The Challenge of Selecting Goals:
Case Studies Regarding the Use of Critical Levels

William Dietrich

95-05 **August 1995**

THE CHALLENGE OF SELECTING ENVIRONMENTAL POLICY GOALS:

CASE STUDIES REGARDING THE USE OF CRITICAL LEVELS

by

William F. Dietrich

Discussion Paper

Center for Science and International Affairs
and Environment and Natural Resources Program

John F. Kennedy School of Government
Harvard University

Please send comments to:
Dietrich Law
William F. Dietrich
Attorney at Law
J.D., M.B.A.. M.P.P.

580 California St. Suite 500
San Francisco, California 94104

Phone: (415) 297-2356
Fax: (415) 283-3301
dietrichlaw@earthlink.net

Copyright ©1995 by William F. Dietrich

All rights reserved. No part of this manuscript may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without express, written permission from the author.

CITATION AND REPRODUCTION

This document appears as Discussion Paper 95-05 of the Center for Science and International Affairs and as contribution E-95-04 to the Center's Environment and Natural Resources Program. CSIA Discussion papers are works in progress. Comments are welcome and may be directed to the author in care of the Center.

This paper may be cited as: William Dietrich. " The Challenge of Selecting Goals: Case Studies Regarding the Use of Critical Levels." CSIA Discussion Paper 95-05, Kennedy School of Government, Harvard University, August, 1995.

The views expressed in this paper are those of the authors and publication does not imply their endorsement by CSIA and Harvard University. This paper may be reproduced for personal and classroom use. Any other reproduction' is not permitted without written permission of the Center for Science and International Affairs, Publications, 79 JFK Street, Cambridge, MA 02138, telephone (617) 495-1351 or telefax (617) 495-1635.

TABLE OF CONTENTS

Executive Summary S-1
Table of Tables iii
Table of Figures iii
Acknowledgements iv
List of Abbreviations v

1.0 Introduction 1
- 1.1 The Selection of the Type of Policy Goal Is a Fundamental Environmental Policy Decision 1
- 1.2 The Critical Level Concept 4
- 1.3 Scope and Purpose of this Analysis 4
- 1.4 Methodology of this Analysis 6
- 1.5 Organization of this Paper 7

2.0 Conceptual Perspectives regarding the Selection of Types of Targets in Environmental Policy 8
- 2.1 Definitions of Targets in General, Critical Levels, and Target Levels 8
- 2.2 The Causal Taxonomy of Three Pollution Problems 9
- 2.3 Framework for Analyzing Scientific Aspects of Target Selection 11
- 2.4 Framework for Analyzing Policy Aspects of Target Selection 18
- 2.5 Framework for Analyzing the Negotiation Aspects of Target Selection for International Environmental Policy 21

3.0 Analysis of Target Selection and the Use of Critical Loads in the Acid Rain Case 24
- 3.1 Definitions of Critical Loads for Acid Rain 24
- 3.2 History of Target Selection and the Development of Critical Loads in the Acid Rain Debate 25
- 3.3 Alternatives to Critical Loads for Acid Rain 28
- 3.4 Analysis: Scientific, Policy, and Negotiation Aspects 30
- 3.5 Lessons Learned 36

TABLE OF CONTENTS
Continued

4.0 Analysis of Target Selection and the Use of Critical Levels in the Stratospheric Ozone Case……..……...39
4.1 Definitions of Critical Levels for Stratospheric Ozone Depletion ...……39
4.2 History of Development of Critical Levels in the Ozone Debate ……... 40
4.3 Alternative Targets in the Stratospheric Ozone Case…… .43
4.4 Analysis: Scientific, Policy, and Negotiation Aspects …… 43
4.5 Lessons Learned……..……. 48

5.0 Conceptual Perspectives regarding the Selection of Types of Targets in Environmental Policy …… 50
5.1 The Challenge of the Climate Change Negotiations……. 50
5.2 Definitions of Critical Levels for Climate Change……52
5.3 History of Development of Critical Levels in the Climate Change Debate…55
5.4 Alternative Targets in Climate Change……. 58
5.5 Analysis: Scientific, Policy, and Negotiation Aspects…….. 59

6.0 Conclusions…….....71
6.1 Conclusions regarding Target Selection…… 71
6.2 Recommendations for the Climate Change Negotiations……...73

Endnotes ……81

Bibliography ……..89

Appendix A: Negotiation Theory ……97
A.1 Collective Action Versus Bargaining……97
A.2 Overview of Relevant Negotiation Theory……...97

TABLE OF TABLES

Table 1: Climate Change "Indicators" …….57

TABLE OF FIGURES

Figure 1: Simplified Causal Taxonomy for Acidifying Deposition, Stratospheric Ozone Depletion, and Climate Change ……..77

Figure 2: Typical Environmental Damage Curve ……....79

ACKNOWLEDGEMENTS

I wish to thank all of the scientists and negotiators who consented to be interviewed for this research. I want to convey special appreciation to Bill Clark, Jill Jager, Nancy Dickson, Marc Levy, Ellis Cowling Ruth Ebert, Joel Sabenorio, and Clovice Lewis for their advice, encouragement, and support during the preparation of this study.

In addition, I am grateful to Joe Kalt, Henry Lee, Ted Parson, Lars Jonsson, and Mimi Goss for comments on earlier drafts of this paper. The Wuppertal Institute and the Social Learning Project at Harvard University kindly assisted with funding expenses for this paper and related research, respectively.

Some of my foundational work on critical loads in European acid rain policy-making during the summer of 1992 was incorporated into this report. This research was performed for the project called "Social Learning in the Management of Global Environmental Risks," directed by Professor William C. Clark and Ms. Nancy M. Dickson of the Center for Science and International Affairs at Harvard University. Grants from the National Science Foundation (Grant No. SES-9011503) and the John D. and Catherine T. MacArthur Foundation partially supported the 1992 efforts.

Finally, I am grateful to Christer,Agren, Leen Hordijk, Jill Tiger, and Harald Dovland for comments on my 1992 draft report on critical loads in the acid rain debate.

Copyright © 1995 by William F. Dietrich.

All rights reserved. No part of this manuscript may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without express, written permission from the author.

SELECTED ABBREVIATIONS

AGGG	Advisory Group on Greenhouse Gases
BACT	Best available control technology
CFGs	chlorofluorocarbons
CH_4	methane
Cl	chlorine
CO^2	carbon dioxide
EPA	U.S. Environmental Protection Agency
FCCC	Framework Convention on Climate Change
GHGs	greenhouse gases
HCFC	hydrochlorofluorocarbon
IIASA	International Institute for Applied Systems Analysis
INC	Intergovernmental Negotiating Committee
IPCC	Intergovernmental Panel on Climate Change
LRTAP	Convention on Long-range Transboundary Air Pollution
N_2O	nitrous oxide
NO_X	oxides of nitrogen
O_3	ozone
ODP	ozone-depletion-potential
ppb	parts per billion
SO_2	sulfur dioxide
TRF	total radiative forcing
UN-ECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
WHO	World Health Organization
VEC	valued environmental component
VOCs	volatile organic compounds

FOREWORD

This paper was written as part of an international research program based at the John F. Kennedy School of Government that has been studying the evolution of national and international responses to the emergence of global atmospheric risks. The program has examined the development of scientific knowledge, policy options, and political goals applied to the three risks of climate change, ozone depletion and acid rain. It has paid particular attention to the potential for < learning > in the management of these problems, both across countries and across problems.

A recurring challenge in efforts to deal with these problems has been the development of science-based goals or targets for management. One of the most interesting such targets to emerge in recent years has been that of "critical levels" or "critical loads".

"Critical levels" (or "critical loads") are generally thought of as threshold concentrations of pollutants that can be tolerated without unacceptable environmental impacts. They are related to classical concepts of ambient standards for health protection, and are similar to approaches that have been used in the protection of aquatic ecosystems from eutrophying pollutants. Their application to ecosystem, as opposed to health, effects of atmospheric pollution first achieved prominence in the 1980s in the formulation of policies to deal with the threat of acid rain.

Some have hailed the "critical levels" concept as a major advance in science based policy making for transboundary environmental risks. Others have been more skeptical. In this paper, William Dietrich provides a critical evaluation of the critical levels idea, its past achievements in application to the problems of acid rain and ozone depletion. He builds on this analysis an assessment of the pros and cons of adopting critical level concepts in efforts to formulate international policy for controlling greenhouse gas emissions and climate change.

EXECUTIVE SUMMARY

This paper addresses the difficult problem of selecting the type of policy goal or target to use in environmental policy-making. It explores the use of alternative types of environmental policy targets, especially thresholds (i.e., "critical loads" or "critical levels") in international negotiations.

The framework for this paper is the "causal taxonomy" or "causal chain" for environmental pollution problems. The causal chain for a typical pollution problem begins with human activities that cause pollutant emissions. Through intermediate processes, these emissions cause adverse impacts to valued environmental components (i.e., states or resources). Then exposure variables influence the extent to which humans, plants, and animals are exposed to the change in the valued environmental component. Finally, the nature of the hazard and the exposure determine the ultimate environmental and human health consequences.

This paper seeks to answer the following questions:

With respect to the causal taxonomy of an environmental pollution problem, what are the advantages and disadvantages of "upstream," "midstream," and "downstream" targets?

Another purpose is to evaluate the usefulness of the specific targets called "critical levels" in environmental policy making. This paper strives to answer the question:

What are the advantages and disadvantages of critical levels as targets?

A third purpose is to apply these results to the climate change negotiations, as policy advice. For climate change, this paper strives to answer two questions:

Should certain critical levels, in the "midstream" target categories, be used as targets, in framing the climate change debate?

Should certain critical levels, in the "midstream" target categories, be used as targets, in developing the first substantive climate change protocol?

The answers to these questions will hopefully assist the parties to the Framework Convention on Climate Change in their deliberations about the extent and timing of reductions in the emission of greenhouse gases.

WFD
Berkeley, California
June 28, 1995

1.0 INTRODUCI ION

In June 1992, great fanfare accompanied the United Nations Conference on Environment and Development. More than one hundred nations signed the Framework Convention on Climate Change ("FCCC"). The parties to the FCCC decided to meet again in Berlin, in April 1995, to work out the first Protocol under the Convention. They originally hoped to set forth targets for reductions in emissions of greenhouse gases [(a),[1]] at that meeting. But the Berlin negotiations turned out to focus on voting rules, "joint implementation" (where a developed country pays for and gets credit for emission reductions in a developing country), the long-term funding and permanent home of the secretariat, and other issues.[2] While progress was made on several fronts,[3] the negotiations failed to produce any agreement on targets. Several key states, including the U.S., Japan, Canada, Australia, and New Zealand, refused any new "targets or timetables" for emission reduction at this time.[4] Rather than agree to a substantive emissions-reduction protocol at this meeting, the Parties set a 1997 deadline for negotiating the first substantive protocol. [5]

1.1 THE SELECTION OF THE TYPE OF POLICY GOAL IS A FUNDAMENTAL ENVIRONMENTAL POLICY DECISION

These negotiations exemplify of one of the most difficult and controversial issues in environmental policy-making: selecting the type of policy goal or target to use, and then choosing a specific target. By the phrase "selecting the type of policy target," I mean choosing a measurement of an action or change somewhere along the causal chain from human activities to ultimate consequences.

[(a)]Footnotes are denoted by letters; endnotes are denoted by arabic numerals.

Figure 1 (at the end of this paper) shows a causal structure or taxonomy for three example pollution problems. As shown, the causal chain for a typical pollution problem begins with human activities (i.e., behaviors) that cause pollutant emissions (i.e., material fluxes). Then, through complex intermediate processes and intermediate material fluxes (e.g., reaction products), these emissions cause adverse impacts to valued environmental components. A valued environmental component ("VEC") is an environmental state or resource, such as the concentration of a pollutant in air or the level of dissolved oxygen in water. Then exposure variables influence the extent to which humans, plants, and animals are exposed to the change in the valued environmental component. Finally, the nature of the hazard and the exposure determine the ultimate environmental and human health consequences.

For pollution,[6] targets could be defined in several types: 1) human activities that generate the pollution, 2) emissions, 3) intermediate processes and material fluxes, 4) impact mechanisms, 5) changes in valued environmental components ("VECs"), 6) exposure to humans, flora, and fauna, and ultimately, 7) environmental and human consequences.[7] For example, regarding a typical pollution problem, one could ask the following sample questions based on one or more measures in each of these categories:[8]

1) How much of this activity do we need, and how much can we do without?

2) How much can emissions be reduced while still (profitably) producing this economic good (or activity)?

3) What effects do these pollutants have on physical, chemical, and biological processes?

4) How do these pollutants and their intermediaries act on valued environmental components?

5) What changes in valued environmental components take place?

6) How much pollution arc people, animals, and plants actually breathing, drinking, or ingesting (i.e., exposure)?

7) What adverse effects are taking place for people, animals, and plants result from this pollution?

