occurs because the model assumes all responses with trigger prices below or equal to the reported CFC price increases are fully implemented, when full implementation is not required to achieve a given reduction in CFC use. During the 2001-2075 period, actual reductions in Case 1E slightly exceed those in Case 1. This induces a corresponding reduction in estimated transfer payments in Case 1E.

e/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

9.3.6 Effects of Combined Action by Industry

Individually, improved responses in each of the five industries analyzed above lower the magnitude of social costs and transfer payments incurred and lessens the reductions simulated in other industries. Collective action by two or more of these industries further reduces the costs of CFC regulation. Exhibit 9-11 shows the results of such joint actions. The first column of the exhibit repeats the Case 1 results first displayed in Exhibits 9-3 through 9-5. The second column shows the results of the Case 1 scenario plus accelerated responses by the mobile air conditioner servicing sector and the solvent sector (Case 1A+B). The following columns show the impacts of successively adding accelerated responses in each of the other three sectors. Thus, the last column of the exhibit (on a following page) shows the impacts of accelerated responses in all five sectors (Case 1A+B+C+D+E).

As expected, the savings in CFC prices, social costs, and transfer payments of joint action exceed the savings when responses are limited to a single sector. If only the mobile air conditioning service sector and the solvent sector were to accelerate their responses (Case 1A+B), social costs, which are $2.7 billion between 1989-2000 in Case 1, decrease by $600 million to $2.12 billion. The addition of accelerated responses in the hospital sector (Case 1A+B+C) decreases social costs by another $150 million to $1.97 billion. The addition of the use of DME in mobile air conditioners decreases social costs by another $550 million. Finally, the addition of chemical substitutes in aerosol uses decreases costs to $1.3 billion--about 49 percent of their Case 1 level. Note that the decreases in costs associated with each additional control depend on the order in which the controls are added. If mobile car air conditioner servicing was added last, rather than first, its incremental savings potentially would be smallest.

Transfer payments similarly are reduced by joint action. Compared to Case 1, transfer payments during 1989-2000 decline by $2.3 billion with accelerated responses in the mobile air conditioner servicing and solvents sectors (Case 1A+B). Another $230 million reduction in transfer payments occurs with the addition of accelerated responses in hospital sterilization (Case 1A+B+C). The addition of the use of DME in mobile air conditioners decreases transfer payments by another $2.1 billion. If all five sectors improve their responses, an overall decrease of $4.8 billion in transfer payments is achieved.

The impacts on long term social costs and transfer payments of combined industrial actions are similarly pronounced. If all five sectors accelerate their responses, long term social costs are reduced by 37 percent of their Case 1 levels. Long term transfer payments are reduced by 38 percent from their Case 1 levels.

The pattern of industry effects is, for the most part, as would be expected. For each case, reductions increase in sectors which accelerate their responses and decrease in all other sectors. Some exceptions to this rule do occur. For example, there are no increased reductions in the mobile air conditioning sector in the combined MAC Servicing/Solvent Case. Recycling CFCs in mobile air conditioning is estimated to be profitable in small and medium repair shops only if CFC prices rise by more than $4.49 per kilogram. Because the acceleration of responses in the solvent sector alone is sufficient to forestall any price increases of this magnitude, no additional CFC reductions beyond those assumed in Case 1 occur in the mobile air conditioning sector.

EXHIBIT 9-11

CFC PRICE INCREASE AND SOCIAL COST ESTIMATES: CASE 1 AND COMBINED INDUSTRY SCENARIOS a/

	Case 1	Case 1A+B	Case 1A+B+C
Social Costs b/			
1989-2000	2,730	2,120	1,970
1989-2075	39,500	33,300	31,800
Transfer Payments c/			
1989-2000	7,280	4,980	4,750
1989-2075	13,600	11,100	10,900
CFC Price Increases d/			
1989	6.69	1.95	1.55
1990	5.32	1.84	1.43
1991	1.84	1.59	1.54
1992	1.60	1.55	1.54
1993	3.93	3.55	3.52
1995	3.77	3.55	3.52
1998	5.48	5.48	5.48
2000	5.48	5.48	5.48

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

EXHIBIT 9-11 (continued)

CFC PRICE INCREASE AND SOCIAL COST ESTIMATES: CASE 1 AND COMBINED INDUSTRY SCENARIOS a/

	Case 1	Case 1A+B+C+D	Case 1A+B+C+D+E
Social Costs b/			
1989-2000	2,730	1,420	1,330
1989-2075	39,500	26,500	24,900
Transfer Payments c/			
1989-2000	7,280	2,640	2,450
1989-2075	13,600	8,440	7,950
CFC Price Increases d/			
1989	6.69	0.39	0.39
1990	5.32	0.39	0.39
1991	1.84	0.39	0.39
1992	1.60	0.39	0.39
1993	3.93	1.84	1.60
1995	3.77	1.84	1.84
1998	5.48	4.97	4.49
2000	5.48	4.50	4.49

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

9.3.7 Summary of Industry Analyses

Accelerated responses in any of these five industrial sectors would reduce the short term costs of CFC regulation. Exhibits 9-12 and 9-13 summarize the results of the industry analyses. The accelerated responses of individual sectors could reduce the rise in CFC prices by as much as $4.74 in the critical initial two years of CFC regulation. In turn, reductions in CFC prices would substantially reduce the transfer payments generated by CFC regulation. Comparisons of results between the five scenarios is complicated by differences in the size of and the nature of responses available within each CFC-using sector. However, under the assumptions described above, the largest gains in terms of reductions in social costs and transfer payments were obtained in Cases 1B and 1D in which accelerated actions by the solvent sector and a switch to DME/CFC-11 mixture in mobile air conditioners were assumed.

In the short term, accelerated response in any one industrial sector frees for use in other sectors CFCs which this sector might have used. Consequently, accelerated responses in any one of these five sectors results in lower CFC reductions in other sectors.

Over the longer term, these accelerated responses have a much smaller effect. The estimated price of CFCs in the years 1998 and beyond is not affected in any of the five cases. The price is determined by the cost of using FC-134a in mobile air conditioning systems and is insensitive to any of the accelerated responses examined here. Impacts of these accelerated responses on social costs, and transfer payments are also much smaller in the years after 1998 than in the years 1989 to 1997, during which adjustment to CFC regulation occurs.

9.4 THE CASE 2 SCENARIO

Given the finding above that accelerated responses in selected CFC-using industries substantially decrease social costs of CFC regulation, it is useful to examine the implications of accelerated responses throughout all sectors in the economy. Other major sectors using CFCs are the foam blowing and refrigeration industries. An alternate scenario to Case 1, labelled Case 2, assumes that all industries respond forcefully to implementing available CFC reduction techniques. Using the two sets of results, it is possible to gauge the range of social costs of CFC regulations.

Exhibit 9-14 shows the assumptions about industrial responses used for the analysis of Case 2.[11] (The responses listed are the same as those shown in Exhibit 9-2.) As before, each response is characterized according to its starting date, penetration time, and maximum reduction potential. Although each of the responses listed in the exhibit is available for use by industry, whether it is actually implemented in any year depends upon the extent of the CFC price rise. Section 9.3 discussed improved responses for five industries. Case 2 repeats these same assumptions. In addition, assumptions about improved responses for the foam blowing and refrigeration industries include:

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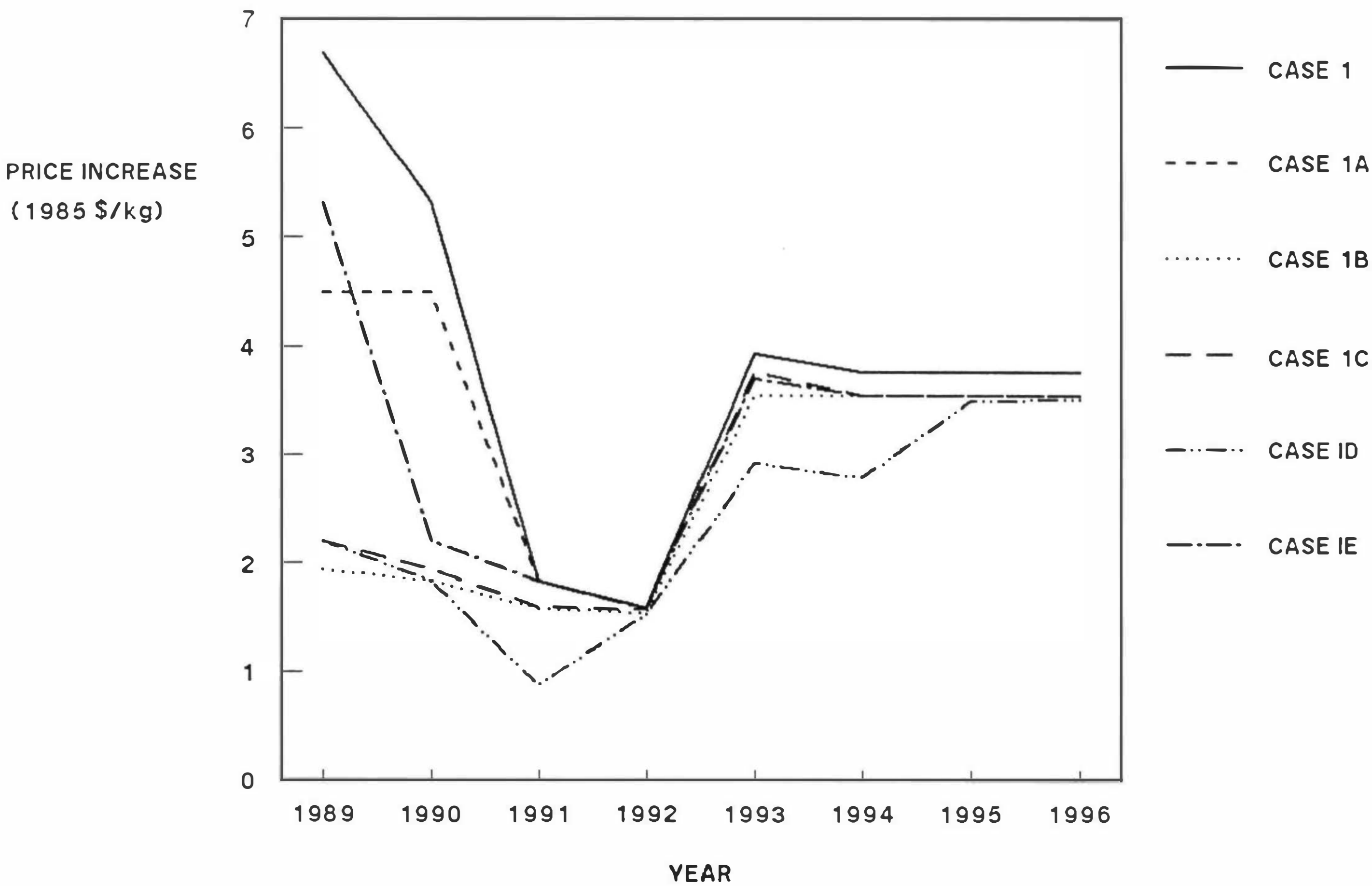
[11] Appendix J contains a listing of all responses simulated to be undertaken in both Case 1 and Case 2.

EXHIBIT 9-12

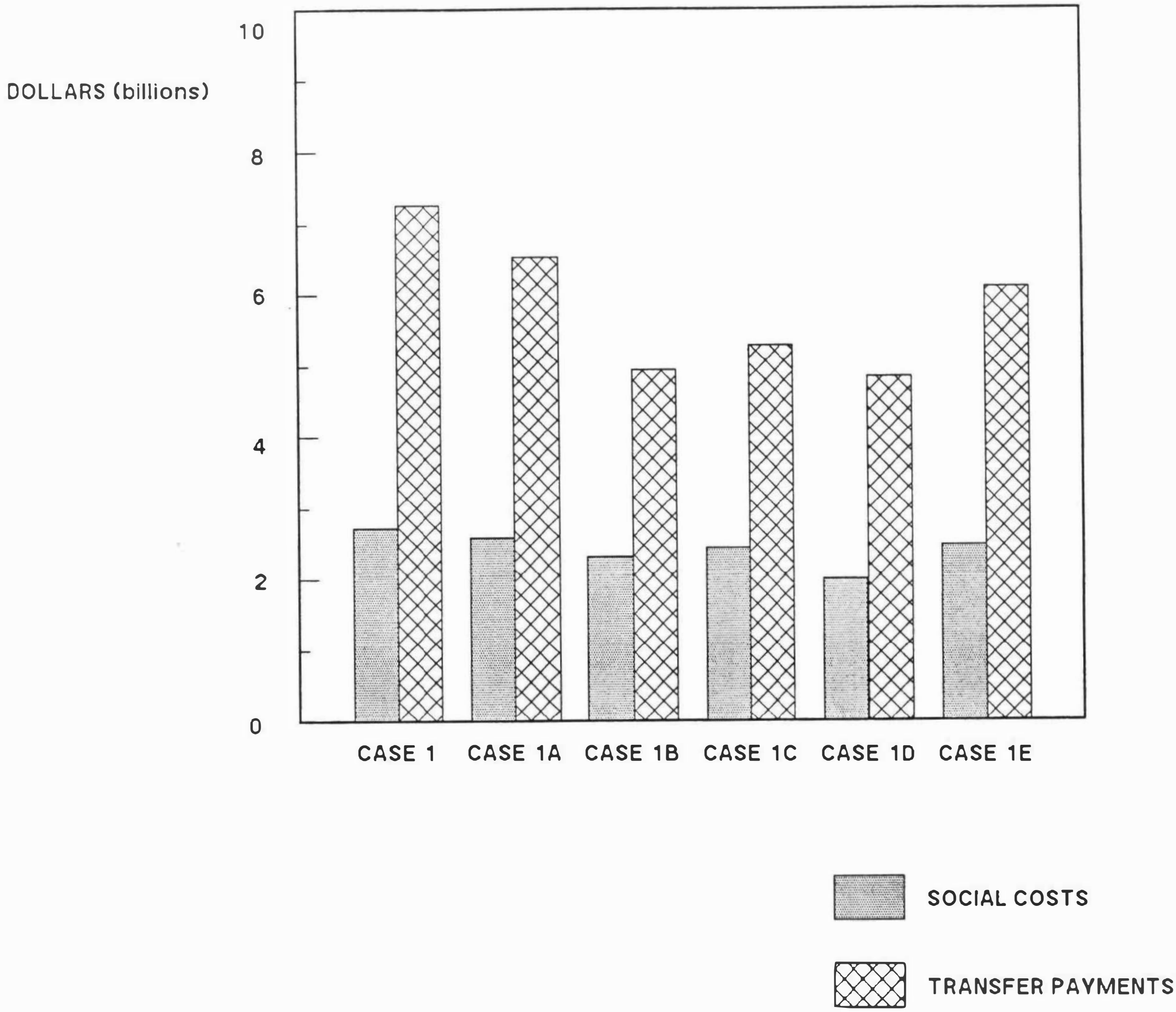
ESTIMATED CFC PRICE INCREASES FOR INDUSTRY SCENARIOS
(Price increases in 1985 dollars per kilogram)



Key: Case 1A = Case 1 with improved responses in mobile air conditioner servicing.
Case 1B = Case 1 with accelerated responses in the solvents sector.
Case 1C = Case 1 with improved responses in hospital sterilization.
Case 1D = Case 1 with use of DME/CFC-12 mixture in mobile air conditioners.
Case 1E = Case 1 with improved adoption of chemical substitutes in the aerosols sector.

EXHIBIT 9-13

ESTIMATED SOCIAL COSTS AND TRANSFER PAYMENTS FOR INDUSTRY SCENARIOS
(in billions of 1985 dollars)



Key: Case 1A = Case 1 with improved responses in mobile air conditioner servicing.
Case 1B = Case 1 with accelerated responses in the solvents sector.
Case 1C = Case 1 with improved responses in hospital sterilization.
Case 1D = Case 1 with use of DME/CFC-12 mixture in mobile air conditioners.
Case 1E = Case 1 with improved adoption of chemical substitutes in the aerosols sector.

EXHIBIT 9-14

CASE 2 ASSUMPTIONS ABOUT TECHNICAL FEASIBILITY OF CFC-CONSERVING TECHNOLOGIES

Sector/ Technology	Start Date a/	Penetration Time b/	Use-Specific Reduction Potential in 1998 c/
Mobile Air Conditioning			
Recovery at Service-Large Shops	1989	3	6.5%
Recovery at Service-Medium Shops	1989	3	19.2%
Recovery at Service-Small Shops	1989	3	7%
DME	1989	3	20%
Solvents			
Terpenes and Aqueous Cleaning	1988	5	50%
CFC-113 Azeotropes	1989	4	12% d/
Housekeeping	1989	1	14%
HCFC-123	1992	10	3%
Hospital Sterilization			
Disposables	1988	5	35%
Alternate Blends	1988	3	35%
Contracting Out	1988	9	5%
Steam Cleaning	1988	1	10%
Refrigeration			
Recovery at Service	1988	4-9 e/	6-27% e/
Recovery at Rework	1988	2	2%
FC-134a	1992	10-21 e/	50-100% e/
Foam Insulation			
Product Substitutes	1990	5	10-80% e/
HCFC-123	1992	3	17-50% e/
HCFC-141b	1991	3	20-50% e/
Flexible Foam-Molded			
Water-Blown Processes	1988	1	63%
HCFC-141b	1991	9	36%
Flexible Foam-Slabstock			
HCFC-123	1992	9	24%
HCFC-141b	1991	9	40%

EXHIBIT 9-14 (Continued)

CASE 2 ASSUMPTIONS ABOUT TECHNICAL FEASIBILITY OF CFC-CONSERVING TECHNOLOGIES

Sector/ Technology	Start Date a/	Penetration Time b/	Use-Specific Reduction Potential in 1998 c/
Foam Packaging			
Product Substitutes	1988	3-5 e/	20-60% e/
HCFC-22	1988	2	0-96%
Aerosols			
Carbon Dioxide	1988	4	50%
HCFC-22 Blends	1988	4	50%

Notes: a/ Year in which technology initially becomes available for commercial use.

b/ Years until maximum use of technology is achieved.

c/ Possible reduction potential for response action in 1998 for this control only. Some technologies can only control a small percentage of an applications use. Thus a number smaller than 100% may not indicate low penetration but may indicate that the control can only eliminate a small percentage of the applications use.

d/ Azeotrope consists of 70 percent CFC-113. The reduction shown reflects the 30 percent reduction in CFC-113 achieved when using the azeotrope and the fraction of the solvent sector adopting the azeotropes.

e/ Ranges reflect differences in assumptions about technical feasibility across subsectors within this subsector (e.g., in some subsectors the reductions are lower than others). Within particular subsectors, the reductions do not exceed 100 percent.

- Recovery at service is available immediately in many refrigeration applications (e.g., chillers, retail food coolers, refrigerators) with a penetration rate from 4 to 9 years. The maximum reduction of CFC use achievable ranges from 6 percent to 27 percent depending on the application.

