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PROCEDURES AND LIMITATIONS OF ASSESSING SOCIO-ECONOMIC IMPACT OF ALTERNATIVE
STRATEGIES FOR PROTECTION OF HEALTH AND THE ENVIRONMENT FROM ADVERSE
EFFECTS OF DEPLETION OF THE OZONE LAYER

Paper prepared by the Secretariat

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I. INTRODUCTION

1. This paper has been prepared in response to a recommendation of the Ad Hoc Working Group at its first session (UNEP/WG.69/10, para. 35 (vi)). It shows the importance of the analysis of socio-economic effects to the formation of ozone policies, shows what types of socio-economic effects must be considered in connection with the ozone depletion theory, reviews available methods of analysing socio-economic effects and discusses their limitations, and provides background information for the expansion of international co-operation to include socio-economic effects, to which little attention has hitherto been given.

II. BACKGROUND: CAUSES AND EFFECTS OF OZONE DEPLETION AND STEPS REQUIRED FOR THE FORMULATION OF OZONE POLICIES

2. Ozone is important because it protects the earth from harmful solar ultra-violet radiation and because it is involved in processes that affect climate. Over the past decade, scientists in many countries have been interested in the possibility that human activities inadvertently modify stratospheric ozone: the ozone depletion theory. Many beneficial human activities which result in pollution of the stratosphere are thought to affect ozone concentrations there. Some are thought to increase ozone, and others are thought to decrease ozone.

3. As understanding of the ozone depletion theory improves, the socio-economic effects which must be considered continue to broaden. The characterization of these possible socio-economic effects and the methods used for analysing them are important in deciding on an ozone policy.

A high degree of uncertainty exists as to the effects of individual substances and the combined effects of all substances. The following table shows substances which have been identified as possible contributors to processes occurring in the stratosphere, the major human activities which lead to their emission, and whether they are thought to increase or decrease total ozone.

<u>Substance</u>	<u>Major activities and uses</u>	<u>Effect on ozone</u>
CFCs	aerosol propellant, foam blowing, air-conditioning, refrigeration, solvent	decrease
CCl ₄ , CH ₃ Cl, CH ₃ CCl ₃ , other Cl-containing compounds	intermediates, solvents dry cleaning, metal cleaning, aerosols, paints, adhesives, textiles	decrease
CO ₂	combustion of fossil fuel, desertification, deforestation	increase
N ₂ O	fertilizer use, agricultural practices	decrease
NO _x	high flying and supersonic aircraft	decrease
	other commercial aircraft	increase
CH ₃ Cl	naturally emitted by the ocean, and possibly slash and burn farming	decrease

CH₄ naturally emitted by many increase
biological processes, but
could be affected by human
activities, e.g. agriculture,
waste disposal

(See annex I for a more detailed discussion of the ozone depletion theory and annex II for a more detailed description of the human activities which may modify the stratosphere.)

4. Theoretical studies are conducted using models of atmospheric processes. Some of these processes are not well understood, and it is difficult to include the many important parameters in the models. However, these models are the only guide available for estimating future effects of present activities and hypothetical future activities on ozone. Although it relies on questionable assumptions about future emissions this kind of information is important in formulating ozone policies. Decision-makers must be aware of the usefulness and the limitations of observations and of models in using this information to formulate policies. Many experts believe that research programmes now in place are capable of reducing or eliminating major uncertainties in the ozone depletion theory itself within the next five to ten years.

5. Theoretical conditions can be compared with observed conditions in order to improve the models. While most observations are currently in fair agreement with models, information is not adequate to test model validity.

6. If projected emissions of various ozone-modifying substances occur, some models currently indicate that significant net depletion will not occur for many decades from any substance or combination of substances. However, the distribution of ozone and other substances may change. This could affect the temperature distribution which could in turn affect climate.

7. Uncertainties relating to climatic effects of ozone depletion may take much longer to resolve than uncertainties associated with the ozone depletion theory itself. Present uncertainties allow for climatic effects ranging from inconsequential to important. Ozone policies will need to be integrated with policies toward carbon dioxide and other atmospheric pollutants because the consequences of policies on the modification of climate and ozone are interrelated. (See annex I for a more detailed discussion of the ozone depletion theory and possible climatic changes.)

8. The possible effects of net ozone depletion on health and the environment are socio-economically important. The uncertainties associated with these effects are much greater than those associated with the ozone depletion theory itself, particularly if net depletion is smaller than natural fluctuations in ozone concentration. Concern about possible effects of net ozone depletion on human health, food production, and ecological balances in terrestrial and aquatic systems has led to surprisingly little research in these important areas.

9. The significant uncertainties in the extent and kinds of biological effects which would occur if there were net depletion are due to the following factors. Relatively little research has been done. It is difficult to simulate natural conditions, and not all important parameters have been identified. Biological effects research is expensive because of the large number of samples required and the long times required, particularly if adaptability is being evaluated.

10. The only biological effect on which definitive information is available is the increase in non-melanoma skin cancer due to an increase in UV-B irradiation. The environmental effects of increased UV-B irradiation have been explored in some laboratory studies and are being examined in limited field studies. Results to date indicate that some crops and species would be harmed by increases in UV-B radiation, although quantitative information, particularly for field conditions, is not available. Repair mechanisms, some of which are initiated by visible light and occur simultaneously with the harmful processes caused by UV-B irradiation, have been identified.