At most of these points in the causal chain linking human behaviors to ultimate effects, a policy target could be set. Take the example of "smog," the main component of which is tropospheric ozone, [(b)] produced by the interaction of volatile organic compounds ("VOCs") and oxides of nitrogen ("No_x"), in the presence of sunlight. Combustion of fossil fuels, especially in vehicles, is responsible for a large share of ozone production. Legislators or regulators could define a policy target for reducing tropospheric ozone in several ways:

1) *Activity/Behavior:* reductions in vehicles miles travelled (by reducing or otherwise satisfying the need for transportation),

2) *Emissions/Changes in Material Fluxes:* reduced tailpipe emissions per mile, decreased concentrations of the ozone precursors (VOCs and $NO_{x)}$,

3) *Intermediate Processes and Material Fluxes:* measures of the mixture and transport of VOCs and NO_X,[9]

4) *Impact Mechanisms:* reduced ozone formation,

5) *Changes in VECs:* ozone concentrations,

6) *Exposure:* fewer humans and crops exposed,

[(b)] Undesirable tropospheric ozone (an irritant to human lungs) must not be confused with desirable stratospheric ozone (which protects us from ultraviolet radiation).

7) *Environmental and Human Consequences:* lower rates of emphysema and asthmatic attacks.

1.2 THE CRITICAL LEVEL CONCEPT

Besides selecting the type of target, policymakers must choose a specific target. Due to its theoretical and practical importance, I examine in depth specific targets based on the threshold amount of pollutants that can be tolerated without significant environmental impacts. This threshold is called the "critical level," or in some contexts, the "critical load." For example, in the acid rain debate, "critical load" generally refers to the amount of acid deposition that sensitive organisms (or elements of the environment) can endure without significant harmful effects.

The critical level concept has become popular in international pollution negotiations through the European acid rain debate, as explained in Chapter 3. Recently, certain scientists and non-governmental organizations have promoted the critical level concept in the climate change debate, as discussed in Chapter 5. I analyze the acid rain and stratospheric ozone depletion cases in order to draw lessons that may be applied to the climate change case.

1.3 SCOPE AND PURPOSE OF THIS ANALYSIS

This paper explores both the selection of the *type of target* and the usefulness of *critical levels as specific targets* in three major environmental problems: acidifying deposition ("acid rain"), stratospheric ozone depletion, and climate change. These are all air pollution issues, and all involve international negotiations. While I do not focus on domestic environmental policy, some of the conclusions may be applied to domestic policy making. Nevertheless, the questions posed below are *limited to international*

negotiations.

One purpose of this analysis is to provide policymakers with guidance regarding the selection of the types of targets for environmental policy. I strive to answer the question:

> *With respect to the causal taxonomy of an environmental pollution problem, under what circumstances should "upstream," "midstream," and "downstream" targets be used?*

Another purpose is to evaluate the usefulness of the specific targets called "critical levels" in environmental policy making.[(c) [10]] This paper strives to answer the question:

> *What are the advantages and disadvantages of critical levels as targets?*

A third purpose is to apply these results to the climate change negotiations, as policy advice. For climate change, this paper strives to answer two questions:

> *Should certain critical levels, in the "midstream" target categories, be used as targets, in framing the climate change debate?*
>
> *Should certain critical levels, in the "midstream" target categories, be used as targets, in developing the first substantive climate change protocol?*

The answers to these questions will hopefully assist the parties to the Framework Convention on Climate Change in their deliberations about the extent and timing of reductions in the emission of greenhouse gases.

My research on the use of critical levels in the climate change negotiations was sponsored by the Wuppertal Institute for Climate, Environment, and Energy, in

---

(c) My initial research on critical loads in the acid rain case was performed for the project called "Social Learning in the Management of Global Environmental Risks, directed by Professor William C. Clark and Ms. Nancy M. Dickson of the Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University.

Wuppertal, Germany. The Wuppertal Institute is the first major institute in Germany to systematically address global environmental problems and the structural changes needed to solve these problems.

The Wuppertal Institute was intimately involved in preparations for first conference of the Parties to the United Nations Framework Convention on Climate Change, held in April 1995, in Berlin. The German Federal Ministry for Environment, Nature Conservation, and Nuclear Safety retained the Wuppertal Institute to serve as the analytical team for the initial round of international negotiations. A previous draft of this paper was submitted as a policy analysis for the analytical team. Dr. Jill Jäger, Director of the Climate Policy Division of the Wuppertal Institute, and Prof. William C. Clark, the former Director of the Center for Science and International Affairs at Harvard University, supervised my research on critical levels in climate change." [11]

1.4 METHODOLOGY OF THIS ANALYSIS

This paper evaluates target selection in general, and critical levels in particular, from three perspectives: scientific basis, policy design, and ease of negotiation. I argue that three factors largely determine whether policymakers should use particular types of targets, and whether within the selected type, they should use critical levels. These factors are: 1) the state of scientific understanding of the environmental problem, 2) the target's usefulness in designing "good" substantive policy responses, and 3) the likelihood that the chosen target will facilitate negotiation and agreement.

To gather information for this study, I reviewed relevant scientific, political, and negotiation literature. I also conducted interviews of key scientists (in both academia and agencies), diplomatic personnel, and economists, in Europe and North America."[12]

1.5 ORGANIZATION OF THIS PAPER

Chapter 2 presents a typical environmental damage function, which helps to explain critical levels. Chapter 2 also discusses the scientific, policy, and negotiation perspectives used to evaluate different types of policy targets. Chapter 3 presents my analysis of target selection and the use of critical loads as targets in the acid rain case. Chapter 4 evaluates critical levels as targets in the stratospheric ozone debate. Chapter 5 discusses target selection and *the use* of critical levels as targets in the climate change negotiations. Chapter 6 presents overall conclusions regarding target selection and summarizes recommended actions for the climate change negotiators.

Footnotes are identified by letters, and endnotes are identified by numbers. Footnotes provide material helpful for understanding the argument. Endnotes provide source citations and additional explanatory material.

2.0 CONCEPTUAL PERSPECTIVES REGARDING THE SELECTION OF TYPES OF TARGETS IN ENVIRONMENTAL POLICY

This chapter first discusses in greater detail the causal taxonomy for three international environmental problems: acid rain,[d] stratospheric ozone depletion, and climate change. This taxonomy provides structure for analyzing target selection and critical levels as targets for these three cases. Next is a brief definition of critical levels and critical loads, in comparison with so; called target levels and target loads. Finally, this chapter presents the scientific, political and negotiation perspectives used to evaluate target-setting in the rest of the paper.

2.1 DEFINITIONS OF TARGETS IN GENERAL, CRITICAL LEVELS, AND TARGET LEVELS

Policy-makers set "targets" in terms of pollutant emissions, pollutant concentrations, impacts, or other variables. The bases for targets often include one or more of the following: environmental or health thresholds, costs, technological feasibility, political considerations, and other factors.

This paper focuses on the threshold-type of target. The term "critical level" refers generally to a threshold beyond which the likelihood of significant adverse effects rapidly increases. For example, in the acid rain debate, people use the term, "critical load," which generally refers to the amount of acid deposition which sensitive organisms (or elements of the environment) can endure without significant harmful effects. [13]

Corollary terms are "target levels" and "target loads." These are what policy

---

[d] The term, "acid rain," is commonly used to refer to what scientists call "acidifying deposition." Acidifying deposition more accuratcly encompasses forms of deposition that are acid or tend to form acid. Such deposition can be either wet (c.g., sulfuric acid droplets) or dry (sulfate particles). For case of reading, this paper frequently uses "acid rain" to refer to acidifying deposition.

makers decide are reasonable goals, based not only on environmental impact, but also on technical, economic, and political considerations. [14] The terms "target level" or "target load" often accompany the terms "critical level" and "critical load." *In this context*, the target level (or load) is related in some way to the critical level (or load).[15] Target loads may be lower than critical loads or they may be higher.[16] For example, in the 1994 Sulfur Protocol under the 1979 Convention on Long-Range Transboundary Air Pollution, target levels are a percentage of the emission reductions necessary to meet critical loads. [17]

To recap, targets mean policy goals measured in a wide variety of ways: human activities, emissions, intermediate reaction product concentrations, pollutant concentrations, exposures, and consequences. Critical levels or loads are based on science; target levels or target loads are politically-determined goals expressly related to critical levels/loads.

2.2 THE CAUSAL TAXONOMY OF THREE POLLUTION PROBLEMS

Figure 1 provides a causal structure or taxonomy for the three cases studied in this paper.[18] The structure starts at the left with human needs and wants, and associated human activities. Proceeding column by column to the right, these activities result in pollutant emissions or changes in material fluxes, e.g., changes in amounts of certain chemicals in the atmosphere. The next column, labeled "Intermediate Processes and Material Fluxes," summarizes key intermediate steps or changes in chemical concentrations. To the right, "Impact Mechanisms," summarizes the mechanisms by which the processes or material fluxes cause adverse impacts. Impacts are "Changes in Valued Environmental Components" ("VECs"), which are attributes of the environment

that humans choose to value.[19] The next column illustrates those variables that influence environmental and human exposures to the impacts. The last column lists environmental and human consequences.

This taxonomy helps us identify different kinds of targets by categorizing the different points in the causal sequence at which policies could interfere with the causal chain. [20] The taxonomy also categorizes the types of targets available. For climate change, "upstream" targets (to the left) pertain to changes in human activities, such as a certain percentage improvement in energy efficiency or a different fuel mix. Moving to the right, the next target is reducing emissions of greenhouse gases ("GHGs"). The current debate has coined the phrase, "targets and timetables," referring to stabilizing and later making percentage reductions in GHG emissions. Moving to the material flux column, policy-makers could set target concentrations of GHGs.[21] Proceeding "downstream," policy-makers could set targets in terms of total radiative forcing, temperature change, sea level rise, or other measures of climate change. Furthest downstream are targets associated with mitigation or adaption. For example, building dikes would prevent exposure to sea level rise. Cloud seeding might offset reduced precipitation.

For ease of reference, this paper divides the taxonomy into three parts. Targets pertaining to human activities and emissions are "upstream" targets. Targets pertaining to intermediate processes, intermediate material fluxes, and valued environmental components are "midstream" targets. Mitigative and adaptive targets are "downstream" targets. One could identity "critical levels" in any column in the taxonomy, but I will apply

the term as scientists and policy-makers have previously used it in the acid rain and ozone cases. Specifically, a critical level is a target measured in terms of either a intermediate material flux, an intermediate process or a valued environmental component. (The shaded cells in Figure 1 show the possible critical levels in the three cases.) This paper focuses on the advantages and disadvantages of *midstream, critical- level targets* compared to *upstream and downstream targets.*

2.3 FRAMEWORK FOR ANALYZING SCIENTIFIC ASPECT'S OF TARGET SELECTION

The Environmental Damage Curve

Figure 2 (at the end of this paper) shows a typical environmental damage curve. [22] At very low levels of pollution, there is no observable damage.[e] Next, damage increases to a threshold humans value as significant.[23] Then, damage increases dramatically as pollution increases. At some point, rising pollution shows "diminishing returns" as damage approaches the maximum level.

The question is, "At what level should public policy attempt to stop the damage?" Clearly, the bounds for policy are the no observable effect level (below which no one cares) and the maximum affect level (above which there is no point in making policy). Between these extremes, a typical damage curve rises steeply.

Policy-makers often design a pollution-control regulation to avoid the steeply increasing segment of the damage curve. In other words, they set the regulatory target to prevent damage above the level of significance.[24]

On the other hand, decision-makers often do not know the shape of the damage

---

[e] In toxicology, the "no observable effect level" or "NOEL" is the highest point at which there are no observable effects. Cf. Gots, 1992, 48

curve. In these cases, the target is a guess. They may set the target with a margin of safety below the estimated significance level to account for uncertainty in the damage function.

Another possibility is that *any* amount of the pollutant or energy may cause damage. Carcinogens and radiation are prime examples. For policy purposes, U.S., German, and French regulators assume no safe threshold of exposure for any carcinogen, [25] but for practical reasons often designate a critical level anyway. But in some cases, the no-threshold hypothesis has supported bans of certain products, such as saccharin in the U.S. Since this characteristic does not apply for the three cases examined below, I consider it no further.

Putting this discussion in "critical levels" terms, the critical level lies just before the steep rise in the damage curve.[f] [26] The assignment of the critical level necessarily involves value judgments regarding what is significant.[g] For the purposes of this paper, "critical" means the level that government-employed or academic scientists assign. Thus, I define critical levels as the independent, scientific view.

In Figure 2, suppose that the broad, gray, vertical line, "T2" represents a scientifically-defined critical level. Policy-makers could set a pollution restriction at the T2 level of pollution to just meet this level, or they could set standards above or below

---

[f] In a simplified sense, the critical level concept is a brother to the medical concept of "threshold" for poisons and drugs, i.e., an amount of a substance below which effects are relatively insignificant for an organism.

[g] For example, a group of scientists may believe that a probability of loss of ten percent of the salmon in an acidified lake represents a significant amount. In contrast, an environmental group may contend that a probable loss of five percent is significant. Industry may contend that fifty percent is significant.

Scientists typically pick species that are fairly sensitive and of some concern. (The latter consideration is a source of bias against ugly, unpopular, or widely unknown species.)

this level.