- FC-134a is expected to be available in 1992 as a substitute for CFC-12 in refrigeration applications. Its use can eliminate CFC use fully in some applications (e.g., centrifugal chillers using CFC-114 and refrigerators), though it takes from 10 years to 21 years to fully penetrate its markets depending on the average lifetime of the equipment used.

- Product substitutes (e.g., thick fiberglass batting as insulation and paper for plates) are available immediately to replace some foam products.

- HCFC-123 is expected to be available in 1992 for use in flexible polyurethane slabstock and some rigid insulating foam industries.

- HCFC-141b is expected to be available in 1991 for use in flexible polyurethane slabstock, molded flexible foam, and some rigid insulating foam industries. Methylene chloride is a feasible alternative in flexible slabstock production, but due to toxicity concerns is not used as an option for reducing CFC use.

- Water-blown processes are immediately available in molded flexible foam production. They have a maximum reduction potential of 98 percent.

- HCFC-22 is available immediately for use in blowing foam for packaging products. Its use is expected to reduce CFC use in this industry by as much as 96 percent.

Exhibit 9-15 compares the results of the Case 1 and Case 2 scenarios. The differences between the two are substantial. Instead of a substantial near-term increase in CFC prices with the imposition of a freeze on CFC use in 1989, as occurs in Case 1, there is no price increase at all using the Case 2 assumptions. No price increase is projected in Case 2 because, in this scenario, sufficient CFC reduction options exist that either save money or can be executed at zero cost, so that it is possible to achieve the reductions necessary to achieve the mandated freeze without a price rise. Price increases using the Case 2 assumptions are also less than half those using the Case 1 assumptions in the medium term. In the longer term, CFC prices increase by about $4.00 in Case 2, about $1.50 less than the price increase occurring in Case 1.

Social costs are significantly less using the Case 2 assumptions. In the short term, Case 2 social costs are slightly more than $1 billion, about $1.7 billion less than the short term social costs of $2.7 billion in Case 1. Over the longer term, Case 2 social costs are about half of the social costs incurred in Case 1.

The reduction in transfer payments in Case 2 is even greater than the reduction in social costs. Transfer payments are reduced significantly in Case 2 because CFC prices do not increase in this scenario until 1993 and even then

EXHIBIT 9-15

COMPARISON OF RESULTS FOR THE CASE 1 AND 2 SCENARIOS: SOCIAL COSTS, TRANSFER PAYMENTS, CFC PRICE INCREASES, AND INDUSTRY REDUCTIONS a/

	Case 1	Case 2	Difference (Savings)
Social Costs b/			
1989-2000	2,730	1,010	(1,720)
1989-2075	39,500	20,800	(18,700)
Transfer Payments c/			
1989-2000	7,280	1,890	(5,390)
1989-2075	13,600	6,880	(6,720)
CFC Price Increases d/			
1989	6.69	0.00	(6.69)
1990	5.32	0.00	(5.32)
1991	1.84	0.00	(1.84)
1992	1.60	0.00	(1.60)
1993	3.93	1.55	(2.38)
1995	3.77	1.59	(2.18)
1998	5.48	4.49	(0.99)
2000	5.48	3.77	(1.71)

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

the price increase is much smaller than in Case 1. Transfer payments in Case 2 are only $1.9 billion in the short term, $5.4 billion less than in Case 1. In the long term, as with social costs, transfer payments in Case 2 are about one-half of those in Case 1.

There are considerable differences in the pattern of CFC reductions by industry in the two scenarios. All industries are assumed to accelerate their responses to CFC regulation in Case 2. However, some industries are assumed to have a greater capability to accelerate their responses than others. Thus the solvent, sterilization, and rigid foam packaging sectors in which substitute chemicals are more readily available increase their CFC reductions, i.e., decrease their CFC use, while other sectors decrease their reductions, i.e., use more CFCs.

9.5 EFFECT OF DELAYS IN THE AVAILABILITY OF CHEMICAL SUBSTITUTES

Using new chemicals to substitute for CFCs will be an important means for achieving CFC reductions. Three important substitutes, FC-134a, HCFC-123, and HCFC-141b, are now undergoing development and/or toxicity testing. This section examines the effect of a one year delay in the commercial availability of these substitutes on the costs of CFC regulation.

The three chemical substitutes currently are not available for commercial use. In most industries, widespread substitution will require several years of research and development. In particular, industries must test the effectiveness of the substitutes and solve technical problems before they can be used. The major future applications of the new substitutes are:

- <u>FC-134a</u>: commercial and home refrigeration, including mobile air conditioning;
- <u>HCFC-123</u>: solvent cleaning and rigid foam blowing; and
- <u>HCFC-141b</u>: rigid foam blowing.

In the cases examined above, FC-134a and HCFC-123 are assumed to be initially available for commercial use (in small quantities) in 1992. HCFC-141b is assumed to be available starting in 1991.

Exhibit 9-16 shows the impact of a one and two year delay in the introduction of these substitutes. For comparison purposes, social costs, transfer payments, and CFC price increases are evaluated for three cost scenarios: Case 1, Case 2, and Case 1A+B. Case 1A+B, representing Case 1 plus improved responses in both the mobile air conditioning and solvent sectors, was chosen as a middle case between Cases 1 and 2.

The analysis shown in Exhibit 9-16 leads to the following principal conclusions:

- Social costs, transfer payments, and CFC price increases are very sensitive to the introduction of chemical substitutes when the implementation of other response actions is limited (Case 1). Short-term social costs (1989-2000) increase by 56 percent in Case 1 with a two year delay. Effects on CFC prices are especially pronounced. In

EXHIBIT 9-16

RESULTS OF THE DELAYED CHEMICAL SUBSTITUTE SCENARIOS: SOCIAL COSTS, TRANSFER PAYMENTS, CFC PRICE INCREASES AND INDUSTRY REDUCTIONS [a/]

	Case 1	Case 1 1 Year Delay	Case 1 2 Year Delay
Social Costs [b/]			
1989-2000	2,730	2,810	4,250
1989-2075	39,500	39,500	41,000
Transfer Payments [c/]			
1989-2000	7,280	10,000	17,400
1989-2075	13,600	16,400	23,800
CFC Price Increases [d/]			
1989	6.69	6.69	6.69
1990	5.32	5.32	5.32
1991	1.84	5.88	5.88
1992	1.60	1.95	5.88
1993	3.93	14.99	50.00
1995	3.77	3.77	5.00
1998	5.48	5.88	17.69
2000	5.48	5.48	5.48

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

EXHIBIT 9-16 (continued)

RESULTS OF THE DELAYED CHEMICAL SUBSTITUTE SCENARIOS: SOCIAL COSTS, TRANSFER PAYMENTS, CFC PRICE INCREASES AND INDUSTRY REDUCTIONS a/

	Case 1A+B	Case 1A+B 1 Year Delay	Case 1A+B 2 Year Delay
Social Costs b/			
1989-2000	2,120	2,150	2,220
1989-2075	33,300	33,300	33,300
Transfer Payments c/			
1989-2000	4,980	5,170	6,330
1989-2075	11,100	11,300	12,500
CFC Price Increases d/			
1989	1.95	1.95	1.95
1990	1.84	1.84	1.84
1991	1.59	1.84	1.84
1992	1.55	1.60	1.95
1993	3.55	4.49	10.84
1995	3.55	3.55	3.77
1998	5.48	5.48	5.48
2000	5.48	5.48	5.48

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

EXHIBIT 9-16 (Continued)

RESULTS OF THE DELAYED CHEMICAL SUBSTITUTE SCENARIOS: SOCIAL COSTS, TRANSFER PAYMENTS, CFC PRICE INCREASES AND INDUSTRY REDUCTIONS a/

	Case 2	Case 2 1 Year Delay	Case 2 2 Year Delay
Social Costs b/			
1989-2000	1,010	1,010	1,030
1989-2075	20,800	20,800	20,800
Transfer Payments c/			
1989-2000	1,890	1,910	1,990
1989-2075	6,880	6,890	7,000
CFC Price Increases d/			
1989	0.00	0.00	0.00
1990	0.00	0.00	0.00
1991	0.00	0.00	0.00
1992	0.00	0.00	0.00
1993	1.55	1.59	1.84
1995	1.59	1.59	1.59
1998	4.49	4.49	4.49
2000	3.77	3.77	4.35

Notes: a/ The assumed stringency and coverage assumptions used are those of the CFC 50%/Halon Freeze case described in Chapter 5. CFCs are regulated with an initial freeze in 1989 at 1986 levels, 20 percent reduction in 1993, and 50 percent reduction in 1998, and halons are frozen at 1986 levels in 1992. The assumed rate of growth in baseline use is the Middle Growth Scenario described in Chapter 4.

b/ Social costs discounted at a 2 percent discount rate and cited in millions of 1985 dollars.

c/ Transfer payments discounted at a 6 percent discount rate and cited in millions of 1985 dollars.

d/ Price increases are for all CFC compounds weighted by ozone depletion potential and are cited in constant 1985 dollars.

1993, there are insufficient controls available in the cost modeling framework to achieve the reductions called for in the Montreal Protocol. As a result, CFC price increases reach $50, the maximum allowable price increase permitted in the modeling framework.

- The costs of regulation also are sensitive to the availability of chemical substitutes when individual industries accelerate their responses. A two year delay with Case 1A+B has a small effect on social costs, but short term transfer payments increase by 27 percent. Most of this increase stems from a price spike with the two year delay in 1993 ($10.84). CFC prices also are higher in other years with the two year delay (e.g., 1991-1992, 1995).

- Social costs, transfer payments, and CFC price increases are most sensitive to the availability of new chemical substitutes during the short term (1989-2000). For example, a one year delay with the Case 1 scenario causes a large price increase of $15 in 1993. The delay in Case 1A+B raises CFC price increases by $0.94, to $4.49 in 1993.

- Delays in chemical substitutes have only a small impact on CFC prices and social costs when industries accelerate their implementation of other responses to CFC regulations. In the Case 2 scenario, there are virtually no impacts because the prices of the new substitutes are higher in most cases than the costs of alternative responses. Thus, minimal use of longer-term substitutes occurs in Case 2, making delay in substitution less relevant.

- Longer-term costs and CFC prices are not very sensitive to the availability date of new chemical substitutes. For example, social costs for 1989-2075 for Case 1 increase by less than 1 percent with the one year delay. Longer-term costs are less sensitive because effects on costs are most significant during the mid-1990s when the initial introduction of the substitutes is expected.

- Longer delays in the availability of these substitutes can have a pronounced impact on the costs of CFC regulation. With longer delays, the response actions evaluated here are insufficient to meet the target reductions mandated under the Montreal Protocol.

9.6 EFFECT OF THE STRINGENCY OF REGULATION ON COSTS

Chapter 5 defined eight stringency options for the control of fully halogenated CFCs and halons. The first option, No Controls, is used in other chapters as a baseline against which the benefits of CFC regulation could be measured. The next four stringency options (numbers two through five) assume four increasing steps in reductions of CFC use: (2) a freeze on CFC use in 1989 at 1986 levels; (3) a freeze followed by a 20 percent reduction in use in 1993; (4) a freeze and a 20 percent reduction followed by a 50 percent reduction (relative to 1986 levels) in 1998; and (5) a freeze, 20 percent, and a 50 percent reduction followed by an 80 percent reduction (relative to 1986 levels) in 2002. All these reductions are assumed to occur worldwide, although not all countries are assumed to participate.

A sixth option assumes that all CFCs are successively controlled to the 50 percent reduction level in 1998 and, in addition, halons are frozen at 1986 levels beginning in 1992. This option replicates the reduction schedule called for in the Montreal Protocol.

Two other options examine United States actions which deviate from those taken by other nations. In the seventh option, the rest of the world is assumed to control CFCs and halons according to the restrictions mandated in the Montreal Protocol. The United States, however, is assumed to institute additional restrictions (a reduction in CFC use of 80 percent of 1986 levels) in 2002. In an eighth option, which given the signing of the Montreal Protocol may be seen as useful for comparison purposes only, assumes no other countries control CFC use.

Exhibit 9-17 shows the social costs of each of these stringency options. Social costs are estimated for both Case 1 and Case 2 and for two time periods, the short term (1989-2000) and the long term (1989-2075). Even though most of these cases assume worldwide action, the costs shown are for the United States only. Thus the costs presented for the last alternative (U.S. Only/CFC 50%/Halon Freeze case), in which only the U.S. imposes CFC and halon controls, are identical to the CFC 50%/Halon Freeze case. This occurs because the only difference between the two alternatives is the choice by other nations of whether to regulate CFCs and halons. In either case, the U.S. undertakes the same actions and only cost results for the U.S. are presented.

The exhibit shows that the costs of reduction vary significantly according to the level of stringency and assumptions of industrial responsiveness. The social costs of a CFC Freeze in the long term are $7.3 billion using the Case 2 assumptions. In the most stringent option, CFC 50%/Halon Freeze/U.S. 80%, social costs are estimated to be nearly $32 billion in the long term. Under Case 1 assumptions, the social costs of each stringency option are much greater. Even the CFC Freeze costs nearly $20 billion in the long term. As in Case 2, the range of costs across each of the stringency options is wide -- long term social costs exceed $65 billion in the most stringent regulatory option.

9.7 EFFECT OF THE METHOD OF REGULATION ON COSTS

To this point, the analysis has not considered the impact of how EPA chooses to restrict CFC production, except to assume that whatever method is chosen, rights to CFC production can be bought and sold in the marketplace. As discussed further in Chapter 11, EPA can choose to implement market-based CFC regulations using three different regulatory approaches:

- allocated quotas in which rights to CFC production and import are allocated to existing producers and importers based on 1986 levels of activity;

- auctioned rights in which rights to CFC production and imports are auctioned to the highest bidder; and

- regulatory fees in which any party desiring to produce or import CFCs must pay a fee to the government.

EXHIBIT 9-17

SOCIAL COST ESTIMATES FOR SEVEN STRINGENCY AND COVERAGE OPTIONS [a/]
(millions of 1985 dollars)

	-----Short Term------ (1989-2000) Case 1	Case 2	------Long Term----- (1989-2075) Case 1	Case 2
2. CFC Freeze	692	50	19,400	7,310
3. CFC 20%	1,720	430	27,800	12,000
4. CFC 50%	2,720[b/]	1,000[b/]	36,600	17,800
5. CFC 80%	2,720[b/]	1,000[b/]	62,300	29,000
6. CFC 50%/Halon Freeze	2,730[c/d/]	1,010[c/d/]	39,500[d/]	20,800[d/]
7. CFC 50%/Halon Freeze/ U.S. 80%	2,730[c/]	1,010[c/]	65,200	32,000
8. U.S. Only/CFC 50%/ Halon Freeze	2,730[d/]	1,010	39,500[d/]	20,800[d/]

Notes: a/ Options defined in Chapter 5. Social costs discounted at a rate of 2 percent. The assumed rate of growth in baseline use is the Middle Growth Scenario.

b/ Social costs equal in short term (1989-2000) because 80 percent reduction is not imposed until 2002.

c/ Social costs equal in short term (1989-2000) because 80 percent reduction is not imposed until 2002.

d/ Social costs equal because regulation stringency is the same in the United States.

This section briefly examines the impacts which the choice of an allocated quota system, as recommended in the proposed rule, could have on the actual level of social costs incurred by society and on transfer payments flowing to CFC producers.

9.7.1 Effect of a Regulatory Fee on Transfer Payments

As discussed above, consumers must pay substantially higher prices for CFCs and CFC-based products under many of the scenarios analyzed here. These transfer payments flow to producers under the allocated quota system, recommended by EPA in its proposed rulemaking. The results cited above indicate these transfer payments would be substantial--ranging from $1.9 billion to $7.2 billion in the period 1989 to 2000 (see Exhibit 9-15).

Some analysts (see, for example, Sobotka (1988)) have questioned whether firms currently producing CFCs should receive such large windfall profits. Sobotka recommends the institution of a regulatory fee on CFC production to redirect a portion of these transfer payments to the government.

Sobotka notes that arguments by producers that increased transfer payments are necessary to fund the development of alternative chemicals are unfounded. Research and development expenses for CFC substitutes, estimated to be approximately $30 million in 1987, are trivial compared to the size of these transfer payments. Also, according to Sobotka, decisions about the development of new chemicals would be made on the basis of the potential profits of the new chemicals, not whether new funding was available to finance the costs of the development.

Producers have also argued that production costs will increase due to CFC regulation because the costs of feedstock chemicals will increase. Sobotka finds an increase in feedstock prices solely due to lower production volumes of CFCs unlikely.

Sobotka also argues the use of a regulatory fee would not likely increase the price of CFCs. The amount of windfall profit accruing from each unit of CFC sold equals the difference between the market price for CFCs and CFC production costs. A regulatory fee less than this difference implicitly increases production costs and reduces windfall profits. A regulatory fee exceeding this difference would force market prices to rise.

As long as rights to CFC production and import are transferable in the marketplace, the method of restricting supply should have little if any impact on the level of social costs and transfer payments anticipated. Buyers' needs and available supply combine to set the market price. Whether or not a regulatory fee is imposed as part of the allocated quota system, buyers' needs and the restrictions on supply will be the same. Therefore the market price will be the same. Because the market price would be the same, the associated social cost would also be identical.

9.7.2 Effect of Allocated Quotas on the Availability of Chemical Substitutes

One recent analysis (DeCanio, 1988) has pointed out that the potential to receive large transfer payments under an allocated quota system could affect the level of social costs and transfer payments incurred. DeCanio compares the result of the allocated quota system to the formation of a cartel organized among CFC producers to restrict output and raise CFC prices. In the case of compliance with regulatory cutbacks, firms restricting output levels and receiving increased profits as a result are free from antitrust penalties.

DeCanio states that under an allocated quota system there is an incentive for producers to delay the development of alternative chemicals to substitute for CFCs. Any useful substitute chemical would have a market price less than that of CFCs. The availability of this chemical in large quantities would force CFC producers to lower their prices and thus decrease their profits. Consequently, a potential for delay exists.

Delay is possible because current CFC producers probably can control the rate of new chemical development. There are only a small number of firms with the technical and/or financial capability to develop these chemicals. One mechanism by which the firms could slow the development is through the joint toxicity testing program recently set up by these producers to test two promising potential CFC substitutes. Because more tests always are possible, an industry agreement could be made to perform another test that would delay new chemical introduction.

The joint toxicity program has another drawback. Although all companies jointly receive increased profits due to the reductions in CFC output imposed by regulation, a single firm acting on its own still would have incentive to market a CFC substitute. Profits gained from the sales of the substitute could exceed the firm's share of the joint windfall profits earned from CFC sales. The incentive to introduce a substitute would be particularly large if (1) other producers did not also market substitutes and (2) the firm maintained only a small share of the existing CFC market. By allowing all companies to monitor each other's progress toward marketing substitutes, and offering a vehicle through which peer pressure can be exerted on individual companies, the joint toxicity program reduces the likelihood companies will market substitutes on their own incentive.