11. Many beneficial human activities may contribute to the modification of the stratosphere. The importance of these activities must be weighed against the possible climatic, health, and environmental effects of modification of the stratosphere.

12. Ozone protection often conflicts with many other important social policies. Policies which promote the protection of ozone could lead to a diminished world food supply if the use of fertilizers were restricted in order to decrease N_2O emissions, or if the uses of CFCs for refrigeration were restricted. Ozone protection also conflicts with various energy conservation measures, such as using the insulating capabilities of CFCs in foam, and taking advantage of the thermodynamic efficiency of CFCs as the fluid used in refrigerators, air-conditioners and chillers. The comfort, health and safety of workers and the general public could suffer if presently existing alternatives were substituted for CFCs. For example, the substitution of hydrocarbons as the propellant in aerosols leads to increased explosions and fires in aerosol filling and warehousing facilities. The substitution of methylene chloride for CFC-11 in foam blowing may lead to worker health problems because of its toxicity. The substitution of ammonia for CFC-12 in home refrigerators would lead to deaths and injuries when leaks occur.

13. A number of steps lead to the formulation of ozone policies:

- (a) Characterize the stratosphere in its natural state;
- (b) Identify the likely effect of human activities on ozone;
- (c) Estimate the health and environmental effects of possible ozone depletion;
- (d) Translate these estimated effects into costs and benefits;
- (e) Assess the socio-economic effects of controlling ozone perturbing substances and activities;

(f) Attempt to forecast trends in production and use of those substances and development of new technology;

(g) Identify and evaluate policy options, the timing for their implementation, the reversibility of possible effects, and the speed with which policies can be changed;

(h) Analyse relative costs and benefits of various policy options;

(i) Choose and implement a policy;

(j) Allocate resources for additional research and information gathering;

(k) Review new information obtained and change policies accordingly.

III. RELEVANCE OF ANALYSIS OF SOCIO-ECONOMIC EFFECTS IN THE FORMULATION OF OZONE POLICIES

14. Consideration of the socio-economic effects of alternative policies benefits decision-making. If international co-operation in ozone policy-making is to occur at some future date, it should be preceded by the analysis of socio-economic effects. The issue is not whether international co-operation in analysis should occur, but rather what such analysis should encompass, how and when it should be done, and who should do it.

15. Analysis of socio-economic effects provides decision-makers with useful tools for structuring an issue, organizing information, and comparing alternative policies. Use of such analysis leads to greater economic efficiency through allocation of resources to activities with the highest net economic benefits. It provides aids for determining the relative importance of values and an equitable distribution of costs and benefits.

16. There are two kinds of socio-economic effects associated with the ozone depletion theory - those resulting from possible modification of the stratosphere and those resulting from contemplated control actions. These effects can be analysed using a variety of methods.

A. METHODS OF ANALYSING SOCIO-ECONOMIC IMPACTS

17. This section contains a general description of methods which can be used to analyse socio-economic effects and their limitations. The possible application of these methods to formulation of ozone policies is also discussed. The choice of a method will depend on the extent to which socio-economic effects are quantifiable, the extent to which these effects can be expressed in monetary terms, the number of policy options being considered, the degree of uncertainty, the effects of uncertainty on possible outcomes, resources, and available expertise.

18. "Socio-economic effects" of a policy encompass its direct and indirect consequences on people and their financial well-being. Examples related to the ozone depletion theory are the incidence of skin cancer and the value of

avoiding it, the increased comfort provided by air-conditioning, the greater nutritional value and palatability of food preserved by refrigeration, the greater production of food because of fertilizer use, and so forth. Social values can be expressed and analysed in monetary units, but for effects that are not primarily pecuniary, this is controversial and there are no standard methods for doing it. It is often preferable to treat social effects in their natural units, e.g., changes in life span, mortality, or illness; time saved; impact on culture and traditions.

19. Methods for estimating costs and benefits will vary with national values and with national economic systems. When valuation is to be in monetary units, possible indices of value are market price; time expressed in terms of wages lost or reduced earning power; replacement cost; repair cost; cost of retraining; willingness to pay for a particular convenience, comfort, service, or good. Valuation sometimes involves personal preferences and values, as well as moral judgements. For example, in doing a cost-benefit analysis, one may be forced to place a value on a human life or human pleasure. Although this is routinely done, implicitly, by individuals and Governments in allocating resources, it can cause controversy when it is done explicitly.

20. It is often difficult to allow for the fact that costs and benefits often unequally accrue to different segments of the population, and may accrue over different time periods. Problems with distribution can be addressed but not avoided by weighing the costs or benefits in some way that adjusts for equity, and by identifying for the decision-maker the effects of a decision on various segments of the population. Distribution of costs and benefits is an ethical problem that economic analysis cannot solve.

21. The process of factoring time into the analysis is referred to as "discounting", and is encountered in any method of economic analysis. Discounting allows a subjective comparison of present and future costs and benefits. It assumes that, in monetary terms, present benefits are more desirable than equivalent future benefits (and conversely, that future costs are more desirable than equivalent present costs), and that all resources have alternative social uses. The discount rate chosen is often different for public and private interests, and discounting is especially controversial and difficult when human lives are at issue.