For example, the vertical line "TI" indicates a target level set below (to the left of) the critical level. If policies keep pollution at TI, the resource will be protected, with a margin of safety. The vertical line "T3" shows a target level set above the critical level. Here, policymakers have decided not to expend the effort required to meet the critical level.

The Role of "Scientific Uncertainty' in Policymaking

One of the chief problems with the above paradigm is developing the damage curve in the first place. Theoretically, if policymakers could agree on the damage curve, the debate would turn to such matters as how much cost to incur for what level of protection. In reality, however, the damage curve, the thresholds, and the efficacy of abatement strategies (to reach selected targets) are all debatable.

Under the widely held assumption that science is supposed to provide a rational basis for policy choices, [27] many view "scientific uncertainty" as a reason to delay policy decisions.[28] The thread of "scientific uncertainty" runs throughout the three cases. Due to the haphazard use of this phrase in political debate, I propose a clarification.

In the political arena, the term "scientific uncertainty" is used to mean either "scientific uncertainty," "scientific disagreement," or "scientific ignorance." I distinguish between these. By "scientific uncertainty," I mean that one or more scientific theories have been put forward, and the predictions given by these theories span a range of values. This situation is, of course, typical. By "scientific disagreement," I mean widespread "disagreement" over which theory or model best represents nature. By "scientific ignorance," I mean that scientists have not yet developed sufficiently rigorous

theories or models to understand a phenomenon well enough to make serious predictions.

While these definitions may not be as rigorous as possible, the key point is to clarify the sloppy use of the term "scientific uncertainty," which usually means that scientists cannot tell policymakers the answer. Uncertainty in predictions always exists. The discipline of management science, particularly decision analysis, has evolved to meet the challenge of making decisions with imperfect information. It is quite another matter to make decisions where the cause and effect relationships are not well understood. This distinction is crucial to the analysis of selecting targets.

Returning to the significance of these phrases for the case studies, the level of scientific uncertainty influences the possible range of outcomes, cost-benefit analyses, and other comparisons of alternative actions. The status of scientific agreement influences the credibility of such estimates. The degree of scientific understanding (lack of ignorance) influences the feasibility of selecting certain targets. If scientists do not understand the causal chain from human activities to ultimate effects, they cannot be sure that a given "upstream" response strategy (such as scrubbing emissions) will have a "downstream" benefit, in terms of reduced consequences. [29]

The Relationship between Science and Policymaking

Furthermore, the assumption that policymakers should rely on scientific "proof" as a basis for policy is debatable. The relationship between science and policy is complex, and its full explication, even for these three cases, is beyond the scope of this paper. But a few perspectives on this relationship are useful here.

Lindblom (1968) contrasts what he calls the "scientific ideal" with the "strategic

ideal." Jasanoff (1990, vii) better names these ideals as the "technocratic approach" and the "democratic approach." Under the technocratic approach, one identifies and formulates a problem, canvasses possible solutions, examines the alternative solutions, and makes a choice.[30] Under the democratic approach, analysis is subordinated to interaction, meaning the interplay of interest groups and politicians, and analysis is simplified as much as possible. Proponents of the democratic approach endorse the partisan use of analysis. [31] They believe that, when people differ over values, beyond some point further analysis cannot help and must be supplemented by interactive policy making.

Actual environmental policymaking is some mixture of Lindblom's scientific and strategic ideals. The conclusion that under circumstances of differing values, further scientific analysis becomes moot, will prove to be important in the case studies considered here.

In a scathing attack on science as a basis for policymaking, Collingridge and Reeve (1986) extend these ideas. While I do not endorse all of their views, the core points help illuminate the relationship between science and policy.[32]

Collingridge and Reeve make two central, pessimistic, arguments to dispel what they allege to be the "myth" that science is useful to policy. First, they argue that relevance to policy, by itself, is sufficient to destroy the delicate mechanisms by which scientists normally ensure that their work leads to agreement.[33] Rather than allowing a long process of theorizing, criticizing, and revising, relevance means that scientist-advocates will drive the debate.[34] Consensus is therefore impossible.[35] Politicians will be forced to compromise without taking into account the literature developed by

"rival armies of technical experts."[36]

Second, they argue that the failure of science to fulfill its purported role does not matter for policymaking.[37] They recommend making incremental decisions, with little call on science, and forgetting about the "myth" of gaining scientific consensus.[38]

To elaborate, Collingridge and Reeve argue that the realities of science are far from supporting its "mythical" power and utility. First, they assert that science does not yield the "truth."[39] Rather, sociologists of science have stressed the provisional nature of all scientific consensus, since agreement is a product of social interactions, negotiations within the implicitly accepted rules of the game of science. [40]

Second, they argue that experts can be expected to disagree,[41] because each scientist must search for a case to please his master and ensure that results fitting that case brought to attention of his paymaster. (This is a very cynical view.)

Third, in each scientific discipline, different fundamentals are agreed upon, including: "what is a problem, what is a solution, what standards of accuracy areappropriate, what techniques may be used ..."[42] Effective communication between disciplines is difficult. [43] For example, industrial hygienists assumed that there was some safe threshold level for lead in the blood, assumed to be 80 micrograms per 100 milliliters. But a geochemist questioned the threshold concept, and set off a vigorous counterattack by the industrial hygienists. [44]

Fourth, Collingridge and Reeve attack the principle of irrelevance, which is that the assessment of a scientific idea should not in any way be influenced by the use to which it might eventually be put.[45] On the contrary, the level of criticism appropriate to a scientific conjecture is determined, at least in part, by the costs which would arise

from using a mistaken conjecture. [46]

Fifth, they argue that policy cannot be based on science, because bands of experts form on each side of any issue.[47]These bands of experts disagree about the precision in various estimates.

Collingridge and Reeve also point out that a political actor may stress the adequacy of scientific information as a basis for her decision, hoping to limit political dispute. [48] Instead, other political actors question the scientific data and its interpretation, and advance rival theories. Thus political debate *widens* to a technical debate about data and interpretation.[49] *This certainly occurred in each of the three case studies herein.* The technical debate about lead in gasoline illustrates this point well: [50] Technical questions could not be answered despite the vast quantities of data available. Many long-settled questions were reopened. Attempts to settle one issue resulted in introducing more new issues. Both sides practiced selective citation to the literature.

In sum, Collingridge and Reeve assert that four problems arise when policymakers try to base their judgements on scientific results:[51] 1) Scientific data are very expensive to acquire, and gathering delays the whole policy process, which is in itself a cost. 2) By the time the results are written up, the policy problem has changed, and the research no longer relevant. 3) Policy is notoriously volatile, while science needs time to produce results. 4) Coordination of the scientific results is needed.

A major Flaw in Collingridge and Reeve's analysis is minimization of the role of science in identifying problems in the first place.[52] Even before attempts to arrive at scientific consensus, early reports identifying problems stir up interest groups, such as

environmentalists, and provide leverage and motivation for bureaucrats and politicians to undertake (or sponsor) further research and initial actions.

Furthermore, despite its drawbacks, the endorsement of a political decision by the scientific community likely performs several beneficial political functions, explained by Ezrahi (1990). These political functions include making the coercive powers of the state acceptable to people, institutionalizing and validating public actions and claims in terms of liberal-democratic values, and overcoming the tension between the need for public action and individual autonomy, among others.[53]

Evaluation of the Scientific Aspects of Target Selection

Nevertheless, Collingridge and Reeve's arguments help to fashion guidance for target selection. I apply some of their critique to the issue of target selection in each of the three case studies. I examine:

- The dependence of the particular target on scientific understanding (i.e., the lack of scientific ignorance),
- The existence or probability of a greater or lesser degree of "scientific agreement" on the issues underlying the target selection,
- The viability of the particular target given the degree of uncertainty of prediction, based on the existing state of the science,
- The likelihood of widening of the debate through focus on scientific and technical issues.

2.4 FRAMEWORK FOR ANALYZING POLICY ASPECTS OF TARGET SELECTION

Importance of Target Selection to Policy Design

The type of target has several dramatic implications for policy design and implementation. To illustrate these, consider the smog example discussed in Section 1.1.

First, who will be regulated? If the goal is to reduce vehicle miles travelled, the policy will be aimed at drivers. If the goal is to reduce tailpipe emissions, the policy will regulate vehicle manufacturers. Clearly, regulating a few large companies seems easier than regulating millions of drivers. Second, who will be regulated is tied to who pays (at least on the first order [54]). Third, who will regulate or encourage the behavior, e.g., local, state, national governments, international organizations, or private individuals or groups? Fourth, what will be measured to determine success? For smog, the possibilities include: vehicle miles traveled, emissions per vehicle, aggregate emissions, smog formation, ambient ozone concentrations, ozone intake per capita, and respiratory-related hospital visits, among others.

Without exhaustively identifying the implications of defining policy goals, the point is clear. *Choosing the type of environmental policy target is central to designing an effective policy.*

In addition, the *terms framing the debate* can also have important consequences for the types of policy responses considered. Turning to critical levels as specific targets, the most prominent implication of critical levels as the terms framing the debate is normative. Critical levels imply that no *significant* damage to the environment (and/or human health) is acceptable. This norm implicitly ignores abatement cost.

A microeconomic model indicates that society should spend resources to control pollution up to the point where the marginal cost of control equals the marginal benefit of control. This model recognizes that the marginal cost of control typically increases dramatically in preventing the last increments of pollution. Moreover, the benefits of preventing the last increments of pollution are typically much less than the benefits of the

first increments. Social welfare (defined to include externalities) is maximized when pollution control extends only up to the equivalence point.

In order to relate the microeconomic model to Figure 2, one must determine the marginal and total cost functions and marginal and total benefit functions. In the limited scope of this paper, I do not attempt to determine these relationships. Suffice it to say that achieving the critical level (i.e., avoiding any significant impact) is frequently a point high on the marginal cost curve.

Those who will bear the costs will likely inject these economic arguments into the political debate. When critical levels frame the debate, economics are folded in when politicians select target levels.[h]

Evaluation of the Policy Design Aspects of Target Selection

While recognizing these issues, it is beyond the scope of this essay to determine the implications of different approaches in terms of the cost-benefit ratios or cost-effectiveness of policies ultimately selected. This paper concentrates on how various target-types and the specific targets of critical levels may affect designing policy responses along the following dimensions:

1) Likelihood of achieving the environmental objective,
2) Ease of implementation,
3) Flexibility, and
4) Aggressiveness.

[h] As described above, target levels recognize technical, economic, and political constraints (related to scientifically-determined critical levels).

2.5 FRAMEWORK FOR ANALYZING THE NEGOTIATION ASPECTS OF TARGET SELECTION FOR INTERNATIONAL ENVIRONMENTAL POLICY

Negotiation analysis for target selection in the acid rain, stratospheric ozone depletion, and climate change cases must take into account the following elements:

1) The problem to be solved is a collective action problem, primarily involving distribution of burdens, not benefits.

2) Critical levels are a scientific concept that can be used to define a principle or a normative goal.

3) Critical levels typically set a low tolerable threshold, translating into an ambitious target. For example, current climate change negotiating positions do not include the substantial emissions reductions and other measures necessary to meet critical levels (in terms of valued environmental components) in the near term.

4) The negotiations include a large number of independent parties with diverse interests.

Summary of Relevant Negotiation Theory

The key negotiation concepts for this analysis include *value creating*, *value claiming*, and the uses of *principles* and *focal points.* Also crucial are the *perceived zone of agreement* and its relationship to *aspirations* and *anchoring.* Appendix A provides a more detailed explanation of the negotiation theory relevant to the three cases discussed in this paper.

Lax and Sebenius (1986) provide a good analytical model integrating two key themes of negotiations: creating joint gains and dividing these gains. They refer to creating joint gains as *"creating value."* Negotiators work to devise an agreement that yields considerable gains to each party, relative to no agreement.[55] Dividing up the gains is *"claiming value."* Value claimers strive to take more of the benefits of the

bargain than their opponents, through such tactics as starting high, exaggerating the value of concessions, and concealing information.[56] In the cases examined here, value claiming focuses on getting other countries to agree to sacrifice (in terms of cost, effort, reduced opportunities) to reduce pollutant emissions.

We often think of negotiations as a process of bargaining from initial positions to a compromise. But another mode of negotiations starts with discussion of *principles* which will determine the outcome. Negotiators may identify some principle, objective standard, or social norm for making the agreement. Ideally, after agreeing on a "fair" principle, negotiators apply the principle to the situation at hand. The details flow from application of the principle. [57] Opponents are more likely to accept solutions derived from a principal they feel is fair.

The critical level approach in its simplest form espouses the principle of "no significant damage to human health or the environment." The critical level/target level approach is the principle that policymakers should start from the critical level (if one exists) in developing targets based on technical, economic, and political factors.

People seem to be attracted to "round numbers" [58] and norms as, *focal points* in negotiations. For example, environmental negotiators often propose emission reductions of 10 percent or 20 percent or reductions based on "equal division." In the three cases, the norms of equal percentage reductions and critical levels are focal points.

The *perceived bargaining set* or *"zone of agreement" is* the range of agreements to which all parties would agree (with more or less benefit to each party).[59] A party's alternatives to agreement limit the bargaining range,[60] since the party could select the alternative if negotiations fail.