To illustrate, the analysis above showed that if the rate at which new chemical substitutes for CFCs are introduced were slowed, transfer payments could increase by as much as $2.7 billion for even a one year delay in the introduction of these chemicals (Exhibit 9-14.) Delays in the development of new chemicals also would increase the social costs of CFC regulation. A system that does not produce large transfer payments for producers (such as an allocated quota with a regulatory fee system) would eliminate any incentive on the part of producers to slow the development of these substitute chemicals.

DeCanio recommends the addition of a regulatory fee to the allocated quota option. The fee would increase the incentive for the development of new substitutes by reducing the size of transfer payments received by producers. With the disincentive for developing new chemicals removed, the joint toxicity program could proceed to accomplish its legitimate goals of providing economies of scale to producers and avoiding duplication of effort.

Consumers and CFC users would not pay more under this system because, as noted above, buyers' needs and the level of restricted supply would not be affected by the imposition of the fee. As a result, the market prices of CFCs would not change.

9.7.3 Effect of Producer-Imposed Allocations

The analyses of this chapter have implicitly assumed that CFCs are always allocated to their highest valued uses. Thus, under an allocated quota option it is assumed that producers always sell CFCs to the highest bidder. Bidders who would not choose to buy CFCs in the marketplace would be those who have less expensive options for reducing CFC use. By allowing individual firms to determine their own actions based on comparisons of CFC costs with the costs of conservation methods, this allocation scheme would minimize social costs. At the same time, selling CFCs to the highest bidder would maximize producer profits (and transfer payments).

In contrast to this assumption, some producers have suggested that they intend to implement programs for allocating CFCs to existing customers based on historical patterns of use. By allocating the remaining supply of CFCs to customers (as opposed to selling the supply at the market-clearing price as assumed in the framework described above), the producers would reduce their opportunity to receive additional profits in the form of transfer payments. According to producers, such allocations would protect existing CFC customers and increase the markets for substitute chemicals once they are developed and therefore would be in the producers' long term interest.

If CFCs were allocated and used in a manner that did not coincide with the most highly-valued uses of the CFCs, then the resulting social costs would be greater than the amounts estimated in this analysis. Social costs would be greater because the least cost methods of reducing CFC use would not be undertaken. Thus, more resources would be used to produce CFC-using products.

As an example, consider the rigid foam packaging industry and the refrigeration industry. The analysis above showed that the foam packaging industry has some low cost options for reducing CFC-12 use such as substituting the use of HCFC-22 as a blowing agent. The refrigeration industry, on the other hand, has fewer options for reducing CFC-12 use in the near term. (Over the longer term, FC-134a will likely be available to substitute for CFC-12.) If CFC-12 is allocated to each industry, foam packaging will use slightly less expensive CFC-12 and save society a small amount of resources. However, the cost of this action will be expensive for society because fewer refrigerators will be produced.

The details of the manner in which such an allocation scheme would work are not known. It would be virtually impossible to prevent the resale of these chemicals once allocated. Consequently, the use of such an allocation scheme would not prevent the estimated transfer payments from being extracted from consumers. It merely allows CFC distributors and manufacturers in CFC-using industries to receive these transfer payments instead of CFC producers.

However, a secondary market (organized among CFC-using industries) cannot operate as efficiently as a primary market. First, the secondary market would impose additional transactions costs on CFC buyers and sellers. The expenses of drawing up contracts, finding brokers to conduct transfers, and obtaining information will be far higher in a situation where new channels of commerce are being established than in the existing CFC distribution system.

Second, under a producer allocation system, individual markets will exist for each CFC compound. In a system where CFCs are sold to the highest bidder, production of different CFC compounds changes according to market demands. Thus, in the case of producer allocations, the solvent industry in which many low cost alternatives to the use of CFC-113 exist would continue using this chemical even though it would be to society's advantage to use less CFC-113. Under the market-based system proposed by EPA, less CFC-113 would be used, allowing more use of other CFCs, such as CFC-12 in refrigeration. Because the trade between CFC-12 and CFC-113 reflects their ozone depletion potential in the EPA market system, no additional ozone depletion occurs but output of the economy increases because CFCs would be allocated to their highest valued use.

9.8 LIMITATIONS

Any comprehensive attempt to measure the costs of a regulatory action requires a number of simplifying assumptions. This section describes those assumptions that most seriously affect the quality of the costs estimated for CFC regulation.

First and most important, these estimates are contingent on the technologies available to reduce CFC use over time. Although the analysis explicitly identifies emerging options for reducing CFC use, it is likely that as CFC prices rise due to regulation, unforeseen opportunities will develop, particularly over the very long time horizon of this analysis. Consequently, long-term costs are likely to be overestimated. The possibility also exists that technologies forecast to come on line at a particular time and cost will be delayed and/or more expensive.

Thus the cost modeling framework developed here should be considered a policy analysis tool and not a system for predicting future events. The model is a useful aggregation of all available knowledge about CFC use. The model cannot, however, predict unforeseen technologies that will emerge as CFC regulation is implemented.

Because the economy has never before adapted to a reduction in CFC use, it is impossible to predict the exact nature of all actions which will be chosen by industries. Thus the precise path of adjustment will almost certainly differ from the course estimated by the model and described in this chapter. However, the information presented here, synthesizing all currently available information about industry responses to CFC reductions, is still the best basis for policy judgments. The cost estimates presented in this chapter should be viewed as indications of the potential order of magnitude of costs, and their changes due to industry responses or regulatory decisions. Actual costs incurred in the future may be very different as new technologies develop.

As an example, since the development of the modeling framework, information has been obtained about an emerging chemical substitute, a mixture of HCFC-22 and HCFC-142b compounds. This mixture may be a replacement for CFC-12 in refrigeration applications, but must undergo testing and development to resolve potential flammability and other problems. If successful, the implementation of this substitute could reduce the costs of CFC regulation.

Second, we were unable to identify usage patterns for a significant portion of CFC use -- as much as 20 percent for some compounds. This percentage represents the difference between the production of CFC compounds and the amount estimated to be consumed in particular applications.[12] The cost estimates presented in this chapter assume that this "unallocated" production is spread among the applications of CFCs in proportion to their identified consumption in 1985. Therefore, the unallocated production is assumed to be controllable at the same mix of response actions available in these applications.

To analyze the significance of this assumption, an alternative cost simulation was performed in which much of the unallocated production was assigned to mobile air conditioner servicing. Compared to response actions in other applications, responses available in mobile air conditioner servicing are more expensive. This allocation increased social costs by 20 percent in the short term. Over a longer period the difference is inconsequential.

Third, the cost estimates presented here do not include some costs that could be of interest. Some transition costs involved in switching from one type of technology to another are not included. An example of the type of transition cost that was not included is the unemployment experienced by workers who are temporarily out of work while new capital equipment is being installed. Also, administrative costs, discussed in Chapter 11, are not included. Finally, these costs do not adequately portray currently undefined risks and associated costs that could occur with the use of substitute chemicals.

9.9 SUMMARY AND CONCLUSION

After a discussion of the methodology used in this analysis, the chapter examined a range of scenarios for the implementation of response actions. Each scenario is defined by three factors relating to the response actions: start date, speed of penetration in the market, and maximum extent of market penetration. Four effects of each scenario were examined: CFC price increases, social costs, transfer payments, and reductions in industry use of CFCs.

The analysis began with the definition of a scenario, Case 1, which combined relatively late start dates, slow rates of implementation, and modest reductions in CFC use for many CFC conservation methods. Then, these characteristics were changed for five industries, one industry at a time. Next, a second major scenario, Case 2, was defined by assuming earlier start dates, more rapid implementations, and greater reductions in CFC use for these same conservation methods. The analysis then examined the impacts on costs of delays in the development of chemical substitutes for CFCs and concluded with estimates of the social costs of the stringency and coverage options described in Chapter 5.

The following points summarize key results of this analysis.

- If the reactions of industries to CFC regulation are slow, then the cost of these regulations could be substantial -- as much as $2.7 billion dollars through the year 2000 and as much as $40 billion through the year 2075. Transfer payments would be even higher; thus, under an allocated quota system alone, using industries and consumers would be worse off while producers would be better off.

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[12] Estimates of the quantity of CFCs used in primary applications are presented in Appendix I and in Volume III, the addenda to this RIA.

- Accelerated responses by industry can considerably reduce social costs. Analysis showed that faster and wider adoption of technically feasible means of reducing CFC use could reduce these costs to $1 billion dollars through the year 2000 (from $2.7 billion) and to $21 billion through the year 2075 (from $40 billion).

- Accelerated responses by industry can have an even larger effect in reducing transfer payments -- from 2.7 billion by 2000 in the worst case described to $1.9 billion by 2000 in the best case described.

- The major decreases in costs of CFC regulation can be achieved by accelerated responses in five key applications: mobile air conditioner servicing, solvent cleaning in electronics, hospital sterilization, short-term chemical substitution in mobile air conditioner manufacturing, and aerosols. Accelerated responses in any one of these areas considerably reduces the cost of achieving reductions in CFC use in 1989 and 1990.

The chapter closed with an examination of how the method of regulation might affect costs. Recent analyses suggest that substantial profits could accrue to producers of CFCs and that the level of social costs could be raised. These analyses also indicate that these problems could be minimized by combining a regulatory fee with a quota system. If producers decided to allocate a short supply of CFCs to users, it is possible that social costs would be higher than these estimates and that resale of CFCs would yield substantial profits for CFC users and distributors.

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CHAPTER 10

BENEFITS AND COSTS OF VARIOUS OPTIONS WITH SENSITIVITY ANALYSIS

The previous several chapters of this final Regulatory Impact Analysis have defined, measured, and, where possible, quantified benefits and costs associated with stratospheric ozone protection. This chapter develops and implements a method to compare benefits with costs. Several characteristics of the benefit and cost streams that make this problem particularly complex are examined in Section 10.1. Section 10.2 presents the methodology for the analysis. Section 10.3 presents the several benefit-cost comparisons and Section 10.4 subjects these results to a sensitivity analysis.

10.1 SPECIAL CHARACTERISTICS OF THIS BENEFIT TO COST COMPARISON

The analysis of stratospheric ozone protection is unavoidably carried out over a period measured in decades to centuries. Two problems follow from this factor -- truncation of benefit and cost streams and great uncertainty. The long time period of the analysis and the nature of the benefits makes uniform quantification difficult. The implications of these factors are discussed in turn.

10.1.1 Truncation of Benefit and Cost Streams

As a result of some action, (e.g., a regulation), benefits (or costs) could accrue during each of a series of years. The set of such benefits (or costs) is referred to as a time stream. If the measurement of a time stream is cut off at a point in time after which it would logically continue, the time stream is said to have been truncated. This is illustrated in Exhibit 10-1, in which a time stream of benefits is represented as beginning at time t1 and continuing to grow. If this hypothetical benefit stream is truncated at time t2, benefits occurring after time t2 (i.e., to the right of the line t2-a) would not be included in the analysis. In effect, such benefits would be valued at zero. If such benefits were the consequence of actions whose costs were estimated to be incurred prior to time t2, truncation of the benefits stream would result in an inappropriate benefit-cost comparison. In this example, because costs occur prior to t2, estimates of net benefits (or estimates of a benefit-cost ratio) would be biased downward.

In the case of stratospheric ozone protection, benefits accrue contemporaneously with costs as well as long afterward for two reasons:

(1) Ozone-depleting compounds have very long atmospheric lifetimes. Therefore, foregoing the use (and emission) of a compound in any given year (presumably at some cost) helps to reduce ozone depletion immediately, as well as for many decades and centuries to come.[1]

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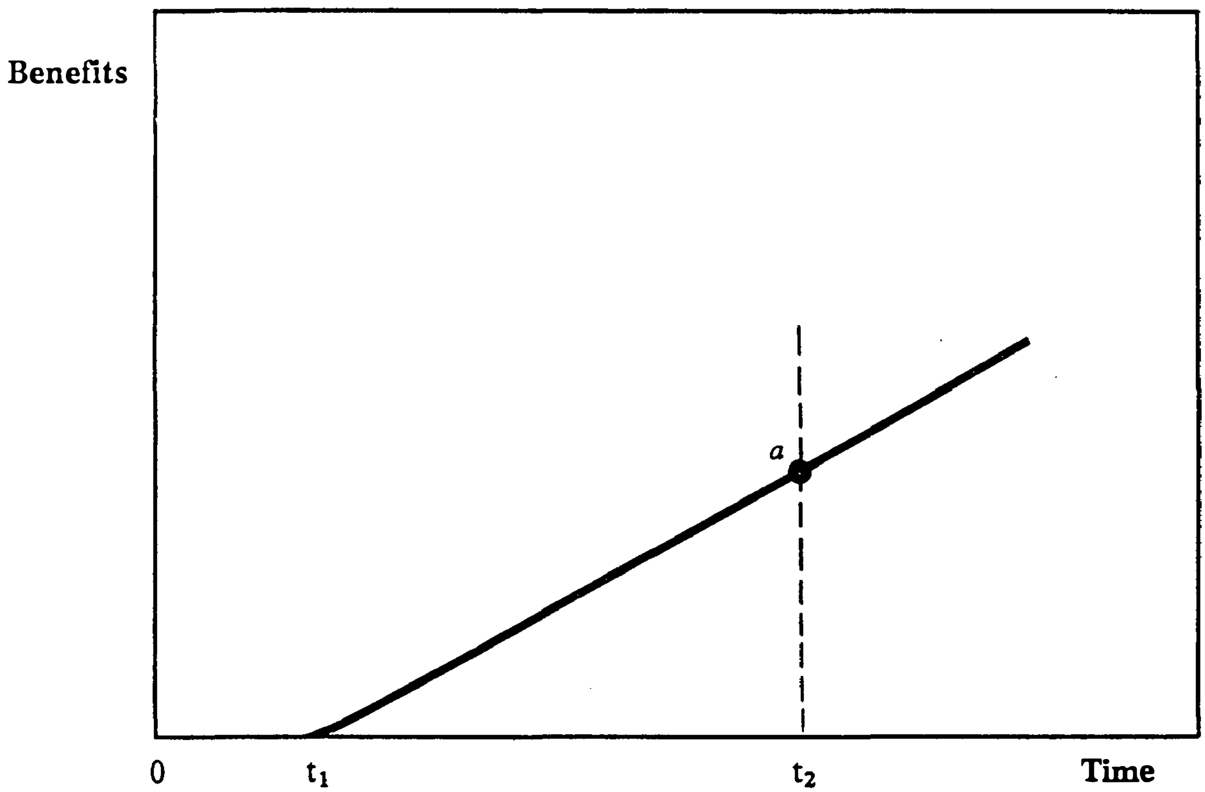
[1] For example, the e-folding atmospheric lifetime of CFC-12 is estimated at nearly 140 years. This means that 38 percent of the CFC-12 molecules remain in the atmosphere 140 years after their release. The benefit of foregoing the use (and emission) of CFC-12 has benefits that extend through this time period and beyond.

EXHIBIT 10-1

EXAMPLE OF TRUNCATED TIME STREAM



(2) Skin cancer risks in humans, a major consequence of ozone depletion, is believed to be associated with cumulative lifetime exposure to UV radiation. Therefore, reduced exposure during the early part of a person's life (realized as a consequence of protecting stratospheric ozone) has benefits for that person later in life (i.e., reduced risk of skin cancer). The benefit of reduced skin cancer incidence is realized after the reduction in exposure occurs.

Because of these two factors, a comparison of benefits and costs measured over the same finite time horizon produces an underestimate of net benefits. Because benefits accrue for long periods after costs are incurred, the underestimate may be significant.

Of note is that extending the time horizon does not necessarily resolve this issue. An arbitrarily long, but finite, time horizon will still generally result in a biased benefit-cost comparison. Although a preferred analytic solution may be to perform the analysis over an infinite period, this is generally not feasible because the system does not reach steady state[2] within the acceptable time limits of the models.

Therefore, although it would be best to avoid truncation, it is not possible to do so in this case. Particular care must be taken in structuring a benefit-cost comparison, and a method for doing so is presented below.

10.1.2 Uncertainty

Evaluating the effects of regulations to protect the stratospheric ozone layer involves measuring complex phenomena over very long periods of time. Factors such as invention, research and development, technological change, and industry and consumer response to price change and altered product and input availability, must be forecasted. While such analyses are difficult, they are often performed in regulatory analysis. In this case the challenge is the very large number of years -- nearly two centuries -- over which such phenomena must be considered.

There is no definitive way to deal with this uncertainty. One must make the most informed projections one can, be clear about their source and their implications, and then subject them to a sensitivity analysis. Such an analysis seeks to vary uncertain assumptions or projections in order to indicate how sensitive the results of the analysis -- and the policy implications that follow -- are to alternative values. Section 10.4 presents a sensitivity analysis of the benefit-cost analysis for this study.

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[2] Once the system reaches steady state, results for an infinite horizon case can be obtained by extrapolation. Acceptable time limits are determined by (1) the costs of running the model and (2) the ability to create appropriate inputs over so long a period

10.1.3 Non-Quantified Benefits

A traditional benefit-cost analysis compares only what can be quantified and transformed into dollar units or monetized. If all of the relevant benefits and costs are quantifiable, no problem exists. If, however, some costs cannot be quantified, a benefit-cost contrast that did not take this into account would overestimate net benefits and be biased in favor of adopting the policy being analyzed. If, on the other hand, some benefits could not be quantified, while all costs could be, the benefit-cost analysis would be biased against adopting the policy.

Reduced skin cancer incidence and mortality provide the major quantifiable benefits. Yet other major factors, such as impacts on aquatic and terrestrial ecosystems, global warming, and the incidence of infectious diseases in humans, are not satisfactorily captured in the quantified benefits examined below. Such benefits, and others discussed in Chapter 8, are difficult or impossible to quantify because doing so involves the resolution of conceptual problems and assembly of data that have not been completed. In many instances some of these issues may never be completely resolved.

The fact that some benefits are quantified and thus conveniently comparable to costs should not blind the policymaker to the existence of non-quantified benefits. Rather, policymakers must array all factors -- costs and benefits; monetized and non-monetized; quantified and non-quantified -- when making policy choices. The task of weighting cost and benefit factors that are presented in different units is extremely difficult. Nonetheless, making sensible choices among complex regulatory alternatives requires that this be done.