22. The discount rate is often taken as the real rate of return on a typical investment. Many feel that the choice of a discount rate inherently undervalues costs to future generations, particularly if the costs are very long-term or may involve human lives. This problem may only be addressed outside the framework of economic analysis.

1. Cost-benefit methodologies

23. Socio-economic effects have been traditionally analysed using cost-benefit methodologies; or which there are several. The key to the effective use of any of these methods is the choice of well-reasoned policies to evaluate, the identification of all relevant effects and their magnitudes, and a neutral valuation of costs and benefits.

24. Cost-benefit methodologies have severe limitations as the sole analytical tool for ozone policy analysis. The large uncertainties regarding both the ozone depletion theory itself and the possible consequences of ozone depletion and the very long time scales involved make valuation very difficult. The complex relationships among potential ozone modifying substances as well as our present inability to quantify the relationship between emissions and effects make the detailed analysis of costs and benefits of questionable usefulness at this time.

(a) Cost-benefit analysis

25. Cost-benefit analysis is a methodology by which the expected costs and benefits of a policy are compared. The goal is to achieve the greatest net benefits. The term "cost-benefit analysis" is often used to describe the situation in which the analysis is carried out in terms of money. It is best suited to choosing among programmes competing for resources. It can be used in making regulatory decisions, but it is not well suited to analysing social issues. Social values must be converted into monetary units before analysis.

(b) Risk-benefit analysis

26. In risk-benefit analysis, risks are left in their natural units rather than converted to monetary terms. Valuation is implicit rather than explicit in this analysis. Risk-benefit analysis allows policy-makers to see more easily the real consequences of a policy.

27. Uneven distribution of risks and benefits over various segments of the population is still a problem, but it may be more visible. Discounting still occurs. It may not be possible to calculate the discount rate which would be implied by a decision, but one cannot avoid the process of discounting where effects occur at different times.

28. Since valuation of benefits can be as difficult as valuation of costs, it is often useful to leave benefits in their natural units as well.

(c) Risk-risk analysis

29. Risk-risk analysis is a variant of risk-benefit analysis. The term draws attention to the fact that competing policies each have their own risks, and that sometimes one must simply choose between the lesser evils. Benefits may be limited to avoidance of certain risks.

2. Cost-effectiveness analysis

30. Cost-effectiveness analysis is an examination of the costs of alternative policies in relation to how effective the policies are in achieving the stated goal. Less frequently, it is used as a method for obtaining the greatest benefits for a given expenditure of resources. This method of analysis is the most useful if either the goal or the available resources are fixed. It has the same kinds of valuation, problems that cost-benefit and risk-benefit analysis have. Costs and benefits can be left in their natural units, but analysis is more difficult. Some valuation problems are avoided by defining the goal because it is not necessary to evaluate costs and benefits of competing goals.

31. Cost-effectiveness analysis would be useful in implementing a stated national policy or international commitment because the goal would be identified. It would be less useful than cost-benefit methodologies in choosing an ozone policy if there are alternative goals.

3. Decision analysis

32. Decision analysis is a technique for evaluating policy alternatives that incorporates elements of economics, systems analysis, probability theory, and decision theory. This is a method for dealing explicitly with uncertainty. It differs from the above methodologies in that they do not require an explicit analysis of uncertainties, although it is possible and desirable.

33. In decision analysis, the consequences of a decision are described in matrices involving critical decision parameters, their possible outcomes with an assignment of probabilities that each of these outcomes will occur, and the respective monetary values or relative desirability of these outcomes. Using mathematical techniques of probability theory, one identifies the decision which is the most desirable, given its likelihood and monetary value. In other words, one identifies the decision with the most valuable expected outcome.

34. Decisions are analysed in terms of critical decision parameters only. A sensitivity analysis must be conducted first to identify those parameters which have the greatest effect on the value of the outcome.

35. Decision analysis is based on an assumption that all risks have been identified, and that reasonable probabilities have been assigned to all possible outcomes.

36. Decision analysis may be especially useful in making decisions regarding ozone policies because of the large uncertainties involved. The complexity of the issue would also benefit from such a framework for analysis. However, it may be that present uncertainties are so large that the resources required for decision analysis are not justified at this time.

4. Worst case analysis

37. Another method for dealing with uncertainties is the use of "Worst case" analysis. This type of analysis is considered conservative, because it may greatly overestimate potential risks. However, use of worst case analysis does not necessarily increase the likelihood that decisions will protect health and environment (or minimize socio-economic effects) to the greatest extent possible. This anomaly can occur if competing policies each have health and environmental risks, and if their relative importance in the worst case differs from their relative importance using most probable or actual values.

38. The worst case method is not recommended as the sole basis for policy decisions because it is often based on unrealistic scenarios. It is useful as an indicator of uncertainty.

B. UNCERTAINTY

39. To the extent that there are major areas of uncertainty, the utilization of any technique can give an illusion of undue precision in the results of the analysis. It is very important that the methods used take uncertainty into account and that the important areas of uncertainty and their effects be presented with the results.