A negotiator's "aspirations" influence the perceived zone of agreement, i.e., they increase or decrease what she thinks is possible.[61] Negotiators sometimes strive to influence aspirations of other parties to shift the zone of agreement.

When one party makes an opening bid or an initial reference to a preferred result, the stated bid tends to affect the expectations of other parties. This is called "anchoring." A negotiator can use a maximum opening bid as an anchor for several purposes: [62] 1) to get information by noting the opponent's response, 2) to modify an opponent's minimum preferences,[63] 3) to provide something to give up or swap,[64] and 4) to make it difficult for an opponent to estimate one's minimum preferences. In this sense, a critical level could be an "anchor." A critical level could expand the zone of possible agreement toward the high end, i.e., more action. Unfortunately, little work has been done on how anchoring functions in a collective action negotiation.[65]

Evaluation of the Negotiation Aspects of Target Selection

In each of the cases, I evaluate how selection of a type of target, or a particular target, such as a critical level, did or could improve the negotiation process using (some or all of) these questions:

1) Does the target help parties create value by expanding the set of possible agreements?

2) Does the target affect aspirations, the perceived zone of agreement, or the outcome?

3) What is the influence of target as a principle or norm?

4) Does the target help achieve an agreement?

3.0 ANALYSIS OF TARGET SELECTION AND THE USE OF CRITICAL LOADS IN THE ACID RAIN CASE

In the acid rain[(i), (j)] debate, European policymakers picked an intermediate material flux, [(k)] namely acidic deposition (in mass per unit land area), as the type of policy target. Further, they relied upon the "critical load" concept to choose specific targets within this type. Therefore, before discussing target selection in the acid rain case, critical loads must be explained.

3.1 DEFINITIONS OF CRITICAL LOADS FOR ACID RAIN

What is a "critical load" with respect to acidifying deposition? It is an amount of acid, such as sulfuric or nitric acid, that will exceed the tolerance of either individual species or ecosystems (depending on how defined). The definition most cited in the European acid rain literature is that used in the pivotal report from the Skokloster (Sweden) Critical Load Workshop, in March 1988:[66].[67]

> "A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge."

Experts involved in response assessment and goal and strategy formulation use a 1991 definition from Hettelingh:[68]

> Critical loads are levels of deposition (sulfur, nitrogen, or total acidity)

[(i)] Acid rain or "acidifying deposition" occurs when air pollutants form acids either in the atmosphere or upon falling to earth. These acids react with alkalies in freshwaters and soils. When acidity overcomes the buffering capacity of alkalies, freshwaters and soils become increasingly acidic. Most aquatic species have some limit to the acidity they can withstand. Likewise, trees suffer when soils are too acid.

[(j)] See footnote (d) regarding use of the term, “acid rain."

[(k)] Acidifying deposition has characteristics of both an intermediate material flux and an intermediate process, since at least some precursor acids undergo chemical transformation in the atmosphere prior to deposition.

below which, according to current scientific knowledge. [sic] no damage to sensitive ecosystems occurs.

Figure 1 provides a simplified schematic of the processes involved in acid rain. Just one or two pollutants are traced through the processes resulting in undesirable consequences. The candidate items for measuring critical levels or loads are shaded. In acid rain, the selected critical load variable is deposition.

3.2 HISTORY OF TARGET SELECTION AND THE DEVELOPMENT OF CRITICAL LOADS IN THE ACID RAIN DEBATE

In policy-making to combat acid rain, critical loads in terms of intermediate material fluxes have played a large role in Europe but a small role in North America. The United States selected emission reductions as the type of target for its acid rain policy. The differences between these two regional outcomes provide important lessons about target selection and the usefulness and political viability of critical loads as a target measure.

Europe

European nations have worked through two fora for control of the precursors to acidifying deposition, the United Nations Economic Commission for Europe (UN-ECE) and the European Community (EC). Since the EC did not include the Scandinavian countries, who initiated the debate on acid rain, most action has taken place under the rubric of the UN-ECE.[l] The UN-ECE's 35 member countries[m] adopted the

---

[l] This focus does not mean to diminish the EC's contribution to controlling acid emissions from its members. The EC's Large Combustion Plant Directive (LCPD) was developed over the period 1983-1988, in the same timeframe as the UN-ECE's 1985 Sulfur and 1988 Nitrogen Protocols. The LCPD sets sulfur and nitrogen emission standards for large power plants. The EC also sets standards for vehicles, which are a major source of NO_x.

[m] The UN-ECE (despite its name) includes the United States and Canada; thus the major North (continued...)

Convention on Long-Range Transboundary Air Pollution ("LRTAP") in 1979 in Geneva. The Convention is a framework for gathering information and negotiating protocols regarding emissions reductions.[69]

LRTAP members have negotiated several protocols:

- The 1984 protocol to finance monitoring activities,[70]
- The 1985 Sulfur Protocol, under which 21 parties (and later, more parties) agreed to reduce $S0_2$ emissions by 30 percent,
- The 1988 NO_x, Protocol, under which 27 parties agreed to freeze NO_x, emissions, and which adopts the concept of critical loads;
- The 1991 Volatile Organic Compounds (VOCs) Protocol, under which 23 parties agreed to a (very flexible) scheme to reduce VOCs.
- The 1994 Sulfur Protocol, which incorporates the critical load concept.[71]

LRTAP will next turn its attention to another protocol, but its scope is not clear at this time. [72]

North America

Turning to North America, in the late 1970's, Canadian meteorologists pointed out that a majority of sulfur deposited in Canada came from the U.S. Canadian scientists estimated critical loads and proposed an interim target loading of 20 kilograms per hectare per year (kg/Ha-yr) of sulfate to protect all but the most sensitive aquatic ecosystems. [73] Based on this value, Canada adopted a 50 percent reduction in SO_2. emissions from its seven easternmost provinces. But Canada was not successful in the 1980's in obtaining similar reductions from the U.S.

The U.S. and Canada formed a Consultation Group on the Long-Range Transport

---

(m) (…continued)
American players have been involved in all of the UN-ECE efforts described in the following paragraphs.

of Air Pollutants, and in August 1980, signed a Memorandum of Intent ("MOI") on Transboundary Air Pollution to facilitate research and future negotiation on emission reductions. Under the MOI, five bilateral Work Groups reviewed the scientific information. There was substantial disagreement between the U.S. and Canadian members of the Work Groups, which impeded progress. Some of these disagreements centered on the critical load approach.

During the 1980's, U.S. domestic politics blocked federal legislation to combat acid rain. The Reagan Administration fought controls and pressed for more research before action. The U.S. invested hundreds of millions of dollars in the National Acid Precipitation Assessment Program ("NAPAP") for research to solve "scientific uncertainties." Finally in 1990, the time was ripe for amending the Clean Air Act. Congress passed and President Bush signed the 1990 Amendments, which included a 10 million ton per year reduction in SO_2 emissions. The 1990 Clean Air Act Amendments ("CAAA") include a tradeable permit system for sulfur dioxide and oxides of nitrogen. Since these pollutants are not uniformly-mixed, the emission trading system could result in greater emission densities and greater deposition rates than desired in certain places ("hotspots"). This scheme implicitly ignores critical loads, although the 1990 Act requires emission reductions at the worst-polluting plants upwind from the Canadian and American lakes and forests of greatest concern. Through NAPAP, the U.S. did attempt to estimate significant damage functions, but this information was not directly used in the legislation.

3.3 ALTERNATIVES TO CRITICAL LOADS FOR ACID RAIN

Overview of Alternative Targets

Alternative types of targets that have been tried or could be tried for acid rain include: [74], (n)

Targets related to Human Activities (Wants and Needs): A) **Technological measures**

1) Pollution control technology standards, such as best available technology (BAT), either,
   a) without respect to cost,
   b) or as economically feasible;

Targets related to Emissions

B) **Percentage emissions reductions** (by precursor) from a base year
   1) Equal percentage reductions
   2) Unequal percentage reductions

C) **Absolute- amount emissions reductions** (by precursor) from a base year

Targets related to Intermediate Processes and Material Fluxes D)**Acidic deposition** ("Critical loads")

Targets related to Valued Environmental Components

E) **Acidity** ("Five percentile critical loads")

F) **"Gap-closure"**
   A critical-load/percentage-reductions hybrid called "gap closure," meaning equal percentage reductions toward achieving 95 percentile critical loads of acidity.

Targets related to Exposure Variables

J) Adaptive measures, e.g.,
   1) Use of different building materials that are less susceptible to acid deposition.

Targets related to Consequences

K) Mitigation measures, e.g.,

(n) Regulatory designs, such as marketable permits and emissions taxes, are outside the scope of this analysis because these are not *targets.* These regulatory designs may implement the above goals. (Note: Technology standards can be both a regulatory design and a specific target within the human activities category.)

1) Adding lime to lakes to change pH.and others.

Descriptions of Alternative Targets

Those types of targets which played an important role in the debate are discussed below.

Human Activities: Pollution Control Technology Standards

Under this target type, participants argue for specific types of technology, or perhaps "best available control technology" ("BACT), for particular types of sources. For example, after the forest-dieback ("Waldsterben") crisis of 1982, West Germany decided to install best available control technology for major sources of SO_2. Germany also proposed that BACT be the goal for the first LRTAP sulfur protocol.

Policymakers have used two variants of best available control technology: BACT without respect to cost and BACT as economically feasible.

Emissions: Percentage Reductions from a Base Year

Under this choice in the emissions category, all countries reduce emissions from a base year by some percentage (equal or unequal). Negotiators proposed this method early in the acid rain debate because there was substantial scientific ignorance and uncertainty about the amount of control necessary. Ignorance included a lack of knowledge of conversion chemistry, deposition characteristics, and various acidification processes. Uncertainty pertained to long-range transport pathways (where did acids from a particular source go). In the face of such difficulties, policymakers turned to simple approaches, which seem equitable at least on face-value, for sharing the burden. In this vein, the Scandinavians proposed in 1978 that each member of the ECE cut emissions of

SO_2 by 30 percent, and this proposal became the basis of the 1985 Sulfur Protocol at Helsinki.[75]

Emissions: Absolute Amount Reductions from a Base year

The late-1980s debate in the United States employed this method of defining the goal. The debate focused on an amount, such as an eight, ten, or twelve million ton reduction in SO_2 emissions from 1980 emission levels (approximately 22 million tons).

Intermediate Materials Fluxes: Critical Loads and Gap Closure

Since 1989, experts in Europe have realized that critical loads in terms of acidic deposition cannot be achieved everywhere. Therefore, the concept of "5 percentile critical loads," meaning achieving critical loads in all except five percent of ecosystems, was put forward as a working model of "meeting" critical loads.[76] Even meeting the five percentile critical loads would be onerous. Therefore, negotiators developed a hybrid method of framing the debate, which is to set target loads as a percentage of the reduction necessary to achieve the five percentile critical loads. This alternative is viewed as more equitable than straight critical loads, because each country would be responsible for the same percentage reduction.[77] This approach is called "gap-closure," and it formed the basis of the negotiations for the second sulfur protocol.[(o)]

3.4 ANALYSIS: SCIENTIFIC, POLICY, AND NEGOTIATION ASPECTS

Providing a Sound Scientific Basis for Policymaking

For several years, European scientists debated whether critical loads could form a valid basis for policy decisions on emission reductions. Problems include:

[(o)] The 1994 Sulfur Protocol contains different emission reductions for different countries, reflecting their different contributions above critical loads. The acceptance of unequal commitments in an acid rain treaty represents an important step toward achieving the environmental objective.

1) Lack of site-specificity in practice;

2) Oversimplification of the acidification process;

3) Representation of a dynamic process with a static measure;

4) Failure of critical loads by pollutant to capture total acidity.

The Europeans made certain compromises in order to accept and use critical loads.

In contrast, in the U.S., scientists have never reached consensus on critical loads, and a muted debate continues to this day. [78] Indeed, in the vein of Collingridge and Reeve (1986), the U.S. political debate in the 1980's widened to a technical debate about lack of scientific understanding and consensus about acid rain and its effects. The debate became mired in detail. President Reagan and Congress sent the scientific community into the "black hole" of the National Acid Precipitation Assessment Program to sort out the science. Congress generally did not use NAPAP's results (since they were not yet published in final form) in creating the 1990 Clean Air Act Amendments.

From the contrast between Europe and North American, several overall conclusions arise. First, one great advantage of critical loads (as specific targets within the intermediate materials fluxes category) is their close relationship to both causes and effects. The critical loads, of course, represent the deposition level corresponding to insignificant effects. As scientists work back from deposition levels, through transport pathways, to emissions, they make the linkage with causes (i.e., SO_2, NO_x, VOC emissions). Thus, the Canadians focused on critical loads and estimated a 20 kg/Ha-yr goal, which provided them with an early, albeit rough, emission reduction goal (a 50% cut).

In contrast, percentage reductions are in terms of emissions. But the relationship to effects may be loose. Similarly, absolute reductions are stated in terms of emissions, but not effects. Thus, the United States ended up with a ten million ton reduction in

SO_2, but it remains unclear whether specific lakes in Canada and the U.S. Appalachian mountains will actually be protected.