10.2 METHOD FOR DEALING WITH TRUNCATED BENEFIT STREAMS

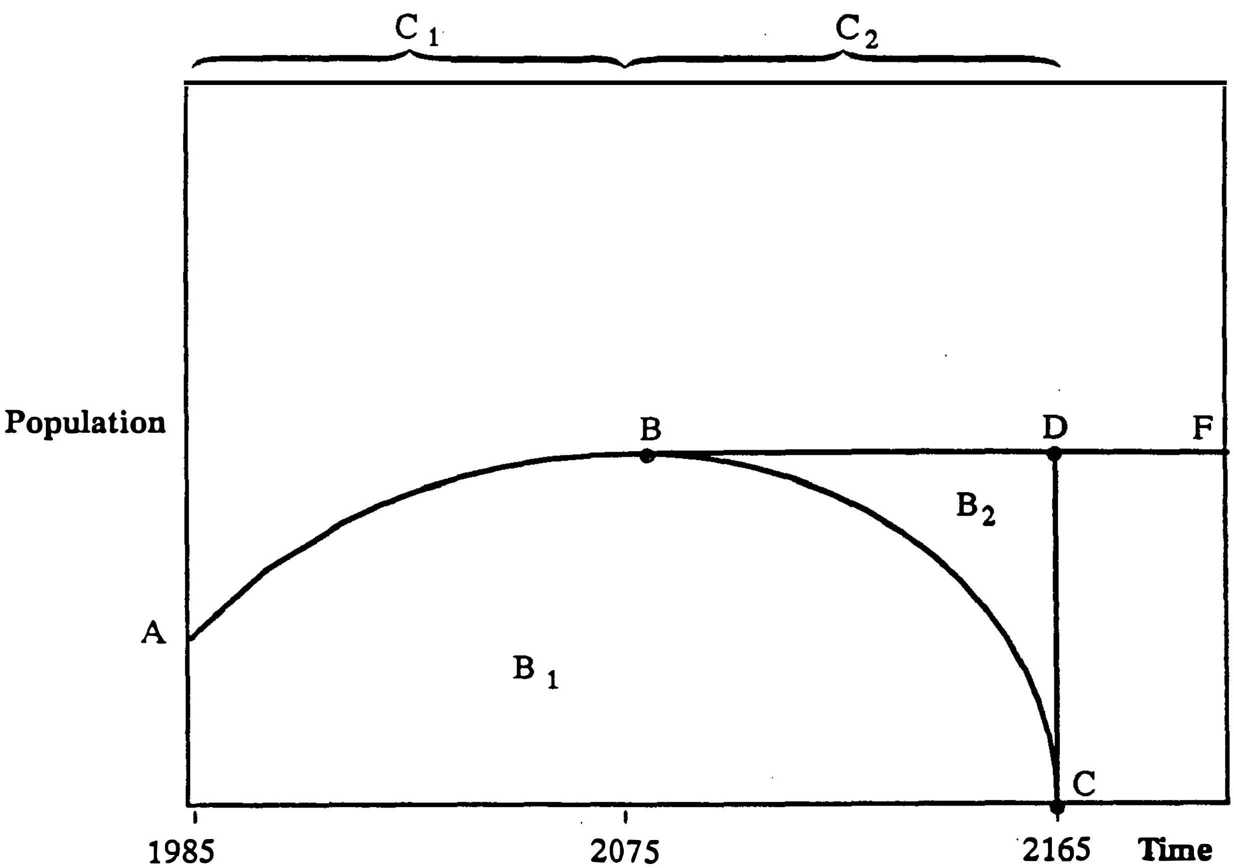
Our goal is to develop a feasible and logical way to contrast the costs and benefits of regulations to protect the stratospheric ozone layer, given that the benefit stream must be truncated. As a result of this truncation, benefits associated with measured and counted costs go uncounted, thus potentially biasing the evaluation against the policy.

The problem of truncation can be more easily examined by referring to Exhibit 10-2, which measures population on the vertical axis and time in years on the horizontal axis. This exhibit plots population over time, and divides it into two groups depending on when the people were born. Line ABC represents the population of people born prior to 2075, with the population today (1985) given by point A. This population group continues to grow until the year 2075. Since line ABC measures the population of only those born prior to 2075, the line has a parabolic shape because, with no new additions, deaths cause this population subgroup to decline. This population declines to zero by 2165 since, by assumption, no one lives for more than 90 years. Another assumption of this analysis is that zero population growth (ZPG) is achieved after year 2075. Thus, total population is given by line ABDF, with segment BDF being horizontal. The population of people born after 2075 is represented by the (increasing) vertical distance between BC and BD. After year 2165, each member of the population will have been born after 2075.

The choice of years, 2075 and 2165, is arbitrary but convenient for the analysis that follows. People born prior to 2075 represent ourselves, our

EXHIBIT 10-2

ILLUSTRATION OF TRUNCATED POPULATION STREAM AND ASSOCIATED BENEFIT AND COST STREAMS



children, and our children's children. The year 2165 represents, by assumption, the last year that someone born prior to 2075 is simulated to be alive. Recall that the goal is to establish a way to contrast benefits and costs, in the context of a truncated benefit stream, that yields plausible and reasonably unambiguous benefit-cost comparisons. We choose the year 2165 to truncate the benefit stream. Recall that the major monetized benefit is the value due to reduced skin cancer incidence and mortality. The aggregate value of this benefit, in turn, depends on the size of the population (as well as incidence of UV radiation and its effects).

To illustrate the methodology, we relate costs and benefits to time and the population relevant to that time. First, we define two benefit concepts:

- Benefit 1 -- the benefit associated with the population of persons alive today and born prior to 2075. This benefit is functionally related to the area under the line ABC in Exhibit 10-2; therefore, we place a B1 in this area.[3]

- Benefit 2 -- the benefit associated with the population of persons born after 2075. Note that someone born in the year 2100 could, by assumption, live to the year 2190. By our truncation at year 2165, any benefits associated with such a person would go uncounted for the period 2165 to 2190. For someone born in 2165, the uncounted benefit period would be 2166 to 2255. Thus, the benefits excluded as a result of the inevitable truncation could be quite large. We place a B2 in the area BDC, recognizing that B2 is an underestimate of benefits beyond 2075 since it excludes any benefits beyond 2165.

Next, we also define two cost concepts:

- Cost 1 -- costs incurred from the present to 2075. These are associated with some of Benefit 1, but also with some of Benefit 2 (as well as benefits that occur beyond 2165, if they were evaluated). This is because some costs incurred in, say, 2050, will result in a life saved of someone born after 2075. However, that benefit is counted as part of Benefit 2. We place a C1 at the top of Exhibit 10-2 to indicate the period of time for which Cost 1 is relevant.

- Cost 2 -- costs incurred from 2075 to 2165. Note that Cost 2 could be associated with Benefit 1 and Benefit 2. That is, someone born in 2025, who would be 65 in 2090, might have his or her life prolonged by a cost incurred in 2076. A C2 is placed in the exhibit to indicate the time period during which Cost 2 is incurred.

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[3] In order to simplify this presentation of the methodology, in this section we do not discuss the benefit stream in terms of present values of dollar amounts. In practice, of course, this is how benefits are measured; i.e., below they are presented in present value terms. Note also that in Exhibit 10-2 "B1" represents benefits that are a function of the area (under line ABC) in which it is placed; this area is not a benefit measure.

Now, we examine a reasonable set of hypotheses about how Benefit 1 and Benefit 2 relate to Cost 1 and Cost 2. If these hypotheses are borne out by the data, they yield an unambiguous conclusion to the benefit-cost analysis, even in the presence of the truncation.

Consider first the following propositions. We know Benefit 2 is likely to be an underestimate of benefits associated with Cost 2. If Cost 2 is less than Benefit 2, even in the presence of the truncation, then it is straightforward to justify Cost 2 based only on the truncated measure of Benefit 2. Now, compare Benefit 1 and Cost 1. If Benefit 1 exceeds Cost 1, the overall net benefits must be positive. It might seem problematic that part of Benefit 1 is associated with Cost 2. But, by the prior conclusion (Benefit 2 exceeds Cost 2), Cost 2 has already been paid for. Thus, Benefit 1 and Cost 1 can be directly compared without concern for the contribution of Cost 2 to Benefit 1.

The method for contrasting benefits and costs requires that, for each regulatory alternative, the B1 to C1 and B2 to C2 comparisons be made. We now examine how to do so for a set of regulatory alternatives when the ranking of the alternatives is of interest. Recall that this analysis examines eight regulatory alternatives: (1) No Controls; (2) CFC Freeze; (3) CFC 20%; (4) CFC 50%; (5) CFC 80%; (6) CFC 50%/Halon Freeze; (7) U.S. 80%/Halon Freeze; and (8) U.S. Only CFC 50%/Halon Freeze. It may be that in contrast to the No Controls Case (i.e., the baseline of no regulation), all alternatives are desirable. The goal is to know which is most desirable.

The following procedure is suggested. First, determine if the B2 to C2 test is passed (i.e., whether B2 exceeds C2 or not; B and C are measured in present value terms). The amount of the B2 - C2 difference is not factored into the analysis because of the speculative nature of estimates so far into the future. Next, measure the B1 - C1 difference for all regulatory alternatives that pass the first test. Each alternative is evaluated relative to the No Controls Case. The B1 - C1 differences are enumerated only for the alternatives that passed the first test (B2 > C2), and the B1 - C1 differences are used for ranking.[4]

10.3 COMPARISON OF BENEFITS AND COSTS

This section presents limited comparisons of benefits and costs for the various alternatives that have been analyzed. These comparisons are limited because they do not incorporate several potentially significant categories of effects, such as pain and suffering resulting from skin cancer or general ecological effects. Therefore, these cost-benefit comparisons must be interpreted carefully. The reader is encouraged to review the detailed assumptions and criticisms associated with the methodologies used in the analysis presented in the appendices.

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[4] In fact, even if B2 < C2, the policy could still have positive net benefits. The truncated benefit stream, Benefit 2, is biased downward, and Benefit 1 may exceed Cost 1 by a sufficient amount to result in positive net benefits. Because the data presented below shows that B2 > C2 in all cases examined, we do not deal with this complication.

The first part of this section discusses the key assumptions and parameters used to measure the costs and the benefits. The second section reviews the specific alternatives analyzed throughout the last several chapters. The last section presents the comparison of the costs and benefits.

10.3.1 Key Assumptions and Parameters

To conduct the benefit-cost comparison, the following key assumptions and parameters have been defined:

- Two time periods are used in the benefit-cost comparison -- (1) 1985 to 2075 and (2) 2075 to 2165. As discussed previously in this chapter, all benefits enjoyed by people born before 2075 are compared to costs incurred by 2075, while costs incurred between 2076 and 2165 are compared to benefits received by 2165 by people born from 2075 to 2165 (even though, as discussed earlier, benefits may accrue after 2165 from costs incurred prior to 2165). The choice of these time periods allows for a reasonable comparison of future costs and benefits from stratospheric ozone protection to be made.

- All costs and benefits that could be quantified are expressed on a present value basis in 1985 dollars. The present values have been determined by applying a two percent real discount rate to the future streams of costs and benefits. (Alternative discount rates are presented in the sensitivity analysis.)

- For purposes of the benefit-cost comparison, the benefits evaluated in Chapters 7 and 8 are compared to the costs presented in Chapter 9 for the "Case 1" and "Case 2" cost assumptions. As discussed in Chapter 9, these cases represent a wide range of assumptions regarding costs of control. If other cost estimates were used, the benefit-cost comparison would be slightly different because the benefit estimates associated with other cost scenarios would be slightly different than the benefits identified for these scenarios due to changes in CFC control options from one cost scenario to the next (e.g., the choice of control options can affect whether the CFC emissions occur promptly or are delayed, which could change the type and magnitude of the benefits). Despite this focus on these two cost scenarios, the results of the benefit-cost comparison would not change significantly if other cost scenarios were evaluated.

10.3.2 Alternatives Analyzed

The costs and benefits of eight regulatory alternatives are analyzed and compared. (A more complete discussion of these alternatives can be found in Chapter 5.)

- No Controls--No controls on CFCs or halons occur. This is the baseline scenario from which the impacts of various control options are measured.

- CFC Freeze--CFC use is held constant at 1986 levels starting in 1989.

- CFC 20%--In addition to the freeze in 1989, a 20% reduction worldwide occurs in 1993.

- CFC 50%--In addition to the freeze in 1989 and the 20% reduction in 1993, a 50% reduction occurs in 1998.

- CFC 80%--In addition to the freeze in 1989, the 20% reduction in 1993, and the 50% reduction in 1998, an 80% reduction occurs in 2003.

- CFC 50%/Halon Freeze--In addition to the freeze on CFC use in 1989, the 20% reduction in 1993, and the 50% reduction in 1998, halon use is held constant to 1986 levels starting in 1992.

- CFC 50%/Halon Freeze/U.S. 80%--Same as the CFC 50%/Halon Freeze case, except that the U.S. reduces to 80% of 1986 levels of CFC use in 2003.

- U.S. Only/CFC 50%/Halon Freeze--Same as the CFC 50%/Halon Freeze case, except the U.S. is the only country in the world that participates.

10.3.3 Comparison of the Benefits and Costs

As discussed above, two time periods are used in the benefit-cost comparison: (1) 1985 to 2075 and (2) 2075 to 2165. All benefits enjoyed by people born before 2075 (i.e., Benefit 1) are compared to costs incurred by 2075 (i.e., Cost 1), while all costs incurred between 2076 and 2165 (Cost 2) are compared to benefits received by 2165 by people born after 2075 (Benefit 2).

The benefits evaluated are divided into two categories--health impacts (which are typically less difficult to quantify) and environmental impacts (which are usually more difficult to quantify). The specific health benefits valued in this analysis include changes in the number of cases and deaths from nonmelanoma and melanoma and changes in the number of cases of cataracts. Exhibit 10-3 summarizes the magnitude of these benefits (relative to No Controls) for people born before 2075. Exhibit 10-4 summarizes these benefits for people born after 2075 (see Chapter 8 for valuation of these benefits and Appendix G for a discussion of the limitations of such valuations).

The specific environmental (non-health) impacts valued in this analysis include UV radiation impacts on agricultural crops, UV radiation impacts on the major commercial fish species, increased tropospheric ozone levels on agricultural production, UV radiation damage to polymers, and impacts on harbors (primarily from storm damages) due to increases in the level of the seas. Exhibit 10-5 summarizes the magnitude of these benefits for the No Controls and

EXHIBIT 10-3

SUMMARY OF THE HEALTH BENEFITS FOR PEOPLE BORN BEFORE 2075 BY SCENARIO
(billions of 1985 dollars)[a/]

Scenario	Value of Avoided Cases		Value of Avoided Skin Cancer Deaths [b/]	Total Value (Benefit 1)
	Skin Cancer	Cataracts		
No Controls	-	-	-	-
CFC Freeze	68	3	3,196	3,267
CFC 20%	70	3	3,272	3,345
CFC 50%	72	3	3,358	3,433
CFC 80%	73	3	3,419	3,495
CFC 50%/Halon Freeze	74	3	3,440	3,517
CFC 50%/Halon Freeze/ U.S. 80%	74	3	3,454	3,531
U.S. Only/CFC 50%/ Halon Freeze	28	1	1,324	1,353

a/ All dollar values reflect the difference between the No Controls scenario and the specified alternative scenario. Estimates assume a 2 percent discount rate.

b/ Assumes the value of an avoided death (reduction in unit mortality risk) to be $3 million. Results for an alternative assumption, e.g., $12 million, can be obtained by multiplying by 4.

EXHIBIT 10-4

SUMMARY OF THE HEALTH BENEFITS THROUGH 2165 BY SCENARIO FOR PEOPLE BORN AFTER 2075
(billions of 1985 dollars) a/

Scenario	Value of Avoided Cases: Skin Cancer	Value of Avoided Cases: Cataracts	Value of Avoided Skin Cancer Deaths b/	Total Value (Benefit 2)
No Controls	-	-	-	-
CFC Freeze	13	+	628	641
CFC 20%	13	+	638	651
CFC 50%	14	+	651	665
CFC 80%	14	+	659	673
CFC 50%/Halon Freeze	14	+	666	680
CFC 50%/Halon Freeze/ U.S. 80%	14	+	668	682
U.S. Only/CFC 50%/Halon Freeze	1	+	52	53

+ = Less than $500 million.

a/ All dollar values reflect the difference between the No Controls scenario and the specified alternative scenario. Estimates assume a 2 percent discount rate.

b/ Assumes the value of an avoided death (reduction in unit mortality risk) to be $3 million. Results for an alternative assumption, e.g., $12 million, can be obtained by multiplying by 4.

EXHIBIT 10-5

SUMMARY OF THE ENVIRONMENTAL BENEFITS THROUGH 2075 BY SCENARIO
(billions of 1985 dollars) a/

Scenario	UV Damage to Crops b/	UV Damage to Fish b/	Damage from Ozone b/	UV Damage to Polymers b/	Sea Level Rise c/	Total Benefits (Benefit 1)
No Controls	-	-	-	-	-	-
CFC Freeze	21.4	6.5	12.7	2.6	3.9	47.1
CFC 20%	23.3	6.7	13.6	3.1	4.3	51.0
CFC 50%	25.7	6.7	14.7	3.4	4.9	55.4
CFC 80%	27.4	6.7	15.5	3.5	5.4	58.5
CFC 50%/Halon Freeze	27.3	6.7	15.5	3.6	4.9	58.0
CFC 50%/Halon Freeze/U.S. 80%	27.7	6.7	15.6	3.6	5.1	58.7
U.S. Only/CFC 50%/ Halon Freeze	8.6	2.4	6.4	0.8	1.4	19.6

a/ All dollar values reflect the difference between the No Controls scenario and the specified alternative scenario. Estimates assume a 2 percent discount rate.

b/ Middle values were used.

c/ Medium values assuming impacts are anticipated were used.

alternative scenarios (see Chapter 8 for valuation of these benefits and Appendix F for a discussion of the limitations of such valuations); the value of these benefits has been estimated through the year 2075.

The costs to achieve the goals of each regulatory alternative are based on the "Case 1" and "Case 2" scenarios discussed in Chapter 9. A summary of these costs is provided in Exhibit 10-6; costs incurred by 2075 (Cost 1) and between 2076 and 2165 (Cost 2) are shown.

Following the methodology set forth above, we first compare B2 and C2. This comparison is shown in Exhibit 10-7. The analysis shows that for all cases B2 exceeds C2. Therefore, we proceed to compare B1 to C1.

Exhibit 10-8 compares the costs of control through 2075 with only the health benefits incurred by people born before 2075 for each scenario. Exhibit 10-9 provides a similar comparison of costs and benefits that includes the health and environmental (non-health) impacts; it also lists major costs and benefits that were not quantified and therefore are not captured by a comparison of monetized values.

As shown in Exhibit 10-9, benefits to all people born by 2075 (Benefit 1) exceed the costs of control through 2075 (Cost 1) for every case. Moreover, it was shown earlier that the benefits after 2075 (Benefit 2) exceed the costs of control incurred after 2075 (Cost 2). From these results, it appears that the benefits of the alternatives analyzed exceed the costs of control for CFCs and halons. However, the quantitative benefit-cost comparison in Exhibit 10-9 is an incomplete summary of all factors that should be considered by policymakers when making policy choices since that comparison includes only those factors that could be quantified and monetized. However, as discussed earlier, several potential benefits of stratospheric ozone protection and costs of control could not readily be quantified and monetized. The major unquantified benefits and costs are enumerated in the last column of Exhibit 10-9. These factors should also be considered when evaluating various policy choices.