1. Costs of uncertainty in decision-making

40. A correct decision might be defined as the one which would be made if all necessary information were available. Uncertainty is the gap between what is known and what is needed to make a correct decision. Where there is uncertainty, analysis can only help to frame the questions. It cannot answer them. Uncertainty is not necessarily unacceptable, because the cost of reducing it can exceed the value of information to be obtained.

41. Uncertainty in decision-making has various kinds of costs. The first kind of cost involves losses incurred because of risk avoidance. Decision-makers may unreasonably prefer certain but moderate benefits or losses to large but uncertain benefits when there is a risk of high net costs. The second kind of cost of uncertainty is due to confusion or lack of boldness on the part of the decision-maker. Alternatives which are more uncertain may be discarded even though their benefits are greater than those of other alternatives. Lack of boldness may cause implementation of a decision to be poorly executed because of a lack of commitment to the decision, thus diminishing its benefits. The third kind of cost of uncertainty is that important costs or benefits may be overlooked entirely.

42. There are many opportunities for incurring the various costs of uncertainty in responding to the ozone depletion problem because uncertainties abound. For example, a decision-maker could incur the first kind of cost by giving insufficient weight to the health and environmental effects of ozone depletion because they are not well characterized, preferring to allow the benefits of continued human activities which may deplete ozone. On the other hand, decision-makers may take actions prematurely or may take actions out of proportion to the risks, not knowing that if they had acted less quickly, better technology would have been available in time to take necessary actions. The second type of cost would be incurred if decision-makers react every time new information becomes available or a new issue is raised, changing policies too quickly or failing to act at all because of the difficulty of choosing among conflicting policies. The third kind of cost would be incurred if a failure to fund vital research or obtain needed information meant that decisions could not be based on sound information. Research on health and environmental effects is an area where such a cost would be incurred because funding for such research may currently be inadequate.

43. In dealing with uncertainty in environmental policy-making, there is often a presumption that conditions that occur naturally are preferable to those which humans create. There is also a tendency to err on the side of controls in order to ensure that the policy chosen will not cause unacceptable harm to health or the environment. These general policies are not easily applied to the formulation of ozone policies, because most human activities which may modify stratospheric ozone are not inherently harmful, but rather, very beneficial. Thus, it is difficult to know whether a particular policy errs on the side of health or environmental caution.

2. Types of uncertainty relating to the ozone layer

44. Decisions regarding ozone policy involve a great deal of uncertainty. In formulating an ozone policy, decision-makers must balance socio-economic effects associated with certain human activities against those which would result from modification of the stratosphere. In order to make decisions, it is necessary to estimate the consequences to the stratosphere of changing particular human activities.

45. In formulating an ozone policy, there are five relationships which link competing socio-economic effects. These relationships each have uncertainties associated with them, and these uncertainties ultimately affect the balancing process and its outcome.

46. The following schematic is helpful in understanding the relationships. Uncertainties in any of these relationships become part of the uncertainty that the decision-maker must face in balancing socio-economic effects of competing policies. Each link is important. Uneven attention to uncertainties in the links is not a good basis for allocating resources unless the neglected link is one that can be strengthened fairly quickly if and when it is determined that a problem exists.

47. The first two links are fairly well characterized for CFCs, with at least a qualitative appreciation in the case of other possible ozone-modifying substances. The third link has been the subject of considerable research, but many important questions remain unanswered. It is expected that 5-10 years of research on atmospheric chemistry and transport at current levels of funding could resolve scientific uncertainty to an extent that will satisfy decision-makers. The last two links, although vitally important to future generations, have received considerably less attention than the other links. Needed biological research cannot be accomplished quickly and is very expensive. The fifth link could be characterized fairly quickly if it were necessary to do so, although characterization would probably be much less costly and certainly more accurate if done in a careful and deliberate manner.

	<u>Type of information</u>	<u>Link</u>
-	socio-economic effects	relationships between socio-economic effects and possible control actions
-	human activities	relationships between human activities and timing and quantity of emissions
-	emissions	relationships between various emissions and their ability to modify the ozone layer
-	atmospheric effects	relationships between health and environmental effects and given stratospheric conditions
-	terrestrial effects	relationships between socio-economic effects and possible health and environmental effects
-	socio-economic effects	

balancing
by
decision
makers

III. THE TIMING AND SCOPE OF INTERNATIONAL WORK

48. International work on socio-economic effects needs to be begun far enough in advance to benefit the international decision-making process. It is likely that information needed for analysis will not be available unless provision is made for obtaining it. Thus, the initial work might be to (a) identify needed information; (b) determine whether it is already available; and (c) begin taking necessary steps in order to obtain needed information.

A. RELATIONSHIP BETWEEN NATIONAL AND INTERNATIONAL ANALYSIS

49. National analyses are of limited usefulness as a basis for international-decision making because of their narrow focus. Nations use analysis of socio-economic effects both in participating in international policy making and in implementing agreed-upon policies on a national scale. In preparing for international negotiations, nations can use such analyses to identify national interest. In implementing policies, they can be used to achieve greater economic efficiency.