Finally, technology standards bear little relationship to effects. They strive to reduce causes as much as technically (and/or economically) possible, regardless of geographic location.

Turning to technical and administrative feasibility, using critical loads requires extensive data gathering, mapping, and modeling efforts for non-uniformly mixed pollutants.[79] These requirements are a disadvantage for the critical load approach with respect to the speed of negotiations and the ease of implementation. On the other hand, the effort poured into estimating and modeling critical loads and source-receptor relationships is beneficial, since the ultimate policies adopted are well-tailored.

Designing Policy Responses

Framing protocols in terms of critical loads likely increases the probability of protecting sensitive ecosystems, lakes, and streams. For non-uniformly mixed pollutants, such as the precursors to acidifying deposition, the location of the source is very important. Emissions from Great Britain and Poland fall heavily on Scandinavia; reducing these emissions is much more important than reducing emissions from Spain.

Nevertheless, due to the scientific ignorance and uncertainty and political situation in 1985, the first Sulfur Protocol employed percentage reductions by country. These reductions bore no correlation to the emissions responsible for damage in the most sensitive areas of Sweden, Norway, Finland, Great Britain, the Czech Republic, and other parts of Europe. [80] Indeed, Spain objected to the Protocol because its emissions have little effect on Scandinavia.

Therefore, European scientists and policymakers embraced the critical loads concept as a target, at least in theory. They set emission reductions for specific countries to protect specific environmental resources. In this sense, using critical loads (including

all the accompanying transport modeling and mapping) matched clean-up efforts to those places where they will do the most good. Money spent on controls will be spent where it will provide the most environmental benefit.

In a further twist, scientists using integrated models determined that even installing best available control technology on many point-sources would not achieve critical loads in the most sensitive areas, e.g., certain lakes in southern Sweden. This revelation spurred environmental groups to call for deeper changes, such as greatly increased energy efficiency, more mass transit, etc. [(p), [81]] Whether these efforts will result in greater protection is unclear at this time.

In a different vein, some U.S. officials assail certain European countries for signing agreements while having less than a full commitment to compliance. They see critical loads are seen as an idealistic, unattainable goal, while the reality is a set of "target loads" that embody a political negotiation over how to spread cost burdens. These American officials hold that target pollutant concentrations or target emission reductions are more straightforward than the critical loads (an intermediate material flux).[82] Without attempting to assess these criticisms, I note that any target is subject to exploitation for good publicity and improved international relations.

Another policy design advantage of the detailed source-receptor, critical load approach in Europe relates to spreading the burden. The crux of implementation will be burden-sharing, which has now evolved to "joint implementation." [(q)] While the matching of sources and receptors in the critical loads approach places the clean-up burden on some poor countries it also makes clear which poor countries need support by

---

[(p)] These proposed changes in human behavior are to the left in Figure 1. Their attractive characteristic environmentalists is their pervasiveness and the augmentation of "end-of-the-stack" methods already dressed (to achieve even deeper emissions reductions).

[(q)] The term "burden-sharing" means financial and possibly technical transfers from richer countries to rer countries. Joint implementation consists of bilateral agreements whereby the funding country undertakes projects in the host country with greater control and less direct transfer.

rich countries through side agreements. Viewed from this perspective, the possible inequitable burden distribution can be an advantage. [83]

Facilitating the Negotiation Process and Agreement

For framing the debate, the advantage of critical loads over the technology standards and emissions reductions is the negotiators' focus on the ultimate environmental objective. (r) In the European acid rain policy debate, critical loads focussed attention on protecting sensitive ecosystems, lakes, and streams. In contrast, percentage emission reductions are not necessarily well calculated to achieve the environmental objective. Absolute reductions may not correspond to the environmental goal. For example, the debate in the U.S. on absolute reductions focussed on costs and fuel and technology choices by electric utilities. Finally, the BACT approach focusses attention on what technologies are available and when future technological improvements will be available.

Regarding framing the protocols, critical loads probably spurred a more ambitious acid rain program in Europe, since the approach leads to stringent pollution control targets in this case.(s) At first, the Scandinavian countries pushed for full attainment of critical loads. Then integrated modeling showed that even with a complete reduction (100%) of all anthropogenic SO_2 emissions, critical loads could not be achieved in Norway, Sweden, the Netherlands and the U.K.[84] This is because technical control options usually do not have 100 percent efficiency and not all sectors (e.g., households) have control technologies. This realization kept pushing countries to try for as much

(r) These observations are not meant to imply that attention to costs, technological options, and fuel choices is inappropriate. All these considerations are crucial. The point is only that as an effects-based method of framing the debate, critical loads constantly bring negotiators back to the environmental goal and questions such as "How can we achieve this goal?" rather than *only* questions like "How much abatement can we afford this year?"

(s) In contrast, percentage reductions or absolute amount reductions are probably influenced more by cost considerations.

reduction as possible, meanwhile framing in terms of meeting the critical loads. The next goal discussed was protecting 95% of ecosystems. This also proved too difficult and costly. The final approach is "gap-closure." Even though the agreed target levels will not meet critical loads, the overall program is probably more ambitious due to framing the debate and protocols in critical loads terms.

Furthermore, critical loads made a contribution to acid rain policy in Europe since it made clear that Europe had to act to reduce all acidifying compounds. Scientists called attention to total acidity as the overall problem. Although policymakers first attended to the largest acid precursor, sulfur, they soon turned to other acidifying compounds. Therefore critical loads increased the aspiration level of negotiators and expanded the zone of agreement.

Critical loads also helped create an objective standard in the form of a computer model. Professor James Sebenius described the important normative effect of the MIT mining model in the Law of the Sea Negotiations, [85] Similarly, the extensive modeling requirements of critical loads created an objective standard upon which policymakers relied. Researchers at IIASA created the Regional Acidification and Information System (RAINS). In Europe (unlike North America) acid rain negotiators regularly rely on RAINS simulations for devising bargaining positions and understanding the costs and other implications of various policies. The results of the model are widely accepted.[86] This is a great benefit for complex negotiations.

In terms of *achieving agreement*, the critical loads concept seemed to help in Europe, but hinder in North America. In the European negotiations, the critical loads coalition gradually overcame opposition favoring other approaches to framing the debate and protocols. [87] Once recalcitrant countries, like the U.K., agreed to the general approach, agreement on protocols probably came more easily. The "moral imperative" of working towards a scientifically determined goal, outweighed other arguments. Arguably,

one result was quicker agreement to the first No_x Protocol.

Despite these observations, critical loads has created political obstacles for certain countries. For several years, certain members of LRTAP objected to the approach.[88] Currently the biggest objector is the U.S. In late 1993, the United States refused to agree to the draft second sulfur protocol because of its critical loads basis. According to an E.P.A. representative, the U.S. decided it will not sign the protocol due to the conflict between the critical loads approach and the adopted Acid Rain Program based on emissions trading.[89] One of the major constraints that U.S. negotiators and agency personnel feel is the threat of lawsuit from either environmentalists or industry or both. Therefore, they believe that the U.S. must achieve what it agrees to in international treaties. Since it could not abide by critical loads, the U.S. would not sign the protocol.

In contrast, some European countries have felt it sufficient to agree to a goal, even if not that certain of accomplishing it. For example, several Eastern European countries, eager to "get into the fold," in the words of one Western diplomat,[90] signed the first sulfur protocol without the financial resources or realistic plans to achieve compliance. But by signing, they hoped to receive aid from other countries, and perhaps eventually comply.

Returning to the North American debate, it is not clear that critical loads delayed a Canada-U.S. agreement or U.S. domestic policy changes, but it is clear that the U.S. resoundingly rejected critical loads in 1982. This may be because of the direct tie between the Canadians' 20kg/Ha-yr of sulfate target and their request for a 50%0 emissions cut in the U.S.[91]

3.5 LESSONS LEARNED

Perhaps the key reason for the different results in Europe (selecting an intermediate material flux target, specifically critical loads) and the United States (selecting emission reduction targets) was acceptance of the critical load approach by

European scientists versus non-acceptance by U.S. scientists. (In addition, powerful U.S. coal and electric utility interests lobbied to keep critical loads off the agenda.) In other words, where (relative) consensus exists among scientists and the problem is relatively well understood (e.g., Europe in the late 1980's), selection of an intermediate materials flux type of target, here critical loads, may build consensus at the policy level. Where scientists do not understand causal links or simply do not agree (e.g., U.S. versus Canada in the early 1980's; U.S. and the second sulfur protocol), such a target may become an obstacle. Along the lines of Collingridge and Reeve, the Canadian-U.S. working group effort turned into a fruitless technical exercise.

Thus, the state of the science influences what is feasible in policy design. For pollution problems, the state typically has to regulate private and public entities that pollute. Therefore, for ease of implementation, states tend to regulate activities or emissions. States must be able to measure progress toward meeting targets. Thus, in the acid rain case in Europe, while deposition is the policy goal for framing the debate and for determining the emissions targets, the protocols use national emissions as the actual policy targets.

The critical loads approach apparently greatly helped the acid rain negotiations in Europe. It helped in three ways: 1) Due to the normative scientific rationale of critical loads, Europeans were able to agree on a principle that facilitated agreement and action. 2) Critical loads probably increased aspirations and pushed up the zone of agreement. The resulting program in Europe is arguably more ambitious than it would be had some other target definition been used. 3) The requirements for burden sharing were made more clear, even though these did not become part of the protocols.

Compared to the alternative targets considered, critical loads do a better job of focusing attention on the environmental objective. In addition, due to research money spent on defining the objective and on modeling transport and deposition processes,

policymakers became better informed about expected policy results.[t]

Finally, critical loads may provide effects-based goals that are unattainable without massive effort. Does this mean the concept ultimately fails? Not necessarily, for what grows out of the approach may be helpful. In Europe, the critical loads approach formed the basis for hybrid agreements ("gap closure"). So ultimately, Europeans turned consensus on both the type of target and the specific target into agreement on policy design.

---

[t] For example, European negotiators of the Second Sulfur Protocol were much better informed about the results of their earlier control agreements than the U.S. Congress was when it passed the '1990 Clean Air Act Amendments.

4.0 ANALYSIS OF TARGET SELECTION AND THE USE OF CRITICAL LEVELS IN THE STRATOSPHERIC OZONE DEPLETION CASE

In the stratospheric ozone depletion debate, policymakers focused on an intermediate material flux, namely chlorine concentrations in the stratosphere, as the basis of policy. Further, they relied on the critical level of chlorine concentrations as a specific target. In the protocols, they translated this critical level target to "source reduction" targets consisting of phase-outs of certain chemicals. "Source reduction" is a "human activities" type of target.

This chapter first explains critical levels for the stratospheric ozone problem, then the history of policy responses. Then it analyzes target selection in this case.

4.1 DEFINITIONS OF CRITICAL LEVELS FOR STRATOSPHERIC OZONE DEPLETION

As shown in Figure 1, the valued environmental components in the stratospheric ozone case are ozone itself and ultraviolet ("UV") radiation absorption. [u] A key intermediate process involves release of chlorine in the stratosphere. Therefore, the critical levels concept could be applied to define targets in terms of ozone, UV radiation absorption, or chlorine concentrations.

---

[u] Ozone in the stratosphere absorbs harmful ultraviolet light from the sun. Since ultraviolet sunlight can cause cancer in humans, we have a great interest in the integrity of the stratospheric ozone layer. Unfortunately, a group of highly useful compounds, the chlorofluorocarbons ("CFCs") destroy stratospheric ozone.

The CFCs are stable compounds used in refrigerators, cooling systems, aerosol propellants, electrical insulation, and in the making of plastic-foam materials. The mechanism by which the CFCs destroy ozone is complex. Simply put, CFCs break down in the stratosphere and release chlorine. The chlorine then breaks down ozone.

4.2 HISTORY OF DEVELOPMENT OF CRITICAL LEVELS IN THE OZONE DEBATE

In response to the theory and prospect of ozone depletion, the countries producing and consuming chlorofluorocarbons ("CFCs") agreed in 1985 to the Vienna Convention for the Protection of the Ozone Layer. The obligations under the treaty were to "take appropriate measures ... to protect human health and the environment" against adverse effects from modification of the ozone layer.[(v)] The treaty was actually signed before scientists published the first hard evidence of declines in the ozone layer, later in the year.[92]

Starting in 1987, a rapid succession of worrisome scientific findings spurred corresponding political action. The Parties to the Vienna Convention adopted the Montreal Protocol, requiring dramatic cuts in CFC consumption. On March 15, 1988, the Ozone Trends Panel released its report confirming CFCs and halons resulted in destroying stratospheric ozone. Further, global concentrations of chlorine had increased, and the ozone layer had decreased by 1.7 to 3.0 percent, depending on latitude. Thus the scientific models had *underestimated* ozone losses.[93] In early 1989, a scientific expedition to the Arctic showed that chlorine compound concentrations were 50 to 100 times greater than predicted. This finding meant that an Arctic ozone hole might soon form, [94] although such a hole has not formed.