10.4 SENSITIVITY ANALYSIS

The analysis in the preceding section indicates that the benefits of stratospheric ozone protection exceed the costs of control of ozone-depleting substances by a substantial margin. This result is sensitive to several key assumptions. The following sensitivities are analyzed to determine how sensitive the results are to each factor:

- Social discount rates of zero, one, and six percent.
- The value of unit mortality risk reduction of two and twelve million dollars.[5]

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[5] As discussed in Appendix G, establishing a value of reducing risks to human life is context dependent. The use of a value of $3 million as a reference case should not be taken by the reader as an indication that all analytical questions have been addressed to support this value. Some authorities, e.g., Moore and Viscusi (1988) and Ashford and Stone (1988), suggest much higher values in cases where non-voluntary risks are reduced.

EXHIBIT 10-6

SUMMARY OF THE COSTS OF CONTROL BY SCENARIO
(billions of 1985 dollars) [a/]

Scenario	Total Costs By 2075 (Cost 1)	Costs Between 2076 and 2165 (Cost 2)
No Controls	--	--
CFC Freeze	7-19	4-9
CFC 20%	12-27	5-11
CFC 50%	13-37	6-11
CFC 80%	22-62	9-23
CFC 50%/Halon Freeze	21-40	7-13
CFC 50%/Halon Freeze/ U.S. 80%	24-65	10-24
U.S. Only/CFC 50%/Halon Freeze	21-40	7-13

a/ All dollar values reflect the difference between the No Controls scenario and the specified alternative scenario. Estimates assume a 2 percent discount rate. Range is for "Case 1" and "Case 2" cost assumptions (see Chapter 9.)

EXHIBIT 10-7

COMPARISON OF BENEFITS AND COSTS BEYOND 2075 (billions of 1985 dollars) a/

Scenario	Benefits Through 2165 for People Born After 2074 (Benefit 2) b/	Costs from 2075-2165 (Cost 2)	Is B2 Greater Than C2?
No Controls	-	-	-
CFC Freeze	641	4-9	Yes
CFC 20%	651	5-11	Yes
CFC 50%	665	6-11	Yes
CFC 80%	673	9-23	Yes
CFC 50%/Halon Freeze	680	7-13	Yes
CFC 50%/Halon Freeze/ U.S. 80%	682	10-24	Yes
U.S. Only/CFC 50%/Halon Freeze	53	7-13	Yes

a/ All dollar values reflect the difference between the No Controls scenario and the specified alternative scenario. Estimates assume a 2 percent discount rate. Range of costs is for "Case 1" and "Case 2" cost assumptions.

b/ Assumes the value of an avoided death (reduction in unit mortality risk) to be $3 million. Includes values of avoided cancer cases and avoided cataracts.

EXHIBIT 10-8

NET PRESENT VALUE COMPARISON OF COSTS AND HEALTH BENEFITS THROUGH 2075 BY SCENARIO (billions of 1985 dollars) a/

	Health Benefits (Benefit 1) b/	Costs (Cost 1)	Benefits-Costs	Incremental Benefits - Costs c/
No Controls	--	--	--	--
CFC Freeze	3,267	7-19	3,248-3,260	3,245-3,260
CFC 20%	3,345	12-27	3,318-3,333	70-73
CFC 50%	3,433	13-37	3,396-3,420	78-87
CFC 80%	3,495	22-62	3,433-3,473	37-53
CFC 50%/Halon Freeze	3,517	21-40	3,477-3,496	23-44
CFC 50%/Halon Freeze/ U.S. 80%	3,531	24-65	3,466-3,507	(11)-11
U.S. Only/CFC 50%/Halon Freeze	1,353	21-40	1,313-1,332	1,313-1,332 d/

a/ All dollar values reflect the difference between the No Controls scenario and the specified alternative scenario unless noted otherwise. Valuation of the health benefits applies only to people born before 2075; costs are estimated through 2075. In all scenarios, benefits through 2165 for people born from 2075 to 2165 exceed the costs of control from 2075 to 2165. Estimates assume a 2 percent discount rate. Range of costs is for "Case 1" and "Case 2" cost assumptions.

b/ Assumes the value of an avoided death (reduction in unit mortaility risk) to be $3 million. Includes values of avoided cancer cases and avoided cataracts.

c/ Change in (benefits-costs) from the indicated scenario to the scenario listed above it, e.g., "CFC Freeze" minus "No Controls," unless noted otherwise.

d/ Compared to No Controls Case.

EXH 0-9

COMPARISON OF COSTS AND BENEFITS THROUGH 2075 BY SCENARIO (billions of 1985 dollars)[a]

	Health and Environmental Benefits	Costs	Net Benefits (Minus Costs)	Net Incremental Benefits (Minus Costs) [b]
No Controls	--	--	--	--
CFC Freeze	3,314	7	3,307	3,307
CFC 20%	3,396	12	3,384	77
CFC 50%	3,488	13	3,475	91
CFC 80%	3,553	22	3,531	56
CFC 50%/Halon Freeze	3,575	21	3,554	23
CFC 50%/Halon Freeze/ U.S. 80%	3,589	24	3,565	11
U S. Only CFC 50%/Halon Freeze	1,373	21	1,352	1,352[c]

Costs and Benefits That Have Not Been Quantified

<u>Costs</u>

Transition costs, such as temporary layoffs while new capital equipment is installed
Administrative costs
Costs of unknown environmental hazards due to use of chemicals replacing CFCs

<u>Health Benefits</u>

Increase in actinic keratosis from UV radiation
Changes to the human immune system
Tropospheric ozone impacts on the pulmonary system
Pain and suffering from skin cancer

<u>Environmental Benefits</u>

Temperature rise
Beach erosion
Loss of coastal wetlands
Additional sea level rise impacts due to Antarctic ice discharge, Greenland ice discharge, and Antarctic meltwater
UV radiation impacts on recreational fishing, the overall marine ecosystem, other crops, forests, and other plant species, and materials currently in use
Tropospheric ozone impacts on other crops, forests, other plant species, and man-made materials

a/ All dollar values reflect the difference between the No Controls scenario and the specified alternative scenario, unless otherwise indicated. Valuation of the health and environmental benefits applies only to people born before 2075; costs are estimated through 2075. In all scenarios, benefits through 2165 for people born from 2075 to 2165 exceed the costs of control from 2075 to 2165. Estimates assume a 2 percent discount rate Costs are for the "Case 2" cost assumptions.

b/ Change in net incremental benefits from the indicated scenario to the scenario listed above it, e g , "CFC Freeze" minus "No Controls," unless otherwise indicated.

c/ Compared to No Controls Case.

- Rate of growth in CFC use is altered; the results above assume growth of approximately 4.0 percent per year from 1986 to 2000 and 2.5 percent per year from 2000 to 2050. A slightly lower case (approximately 3.4 percent per year from 1986 to 2000 and 2.5 percent per year from 2000 to 2050) is also analyzed.

- Previous results used the DNA action spectrum; the erythema spectrum is substituted.

- To capture uncertainties in the dose-response coefficients, low and high values are evaluated based on the statistical variation about each coefficient (± one standard error about each coefficient).

- The value of unit mortality risk reduction has been adjusted over time at the rate of growth in per capita income (averaging approximately 1.5 percent real growth per year from 1985 to 2075, with no growth thereafter); this assumption is evaluated at one-half and double this rate of growth.

- Protocol participation rates for other parts of the world are altered to provide lower and higher estimates than assumed in the analysis above. These participation rates are indicated below (the middle assumptions were used for the base case estimates):

	U.S.	Other Developed Countries	Developing Countries
High	100%	100%	100%
Middle	100%	94%	65%
Low	100%	75%	40%

  An additional case was also examined assuming that no additional developing nations sign the Protocol. In this case, developing nations are estimated to have approximately a 2.5 percent participation rate while developed countries participate at a 94 percent rate.

- The technological rechanneling estimates used above are evaluated at a higher level, lower level, and at a zero impact level. These rates are presented below as a percent of the assumed growth rate in CFC use (the middle assumptions were used for the base case estimates, see Appendix C):

	Amount of Reduction	U.S. and Other Developed Countries	Developing Countries
High	CFC Freeze	0.375	0.5
	CFC 20%	0.375	0.375
	CFC 50%	0.250	0.250
	CFC 80%	0.250	0.250
Middle	CFC Freeze	0.5	0.75
	CFC 20%	0.5	0.625
	CFC 50%	0.375	0.5
	CFC 80%	0.375	0.5
Low	CFC Freeze	0.75	0.875
	CFC 20%	0.75	0.75
	CFC 50%	0.50	0.625
	CFC 80%	0.50	0.625
None	All cases	1.00	1.00

- The rates of growth in trace gas concentrations, specifically methane, CO2, and N2O, are altered to provide lower and higher growth rates than used in the results presented above. These lower and higher growth rates are presented below, along with the middle assumptions used for the base case estimates:

	Methane	CO2	N2O
High	1% annual compounded growth	NAS 75th percentile	0.25%/year
Middle	0.017 ppm/year	NAS 50th percentile	0.20%/year
Low	0.01275 ppm/year	NAS 25th percentile	0.15%/year

- The upper limit on ozone depletion used in the analysis is varied. In the base case assumptions, ozone depletion is artificially constrained at 50 percent due to model limitations. Alternative limits of 30 percent and 95 percent are examined.

- The baseline mortality rates are reduced to examine the implications of changes in lifestyle or medical technology that result in reduced mortality from skin cancer. First, skin cancer mortality rates are reduced exponentially so that by 2100 rates decline from 1985 levels by 25 percent. This decline, which is not evidenced in current data, would require that people significantly alter their outdoor behavior, thereby reducing exposure.[6] Second, all mortality rates (including skin cancer mortality rates) for individuals age 35 and older are reduced by 25 percent, 50 percent, and 75 percent by 2100. Significant improvements in medical technology (including the detection and treatment of all cancers, including skin cancers) would be required in order to achieve these reductions in mortality. Of note is that by`reducing all the mortality rates, the expected lifetime of individuals in the analysis increases by 1.7, 3.6, and 5.7 years by 2100, respectively.

For all of the above sensitivity analyses, comparisons are made between two scenarios only -- the No Controls scenario and the CFC 50%/Halon Freeze scenario. These two cases are shown to indicate the magnitude of the changes in costs and benefits due to each sensitivity analysis. For all sensitivities only the health benefits due to avoided deaths are shown; these benefits provide the vast majority of all quantifiable health and environmental benefits from stratospheric ozone protection. Also, only the costs estimated based on the "Case 2" cost assumptions scenario are shown. Exhibit 10-10 summarizes the results from the sensitivity analyses.

Also shown in Exhibit 10-10 are the following two cases:

- Low discount rate and high value of life, shows the combined effects of assuming a 1 percent discount rate and a $12 million value of life growing at the rate of growth of GNP per capita.

- High discount rate and low value of life, shows the combined effects of assuming a 6 percent discount rate and a $2 million value of life growing the rate of growth of GNP per capita.

The results for these two cases are shown for each of the control cases discussed above.

[6] The cost of foregoing outdoor activity (e.g., foregoing recreation) is not estimated in this analysis. These costs would be substantial.

EXHIBIT 10-10

SUMMARY OF RESULTS OF SENSITIVITY ANALYSES FOR COSTS AND MAJOR HEALTH BENEFITS FOR PEOPLE BORN BEFORE 2075 (Estimates assume a 2 percent discount rate)[a/]

Sensitivity	Ozone Depletion in 2075 (%)	Additional Deaths by 2165 (10^6)	Value of Lives Lost (10^9)	Control Costs (10^9)	Net Present Value of Benefits - Costs (10^9)
1 <u>Base Case</u>					
No Controls	50 0	3 74	3,581	-	
CFC 50%/Halon Freeze (Protocol)	1.9	0.09	141	21	
Difference	48.1	3.65	3,440	21	3,419
2. <u>Discount Rates</u>					
A 0 Percent Discount Rate					
No Controls	50.0	3 74	44,200	-	
CFC 50%/Halon Freeze	1.9	0.09	986	60	
Difference	48 1	3.65	43,214	60	43,154
B. 1 Percent Discount Rate					
No Controls	50.0	3.74	12,140	-	
CFC 50%/Halon Freeze	1.9	0.09	1,232	35	
Difference	48.1	3.65	10,908	35	10,873
C 6 Percent Discount Rate					
No Controls	50.0	3.74	63	-	
CFC 50%/Halon Freeze	1.9	0.09	9	5	
Difference	48.1	3 65	54	5	49
3. <u>Value of Unit Mortality Risk Reduction (VUMRR)</u>					
A VUMRR at $2 million					
No Controls	50.0	3.74	2,387	-	
CFC 50%/Halon Freeze	1 9	0.09	94	21	
Difference	48.1	3.65	2,293	21	2,272
B. VUMRR at $12 million					
No Controls	50.0	3.74	14,325	-	
CFC 50%/Halon Freeze	1.9	0.09	564	21	
Difference	48.1	3.65	13,761	21	13,740

a/ Unless noted otherwise, ozone depletion is constrained to 50 percent.

EXHIBIT 10-10

(continued)

SUMMARY OF RESULTS OF SENSITIVITY ANALYSES FOR COSTS AND MAJOR HEALTH BENEFITS FOR PEOPLE BORN BEFORE 2075
(Estimates assume a 2 percent discount rate)[a/]

Sensitivity	Ozone Depletion in 2075 (%)	Additional Deaths by 2165 (10^6)	Value of Lives Lost (10^9)	Control Costs (10^9)	Net Present Value of Benefits - Costs (10^9)
4 Slower Growth in Baseline CFC/Halon Use					
No Controls	44.7	3.41	3,178	-	
CFC 50%/Halon Freeze	1.6	0.08	122	18	
Difference	43.1	3.33	3,056	18	3,038
5. Erythema Action Spectrum					
No Controls	50.0	3.28	3,152	-	
CFC 50%/Halon Freeze	1.9	0 08	127	21	
Difference	48.1	3.20	3,025	21	3,004
6 Dose Response Coefficients					
A. Low Dose Response Coefficients					
No Controls	50.0	1.94	1,945	-	
CFC 50%/Halon Freeze	1.9	0.06	100	21	
Difference	48.1	1.88	1,845	21	1,824
B High Dose Response Coefficients					
No Controls	50.0	6.89	6,287	-	
CFC 50%/Halon Freeze	1.9	0.12	184	21	
Difference	48.1	6.77	6,103	21	6,082
7 Growth Rates in Value of Unit Mortality Risk Reduction (VUMRR)					
A. VUMRR Grows at 1/2 x Rate of GNP/Capita					
No Controls	50.0	3 74	1,825	-	
CFC 50%/Halon Freeze	1.9	0 09	79	21	
Difference	48.1	3.65	1,746	21	1,725
B. VUMRR Grows at 2.0 x Rate of GNP/Capita					
No Controls	50 0	3 74	13,598	-	
CFC 50%/Halon Freeze	1 9	0 09	465	21	
Difference	48.1	3 65	13,133	21	13,112

a/ Unless noted otherwise, ozone depletion is constrained to 50 percent.

EXHIBIT 10-10
(continued)

SUMMARY OF RESULTS OF SENSITIVITY ANALYSES FOR COSTS AND MAJOR HEALTH BENEFITS FOR PEOPLE BORN BEFORE 2075
(Estimates assume a 2 percent discount rate)[a/]

Sensitivity	Ozone Depletion in 2075 (%)	Additional Deaths by 2165 (10^6)	Value of Lives Lost (10^9)	Control Costs (10^9)	Net Present Value of Benefits - Costs (10^9)
8 Global Participation Rates					
A High Participation					
No Controls	50 0	3.74	3,581	-	
CFC 50%/Halon Freeze	0.9	0.05	95	21	
Difference	49.1	3.69	3,486	21	3,465
B. Low Participation					
No Controls	50.0	3.74	3,581	-	
CFC 50%/Halon Freeze	3 5	0.16	216	21	
Difference	46.5	3.58	3,365	21	3,344
C. Developing Nations Signatories Only					
No Controls	50.0	3.74	3,581	-	
CFC 50%/Halon Freeze	3.3	0.15	201	21	
Difference	46.7	3.59	3,380	21	3,359
9. Technological Rechanneling					
A High Technological Rechanneling					
No Controls	50.0	3.74	3,581	-	
CFC 50%/Halon Freeze	1.7	0 08	130	17	
Difference	48 3	3.66	3,451	17	3,434
B Low Technological Rechanneling					
No Controls	50.0	3.74	3,581	-	
CFC 50%/Halon Freeze	2.2	0.10	149	27	
Difference	47.8	3 64	3432	27	3,405
C. No Technological Rechanneling					
No Controls	50.0	3.74	3,581	-	
CFC 50%/Halon Freeze	3.0	0.13	183	51	
Difference	47 0	3 61	3,398	51	3,347

a/ Unless noted otherwise, ozone depletion is constrained to 50 percent

EXHIBIT 10-10
(continued)

SUMMARY OF RESULTS OF SENSITIVITY ANALYSES FOR COSTS AND MAJOR HEALTH BENEFITS FOR PEOPLE BORN BEFORE 2075
(Estimates assume a 2 percent discount rate) a/

Sensitivity	Ozone Depletion in 2075 (%)	Additional Deaths by 2165 (10^6)	Value of Lives Lost (10^9)	Control Costs (10^9)	Net Present Value of Benefits - Costs (10^9)
10 Other Trace Gas Growth					
A Low Trace Gas Growth					
No Controls	50.0	3.92	3,825	-	
CFC 50%/Halon Freeze	3 6	0.16	226	21	
Difference	46.4	3.76	3,599	21	3,578
B. High Trace Gas Growth					
No Controls	42 9	3.36	3,136	-	
CFC 50%/Halon Freeze	-0.8 b/	-0.03 c/	12 d/	21	
Difference	43.7	3.39	3,124	21	3,103
11. Limit on Ozone Depletion					
A Limit of 30% Ozone Depletion					
No Controls	30 0	1 97	2,088	-	
CFC 50%/Halon Freeze	1 9	0.09	141	21	
Difference	28.1	1.88	1,947	21	1,926
B Limit of 95% Ozone Depletion					
No Controls	52.3	5.09	4,556	-	
CFC 50%/Halon Freeze	1 9	0.09	141	21	
Difference	50 4	5.00	4,415	21	4,394
12. Reduction in Baseline Mortality Rates					
A 25% Reduction in Baseline Skin Cancer Mortality					
No Controls	50.0	2.83	2,747	-	
CFC 50%/Halon Freeze	1.9	0.07	114	21	
Difference	48.1	2.76	2,633	21	2,612

a/ Unless noted otherwise, ozone depletion is constrained to 50 percent.

b/ Increased ozone abundance.

c/ Lives saved due to increased ozone abundance

d/ Includes value of lives saved

EXHIBIT 10-10
(continued)