50. Nations generally favour policies designed to achieve a national optimum. However, a national optimum would rarely coincide with the international optimum. International policies should be a reasonable compromise between national optima and the international optimum. In order to achieve this, both national and international analyses of socio-economic effects are needed.

B. BENEFITS OF INTERNATIONAL CO-OPERATION

51. If international policy making is to be feasible, co-operation on defining possible control scenarios should begin beforehand. If it does not, nations may develop and evaluate control scenarios which are incompatible. The timing and scope of such work would depend greatly on the results of scientific assessments.

52. There are several important benefits which might be achieved through international co-operation in the analysis of socio-economic effects and in subsequent policy formulation:

(a) Co-operation decreases the resources needed by each country to the extent that duplicative work can be avoided and costs shared;

(b) Sharing experiences and ideas brings about more efficient national decisions, and may reduce administrative costs;

(c) International co-operation among experts promotes communication, and leads towards international consensus on the assessment of data, towards co-ordinated research, and to more rapid progress than if publication were the only method of communication;

(d) It is possible to increase the economic efficiency of policies due to a greater range of policy options and opportunities for trade-offs among nations.

53. The disadvantages of international work are essentially the same in any international work - the delays and expense of co-ordination, and the difficulties of reaching consensus where there are differing political, cultural, and philosophical views.

C. DESIRABLE CHARACTERISTICS OF INTERNATIONAL WORK ON SOCIO-ECONOMIC EFFECTS

54. Regardless of the institutional framework chosen for international work on socio-economic effects, the following characteristics are desirable:

(a) World experts should be brought together to discuss published analyses which have been performed by Governments and others, to assess new developments in the science and their relevance to socio-economic effects, to develop methods for national and international analyses of socio-economic effects, to identify needed information, and to recommend future work;

(b) Experts should prepare succinct assessments on which national and international decision-makers can rely. These assessments should serve as a consensus of world experts. Assessments are most useful to all national decision-makers if they are neutral compilations of facts. Mixing assessments and policy formulation tends to make the assessments more subjective, and may tend to politicize them. Policy-making and assessment should be separated institutionally as much as possible. Individual members may have policy responsibilities, but their input is likely to be more valuable if they do not;

(c) These world experts should be brought together with world experts on science, technology, and information exchange in a forum in which they can exchange ideas and co-ordinate their efforts.

D. POSSIBLE INSTITUTIONAL ARRANGEMENTS FOR BEGINNING
INTERNATIONAL WORK ON SOCIO-ECONOMIC EFFECTS

55. If international co-operation is expanded to include analysis of socio-economic effects, it is appropriate to consider the framework in which such work could occur. It may be that the convention is the best forum for all international work on socio-economic effects. Timing or other considerations may make other for a desirable, perhaps on an interim basis. Another possible international forum for such work is the Co-ordinating Committee on the Ozone Layer (CCOL). The Organization for Economic Co-operation and Development has much expertise to offer, but its limited membership limits its role and effectiveness.

56. CCOL was created through the World Plan of Action in 1977. It was assigned several explicit duties, as were other organizations. Although the need for work in the area of socio-economic effects was addressed in the World Plan of Action, no organization was specifically given a mandate to do this work. Some have inferred a mandate to CCOL.

57. CCOL meetings are attended by national experts and experts from international technical organizations. Working groups are formed to discuss recent results in the areas of atmospheric processes, monitoring, modelling, and health and environmental effects. Succinct assessments suitable for use by policy-makers are prepared. These assessments are highly regarded as representing an international consensus of scientific experts. CCOL's institutional characteristics would also be desirable in work on socio-economic effects (as discussed in Section C above).

58. CCOL is useful as a model for international co-operation on technical subjects. Because the role of CCOL as a forum for discussing socio-economic effects is a topic of current debate, and because this debate may affect the recommendations of the Ad Hoc Working Group, this issue is discussed in annex III.

IV. CONCLUSIONS

59. Many beneficial human activities may modify the ozone layer. These activities and the consequences of possible ozone modification are socio-economically important. The analysis of socio-economic effects is an integral part of ozone protection. Analysis is useful, both as a tool for advancing understanding of the problem and as a precursor to possible policy formulation.

60. Several methods can be used for analysis. Each has its limitations. Analysis is only a tool in decision making. Uncertainties and subjective factors must be considered in applying the results of any analysis.

61. Co-operation on socio-economic effects has several important benefits, and should be included in the convention. Co-operation should begin well in advance of international policy formulation so that needed information can be identified and obtained.