Model deficiencies led scientists and, later, policymakers to place growing reliance on another concept: the total abundance of chlorine in the atmosphere or "chlorine loading," also discussed in terms of chlorine concentrations. In addition, experts decided

---

[(v)] Note that the Vienna Convention contains no more specific reference to thresholds or critical levels. The goal is simply to prevent "adverse effects."

that the calculated ozone-depletion-potential ("ODP") value for a given chemical could be a misleading indicator. Therefore, scientists began to estimate the effect of compounds on chlorine loading, rather than the end-effect on ozone.[95] This means stepping back two columns in Figure 1.

Researchers estimated that total chlorine concentration in the atmosphere was three parts per billion (3 ppb) in 1985, approximately five times the pre-CFC levels. Based on this new approach, the U.S. Environmental Protection Agency (U.S. EPA) reexamined chlorine-containing substances. The U.S. EPA realized that major contributors to atmospheric chlorine included carbon tetrachloride and methyl chloroform. Each compound was responsible for about 16-17 percent of total anthropogenic chlorine loading.[96] These two compounds were not regulated by the Montreal Protocol. *Thzv realization appears to be the first important effect of using critical levels in the ozone debate.*

The First Meeting of the Parties to the Montreal Protocol convened in Helsinki on May 2, 1989. According to a U.S. observer and former negotiator, these meetings were much different than earlier meetings in terms of the sense of urgency, extent of consensus, and breadth and level of participation.[97] The U.S. EPA presented its latest estimates of future chlorine loading of the atmosphere under different emissions scenarios. [98] Many governments changed their previous policy positions and pushed for an early phaseout of a broad range of chemicals.

The Assessment Panel under the Montreal Protocol presented its influential Synthesis Report in mid-1989. New calculations showed that under the existing Montreal Protocol, chlorine levels could reach 11 ppb by the end of the 21st century. The Report

indicated that only the early elimination of all CFCs, plus carbon tetrachloride and methyl chloroform, and only a transitional reliance on the proposed hydrochlorofluorocarbon ("HCFC') substitutes, would allow an ozone recovery. Chlorine levels were expected to rise to four parts per billion even under the most optimistic assumptions about controls. It was also impossible to quantify effects, except for future rates of skin cancer and eye cataracts. The Synthesis report recommended a complete, timely phase-out of all major ozone-depleting substances.

Scientists presented the following chlorine loading estimates to the negotiators.[99] Pre-industrial chlorine levels were likely 0.6 ppb, from naturallyoccurring methyl chloride. When the Antarctic ozone hole had begun to appear in the 1970's, the level was 1.5-2.0 ppb. By 1985, chlorine loading had reached 3 ppb. The forecast was an increase to 3.5 - 3.6 ppb by 1990. Thus, scientists concluded that the critical level for a "safe" chlorine concentration was 2 ppb, i.e., the concentration at which the Antarctic springtime ozone levels had begun to drop.

As a result of the new scientific findings (including the total chlorine approach) and the realization that all ozone-depleting substances needed to be phased-out, the Parties at Helsinki signed a non-binding declaration discussing phaseout of CFCs as soon as possible, but not later than 2000, and phaseouts of halons and control of other substances. At the next meeting, in London in 1990, the Parties agreed to accelerate phase-outs, with many substances gone by the year 2000. The parties agreed to phase out methyl chloroform, and set dates for import restrictions discussed under the Montreal Protocol. [100] In Copenhagen, the Parties agreed to accelerate phase-outs and to add more chemicals to the phase-out lists.

4.3 ALTERNATIVE TARGETS IN THE STRATOSPHERIC OZONE CASE

Because the debate started around chlorofluorocarbons, the initial terms defining the debate were restrictions on production (or equivalently, consumption) of CFCs. This chemical-by-chemical approach included several, somewhat overlapping, alternatives:

Targets related to Human Wants and Needs:

A) **Source reduction** (by consumption of each compound) from a base year (including bans, which are 100 percent reductions, e.g., the ban of CFCs in consumer aerosol sprays).

B) **Product sustitution** (companion to source reduction)

1) Substitution of HCFCs for CFCs.

Targets related to Emissions

C) **Percentage emissions reductions**

D) **Absolute-amount emissions reductions** from a base year

Targets related to Intermediate Processes and Intermediate Material Fluxes

E) **Chlorine concentrations** in the stratosphere

Targets related to Valued Environmental Components

F) **Ozone concentrations**

Targets related to Exposure Variables

G) **Adaptive measures**, e.g.,

1) Required use of sunscreen and umbrellas when outdoors.

Targets related to Consequences

H) **Mitigation measures**, e.g.,

1) Medical programs providing more frequent skin cancer checkups,

and others.

4.4 ANALYSIS: SCIENTIFIC, POLICY, AND NEGOTIATION ASPECTS

Providing a Sound Scientific Basis for Policymaking

For *framing the debate*, "midstream" targets, i.e., critical levels, won over other alternatives. The primary disadvantage of the "upstream" measures (and targets), such as

phase-outs (i.e., source reduction) for *framing the debate* was insufficient correlation with effects (e.g., reduced skin cancers). For example, in the early debate, the U.S. had already banned aerosol uses, while the EC resisted such a move. Since aerosols were a large share of consumption and had easy substitutes, the ban was a legitimate option. But the ban argument lacked a solid estimate of benefits. Later, with harder evidence on ozone depletion and a more solid connection between emissions and depletion, the EC agreed to the aerosol ban.[101]

The disadvantage of the "downstream" measures (as targets) were their lack of practicality. For example, reducing human exposure, through sunscreen and umbrellas, would do nothing to mitigate the heightened risks for animals and crops.

Focusing on the intermediate material flux, namely the total chlorine concentration, had several substantive advantages compared to alternative targets. First, critical levels were superior to the alternatives for framing the debate because critical levels were closely related to both causes (e.g., CFC emissions) and effects (e.g., reduced ozone leading to increased skin cancer).

Second, they focussed efforts on the ultimate environmental objective. They were closely related to causes, i.e., CFC emissions, and to effects, in terms of decreased in stratospheric ozone. They were simpler to estimate than the alternative critical level measure, ozone itself. Scientists could track actual chlorine loading over time and compare it to (limited) historical data.

On the other hand, total chlorine levels had disadvantages too. For example, the global average ignored region-specific effects (e.g., substantial ozone losses at poles). Nevertheless, both scientists and policymakers used total chlorine levels to define the

overarching target in the debate after 1989.

The "midstream" targets did not deliver these benefits without a struggle. Two measures vied for the place of the critical level used in negotiations: ozone concentrations and chlorine concentrations. Prior to 1989, scientists had focused on models that estimated the amount of ozone in the stratosphere under varying emissions of ozone-depleting substances. Unfortunately, these models did not explain the large ozone losses measured over northern latitudes. Furthermore, modeling ozone concentrations required an extensive data gathering and modeling effort to understand relationship between ozone depleting substances, chlorine loading, and stratospheric ozone reduction. These requirements were a disadvantage to ozone as a critical level measure. Therefore, scientists stepped back to an item that was easier to estimate, chlorine concentrations in the stratosphere.[w]

Designing Policy Responses

Critical levels were superior to the alternatives for *framing the debate* because critical levels demonstrated the need to be comprehensive, i.e., to regulate all gases contributing chlorine to the stratosphere. Once the contributions of chemicals such as methyl chloroform were recognized, policymakers moved to restrict them.

Critical levels were not used *in framing the agreements*, however. The Montreal Protocol and its amendments specify a "human activities" type of target, source reduction. They are expressed as percentage consumption reductions from a base year, by compound. Arguably there was still sufficient difficulty quantifying the relationships

(w) Thus, scientists stepped back two columns in Figure 1, from the valued environmental component, namely stratospheric ozone, to the reactant (an intermediate materials flux) in the intermediate process, namely chlorine.

between ozone-depleting compound emissions, release of chlorine, and decline of ozone, that both scientists and negotiators pushed ahead with a source-reduction approach.

In addition, for framing the agreements, the chief advantage of the source-reduction-by-compound approach was ease of implementation. With only a few producers of CFCs, production could be tracked at the national level (keeping specific firm's outputs confidential).[x]

In sum, the effects of critical levels on designing policy responses were to increase the number of chemicals to be controlled and to speed up the schedule of reductions. In other words, critical levels facilitated speedy, comprehensive, aggressive agreements to phase-out a group of otherwise highly desirable chemicals.

Facilitating the Negotiation Process and Agreement

Critical levels, expressed as chlorine concentrations, provided a useful focal point for debate. Although the concept of ozone-depleting potential had already been used to provide a yardstick for threatening compounds, the total chlorine loading approach provided a simplifying, umbrella concept against which protocols, and later, progress, could be measured. Policymakers set their sights on the ultimate goal, and in record time (compared to other international agreements), achieved it.

Critical levels effectively expanded the zone of agreement. Both scientists and diplomats broadened their thinking from a gas-by-gas approach to a single measure that encompassed the effects of all the gases. This switch spurred the inclusion of carbon tetrachloride, methyl chloroform, and other gases in the London and Copenhagen

---

[x] While this advantage did not extend to the more widely-used compounds, such as carbon tetrachloride, it did apply to the CFCs.

amendments.

Critical levels also helped raise the upper bound of possible agreement (i.e., increased aspirations). Although critical levels deserve some credit, focusing events and other circumstances were probably more important, as explained below.

Stepping back from this praise for the concept of critical levels, there are several other factors that helped nations achieve relatively quick agreement on stratospheric ozone.[102] First, few countries were interested, since only twelve nations produced significant amounts of CFCs.(y) In addition, there were only a few major private parties, i.e., CFC producers. While they fought regulation for years, in 1986 and 1988, firms changed their positions to support controls.[103] Second, by the mid-1980's, the availability of affordable substitutes seemed clear. Third, the total cost of phasing out CFCs was not estimated to be that great (at least after producers determined likely substitutes). Fourth, two discoveries, the Antarctic ozone hole and the decline in mid-latitude ozone concentrations (where the majority of producer country populations lived) served as focusing events.[104] These discoveries indicated a major crisis. Public opinion and public officials responded. Fifth, the linkages between cause and effect were fairly well understood. Sixth, the non-producer developing countries were motivated to participate in order to avoid trade restrictions.

In conclusion, the concept of critical levels most clearly helped the parties reach a comprehensive agreement by causing scientists and decisionmakers to broaden the list of

(Y) Much of the disagreement along the way occurred between the U.S. and the European Community, although Japan and the Soviet Union were important players. Arguably another helpful factor was that the major parties were all developed countries, who were used to negotiating with each other on environmental matters, and who had the resources to pay for the transition

compounds to be controlled. Critical levels also made clear the extent of action needed, by making clear the connection between emissions and effects. But the credit probably stops here. The parties took such quick and comprehensive action partly due to dramatic focusing events, reduced cost of action, widespread public support, and reversal of industry opposition.

4.5 LESSONS LEARNED

The ozone case teaches several lessons regarding target selection and critical levels in the "midstream" target-types:

First, expressing the critical level in terms of what one is trying to protect (the valued environmental component) may not always be desirable. Scientists had to step back from the valued environmental attribute, ozone, to an intermediate material flux, chlorine. They had to step back because of scientific ignorance, difficulties in modeling, and uncertainty in prediction.

Second, critical levels can be useful in a situation where consensus exists among scientists and the problem is relatively well understood. Conversely, where scientists do not understand causal links, do not agree, or where there is much uncertainty, critical levels may be just too controversial to be useful to politicians.

Third, in the ozone case, exogenous political and economic factors meant that few roadblocks stood in the way of a critical level approach. Where these factors do not open the way for the critical levels approach, the approach may not be accepted, since it sets high aspirations and usually calls for substantial sacrifice.

Finally, while *framing the debate* in terms of intermediate materials fluxes (critical levels) was beneficial, *framing the protocols* were more easily accomplished in terms of

"upstream" measures. Since there were few producers and few chemicals, the protocols use source-reduction goals by pollutants (i.e., phase-outs and bans) as the measurable policy targets.

5.0 ANALYSIS OF TARGET SELECTION AND THE POTENTIAL USE OF CRITICAL LEVELS IN THE CLIMATE CHANGE CASE

5.1 THE CHALLENGE OF THE CLIMATE CHANGE NEGOTIATIONS

The negotiations to minimize and adapt to climate change induced by anthropogenic greenhouse gas emissions are the most difficult international environmental negotiations ever attempted. Never has an issue had the *combination* of such great uncertainty, complexity, cost, potential for division, and need for universal participation.

Climate change entails greater *uncertainty* about processes and impacts than did acid rain, stratospheric ozone, or maritime pollution. Since so much natural variability hides climate trends, it is hard to assess climatic changes. Moreover, the climate system is arguably more *complex* than the marine pollution or long-range transport pollution problems humans have faced.

The potential *costs* of addressing climate change are estimated in hundreds of billions of U.S. dollars, whereas the cost of acid rain control measures are an order of magnitude less. [z] Even the difficult Law of the Sea negotiations only dealt with possible lost opportunities, not tangible billions to be spent.