SUMMARY OF RESULTS OF SENSITIVITY ANALYSES FOR COSTS AND MAJOR HEALTH BENEFITS FOR PEOPLE BORN BEFORE 2075
(Estimates assume a 2 percent discount rate)[a/]

Sensitivity	Ozone Depletion in 2075 (%)	Additional Deaths by 2165 (10^6)	Value of Lives Lost (10^9)	Control Costs (10^9)	Net Present Value of Benefits - Costs (10^9)
B 25% Reduction in All Mortality Rates					
No Controls	50 0	3 12	2,903	-	
CFC 50%/Halon Freeze	1.9	0.08	119	21	
Difference	48 1	3.04	2,784	21	2,763
C. 50% Reduction in All Mortality Rates					
No Controls	50 0	2 25	2,100	-	
CFC 50%/Halon Freeze	1.9	0.06	92	21	
Difference	48 1	2.19	2,008	21	1,987
D. 75% Reduction in All Mortality Rates					
No Controls	50 0	1.23	1,169	-	
CFC 50%/Halon Freeze	1.9	0.04	59	21	
Difference	48 1	1.19	1,110	21	1,089
13 Low Discount Rate and High Value of Unit Mortality Risk Reductions					
No Controls	50 0	3 74	48,560	-	
CFC Freeze	6 9	0 32	4,476	14	
Difference	43.1	3.42	44,084	14	44,070
No Controls	50.0	3.74	48,560	-	
CFC 20%	5.6	0 25	3,544	21	
Difference	44.4	3.49	45,016	21	44,995
No Controls	50.0	3 74	48,560	-	
CFC 50%	4.0	0.17	2,492	30	
Difference	46 0	3 57	46,068	30	46,038
No Controls	50.0	3.74	48,560	-	
CFC 80%	2.7	0.12	1,744	48	
Difference	47.3	3.62	46,816	48	46,768
No Controls	50 0	3.74	48,560	-	
CFC 50%/Halon Freeze	1 9	0 09	1,412	35	
Difference	48 1	3 65	47,148	35	47,113

a/ Unless noted otherwise, ozone depletion is constrained to 50 percent

EXHIBIT 10-10
(continued)

SUMMARY OF RESULTS OF SENSITIVITY ANALYSES FOR COSTS AND MAJOR HEALTH BENEFITS FOR PEOPLE BORN BEFORE 2075
(Estimates assume a 2 percent discount rate) a/

Sensitivity	Ozone Depletion in 2075 (%)	Additional Deaths by 2165 (10^6)	Value of Lives Lost (10^9)	Control Costs (10^9)	Net Present Value of Benefits - Costs (10^9)
No Controls	50.0	3 74	48,560	-	
CFC 50%/Halon Freeze/ U S 80%	1 6	0.08	1,236	53	
Difference	48.4	3.66	47,324	53	47,271
No Controls	50.0	3.74	48,560		
U.S. Only/CFC 50%	27.4	2.54	31,684	35	
Halon Freeze	22.6	1.20	16,876	35	16,841
Difference					
14 <u>High Discount Rate and Low Value of Unit Mortality Risk Reductions</u>					
No Controls	50.0	3.74	42		
CFC Freeze	6.9	0.32	11	1 1	
Difference	43.1	3.42	31	1.1	30
No Controls	50.0	3.74	42		
CFC 20%	5.6	0.25	9	2	
Difference	44.4	3.49	33	2	31
No Controls	50.0	3.74	42		
CFC 50%	4.0	0.17	7	4	
Difference	46.0	3.57	35	4	31
No Controls	50.0	3.74	42		
CFC 80%	2.7	0.12	6	7	
Difference	47 3	3.62	36	7	29
No Controls	50 0	3.74	42		
CFC 50%/Halon Freeze	1.9	0.09	6	5	
Difference	48.1	3.65	36	5	31
No Controls	50.0	3.76	42		
CFC 50%/Halon Freeze U.S. 80%	1.6	0.08	6	7	
Difference	48.4	3.66	36	7	29
No Controls	50.0	3 74	42		
U S. Only/CFC 50%/ Halon Freeze	27 4	2 53	23	5	
Difference	22 6	1.21	19	5	14

a/ Unless noted otherwise, ozone depletion is constrained to 50 percent

CHAPTER 11

DESCRIPTION AND ANALYSIS OF REGULATORY OPTIONS

This chapter presents and evaluates the range of regulatory options considered for limiting the production and consumption of chlorofluorocarbons (CFCs) and halons. It explores two generic types of regulatory approaches -- the use of economic incentives and the use of more traditional engineering controls or product bans. Within each of these general approaches, several options are discussed and evaluated. Specifically, the chapter focuses on the following five regulatory options:

- auctioned rights;
- allocated quotas;
- regulatory fees;
- process and engineering controls and product bans; and
- hybrid combinations of allocated quotas plus controls/bans and allocated quotas plus fees.

Economic incentive approaches (auctioned rights, quotas, and fees) generally provide incentives through higher CFC/halon prices for firms to reduce their use of these chemicals. Those firms who can make relatively low-cost reductions will do so, while those firms who do not have such options will continue to use CFCs or halons, albeit at a higher price.

The first section of the chapter discusses the design of each of these options. In developing these designs, a wide range of possibilities was evaluated. For example, in the case of auctioned rights, auctions could be held at specific times and places with only attendees bidding, or they could be conducted through the mail. Bidding could be limited to certain people or open to anyone. The process used in selecting among the many possible design options for each of the five approaches was to create the most straightforward option possible so as to facilitate its potential to be successfully implemented and to choose design characteristics in light of the following evaluation criteria:

- Environmental protection;
- Economic costs and efficiency;
- Incentives for innovation;
- Equity;
- Administrative burden and feasibility;
- Compliance and enforcement;
- Legal certainty; and
- Impacts on small business.

The analysis of the five options against these criteria draws from several sources. Cost estimates, including transfer payments, were developed from the Integrated Assessment Model described in earlier chapters and in Appendix I. Estimates of administrative burdens were drawn from a separate study of this aspect of costs presented in Appendix M. Impacts on small businesses were assessed as part of the Regulatory Flexibility Analysis presented as Appendix L. Other information and discussion draws from numerous meetings of the

Stratospheric Ozone Protection Workgroup which contains representation of interested offices within EPA and from a series of meetings with CFC and halon user and producer industries.

The remaining sections of this chapter analyze and evaluate the five options. Given the complexities of the options, a simple quantitative evaluation was not possible. However, considerable information was developed to provide a basis for comparing, both quantitatively and qualitatively, the options under consideration.

11.1 DESCRIPTION OF REGULATORY OPTIONS

For each of the five options listed above, this section presents a brief summary of how that option would be structured and then a discussion of key design features. For simplicity, the discussion focuses on CFCs. Section 11.3 below discusses the same options in the context of halons and explains why the two families of chemicals are being treated separately.

11.1.1 Auctioned Rights

SUMMARY OF SYSTEM DESIGN

CFC rights would be auctioned to any interested party. Firms using or producing CFCs could elect to participate in the auction. The number of rights auctioned would be determined by the desired regulatory goal (e.g., production freeze, 20% or 50% reduction) and could be reduced over time to reflect a CFC phasedown. Revenues from the auction would go to the U.S. Treasury.

The right would allow a firm to produce a specified amount of CFCs (the amount would be specified as so many kilograms of CFC-11 or CFC-12, 1.25 times that amount of CFC-113, etc.). CFC production in any given year would equal the quantity of rights auctioned. Multi-year rights and banking are inconsistent with meeting the annual obligations for production limits required in the international protocol and therefore would not be allowed. (Firms could, however, use the rights to buy CFCs and then stockpile the chemicals themselves or rights permitting specific levels in each of two or more years could be auctioned.)

Firms now producing CFCs are likely to participate and obtain rights directly through the auction. They would then have the option of selling CFCs that have already been permitted to their customers (presumably for a higher price reflecting their auction bid). Alternatively, they could also sell CFCs to user firms that had directly obtained rights at auction or in secondary markets. Similarly, user firms could elect to buy CFCs from any producer that had already obtained rights at auctions (or from wholesalers or processors that had rights), or they could elect to buy rights separately at auction or on a secondary market and then assign them to their suppliers at the time of CFC purchase. Most CFC users would probably not become directly involved with rights, but would instead rely on their existing distribution chain to obtain the required rights and CFCs.

EPA recordkeeping would begin with an account being established for each winning bidder at the time of auction. Future transactions would be credited and debited against that account, similar to a checking account at a bank.

Because all rights eventually reach the hands of the CFC producers (or importers), monitoring compliance involves ensuring that the five CFC producers and ten or so importers have total rights equal to or greater than their actual production/import levels.

DISCUSSION OF DETAILED DESIGN FEATURES

• Number of rights. The Montreal Protocol and discussions of domestic rules have focused on setting regulatory goals, directly linked to CFC production and domestic consumption. This simplifying assumption is appropriate because it reflects the very long atmospheric lifetimes of CFCs which minimizes any need to be concerned about prompt versus delayed emissions. To the extent the regulatory requirement involves a gradual or stepwise phasedown of production, the number of rights issued would likewise be diminished over time.

> The number of rights would be determined by the regulatory goal (e.g., a freeze, 20%, 50%, reduction) and be modified to reflect any changes in that goal over time.

• Definition of rights. Rights could be defined for each type of CFC (CFC-11, -12, -113, etc.) or a standard CFC depletion unit could be developed and used for any of the regulated CFCs based on its relative depletion potential (e.g., a pound of CFC-11 and -12 would be 1 unit, a pound of 113 would be 0.8 units, etc.). The latter system results in a larger market, provides additional flexibility to firms, and does so without sacrificing the goals of environmental protection. The UNEP protocol recognizes the desirability of permitting trading among CFCs based on their relative ozone-depleting potential.

> A standard CFC depletion unit would be defined and trading among regulated CFCs would be permitted based on their relative ozone-depleting potential.

• Length of right. Rights could be for an amount of CFCs consumed during a single specified year (e.g., 100 kilograms in 1987), an amount which could be consumed annually for several years (e.g., 100 metric tons for each year from 1990 to 1994) or they could specify a total amount over a given a period of years (e.g., 500 kilograms from 1990-1994). Rights of several years duration could reduce the frequency of required allocations as well as ease the transition to tighter standards. However, the terms of an international agreement appear to limit EPA's flexibility in developing multi-year design features. Also, enforcement and compliance monitoring would be hindered by rights of long duration, since in many cases EPA would not be able to evaluate compliance until the end of the multi-year period.

> Rights will specify a quantity of CFCs for each year or for each of several years.

• Banking of unused rights. A related issue is whether rights that are issued for a specified time period should be able to be "banked" and used sometime after that date. While the use of either banked or multi-year rights provides increased flexibility and certainty for industrial planning, neither use adversely affects the environment -- while more production or use might occur in a particular year, that would only result if less than permitted production occurred in a prior year. Once rights are sold, it is assumed that the emissions have occurred and may not care what year they are actually used. However, banking does not appear consistent with the formula for determining compliance in the international agreement, and it would also complicate domestic compliance monitoring. Firms seeking additional flexibility would have to stockpile CFC supplies instead of rights.

Banking of unused rights would not be permitted. It is inconsistent with the international agreement.

- Allocation of rights. Rights could be initially allocated either by distributing them to past CFC user industries (or producers, see quota option, below) or by auctioning them. In general, the first option -- grandfathering past users or producers -- involves granting them a potentially valuable property interest (CFC rights) and may be criticized primarily on equity grounds (e.g., why benefit current users and producers and discriminate against future users and consumers). Because of the large number of CFC users, giving rights directly to them would be administratively quite complicated. The second option -- auctions -- would be more equitable. Furthermore, under an auction instead of the revenues raised in accomplishing this regulatory objective initially going to past producers or users, it would go to the federal government in the form of the auction price. However, legal concerns have been raised about EPA's authority to hold an auction that would result in revenues greater than the costs of administering the program. A third possible option would be to give production rights to producers and consumption rights to user industries. However, this option would not substantially reduce the market power of producers and would not be feasible administratively because of the many thousands of user firms.

Initial allocation would be based on auctions.

- Participation in the auction. Auctions could be open to any interested party or they could be restricted to bona fide producers or users. A "producers only" auction would be limited to seven firms (possibly plus importers) and might not create enough of a market to avoid market domination or possible collusion among one or more firms. An auction limited to users could involve 40,000 firms or more, but only a small portion are likely to participate with the remainder probably relying on their CFC distribution chain to provide them with CFCs that have already been permitted at the time of production. If the auctions were open to both producers and users, maximum flexibility might be achieved. Large or small users across all industries, along with chemical producers (and wholesalers and reprocessors) could participate. Barring non-users or non-producers might seem attractive, but would involve the administratively complicated task of qualifying who was or was not a real user. Nonparticipants or firms not winning adequate rights at auction could satisfy their requirements through their CFC distribution chain or through secondary market transactions and would not likely become involved with rights at all.

Auctions would be open to anyone.

- Structure of auctions. Many different types of auctions are possible, including those with open versus sealed bids and those where winning bids pay the same or different prices. The structure of the auction may influence its competitiveness, efficiency, and its final price. Sealed bids have the advantage of being able to be done through the mails and therefore would not require representation at one central location. They also may more directly reflect the value of the right for an individual firm rather than what the party thinks an oral auction will produce. However, sealed bids limit the firm's flexibility to respond to information made available during the oral bid. Once all the bids have been assembled, the winning ones could be awarded from the highest bid on down until all the rights are assigned. Alternatively, the same price (as established above) could be charged to all firms submitting bids above the lowest accepted one (a uniform price auction). This latter approach would reduce the overall costs to firms (the transfer costs) without substantially reducing incentives for reducing emissions, but might encourage firms to bid higher than they expect to pay. While set asides (e.g., a portion of total rights) could be earmarked for certain users or for small firms, this option may not be necessary if an active secondary market develops.

<u>The structure of the auction would involve sealed bids. The rights would be awarded based on the highest bid to the lowest successful bid until the supply is exhausted. A uniform auction price could be set or another mechanism could be used for determining price</u>.

- <u>Trading of rights</u>. Once the initial allocation has been completed through auctions, parties may transact the purchase or sale of rights. These secondary market transactions would provide greater flexibility for firms electing not to participate in the auction or whose bids were not accepted. It also provides greater flexibility for firms to meet short-term changes in their business activity (e.g., they may have bought either too few or too many rights). An active secondary market will also correct any inefficiencies at the time of the initial auction moving the system in the direction of lower total costs. The advantages of trading must be evaluated in the context of possible increases in administrative burden. To create an active market requires an effective and timely recordkeeping system be established to allow producers and possible buyers of rights to validate transactions before they are completed.

<u>Unrestricted trading of CFC rights would be encouraged</u>.

- <u>Recordkeeping requirements</u>. To ensure the integrity of any trading system and to determine compliance, some form of recordkeeping will be necessary. At the time of the initial auction, winning bidders could be awarded rights and at the same time have an EPA account established. EPA (or its designee responsible for operating the system) would have to be notified of any future transactions involving those rights and appropriate accounts would be debited or credited accordingly, along the lines of a checking account. Eventually rights would move along the chain of chemical distribution (from users to processors to CFC producers) where they would be held. CFC producers would have to have adequate rights, either bought at the auction or obtained from customers, to match their production. EPA would monitor compliance by periodically comparing the number of rights surrendered by a CFC producer (or importer) with its actual production data. In order to check production records, EPA would also need to review records on production. Buyers and sellers of rights would have to register each transaction with EPA (or its designee) and chemical producers could only sell CFCs equivalent to their rights total bought at the auction or obtained in exchange from sales to users. Administrative burdens would depend on how effectively the tracking system operated

A recordkeeping system to track all rights transfers would be established by EPA as a compliance and enforcement mechanism. Records would also be required of all producers/importers.

- Recycling of CFCs. The regulatory and permitting system described above is based on limiting new production of CFCs over time and does not restrict the continued recycling and reuse of past CFC production. Indeed, because rights are required for only newly produced or "virgin" CFCs, this system provides an incentive for recycling. Recycled CFCs may, however, create some difficulties from an enforcement perspective. Recycled CFCs could be permitted through a crediting system which would be consistent with rights required for virgin CFC production. While recycling activities are now used by a limited number of firms, this practice is likely to become more widespread over time and may involve thousands of firms. Alternatively, EPA could allow recycling without rights or could simply require that all recycled CFCs be labelled.

Recycled CFCs would be kept apart from the rights system; no labelling of recycled CFCs would be required.

- Detection and definition of violations. The ability to enforce against users and producers of CFCs will necessarily differ under a rights system than under more traditional EPA regulations which include specific emission limits over specified and relatively short periods of time. Firms may be out of compliance because they have purchased and used CFCs without rights, have produced and/or sold CFCs without adequate rights or to parties lacking their own rights, or they may have fraudulently sold rights. Moreover, EPA may have to determine the liable party in fraudulent activities which could be complicated due to the large number of participants in the system, and could hinder enforcement. EPA will have to develop an enforcement policy to accompany this regulatory package which defines the nature of a violation, rules governing liability, and the basis for calculating penalties.

Violations and accompanying penalties will be defined as part of a penalty policy developed in conjunction with this regulation.

11.1.2 Allocated Quotas

SUMMARY OF SYSTEM DESIGN

Based on the regulatory goal (e.g., production freeze, or 20% or 50% reduction) production and consumption quotas would be allocated to the five CFC producers and ten or so importers based on their historic 1986 market share. As demand for products made with CFCs continues to increase over time, these limits on supply will result in a shortfall of supply relative to demand and could result in increases in the CFC market price. Individual CFC users are then faced with the decision of whether to take steps to reduce consumption or to pay the higher costs of CFCs. Producers could be allowed to trade their quotas to provide added flexibility (e.g., shifts in business plans or the desire to close specific facilities).

EPA would issue rights only to the seven producers and fourteen or so importers. Periodic reports would be submitted to EPA by these firms to verify compliance with production levels contained in rights. Occasional site visits could further verify compliance. No rights or enforcement would involve CFC users.

DISCUSSION OF DETAILED DESIGN FEATURES

• Production and consumption limits. The total production and consumption limits would be determined by the regulatory goal. Since international and domestic regulatory discussions have focused on limiting production and consumption as the key parameter, this approach should be straightforward. Production and consumption limits would be set on an annual basis (e.g., annual production equal to 1986 levels) to reflect current levels of control. If the regulatory requirement is reduced over time, the overall production and consumption limit and allocations to producers/importers would also be reduced. Trade-offs among the regulated chemicals would be permitted based on their relative ozone-depletion potential.

> Total production and consumption limits would be determined by regulatory goals. Trade-offs among regulated chemicals would be permitted based on their relative ozone-depleting potential.