62. CCOL as an institution has much to offer as a model or as a forum for international work on socio-economic effects.

BIBLIOGRAPHY

- National Research Council, Causes and Effects of Stratospheric Ozone Reduction, An Update, Washington, D.C. , National Academy Press, 1982.
- Co-ordinating Committee on the Ozone Layer, Report of the Fifth Session, Copenhagen, Denmark, 12-16 October, 1981.
- World Plan of Action on the Ozone Layer, Adopted by the UNEP Meeting of Experts Designated by Governments, Intergovernmental, and Non-Governmental Organizations on the Ozone Layer, Washington, D.C., 1-9 March, 1977.
- Robert Dorfman and Nancy Dorfman, Economics of the Environment, New York, W.W. Norton & Co, 1972.
- R. Dorfman, ed., Measuring Benefits of Government Investments, Washington, D.C., Brookings Institution, 1968.
- W. Wood and H. Cambell, Cost-Benefit Analysis and the Economics of Investment in Human Resources, Kingston, Ontario, Industrial Relations Center, Queen's University, 1970.
- Orris C. Herfindahl and Allen V. Kneese, Economic Theory of Natural Resources, Columbus, Ohio, Charles E. Merrill Publishing Company, 1974.
- Ruth P. Mack, Planning on Uncertainty, Decision Making in Business and Government Administration, New. York, John Wiley & Sons, 1971.
- Ingo Walter, ed., Studies in International Environmental Economics, New York, John Wiley & Sons, 1976.
- National Academy of Sciences, Decision Making for Regulating Chemicals in the Environment, Washington D.C., 1975.
- J.E. Matheson, R.A. Howard, and K.L. Miller, eds., Readings in Decision Analysis, Menlo Park, California, Stanford Research Institute, 1976.
- A. Myrick Freeman III, Robert H. Haveman, and Allen V. Kneese, The Economics of Environmental Policy, Santa Barbara, California, Wiley/Hamilton, 1973.

Annex I

THE OZONE DEPLETION THEORY

1. Ozone is important because it protects the earth from harmful solar ultra-violet radiation (UV-B) and because it helps maintain the earth's natural heat balance that controls climate. Ozone concentration, which is highest in the stratosphere, is determined by a balance among ozone-creating reactions, ozone-destroying reactions, and atmospheric mixing processes. Ozone is created through the reaction of diatomic molecular oxygen and atomic oxygen at high altitudes. Ozone is destroyed in a variety of ways. The most important processes are thought to involve Cl, NO, and OH in catalytic cycles. Following a reaction of one of these substances with ozone, the reaction product reacts with either ozone or atomic oxygen to regenerate Cl, NO, or OH and the cycle begins again.
2. Ozone concentration is affected by temperature and by the intensity of radiation at certain wavelengths. Thus, it varies greatly with season, time of day, latitude, and solar activity. The balance between ozone formation and ozone destruction is affected by many natural phenomena, and the relationships between them are not understood completely. The atmospheric concentration of certain chemicals, occurring naturally or as a result of human activities, may also affect the balance between ozone formation and removal, and thereby change ozone concentration. Some of these chemicals can take decades to reach the stratosphere. Thus, if present human activities ever have a measurable effect on the atmosphere and ozone, it may take many years to detect it. Since removal from the stratosphere is also slow, the effects of present activities may persist.
3. Emissions of present interest which result from human activities are CFCs, N₂O, NO_x, methyl chloroform, CO₂, and CCl₄. Natural emissions of methyl chloride and methane are also of interest, both from the standpoint of atmospheric chemistry and from the standpoint of possible changes in natural emissions through human activities.
4. Although total ozone has the greatest effect on the flux of UV-B radiation, the presence of suspended matter in the atmosphere is also effective in blocking harmful radiation. Sources of such matter can be natural, e.g., volcanoes, or anthropogenic, e.g., aerosols formed as a result of SO_x emissions.
5. Current calculations indicate that there may be a warming of the lower atmosphere and cooling of the upper atmosphere (greenhouse effect) primarily due to the build-up of CO₂. Other substances which could contribute to the greenhouse effect include CFCs, nitrous oxide (N₂O), and possibly other gases.
6. Changes in the vertical temperature profile atmosphere could lead to climatic changes on earth, although present uncertainties allow for effects ranging from inconsequential to significant. Possible effects include benefits in some regions through improved atmospheric conditions for food production or improved comfort levels. Changes in climate could also result in over-all food shortages, flooding, desertification, or loss of land mass due to melting of the polar ice caps. Neither the extent of climate change nor the possible effects of such a change can be even qualitatively

appreciated with the current state of knowledge. It could be that only inconsequential effects will occur, but the possibility of significant climatic effects and possible resulting harms should be of concern to decision-makers.

7. Current calculations indicate that due to the presence of multiple sources of modification of the stratosphere, changes in the total ozone column might not occur in the near future. Changes in the distribution of stratospheric ozone are calculated to occur much sooner. Such changes would be important circumstantial evidence of the validity of the ozone depletion theory and the usefulness of the models.

Annex II**HUMAN ACTIVITIES WHICH MAY MODIFY STRATOSPHERIC OZONE
AND THEIR SOCIO-ECONOMIC IMPORTANCE**

1. Various human activities lead to emissions which may contribute to the modification of stratospheric ozone. Currently available technologies are limited in their ability to reduce these emissions. These activities are important to national economy, culture, laws, and so forth and would be the subject of national assessments.

Sources of nitrogen oxides

2. The chemically active oxides of nitrogen in the stratosphere arise mainly from photo-oxidation of N_2O . With current knowledge, it is not possible to actually predict when or to what extent N_2O might affect the stratosphere, nor the socio-economic impacts of alternative policies.