In terms of *political conflict*, the interests of the northern hemisphere and the southern hemisphere are (generally) diametrically opposed on climate change. The North sees controls in the South as essential. The South wants no restrictions on its

---

[z] Schelling (1992, 3-4) compares the estimated costs of dealing with stratospheric ozone depletion, acid rain and climate change as follows: The cost of chlorofluorocarbon phaseout was a few billion dollars. The cost of sulfur dioxide reduction was in the tens of billions per year for some period. The cost of holding CO_2 emissions constant or reducing by 50 percent is perhaps in the hundreds of billions in perpetuity.

growth and development and points out that the North is to blame for elevating carbon dioxide levels to the danger point. Reducing emissions of carbon dioxide potentially means affecting the way people all over the world heat their homes, light their lamps, and travel to and from work. Global cooperation will he essential to any effective scheme to address the problem.

In December 1990, the U.N. General Assembly established the Intergovernmental Negotiating Committee (INC) to negotiate a convention containing "appropriate commitments" to deal with climate change. Through six negotiating sessions, the INC developed and adopted the Framework Convention on Climate Change (FCCC).

Article 2 states the objective of the FCCC as:

> ... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.[105]

The stated objective includes some notion of a threshold beyond which anthropogenically-caused concentrations of greenhouse gases ("GHG") would threaten ecosystems, food production, and sustainable development. This is the critical level

concept, in terms of intermediate materials fluxes, i.e., a "midstream" target.

Although the FCCC would imply *framing the protocols* in terms of critical levels, most countries are *framing the debate* and suggested protocol targets in terms of "targets and timetables," i.e., *percentage emission reductions of greenhouse gases from a base year*.

Some players in the climate debate, namely scientists and non-governmental organizations, have argued that targets for minimizing climate change should be based on critical levels. One of this paper's chief goals is to indicate whether negotiators should abandon the emission reduction targets and instead use some form of critical levels as

targets. Before launching into the analysis, a review of the science is necessary.

5.2 DEFINITIONS OF CRITICAL LEVELS FOR CLIMATE CHANGE

Distinguishing Anthropogenic Climate Change from Natural Climate Change

The first task is to discuss the role of human activities in climate change. Climate varies naturally, and scientists have not yet developed the knowledge and models necessary to predict climate changes very well. Second, human activities, such as farming, clearing land for urban development, and polluting the air with carbon dioxide and other greenhouse gases ("GHGs"), all contribute to climate changes. Third, the climate change negotiations focus on the anthropogenic changes in greenhouse gas concentrations and how these affect climate.

These distinctions have important policy implications. It is difficult to determine whether and by how much humans have affected whatever climate change would naturally be occurring. For example, while global-mean temperature has increased by 0.3-0.6°C over the past 100 years, the natural variability of the climate system could explain this change.[106] However, scientists believe that it is more likely that anthropogenic increases in greenhouse gas concentrations have enhanced the natural greenhouse effect and contributed to this warming.[(aa)] But, it is also possible that a natural cooling has overshadowed an even larger anthropogenic increase in GI-IG and associated enhanced greenhouse effect.

Therefore the determination of critical levels is plagued by the uncertainty of

---

[(aa)] The Earth absorbs short-wave solar radiation, and re-emits long-wave infrared radiation. The solar short-wave radiation passes through the clear atmosphere relatively unimpeded. In contrast, the long-wave radiation emitted by the Earth is absorbed by a number of trace gases in the atmosphere. The result is a warming of the atmosphere and surface.

As humans have burned fossil fuels and undertaken industry, the concentrations of these trace gases has increased. This has led to the "enhanced greenhouse effect" (IPCC, 1990, xi).

natural climate variability, natural changes in greenhouse gases, and anthropogenic changes not related to greenhouse gases. For example, how can we determine a critical level for sea level rise due to our emissions of greenhouse gases, when both natural variability and other human activities may contribute to the sea level rise? For the purposes of this analysis, I will not attempt to resolve these issues, but rather I will focus on anthropogenic changes in the concentrations of greenhouse gases. Where the language below refers to the effects of human activities or GHGs, I mean anthropogenic changes in the concentrations of greenhouse gases.

Types of Critical Level Measures for Climate Change

Of the three cases, the critical level concept is least transferable to the climate change problem because the pollutants are uniformly-mixed but the effects are highly variable in different locations. Like the stratospheric ozone problem, anthropogenic climate change results from uniformly mixed pollutants.[bb] Thus while the effects

might he site-specific, they are driven by changes in the globally-averaged concentrations of greenhouse gases.

There are two broad types of possible critical levels in the climate change debate: rate of change measures and absolute change measures. For temperature, these are the

---

[bb] The reader should keep in mind two crucial differences when comparing the climate change and stratospheric ozone cases to acid rain: First, the first two cases are global, but transport of acidifying substances is mainly a regional phenomenon. Thus in acid rain, the source of the acid falling in a particular place (a "receptor"), e.g., a lake in southern Sweden. can be generally traced to emissions at particular places ("sources"), such as power plants in Great Britain. Therefore, policies strive for emission reductions at particular sources. In contrast, it matters not where ozone depleting compounds or greenhouse gases are emitted. They *will* travel long distances and mix in the atmosphere so generally that the source's location becomes irrelevant.

In different words, acidifying compounds *are non-uniformly mixed;* while ozone depleting compounds and greenhouse gases become *uniformly mixed.* We worry about critical acid loads in terms of *localized* concentrations, but we worry about critical levels of ozone depleting substances and greenhouse gases in *global* terms.

rate of warming and the ultimate amount of warming. In the short-run, the rate will be useful. In the long-run, the ultimate warming will be important. For sea-level rise, the measures are the rate of sea level rise and the ultimate amount of sea-level increase. For other critical levels measures, similar considerations apply.

A further distinction is "global-average" versus local. Global climate change is manifested at the local level, depending on many localized variables. Local effects depend upon ecosystem type, local weather patterns, and the like. While some proposed critical level variables are expressed in global or global-average terms, the critical levels pertain to local effects. After discussing the "global-average" type measures in the literature and the debate, I will return to these localized effects and measures.

Various participants in the climate change debate have made attempts to define a set of indicators of climatic change. Scientists and representatives from international organizations, academia, and non-governmental organizations met at Villach and Bellagio in 1987 to discuss the impacts of climate change. They found that changes to midlatitude forests and sea levels were particularly sensitive environmental indicators. [107] For forests, they predicted that dieback of mid-latitude forests would occur at 0.3°C per decade. However, such drastic effects would not occur for forests generally (and would instead occur more slowly for only portions of the forests) if the rate of temperature change was limited to 0.1°C per decade.[108] For sea level rise, they pointed out that the historical experience of industrial societies (for example, in building dikes) was limited to changes of two to three centimeters per decade, which corresponds roughly to the 0.1°C per decade warming. So for both indicators, they suggested a possible "target warming rate" of 0.1°C per decade (0.18°F/decade) or, equivalently, 1°C per century.[109] These figures represent critical levels, beyond which significant impacts might occur.

Many critical level measures are possible: greenhouse gas concentrations, temperature change, and sea-level rise, among others. Moreover, because climatic effects are localized, critical level measures must be developed by local area. But in the 1980s much discussion focused on global-average types of measures. For example, a rate of change of global-average, surface-air temperature could be an index for climate change. So could a rate of increase of total radiative forcing. But ultimately a "basket" of localized indicators would be needed.

The Advisory Group on Greenhouse Gases' ("AGGG") Working Group #2 developed a set of "climate change indicators," which are essentially targets based on critical levels. Table 1 summarizes these critical levels. According to the working group report, limiting climate change so as not to exceed these levels would minimize the risk of flooding of vulnerable coastal zones and the risk of severe impacts on ecosystems.

Since neither the Intergovernmental Panel on Climate Change ("IPCC") nor the Intergovernmental Negotiating Committee ("INC") has not adopted such a list of critical levels, the AGGG Working Group's target levels are the most complete set currently in the public discourse. However, these target levels do not enjoy widespread support.[110]

According to one noted climatologist, the next step should be to develop ecological indicators of critical levels, i.e., a "suite of biological indicators" to accompany the physical indicators, such as temperature and sea level rise.[111] These organisms might be useful as the "canary in the coal mine," to warn us of impending problems.

5.3 HISTORY OF DEVELOPMENT OF CRITICAL LEVELS IN THE CLIMATE CHANGE DEBATE

Given that brief synopsis of scientific research on critical levels, let us turn to politics. The most significant political action regarding critical levels in the climate change debate was the adoption of the Framework Convention on Climate Change.

Article 2 states the objective as:[112]

... s**tabilization of greenhouse gas concentrations** in the atmosphere at a level that would prevent **dangerous anthropogenic interference** with the climate system. Such **a level** should be achieved within a time frame sufficient **to allow ecosystems to adapt** naturally to climate change, **to ensure that food production is not threatened** and **to enable economic development** to proceed **in a sustainable manner**.[113] [Emphasis added.]

Analysis of this language reveals several points. The Parties have already framed the debate in terms of intermediate materials fluxes, i.e., greenhouse gas concentrations. This implies concern with both emissions and sinks. The target refers to stabilization, not reductions.[cc] Stabilization could refer to keeping concentrations at today's level, e.g., about 300 ppm of CO., or at some future level, e.g., doubling or tripling of concentrations. [114]

The reference to ecosystems adapting naturally recognizes that climate change is likely already underway. Not threatening food production means averting large changes in precipitation and temperature that make existing farms and/or crops fail.[dd] This also could refer to slowing climate-induced desertification.

For the purposes of this paper, the two key points are: 1) the treaty focusses on concentrations of GHGs, and 2) the three valued environmental and human components (namely, ecosystems, food production, and economic development) could indicate some sort of critical level approach. Thus the parties have already broached the subject of critical levels, at least in terms of GHG concentrations.[115]

[cc] Stabilization could mean reductions for some countries and increases for others.

[dd] While harming agriculture in some areas, warming and increased precipitation may actually help agriculture in other areas.

TABLE 1

CLIMATE CHANGE "INDICATORS"
From Working Group 2 of the
WMO/ICSU/UNEP Advisory Group on Greenhouse Gases (AGGG)

SEA LEVEL RISE
"Targets:

A maximum rate of rise of between **20** and **50 mm per decade**.
A maximum sea-level rise of between **0.2** and **0.5 m** above the 1990 global mean sea level."

MEAN GLOBAL TEMPERATURE
"Targets:
A maximum rate of change in temperature of **0.1 °C per decade** ..." [realized warming].

Two absolute temperature targets for committed warming were identified. These limits entail different levels of risk:*

(i) A maximum temperature increase of **1.0 °C** above pre-industrial global mean temperature.

(ii) A maximum temperature increase of **2.0 °C** above pre-industrial global mean temperature."

GHG CONCENTRATIONS

Targets:

"Maximum $C0_2$ -equivalent concentrations of **330 to 400 ppm"****
"Maximum $C0_2$ equivalent concentrations of **400 to 560 ppm"****

[Emphasis in original.]

Source: Rijsberman, F.R. and R.J. Swart, eds., 1990, viii-ix. *Targets and indicators of climatic change.* Stockholm: Stockholm Environment Institute.

Notes:
* The difference in risk between these two targets is that temperature increases beyond 1.0 °C "may elicit rapid. unpredictable, and non-linear responses that *could* lead to extensive ecosystem damage."

** The concentration ranges relate to the possible range of climatic responses to stay below the temperature change targets. The Working Group relied upon the IMAGE simulation model to make these estimates.

5.4 ALTERNATIVE TARGETS IN CLIMATE CHANGE

For combating the enhanced greenhouse effect, the Parties could discuss or draft a protocol that includes, but is certainly not limited to the following types of targets:[116]

Targets related to Human Wants and Needs

A) **Efficiency (technological) targets**

1) Energy efficiency standards for homes, commercial buildings, and appliances,
2) Automobile efficiency standards.

B) **Behavior modifications**

1) Reducing deforestation,
2) Structural changes in land use, such as greater densities and jobhome clustering,
3) Changes in agricultural practices, such as altered use and formulation of fertilizers.

Targets related to Emissions

C) Percentage emissions reductions (by GHG) from a base year

1) Equal percentage reductions,
2) Unequal percentage reductions.

D) **Absolute-amount emissions reductions** (by GHG) from a base year

E) **Others**

1) Targets of shifting from high-carbon fossil fuels, such as coal, to low CO, -emitting fuels, such as natural gas,
2) Targets related to shifting from fossil-fuels to non-fossil fuels, e.g., replacing fossil fuels with alternative energy sources in electric power generation,
3) Structural changes in transportation, such as increased mass transit,
4) Target reductions of methane emissions.

Targets related to Intermediate Processes and Intermediate Material Fluxes

F) **Greenhouse gas concentrations** *(chosen in the FCCC)*

G) **Goals for effectiveness of GHG sinks** (pertaining to measures to use, prevent the destruction of, and increase sinks), e.g.,

1) Disposal of CO, in the deep ocean,
2) Forest growth enhancement.

Targets related to Valued Environmental Components

H) **Climate- change- related variables**

1) Rates of change of temperature, sea-level rise, and others
2) Absolute changes in temperature, sea-level rise, and others

I) **Direct mitigation of changes in VECs,** e.g,

1) Cloud seeding where precipitation drops

Targets related to Exposure Variables

J) **Adaptive measures**, e.g.,

1) Sea walls and dikes.