• Allocation of production and consumption limits. Total production and consumption limits could be allocated among existing producers and importers based on historic levels. Allocation could be based on 1986 levels. Auctions involving the seven producers and fourteen importers represent an alternative allocation system. However, with the small number of firms involved, market dominance and possible collusion could be a problem. An auction among producers would, however, address concerns about equity, but might raise additional legal issues. Under an auction, the revenue created by the regulatory scarcity would go to the U.S. Treasury instead of the chemical companies. These reveues could then be appropriated by Congress and directed toward projects to improve the social welfare.

> Production and consumption rights would be allocated among current producers and importers based on historic market share.

• Banking of unused quotas. Producers may decide not to produce their full quota in any given year and "bank" the unused portion for future years. Banking provides added flexibility for producers and users and will allow them to better accommodate year-to-year fluctuations in demand for CFCs due to the business cycle. However, banking complicates compliance monitoring. While producers may stockpile production in any given year consistent with their quota, banking of rights is not consistent with the terms of the international protocol.

> Banking of unused production rights is not consistent with the international agreement and therefore would not be allowed.

• Trading of allocated quotas. Once initial allocations are determined, firms could be given the option of using their quotas themselves or trading them to other producers. (Because of the capital expense of a CFC production facility and the likely scheduled phasedown of allowable production, it is unlikely that new producers would want to enter the market.) If trading among producers were permitted, this would allow greater flexibility for existing chemical producers to gradually reduce, consolidate or eliminate their production facilities. However, fewer producers might result in greater market dominance. All trades would have to be recorded with EPA.

Trading among producers and among importers of their quotas should be permitted.

- Recordkeeping requirements and compliance monitoring. Producing and importing firms would be required to maintain records of quantities of the regulated chemicals produced and imported and to submit reports periodically to EPA. Producers would also be required to keep records which serve as checks on their production figures. EPA would conduct periodic site visits to verify information. All producers and importers would be required by regulation to report their activities related to the controlled chemicals.

Recordkeeping, reporting and monitoring would focus only on producers and importers.

- Recycling of CFCs. Because the above system focuses on production limits, any recycled CFCs would not be counted against the yearly quota. In fact, recycling could be encouraged by the higher market price of virgin CFC production. Moreover, since only records of new production would be required, no permitting or reporting would be required. If, for enforcement or monitoring purposes, it were important to distinguish recycled CFCs from virgin production, labelling could be required.

No restrictions would be applied to recycled CFCs.

- Definition of violations. Producers or importers may be out of compliance by producing quantities in excess of their quota. Periodic reporting of production would be required to aid EPA in making this assessment.

Penalties will be defined consistent with current statutory language as part of a policy developed in conjunction with the regulation.

11.1.3 Regulatory Fees

SUMMARY OF SYSTEM DESIGN

Under this regulatory option the price of CFCs is increased directly by EPA in order to provide an incentive for firms to reduce their use of CFCs. The regulatory fee would be set (based on EPA analysis or a predetermined cost index) at a level thought adequate to achieve the desired regulatory goal. Future modifications to the initial fee level could compensate for missing the mark, though not without some time lag. In addition, the fee could be increased over time to reflect the phase-in of more stringent reduction targets. The fee would be collected directly from CFC producers/importers with revenues going to the U.S. treasury.

DISCUSSION OF DETAILED DESIGN FEATURES

• Scope of fee. The fee would be assessed against the regulated chemicals based on their relative ozone-depleting potential. For example, the fee on CFC-11 would be higher than that on CFC-113. Since CFC production costs will not have changed, the fee would be in excess of the current market price of CFCs (e.g., a fee of $.50/pound would approximately double the current price of CFC-12).

Fees would cover all regulated chemicals and be based on their relative ozone-depleting potential.

• Payment of fees by producers and importers. Fees would be collected from chemical producers and importers. While these firms are likely to pass on the costs of the fee to their customers, it will be administratively easier to collect the fee directly from the seven producing companies and from importers. The total amount paid would be based on the quantity of the fee as determined by EPA regulation and the quantity of regulated chemicals produced or imported. The latter information should be readily available as part of periodic reporting requirements to EPA.

Fees would be collected from chemical producers and importers.

• Initial setting of fee amount. The goal of the regulatory fee is to provide an adequate economic incentive for enough firms to reduce their consumption of the regulated chemicals to meet a regulatory goal (e.g., a freeze, 20% or 50% reduction). Thus, in determining the initial fee schedule, EPA must evaluate the likely decisions by firms -- to either pay the fee and continue to use CFCs or to take alternative steps to reduce consumption. Given the diversity of firms, this analysis is not a simple one. If the fee is set too low, the regulatory goal will not be satisfied and the U.S. would be out of compliance with its international obligations. If it is set too high, firms may make unnecessary expenditures to reduce CFC consumption.

Based on an analysis of likely firm behavior, with some margin of error to ensure compliance, EPA will determine the initial level of a fee.

• Shifts in fee over time. The fee may have to shift over time to compensate for missing the target regulatory goal or to achieve changes in the goal (e.g., a scheduled production phasedown). Such shifts could be determined by administrative action or they could be predetermined with automatic increases in the fee if not enough reductions occur, or automatic decreases in the fee if reductions in excess of the regulatory goal occur. However, in changing the fee EPA must consider that industry's response may lag by one or more years, and that considerable annual variability in CFC demand due to the business cycle may mask changes in use due to the amount of the fee alone.

A self-adjusting fee formula should be included in the regulation with periodic assessments of the formula based on administrative discretion.

• Monitoring and enforcement. Periodic reports of production would be required of producers and importers. Checks on production would also be required. These reports, along with the amount of the fee set by regulation and adjusted accordingly, would be used as the basis for determining the amount of fee owed by a firm. EPA would conduct periodic audits to determine accuracy of reports.

Reporting of production would be required by producers and importers. This would provide a record for assessing fees and a basis for enforcement.

• Definition of violation. A violation would occur for every day that a company owed but did not pay a fee. This would apply if a firm were found to be underreporting its production. At a minimum, the fine could be based on the amount of the fee not paid. Periodic site visits would aid EPA in verifying production quantities reported to EPA.

A penalty policy would be defined in conjunction with the development of the regulation consistent with current statutory requirements.

• Recycling of CFCs. Since only new production would be assessed a fee, recycled CFCs would not be subject to this charge. No permitting or recordkeeping would be necessary. If labelling of recycled CFCs would assist in enforcement, it could be required.

No requirements would be placed on recycled CFCs.

11.1.4 Engineering Controls and Bans

SUMMARY OF SYSTEM DESIGN

In line with the usual EPA approach to limiting emissions of a pollutant, the Agency could develop a series of specific control measures requiring targeted CFC user industries to reduce their consumption of these chemicals. For example, EPA could ban the use of CFC-blown packaging, require recovery and recycling from users of CFCs in automobile air conditioning, and require substitution or recycling of CFCs used in sterilization. The list of controls would be developed based on considerations of costs, effectiveness, administrability, and other concerns and would be administered through the EPA headquarters and regional offices, along with state and local pollution control agencies.

DISCUSSION OF DETAILED DESIGN FEATURES

• Selection of regulations. EPA contractors and staff have developed engineering cost data on controls for each of the major uses of CFCs. Based on this analysis, EPA would select control options based on the following criteria: currently available technologies; relatively low cost of reductions; administrative burden and enforceability; quantity of reductions achieved; and effects on small businesses. Specific regulations could include engineering or process controls, product substitutes or bans.

<u>EPA would select specific regulations aimed at achieving low-cost reductions based on currently available technologies, and other traditional Agency concerns</u>.

- <u>Quantity of reductions required</u>. The number of specific regulations will be determined by the amount of reduction achieved by each, the likely growth in non-regulated uses of CFCs, and the regulatory target (e.g., freeze, 20% or 50% reduction). A priority listing of regulations could be developed as part of the proposal with the top several taking effect in the near-term, with others down the list taking effect only as required to meet the regulatory goal. Like an emissions fee, EPA would have to carefully analyze current CFC markets and uses to determine the likely quantity of reductions required in order to avoid over- or under-regulation. However, future modifications to the list of requirements would involve time lags, and EPA could not ensure that it satisfied its obligation under the international agreement.

<u>EPA would publish a priority list of specific controls and items on the list would take effect, as necessary, over time to meet regulatory requirements</u>.

- <u>Compliance and enforcement</u>. CFC regulations would be enforced in the same manner as other EPA regulations. Recordkeeping and reporting requirements would be established which would allow EPA to determine compliance with the regulations. Site visits would allow for inspection of records, operation of control equipment and work practices. Where appropriate, rights would be issued, reports required, and site visits undertaken. Where control equipment is required, allowable levels of emissions, test methods and performance test requirements would be established. Where bans are instituted, compliance monitoring might primarily involve reporting. Given the large number of firms which might be affected, substantial resources may be required and regional offices along with State and local agencies would be involved.

<u>Compliance and enforcement activities would follow traditional EPA practices</u>.

11.1.5 Hybrid Approaches

<u>SUMMARY OF SYSTEM DESIGN: ALLOCATED QUOTAS PLUS CONTROLS/BANS</u>

This hybrid approach would set a production ceiling based on the regulatory goal and allocate quotas to current producers/importers. In addition, EPA could specify one or more regulations requiring specific industry sectors to reduce emissions. The specific regulations would be based on potential costs, reductions and administrative feasibility. Those industries where low-cost reductions are possible, but might not be taken, would be likely candidates for regulation. The specific regulations could take effect at the start of the regulatory program or they could be prospective, taking effect in order to meet more stringent deadlines. They could act as guidelines (e.g., be voluntary) or they could be mandatory.

<u>SUMMARY OF SYSTEM DESIGN: ALLOCATED QUOTAS PLUS REGULATORY FEES</u>

This hybrid approach would ensure that the Protocol's reduction requirement were satisfied by only allocating the allowable production and consumption rights to producers and importers as described above under Option 2. In addition, EPA would require a regulatory fee on consumption (defined as production plus imports minus experts) aimed at capturing the transfers (windfall profits) accruing to the producers and importers. By capturing this windfall, the addition of a fee to the quota system would remove any economic incentive by the producers to delay the introduction of chemical substitutes and thus have both environmental and economic advantages over the allocated quota system alone.

11.2 EVALUATION OF REGULATORY OPTIONS

This section presents the criteria used to evaluate each of the options and analyzes each option based on those criteria. The criteria are:

- Environmental protection;
- Economic costs and efficiency;
- Incentives for innovation;
- Equity;
- Administrative burdens and feasibility;
- Compliance and enforcement;
- Legal certainty; and
- Impacts on small businesses.

The goal of environmental protection involves evaluating the control option to determine whether it ensures that a specific regulatory goal (e.g. production freeze, 20 or 50 percent reduction) will be achieved. This criteria is particularly important in this program area, because failure to obtain that goal in any given year would result in the United States' failing to meet its obligation under the international protocol.

Economic costs and efficiency are important considerations because of the widespread use of CFCs throughout many industrial categories and the desire by EPA to minimize the economic burden of its actions. Cost estimates are based on analysis using the Integrated Assessment Model detailed in Appendix I. Output from this model also provides a basis for examining the magnitude of transfer payments which will be discussed in the section below dealing with equity.

Providing strong across-the-board incentives for innovation is critical because of the ten-year period and increasing stringency of the proposed reductions. Long-term costs of compliance could be substantially reduced if timely research and development into low-cost alternatives, new chemicals, and controls occurs before such measures are required.

Administrative burdens differ substantially among these options and are presented in detail in Appendix M and are summarized below in this section.

Legal certainty relates to EPA's statutory authority under the Clean Air Act for implementing the approaches under consideration.

Finally, a Regulatory Flexibility Analysis was conducted and is summarized below and presented in Appendix L. This study focussed on potential impact on small businesses and the possibility of plant closures, particularly in the foam blowing industry.

11.2.1 Environmental Protection

The regulatory approaches considered in this analysis differ substantially in terms of their ability to ensure that a specified goal of environmental protection (e.g., freeze, 20 or 50 percent reduction) will be satisfied.

Four approaches -- allocated quotas, auctioned rights and the two hybrids -- provide straightforward mechanisms for achieving a set level of CFC reduction. Under auctioned rights, the quantity of rights available at auction would be linked directly to the specified environmental goal. Because this goal is specified in terms of a baseline level of production, the number of available rights at auction can easily be calculated. Under the allocated quota and hybrid options, the amount allocated to producers and importers would also directly reflect the desired environmental goal.

Regulatory fees by themselves present a more difficult situation. EPA would establish the fee based on its assessment of the required price incentive to achieve the desired reduction in CFC production. Given the many factors affecting a firm's decision to reduce its consumption of CFCs or to continue their use at a higher price, the fee may not result in the required level of reductions. This situation is likely given the past volatility in CFC demand driven by general economic conditions. Thus, in years where the U.S. economy is expanding, demand for products produced with CFCs will also be expanding and CFC production levels would likely exceed the specified limits. While increases to the fee in higher years could compensate for missing the mark, this would put the United States in the position of being out of compliance with its obligations under the international protocol. To compensate for these potential problems, EPA would have to set the regulatory fee at a higher level to provide for an adequate margin of safety.

A similar problem could develop in the case of the engineering controls/ban option. While EPA would promulgate regulations sufficient to reduce CFC use in line with the regulatory goal, it is possible that growth in unregulated uses would offset these reductions, thus jeopardizing U.S. compliance with its international protocol obligations. Moreover, EPA could not assume 100 percent compliance for those firms subject to regulation. As a result, a margin of safety would have to be maintained to safeguard against violating environmental protection goals. However, the problem of ensuring that the regulatory goal is achieved is avoided in the two hybrid options by combining quotas with fees or engineering controls/bans.

11.2.2 Economic Costs and Efficiency

Estimates of economic costs for various control stringencies and coverage were presented in Chapter 9. These costs were developed using the Integrated Assessment Model (IAM) which is discussed in greater detail in Appendix I.

These cost estimates provide only a limited basis for comparing the costs under the different regulatory options. In fact, economic theory would suggest that the three economic-based approaches should result in the same costs of meeting a specified reduction goal. As a result, these three options cannot be distinguished using the IAM However, by modifying assumptions to the model to reflect possible behavioral responses to economic incentives, it might be possible to gain some insights to the costs of economic-based approaches in general.

Exhibit 11-1 summarizes the economic cost estimates under three scenarios defining a range of responses by CFC users and producers. It shows that aggregate costs through the end of the century would differ substantially depending on the rate at which firms institute available lower cost reduction measures. Thus, for the scenarios discussed in Chapter 9, the costs range from $1,010 million for the Case 2 Cost Scenario in which firms adopt CFC conservation measures relatively quickly to $2.7 billion for the Case 1 Cost Scenario in which firms adopt these conservation measures more slowly. Under an intermediate scenario in which only automobile air conditioning services and electronics industries adopt CFC conservation measures quickly (Case 1A+B), the costs were estimated to be $2.1 billion through the year 2000. While the costs through 2075 also vary, the percentage differences among cases is substantially less over this longer time period.

Thus, an important factor in evaluating the costs and economic efficiency among the regulatory options is the extent to which each provides incentives for lower cost reductions to be realized in the short term. While no quantitative information is available to distinguish among the economic-based approaches based on differing behavioral responses, the general point can be made that economic costs will be reduced and efficiency improved substantially if low cost reductions are taken in the initial years following implementation of any regulation.

Given the large number and diverse nature of industrial users of CFCs, developing specific engineering controls and product bans by themselves as the basis for meeting the regulatory goal would not likely result in capturing the lowest-cost available reductions. EPA regulations would necessarily be developed based on "model" firms and therefore might result in too great or too little reductions and associated costs for individual firms. Moreover, certain industries where low cost reductions might be available would be difficult to regulate because of the large number of affected firms or because the controls would be achieved through changes in work practices which cannot easily be monitored.

While no cases were examined based on specific options available for direct regulation, a qualitative assessment based on the considerations raised above would suggest that economic costs would be greater than under the economic incentive approaches, but the extent of the higher costs would depend on the degree to which firms responded to price increases by reducing their use of CFCs and halons. In fact, it is conceivable that a set of engineering controls and bans could actually result in lower costs than any of the economic incentive approaches if a substantial number of firms delayed making reductions in response to CFC price incentives. The results of the cost scenarios presented above illustrate this possibility.

The hybrid approach linking quotas with selective engineering controls/bans attempts to respond to the concern that firms in certain industries may not be sensitive to CFC price increases and would instead elect to continue their use of CFCs. By requiring that certain low-cost reductions be taken, this option reduces demand for CFCs. To the extent these reductions would have been taken

EXHIBIT 11-1

SHORT-TERM SOCIAL COST ESTIMATES (1989-2000) FOR DIFFERENT COST ASSUMPTIONS: CASE 6 - CFC 50%, HALON FREEZE

	Cost[a/] (millions of 1985 dollars)	Transfers[b/] (millions of 1985 dollars)
Case 1 Scenario	2,730	7,280
Case 1A+B Scenario	2,120	4,980
Case 2 Scenario	1,010	1,890

a/ Assumes 2% real discount rate.

b/ Assumes 6% real discount rate.

Source: See Exhibits 9-11 and 9-15.

anyway under the economic incentives options, economic costs would not differ between these approaches. To the extent however, that some regulated firms may face higher compliance costs, overall costs are increased and economic efficiency is reduced.

11.2.3 Equity

There are two important issues concerning equity that arise in evaluating these regulatory options. How do the options vary in terms of the quantity and beneficiary of any transfer payments? Which industries would likely bear the costs of reducing use under the engineering controls/ban options?

Under the three economic incentive systems and the hybrid option, potentially substantial amounts of transfers (e.g., the amount of the auction price, fee or quota) would be created. Because only those firms who are targeted for reductions would incur costs, the engineering controls/ban option would not result in the creation of any transfer payments.

Under the cases examined above in Exhibit 11-1, the amount of the transfers varied from $1.9 billion through 2000 in the Case 2 Scenario to $17.3 billion over the same period for the Case 1 Scenario. This range suggests that options which provide the strongest inducement for low-cost reductions to be realized early would substantially reduce the quantity of transfer payments paid by consumers. In fact, it is clear that from the perspectives of fairness and efficiency, the greatest loss could occur if firms with low cost reductions fail to make them, resulting in harm to firms that cannot reduce emissions in the short term or survive price hikes.

In the case of auctioned rights and the regulatory fee, the transfers would go from CFC user industries and consumers to the U.S. Treasury. The quantity of transfers would be the revenue raised by the fee or the auction. In the case of allocated quotas, transfers would accrue to the CFC producers and importers. In the case of the hybrid of quotas plus fees, the transfers would be split between the U.S. Treasury and CFC producers and importers.

In theory, equity is better served when monies are returned to the Treasury to be distributed in turn to citizens through programs deemed by Congress to be most socially beneficial. The quantity of transfers would be determined by the CFC price increases charged by the producers/importers. In theory, the revenues in each of these options should be equal. However, CFC producers might elect to limit price increases over time to minimize near term impacts on their customers in order to ensure future markets for chemical substitutes. To the extent producers limit price increases (and allocate their quotas to users instead), transfers would be reduced under this option, however, economic efficiency would be compromised.