3. Much N_2O is formed naturally by bacterial in soil. Emissions are associated with: agricultural practices such as the use of fertilizers; disposal of human and animal wastes; and perhaps high temperature combustion. Thus, N_2O emissions are closely tied to food production practices. N_2O is emitted as a consequence of natural or synthetic fertilizer use. Emissions may be reduced by changing agricultural practices, but any policies which affect fertilizer use may affect food production. Other practices involving combustion (e.g., use of automobiles, emissions from power plants) may also produce N_2O . Activities associated with N_2O emissions have major socio-economic significance and would be exceedingly difficult to change quickly or substantially.

4. The first potential ozone perturbing substances to achieve international recognition were NO_x emissions from high-flying supersonic aircraft, e.g., proposed commercial supersonic aircraft, Concorde. Theoretical studies still indicate that NO_x emissions at high altitudes (above 20 km) would result in depletion of stratospheric ozone. NO_x is also emitted at lower altitudes by subsonic aircraft, but these emissions may lead to an increase in local ozone concentration, compensating to some extent for decreases at higher altitudes. NO_x emissions are thought to be an inevitable consequence of the use of internal combustion engines.

Sources of chlorine

5. The sources of Cl which have received the most attention are CFC-11 (CCl_3F) and CFC-12 (CCl_2F_2). Other sources of stratospheric chlorine include methyl chloride (CH_3Cl), carbon tetrachloride (CCl_4), methyl chloroform (CH_2Cl_3), and other CFCs (-113, -114, -115, -22, etc.). Of these, only methyl chloride is thought to be emitted due to natural processes.

6. Not all chlorine-containing chemicals have the same ozone depletion potential. Some are easily broken down in the lower atmosphere and thus do not reach the stratosphere to any appreciable extent. The relative ozone depletion potential, in combination with the quantity released, is used to calculate the effect on ozone. It is important to consider relative ozone depletion potential in assessing policies toward various human activities which may modify the ozone layer and their socio-economic effects.

7. CFC-11 and CFC-12 are believed to have the greatest ozone depletion potential (by weight) and the greatest economic significance among the chlorine-containing compounds. Their principle uses are discussed below.

Aerosol propellants

8. Aerosol propellants continue to be a major world use of CFCs, representing more than one third of 1980 world production (as reported by the Chemical Manufacturers Association). Compared with alternative propellants, CFCs offer: superior product performance, smaller capital costs but higher materials costs, much greater safety in the plant and in the distribution chain (primarily a fire hazard), and slightly greater safety to users. Other product application methods are, sometimes available. Hydrocarbon propellants and CO₂ can be used in many products, but CFCs are often preferred despite the higher materials costs. Some countries prohibit or restrict the use of hydrocarbons as aerosol propellants for safety reasons.

Refrigeration and air-conditioning

9. Refrigeration, air-conditioning, and heat pumps accounted for about one third of 1980 world production of CFC-11 and CFC-12, and relied mainly on CFC-12. Other CFC refrigerants include CFC-22 and a blend of CFC-22 and CFC-115. The ozone depletion potential of CFC-22 and CFC-115 is calculated to be about 5 per cent and 30 per cent respectively, of that of CFC-11.

10. CFCs offer advantages of energy efficiency, economy, reliability, and low toxicity and non-flammability in case of leaks. CFCs are a small part of the monetary value of the equipment, but contribute greatly to its value. Without them, existing equipment would not function.

11. Refrigeration is vital in the present food distribution systems of many countries, preventing waste and preserving nutritional value. Refrigeration is also important in health care, for preserving blood, laboratory specimens, and pharmaceuticals.

12. Air-conditioning is becoming increasingly important in many parts of the world and has contributed greatly to economic development in some regions. The comfort it provides benefits health and productivity. Air-conditioning increases energy consumption, but sound architectural practices and equipment design can be used to decrease its energy demands. CFCs provide better thermodynamic efficiency than other heat transfer fluids. Air conditioning in automobiles and in the workplace has been found to greatly improve safety.

13. Residential air conditioning is based primarily on CFC-22. Automobile air conditioning uses primarily CFC-12. Large commercial and industrial systems use CFC-11, -12, or -22 although use of only CFC-22 in future installations is feasible.

14. Heat pumps use CFC-12 and CFC-22. They provide heating or cooling and are becoming increasingly important, especially in temperate climates, because of their efficient use of energy.

Plastic foams

15. CFC use in foams accounted for about a quarter of 1980 world production of CFC-11 and CFC-12. CFCs are used as the blowing agent (to enhance bubble formation) in the production of foams. Methylene chloride or pentane can be substituted in many applications, although they have important drawbacks in the area of worker safety. Foams which are made with CFCs are used in furniture, insulation, and packaging. The presence of CFC-11 in insulating foams greatly enhances their insulating capabilities for a given thickness of material. Direct substitution of other insulating materials in current applications is often impossible. Alternative technologies are available for many of these applications, but with important loss of energy efficiency in addition to increased costs and bulkiness. Recovering and recycling CFCs emitted during foam blowing is presently not cost-effective. Research is being conducted in several countries on methods for reducing these emissions.

Other uses of CFCs

16. All other uses of CFC-11 and CFC-12 combined comprise less than 10 per cent of 1980 world production. Other uses include: use of CFC-12 as a diluting agent to prevent explosions in the sterilization of medical devices and certain foods with ethylene oxide; freezing certain expensive, fragile foods quickly; use of CFC-11 as a solvent, including cleaning coal to reduce SO_x air pollution.