Another implication of the substantial transfers for producers created by the allocated quota system is the potential economic incentive that could result in the delayed introduction of new chemical substitues. Producers may seek to avoid reducing their windfall profits by delaying these chemical substitutes. The net effect of any such delays would be higher costs of control to society and decreased enviromental protection. (DeCanio, 1988; Sobotka, 1988).

Engineering controls and bans and the hybrid approach (to a lesser extent) present possible inequities of a different nature. Under these options, specific industries would be targeted for reductions and therefore would bear the entire costs of protecting the environment. However, if regulations were aimed only at lowest cost reductions and excluded firms that were outliers (i.e., had high costs), this would not be an issue.

11.2.4 Incentives for User Innovation

Incentives for user innovation are important given the phase-down of allowable reductions over an approximately ten year period. To the extent timely investments are made in developing future low-cost reductions, the overall costs and efficiency of achieving that goal will be substantially improved.

The three economic-based approaches and the hybrid options all provide across-the-board incentives for user industry innovation. Since all firms face higher costs of using CFCs, all have the incentive to search for alternatives to their current reliance on these chemicals.

In contrast, the engineering controls/ban approach would not provide an across-the-board incentive for innovation. By only targeting certain CFC user industries, no incentive would exist for other industries to innovate away from using CFCs. In fact, because demand for CFCs would be reduced reflecting those regulated firms, CFC prices would not likely change substantially and unregulated users might actually increase their use over time. Moreover, firms might hold off making reductions in order to avoid possible problems (e.g. tighter baseline, conflicting technology requirements) if EPA promulgated regulations for their industry in future years.

11.2.5 Administrative Burdens and Feasibility

This section evaluates the administrative costs associated with each of the six options. It examines both burdens placed on EPA and industry, and divides those costs into a start-up costs (e.g., one-time costs to develop compliance, reporting and recordkeeping systems) and annual operating costs (e.g., annual costs to comply with reporting and recordkeeping activities). Appendix M provides a detailed study of these costs and assumptions which are summarized in this section.

The regulatory options differ substantially in the administrative costs to both EPA and industry. In general, the four economic-based approaches result in relatively low administrative costs, while the two approaches involving engineering controls/bans necessitate more substantial resource burdens. Exhibit 11-2 provides a summary of these administrative costs.

a. Auctioned Rights. EPA's start-up costs involved in this option primarily involve developing and testing various aspects of the auction system and establishing a computer tracking system for recordkeeping purposes. Industry start-up costs are primarily concerned with establishing procedures for assessing the CFC market and determining whether and how much to bid at auction.

The operations phase of this option involves EPA holding an annual auction, and recording and tracking all transactions. The costs of tracking transactions

EXHIBIT 11-2

COMPARISON OF ADMINISTRATIVE BURDEN ESTIMATES

Phase	Auctioned Rights	Allocated Quotas	Regulatory Fees	Direct Regulations	Allocated Quotas Regulatory Fees	Allocated Quotes Direct Regulation
Start-Up	EPA	EPA	EPA	EPA	EPA	EPA
	$1 9 million	$1 0 million	$1 1 million	$0 6 million	$1 6 million	$1 4 million
	1 9 FTE	1 1 FTE	1 7 FTE	0 2 FTE	2 2 FTE	1 2 FTE
	Industry	Industry	Industry	Industry	Industry	Industry
	$37 9 million	$0 5 million	$0 4 million	$226 8 million	$0 9 million	$225 6 million
Operations	EPA	EPA	EPA	EPA	EPA	EPA
	$4 8 million	$2 1 million	$1 2 million	$23 0 million	$2 8 million	$24 9 million
	25 2 FTE	13 8 FTE	7 6 FTE	32 6 FTE	14 8 FTE	45 9 FTE
	Industry	Industry	Industry	Industry	Industry	Industry
	$45 7 million	$1 9 million	$0 5 million	$122 4 million	$2 1 million	$123 7 million
Total Cost Through The First Year Of Operations	EPA	EPA	EPA	EPA	EPA	EPA
	$6 7 million	3 1 million	$2 3 million	$23 6 million	$4 4 million	$26 3 million
	27 1 FTE	14 9 FTE	9 3 FTE	32 8 FTE	17 0 FTE	47 1 FTE
	Industry	Industry	Industry	Industry	Industry	Industry
	$83 6 million	$2 4 million	$0 9 million	$349 2 million	$3 0 million	$349 3 million

* Does not include the expense of engineering and cost studies to develop regulations

Source: See Appendix M.

will depend on the total number of such actions and on how efficiently the recordkeeping system works (e.g., the number of problem transactions). Initial estimates suggest that EPA operating costs will not be substantial, however, they will be higher than for either of the other two economic incentive approaches. This system would also be complex from an administrative standpoint due to the annual auctions, and the need to monitor the potentially large number of trading transactions each year.

Total industry operating costs will depend on the number of firms who elect to participate in the auction and the number of transactions which occur afterwards. Initial estimates are that annual administrative costs to industry could be on the order of $46 million. The majority of these burdens are associated with the buying and selling of rights. Unlike the other two economic incentive approaches where almost no administrative costs would be incurred by CFC user industries, to the extent some percentage of CFC user firms wanted to obtain their own rights, under this option they would incur some relatively small administrative costs.

b. Allocated Quotas. Because this option only involves allocating quotas to the seven CFC producers and fourteen importers, the total costs of starting and operating this system is relatively low although the costs incurred in developing the allocations is significant. Moreover, because fewer trades are likely to occur than under auctioned rights, industry's costs of participating and EPA's costs of tracking are substantially reduced. Compliance only involves the few producers and importers. In terms of feasibility, this approach is most easily implemented.

c. Regulatory Fees. The administrative costs associated with this option are similar in magnitude to those resulting from allocated quotas. Since fees would be assessed at the point of production or importation, only those few firms involved in these activities would be involved. CFC user industries would simply pay a higher price for CFCs at the time of purchase to their suppliers reflecting the regulatory fee. EPA compliance monitoring and enforcement would be limited to the few CFC producers and importers.

d. Engineering Controls/Bans. Because of the large number of firms that use CFCs, the administrative costs of this approach were estimated to be substantially greater than the previous options. For example, for the purposes of illustrating this option, three specific regulations were imposed: a ban on the use of CFC-12 in blown packaging; a reduction in the use of CFC-12 in large automobile air conditioning shops; and a reduction in the use of CFC-12 in medical sterilization. The number of facilities assumed to be affected by these regulations were 100 for foam packaging, 20,000 for automobile air conditioning, and 150 for medical sterilization.

The start-up phase would require each affected facility to prepare a compliance plan stating how it intended to meet the EPA ban or work practice, or demonstrating the facility's ability to meet required performance standards. For example, in the case of a ban on foam packaging, facilities could substitute one of several possible alternative blowing agents. In the case of automobile air conditioning, firms would add specialized equipment allowing the recovery and recycling of CFC-12 as part of the regulation maintenance of air conditioners. The purpose of the compliance plan is for the facility to notify EPA of its intentions. Where facilities must put on control equipment to recover a specified percentage of CFCs or to meet a specified emission limit for example, the facility would be required to submit an initial performance test report which demonstrates the facility's ability to meet the required level of recovery or emission limit and which establishes the operating parameters at which compliance is achieved. Because of the large number of firms required to file such plans or initial reports, the total industry start-up costs were estimated to be $227 million. However, to the extent outright bans instead of emission control are required, costs could be substantially reduced.

Industry operating costs would also be substantial, reflecting the reporting requirements and the costs associated with occasional site visits to review compliance. Annual operating costs associated with administrative requirements were estimated to be approximately $122 million. Because more regulations than the three examined might be necessary, depending on the level of reduction required, this figure may underestimate actual costs.

EPA start-up and operating costs would also be substantially greater than under the previous regulatory options. Agency staff would be required to review the compliance plans to make certain that proposed actions would result in the required level of reductions. They would also have to modify the compliance plans, where necessary, to provide a basis for compliance monitoring and enforcement. On a monthly basis, EPA would review compliance reports to determine if the facilities are meeting the required work practice or emission reduction required. Finally, site visits would be conducted to review compliance.

In addition to EPA Headquarters staff, enforcement against a large number of firms would necessarily involve EPA Regional offices and state and local air pollution control agencies. The costs of coordinating and involving several additional layers of agencies has not been estimated in this analysis, but could be substantial. However, such costs could be substantially reduced to the extent that bans instead of control limits are utilized.

e. Hybrid -- Allocated Quotas Plus Controls/Bans. This option combines the administrative requirements of allocated quotas with a subset of those requirements associated with the previous option. Depending on the number of firms affected by the engineering controls/ban regulations adopted under this approach, the administrative costs to industry and EPA could be substantial.

In Appendix M, the analysis assumes that two regulations are promulgated. The use of CFC-12 is banned in foam packaging and CFC-12 must be recycled by large automobile air conditioning shops. Because of the large number of affected facilities (particularly in the case of automobile air conditioning), the initial estimate of administrative costs are substantial.

Industry first year start-up and operating costs were estimated to total over $348 million. Of this amount, about $121 million were annual operating costs associated with quarterly reporting and occasional site visits. EPA costs, particularly during the operational stage, would also be substantial.

f. Hybrid -- Allocated Quotas Plus Regulatory Fees. This option combines the administrative requirements of allocated quotas with those of regulatory fees. Because of the similarity in the administrative requirements of both of these market-based options, total costs of starting up and operating this hybrid option is about the same as the relatively low costs of the allocated quota option itself. Compliance monitoring and enforcement would be limited to the few CFC producers and importers.

11.2.6 Compliance and Enforcement

The regulatory options were designed in a manner to facilitate compliance and enforcement. In the case of the economic-based approaches, all compliance and enforcement actions focus on the few CFC producers and importing firms. These firms would be required to keep track of and report their CFC-related activities and would be monitored periodically to determine if they were in compliance. Given the high capital costs associated with developing new production facilities, "black market" CFCs are unlikely to become a problem. Importation limits may be monitored by U.S. Customs.

In the case of the engineering controls/bans option, substantial efforts and resources would be required to monitor compliance. Depending on the number of firms affected by direct regulations, EPA's ability to ensure compliance, and, where necessary, to take enforcement action might be limited by resource constraints. Moreover, the implementation of this option would necessarily involve EPA Regions and State/local agencies. Given the large number and diverse nature of CFC-using industries, it is likely that if this option were selected, that compliance and enforcement could be substantially more difficult. However, to the extent outright bans used instead of control requirement, administrative costs will be substantially less.

Under the hybrid approach of quotas plus controls/bans, compliance and enforcement would combine the activities of both allocated quotas and engineering controls/bans. Thus, the approach has the advantages and disadvantages of each of these options. However, to the extent fewer mandatory regulations are utilized, the difficulties associated with compliance and enforcement under the controls/ban option would be reduced. Finally, the hybrid of quotas and fees by only involving producers and importers represents a straightforward administrative process.

11.2.7 Legal Certainty

Section 157(b) of the Clean Air Act provides EPA with the authority to regulate "any substance practice, process, activity" (or any combination thereof). This clearly provides EPA with broad authority in terms of its traditional approach to engineering controls or bans. However, the economic-based approaches represent a departure from past regulations and raise legal issues concerning Congressional intent and EPA authority.

Specifically, under the auctioned right and regulatory fee options, substantial revenues would be raised for the U.S. Treasury. The legal issue is whether EPA has the authority under the Clean Air Act to raise revenues in excess of the cost of operating a program. The hybrid approach linking allocated quotas plus fees would avoid undermining the regulatory program if the fee part of the program was invalidated.

No legal issues have been raised in the context of the other options

11.2.8 Impacts on Small Business

To determine the impact on small businesses, a Regulatory Flexibility Analysis (RFA) was performed. This analysis is summarized here and included in Appendix L.

The purpose of a Regulatory Flexibility Analysis (RFA) is to evaluate impacts of regulatory options on small businesses and to evaluate alternatives to minimize those impacts consistent with achieving the desired regulatory goal.

The RFA first examined the range of industries using CFCs or halons to identify those where these chemicals are a significant percent (greater than five percent) of final product or service. Thus, the analysis assumed that where CFCs or halons are only a small part of total costs, any expenses incurred in complying with the regulation would not substantially impact the affected firms.

Based primarily on this initial screen, the analysis focused on the foam blowing industry as the only industry group with a large percentage of small businesses and a potential to be affected substantially by regulations on CFCs. The detailed analyses of this industry was limited due to the availability of information on individual firms. However, based on data that was publicly accessible, the RFA focused on the extent to which compliance costs would exceed five percent of total product costs and the extent to which firms using CFCs could be forced to close due to loss of markets to product substitutes (e.g., replacement of fiberglass for CFC-blown insulation).

The results of this analysis suggest that a relatively small percentage of market share may be lost particularly in the CFC-blown foam packaging and to a lesser extent in CFC-blown insulation industries. The loss of market share by these firms does not automatically translate into the closure of existing firms. Because substantial growth in these markets would have occurred in the absence of CFC regulation, the analysis assumed that losses in market share would first foreclose the entry of new firms into the market before forcing existing firms to shut down. Using these assumptions, the analysis found that using the Case 1 cost scenario (in which the penetration of alternative products into foam markets is reduced), virtually no existing foam facilities were forced to shut down. Using the Case 2 cost scenario (in which the penetration of alternative products into foam markets is increased), approximately 20 percent of foam facilities in the insulating boardstock and packaging industries are estimated to shut down. Even this 20 percent, however, can avoid shutting down if they are willing to suffer lower profits in the short term while switching to alternative blowing agents predicted to become available in the mid-1990s.

The estimated loss in market share is also substantially lower if firms in other industries act in a timely manner to reduce their use of CFCs. Furthermore, some segments of the foam industry are not likely to be affected at all. For example, the food packaging industry recently announced an agreement with environmental groups to switch to HCFC-22 by the end of 1988.

11.3 REGULATORY APPROACH FOR HALONS

Because they contain bromine, which is considered to be a substantially more effective ozone-depleting chemical than chlorine, Halon 1301, 2402, and 1211 are also included in the international protocol and in the proposed domestic rule. Chapter 6 examines in detail the effects on ozone depletion of varying levels of control of halons including the possibility of excluding these chemicals from regulation.

Because halons have substantially different emission characteristics and because greater uncertainties exist concerning their relative ozone-depleting potential, they are treated separately from the CFCs in the protocol and the proposal. In addition, primarily because of limited information about current worldwide production, use and emissions, the international agreement took the interim step of freezing production at 1986 production levels beginning in approximately 1990 but did not call for reductions.

The options discussed above are also possible for regulating halons. In general, the same issues and concerns about these options raised in the context of CFCs are also applicable to these chemicals. Thus, regulatory fees and engineering controls/bans would not ensure that the regulatory goal was satisfied. The same legal issues and concerns about transfer payments would develop. Administrative burdens would be greatest in the options involving engineering controls/bans.

Halons are substantially more expensive than CFCs. Furthermore, unlike CFCs which are critical elements of products, the only time halon emissions are essential is in putting out a fire. As a result of the unique characteristics, it may be possible to significantly reduce the current level of halon emissions. The halon producer and user industries have recently initiated a program aimed at cutting back emissions from testing, servicing and accidental discharge of total flooding systems and from training using handheld systems. These steps could substantially reduce current halon emissions. As a result, most of the ongoing halon production would be contained in cylinders unless used to extinguish a fire.

11.4 SUMMARY OF REGULATORY OPTIONS

This chapter has defined and evaluated six different approaches for regulating CFCs and halons. It examined the results of several different studies in comparing these options. Criteria used in this evaluation include economic costs, equity considerations, administrative burdens, legal issues and impacts on small businesses. While many of these comparisons could be made only in a qualitative manner, nonetheless, several important distinctions were highlighted between these options.

Exhibit 11-3 summarizes the results of this review. It shows that for several options, significant issues were raised which could undermine their viability. Auctioned rights raises the issue of market uncertainty, particularly in its early years of operation. Regulatory fees and engineering controls/bans alone do not ensure that the regulatory goal will be satisfied. Administrative costs under the engineering controls/ban and the hybrid approach could be substantial.

EXHIBIT 11-3

SUMMARY OF ISSUES RELATED TO CFC REGULATORY OPTIONS

Evaluation Criteria	Options					
	Auctioned Rights	Allocated Quotas	Regulatory Fees	Controls/Ban	Hybrid -- Quotas/Controls	Hybrid -- Quotas/Fees
Environmental Protection	Right number directly linked to regulation goal	Quotas directly linked to regulation goal	No certainty; would have to modify fee over time	No certainty; may have to add controls to offset increases in unregulated uses	Quotas directly linked to regulatory goal	Quotas directly linked to regulatory goal
Economic Efficiency	Efficiency achieved if low cost reductions achieved 1/	Efficiency achieved, if low cost reductions realized 1/	Efficiency achieved, if low costs reductions realized 1/	Not all low cost reductions assessable to direct regulation	Some low cost reductions guaranteed, some efficiency sacrificed	Efficiency achieved if fees reflect market prices
Equity	Large transfers from users to treasury 2/	Large transfers to producers 2/	Large transfers from users to treasury 2/	Those industries unaffected avoid burdens	Transfers reduced; cost to regulation firms	Transfers reduced, incentive to delay substitutes eliminated
Administrative Feasibility	Easy to administer through producers/ importers	Easy to administer through producers/ importers	Easy to administer through producers/ importers	Potentially large number of users involved	Depends on number firms affected by industry-specific regulations	Easy to administer through producers
Legal Certainty	Legal uncertainty related to auctions	No problems identified	Legal uncertainty related to fees	No problems identified	No problems identified	Legal uncertainty related to fees
Incentives for Innovation	Across-the-board incentives	Across-the-board user incentives	Strong across-the-board incentives	Only incentives for targeted industries	Across-the-board incentives	Across-the-board incentives
Compliance and Enforcement	Involves only producers/importers	Involves only producers/importers	Involves only producers/importers of regulations	Could involve many firms	Depends on quantity and coverage	Involves Quotas on producers

1/ Concern exists that some industries -- particularly those like car air conditioners and computers where CFC prices are a tiny fraction of total product costs -- would not take full advantage of low cost of reduction opportunities and instead would absorb the costs of fees, rights, and quotas By doing so, the costs of these approaches would increase to other industries and economic efficiency would be sacrificed

2/ Transfer costs are those expenses incurred in paying for rights, fees, or quotas in excess of the costs directly incurred/putting on controls, switching to substitutes) by reducing CFC use

Because of these above concerns, it appears that allocated quotas offers the most attractive approach to limiting the use of CFCs and halons. This approach was very similar to auctioned rights in that it should provide for economically efficient reductions. Moreover, it involves a minimum of administrative costs, is the most easily enforced option, and does not raise any potential legal issues. The major concerns about allocated quotas involve the effects of the potential windfall profits to the producers from government restrictions on supply and the possibility that user firms will be slow to implement low cost reduction measures. The two hybrid options, either alone or in conjunction, could effectively address these concerns.