17. CFC-113 and, to some extent CFC-11, are used as solvents, particularly in high quality cleaning applications. CFCs are important in the cleaning of electronics components, metal, plastic, and glass, and in certain critical drying applications. High quality cleaning is important in the manufacture of semiconductors, aircraft, computer, medical, and military devices. CFCs have advantages of worker safety and energy efficiency, and are presently of critical importance in some applications.

Other important sources of stratospheric chlorine

Methyl chloroform

18. Methyl chloroform is an important source of stratospheric chlorine. Its principal source of emissions is metal cleaning. Other significant uses include aerosols, adhesives, textiles, paints, and inks.

Methyl chloride

19. Methyl chloride is another important source of stratospheric chlorine, but unlike the other sources is primarily natural. More than 90 per cent of methyl chloride which is emitted is not manufactured in a chemical plant, but rather in nature. The fact that there is a large natural source of stratospheric chlorine indicates that although the stratosphere may be modified by additional chlorine, it has chlorine-removal mechanisms. The most important source of methyl chloride which has been identified is the ocean. Another possibly significant source of emissions is slash and burn farming, which is widely practiced in some countries. The contribution of this practice to total methyl chloride emissions is not known. This method of clearing land is harmful to the soil. Thus, an ozone policy which required a decrease in the use of this technique would have a beneficial effect on agriculture, although it may be difficult to implement.

Carbon tetrachloride

20. The vast majority of carbon tetrachloride is used as an intermediate for making other halomethanes. Many countries have restricted the use of carbon tetrachloride in metal cleaning as a solvent, in dry cleaning because of its carcinogenicity.

Sources of carbon dioxide

21. The build-up of CO₂ and consequent cooling of the stratosphere through the greenhouse effect would probably increase concentrations of stratospheric ozone. The most significant cause of CO₂ build-up is believed to be the combustion of fossil fuel. Agricultural practices and possible climate changes resulting from human activities could lead to deforestation and desertification. Such practices would diminish the earth's capability to remove CO₂ through photosynthesis. Thus, world energy policies, land use, and agricultural practices would have to be considered in formulating ozone policies. Some present methods for reducing the use of fossil fuels require increased use of CFCs, e.g., foam insulation, energy-efficient appliances (which require more CFCs per unit), and increasing use of heat pumps.

Sources of methane

22. An increase in methane emissions would lead to increased ozone concentration because methane stops catalytic cycles by which ozone is destroyed. Human activities are thought to have an insignificant effect on total methane emission. Methane is produced in enormous quantities in all parts of the biosphere, by for example, cows, micro-organisms and plants. These emissions might be affected by practices in the areas of agriculture, land management, waste disposal, natural gas and oil drilling, or by any activity that affects the biomass of the earth.

Annex III

POSSIBLE ROLES OF CCOL IN INTERNATIONAL WORK ON SOCIO-ECONOMIC EFFECTS

1. An issue currently being considered by UNEP and CCOL member countries is whether CCOL should undertake work on socio-economic effects. Examples of ways in which CCOL might do so, relying on a mandate arguably implied by the World Plan of Action on the Ozone Layer, are the following:

(a) Socio-economic experts could meet under the CCOL name and framework, but completely or partly independent of the scientific meetings (The timing of these meetings might overlap with regular CCOL meetings, and certain sessions could be held jointly);

(b) Socio-economic work could be included on the agenda of its regular meetings without any other changes other than the addition of socio-economic experts to the people now participating.

Disadvantages of CCOL as a forum for work on socio-economic effects

2. The credibility and usefulness of CCOL could be harmed. Because CCOL is a very useful scientific forum, any possible effects on its credibility and effectiveness should be given careful scrutiny. Work related to socio-economic effects is much closer to the policy-making process, and its inclusion in CCOL's agenda might politicize CCOL, thus reducing its credibility as a scientific body.

3. If socio-economic effects are to be fully discussed, then it is important to discuss the technology and uses of potential ozone-perturbing substances as well. The addition of these topics might also serve to politicize CCOL and dilute its scientific usefulness.

4. Socio-economic effects will need to be considered under the convention regardless of what CCOL does. Since the work is not already being done by CCOL, duplicative forums could be avoided.

Advantages of CCOL as a forum for work on socio-economic effects

5. Most of the kinds of activities needed in the area of socio-economic effects are now being carried out for the science (assessing the state of knowledge, recommending future research, bringing world experts together for discussions). Thus, the institutional framework already exists and is functioning well.

6. International regard for the work of CCOL would add impetus to socio-economic work.

7. Socio-economic experts should be communicating with the world's scientists so that their work is based on the latest scientific information. Many find the contact among scientists in the areas of health and environmental effects and atmospheric effects to be very worthwhile because of the relationships among the effects, and similar arguments could be made for adding socio-economic effects work.

8. It would be useful if a forum such as CCOL, which does not make policy recommendations, assessed available information on socio-economic effects. As with scientific information, the assessment might be applied in decision-making, but the assessment itself would be divorced from policy analysis.