Targets related to Consequences

K) **Mitigation measures**, e.g.,

1) Proportions of crops switched.

and others.

5.5 ANALYSIS: SCIENTIFIC, POLICY, AND NEGOTIATION ASPECTS

Providing a Sound Scientific Basis for Policymaking

As in the acid rain and stratospheric ozone cases, the major substantive advantages of using "midstream" targets in climate change is the close relationship to both causes (i.e., GHG emissions and changes in the radiation budget) and effects (e.g., warming and sea level rise). For example, the influences of GHG mixtures on the radiation budget is neither constant nor linear.[117] Therefore, a temperature measure would track the changes in Earth's radiation budget better than a GHG emissions measure.

One of the major challenges to using the concept of critical levels in the climate change negotiations is the existing lack of scientific understanding necessary to determine relevant, localized, critical levels. In contrast, framing the debate and early protocols in terms of energy efficiency improvements or emissions reductions will be easier. This does not mean that identifying critical levels is a waste of time, it means that at the time

of this writing, critical levels are not yet sufficiently mature for use. [118]

To explain, although scientists have been working to understand the physical processes of the enhanced greenhouse effect, they do not yet understand key processes that well. Example processes that need further study are the transfers of energy between the atmosphere and ocean, between the atmosphere arid land surfaces, and between the upper and deep layers of the ocean. Scientists also have many questions about cloud feedback, the treatment of sea-ice, and convection.[119]

Cloud feedback well illustrates the uncertainty. Cloud feedback consists of the factors affecting cloud amount and distribution and the interaction of clouds with solar and terrestrial radiation. Cloud feedback is responsible for a factor of two uncertainty in the size of the warming. [120]

In other words, the links in the causal chain in Figure 1 are not well understood. Key outstanding questions include, but are not limited to: [121]

- What will be the future natural and anthropogenic emissions of GHG?
- What will be the relative importance of different gases over time?
- What are the relationships between anthropogenic emissions and atmospheric concentrations of GHG[(ee)]
- What are the relationships between atmospheric climatic response and GHG concentration changes, e.g.,
  - the temperature response
  - the effect on the frequency and severity of extreme weather events (hurricanes, floods)?
- What is the relationship between sea level rise and temperature?

[(ee)] The uncertainties in future concentrations stem from lack of knowledge regarding the sources and sinks of GIIG. Since natural sources and sinks are sensitive to climate, changes in concentrations may have impacts on sources and sinks.

- How do the GHG concentration changes translate into localized effects?

Unfortunately these are complex phenomena, many of which are not linear. Researchers around the globe are working to understand and model these relationships. For example, at National Institute of Public Health and Environmental Protection ("RIVM") in the Netherlands, scientists are building the Integrated Model for the Assessment of the Greenhouse Effect ("IMAGE2"), an integrated model that simulates climatic effects in grids of one-half degree longitude by one-half degree latitude. Being "integrated" means that this model simulates GHG emissions, emission controls, changes in radiative forcing, changes in key environmental variables (like temperature), and socioeconomic impacts. The model also includes feed-back loops.[122] This is the type of effort needed to understand the key linkages and to develop a set of critical level measures.

In sum, midstream targets in the intermediate process and intermediate materials flux column and the VEC column suffer the disadvantage of requiring more knowledge than targets in the human wants or emissions columns. The lack of understanding of fundamental climate change processes makes it difficult to link proposed policies to VEC targets. Similarly, because of our lack of understanding of the carbon cycle, setting targets in terms of CO_2. concentrations is problematic. Thus critical level targets expressed in terms of either intermediate processes or VECs currently have less analytical support than targets expressed in terms of emissions or human activities. This is a major disadvantage for using critical levels in the climate change negotiations. Furthermore, the high stakes involved mean that interest groups will tend to emphasize what is unknown or uncertain to stall the negotiations.

This analysis engenders three recommendations. First, due to the lack of knowledge and poor prospects for understanding these linkages in the near future, I *recommend against framing the debate in terms of critical levels (i.e., "midstream" type targets) in the early round of negotiations and in the first protocol.*

Second, *I recommend that policy-makers continue (and possibly increase) support for research and computer modeling efforts that will ultimately result in an improved understanding of the causal taxonomy and identification of critical leveLs.*[ff] As scientists make progress, the usefulness and defensibility of critical level targets for climate change will increase. Over the decades of future negotiations and action regarding climate change, critical levels could provide useful yardsticks for assessing progress in protocols and in implementation.

Each Party that learns about its particular, local, critical levels will understand its interests more clearly. Such knowledge may reveal previously unrecognized impacts a Party may suffer. When Parties understand their interests, they will be more eager to build coalitions with others of similar interests. (This depends upon how divergent interests are.) This process of clarifying interests may facilitate deal-making.

Third, when scientists have gained sufficient understanding to insert critical levels into the negotiations, *I recommend that negotiators and scientists focus on critical levels based on GHG concentrations, rather than climate change measures.* It is *relatively* easier to understand the linkage between GHG sources/sinks and concentrations than between

[ff] For example, the current generation of models is poorly equipped to model transient effects. One cannot predict what a 20 ppm CO_2 increase means translates to, in terms of warming. Does 20 ppm imply 0.01, 0.1, or 0.015°C/decade change? Are such temperature changes smooth, discontinuous, or step functions? (Minter, 1994).

GHG sources/sinks and climate changes. In other words, understanding concentrations in the causal taxonomy requires less information than understanding changes in the valued environmental components themselves. This recommendation follows the experience of the stratospheric ozone case, where negotiators ended up using chlorine concentrations, rather than the VEC itself (ozone concentrations).

Designing Policy Responses

One problem with using critical levels as targets is lack of a single global critical level target. [(gg)] Climate change impacts will be vastly different for different countries.[123] For example, scientists have estimated that summer soil moisture may increase by 5 to 10 percent in southeast Asia but decrease by 15 to 25 percent in southern Europe and central North America.[124] Climate change will even have beneficial impacts (warmer winters, [125] improved agriculture) for some countries.

Therefore, based on potential local impacts, countries will have different preferences for the concentration of greenhouse gases. Island nations and nations with large, low-lying deltas will want lower GHG concentrations because they are at greatest risk from sea-level rise. Developing countries that have largely agricultural economies and that would suffer decreased precipitation or lower summer moisture may accept a slightly less stringent GHG target. On the other side of the spectrum, high latitude countries that are likely to receive warmer temperatures, longer growing seasons, and increased precipitation would have minimal incentives to fight climate change.

A possible solution to this problem is to use one or more global index critical level

[(gg)] This observation applies regardless of the critical level measure, e.g., rate of temperature change, rate of sea level change. concentration of GHG.

measures. For example, the *index* measure of global-average rate of temperature change of 0.1°C/decade might be proposed as *a proxy* for localized critical levels. But such a measure would not represent the interests of individual countries very well.

In comparison, equal percentage emission reductions as targets would suffer the same lack of a single global target. Similarly, efficiency and behavioral measures would lack a single global target. However, targets defined in terms of emission reductions or efficiency measures will be easier to allocate *unequally*.[126] Of course, unequal distribution of burdens is already part of the FCCC (in that developed countries bear the early burdens). But negotiating, implementing, and enforcing unequal commitments will be easier if targets are expressed in terms of emission reductions than in terms of concentrations or VECs.

Turning to implementation issues, monitoring GHG concentrations may be relatively easier than monitoring other types of targets. On the other hand, one must attempt to differentiate the anthropogenic contribution.

Monitoring anthropogenically-induced climate change will likely be the most difficult. This will require distinguishing between natural and human factors the affect climate variables.

Targets related to human wants and needs (energy efficiency and behavior) will he difficult to monitor because fossil fuel use is ubiquitous, rather than limited to a collection of power plants and factories (as in acid rain) or a small set of CFC factories (as in ozone).

Similarly, monitoring emissions reductions will be difficult. However, compared to the other types of targets, it may be the easiest.

Facilitating the Negotiation Process and Agreement

In terms of achieving an agreement at this time, the climate change negotiations suffer from a number of huge obstacles, some of which might be exacerbated by framing the debate and/or protocol in critical levels terms. Obstacles include: the large number of parties and the divergence of interests between developed and developing countries.

The large number of parties in the climate change negotiations makes achieving consensus difficult, due to widely varying interests. As the number of parties increases, the probability increases that an agreement (if attained at all) will be "partial" in at least one of three ways: 1) it will cover only some of the agenda items; 2) it will leave some disagreement latent in an ambiguous text; or 3) it will be signed and accepted by only some of the parties. [127]

Perhaps the largest obstacle is the tremendous gulf between the positions of the developed and developing worlds. Many developing countries are highly mistrustful of the entire proposal that economic development be drastically altered to minimize climate change.[128] Their feeling is that the developed nations have had a "free ride" by burning fossil fuels for their industrial revolutions, thereby emitting great amounts of CO_2 and putting the atmosphere in a precarious state. They hear hypocrisy in suggestions by industrialized countries to restrict developing country growth or hold back use of existing technologies. Some developing country spokespersons have used the term "neocolonialism" to describe the proposed Northern control that a climate change treaty might bring.

The above dichotomy between North and South is generalized: there are also divisions within the two groups. The developing countries are split into at least three

blocs. The Alliance of Small Island States (AOSIS), who are quite concerned about sealevel rise, favor stringent controls. In contrast, the Organization of Petroleum Exporting Countries, led by Saudi Arabia and Kuwait, oppose emission limitations. Third, the Group of 24 have demanded commitment from the developed countries for emissions reductions and for financial and technology transfer.

In the North, the Netherlands (concerned about flooding), Germany, and the Nordic countries propose the greatest level of action. The other OECD countries have committed to reduction or stabilization of greenhouse gases in one way or other, although not as much as the activists in the first group.

Another key point is the importance of getting the U.S. to participate. Currently, the U.S. contributes approximately 30 percent of world carbon dioxide emissions. The Clinton Administration has reversed its predecessor's refusal to act,[hh] but as of this writing, the U.S. is reluctant to endorse strict commitments to emission reductions.[129] But the current U.S. plan is basically a collection of energy efficiency policies that make sense for other economic and environmental reasons. The chief U.S. concern has historically been cost. As discussed in Chapter 3, the U.S. recently rejected the critical loads approach in acid rain because it did not fit with current law. In a similar vein, the U.S. is likely to object to a critical levels approach in climate change because such an approach may not be enforceable.

This discussion illustrates some of the political obstacles to progress on climate change. Sebenius (1993) has made further observations regarding the potential for blocking coalitions. He identifies four bases of "blocking coalitions" in climate change

[hh] Clinton and Gore, 1993.

and other international environmental negotiations. The four bases are interest, ideology, opportunism, and science.[130] A climate change agreement faces potential blocking coalitions on all four bases. With respect to interest, some countries might benefit from warming; some are major producers of fossil fuels; some, like China, are planning on vast development of coal for economic growth. As just an example of the potential pressure, when the E.C. proposed an internal carbon tax, the oil-producing Gulf nations threatened the E.C. with cutting off diplomatic relations.[131] With respect to ideology, developing countries complain about potential "neo-colonialism." With respect to using leverage to strengthen one's position,[132] the developing countries can use climate change as leverage to obtain money and technical assistance from the industrial countries. With respect to science, the uncertainties and ignorance discussed above allow some countries to resist agreement (e.g., the U.S. under the Bush Administration).

Returning to critical levels, given the current state of knowledge, a critical loads approach would probably include a handful of indicators, like those in Table 1. The central problem with framing the debate in terms of critical levels at this time is the lack of knowledge about the relationship between anthropogenic changes in GHG and local climatic impacts, as discussed above. It would be a mistake to engage diplomats in extensive negotiations over what numbers to choose as critical levels along, say, ten different dimensions. According to a British diplomat, prior to the UNCED Conference in Rio, most of the INC meetings focused not on scientific issues, but on transfer of funding and technology and organization of the secretariat.[133] The negotiators do not expect to debate science, they expect scientists to give them information on which

they can make political decisions about resources and commitments.[ii] When science has better defined critical levels, they might well be useful as background reference goals in the debate.

Returning to the issue of reaching an agreement, suppose the first proposed protocol was based on today's understanding of the critical level for the global-average surface-air rate of temperature change. Suppose this measure were used as an index for global warming, and in turn, a proxy for climate change. Past studies suggest a critical level target rate of change of 0.1°C/decade. This may imply enormous CO_2 emissions reductions, perhaps on the order of 60 percent.[134] The burden of such reductions would first fall on the industrial countries,[jj] but such reductions would ultimately have great impact on the developing countries (requiring alternatives to coal, limiting energy use per capita, etc.).

Currently the political will to adopt a critical level target requiring a 60 percent CO_2 cut does not exist.[135] Besides the hot summer of 1988, there have not been focusing events, like the Antarctic ozone hole, to stir public opinion. Such a goal would require tremendous lifestyle and structural changes in the developed countries. Such changes will occur gradually (if at all).[kk]

[ii] Probably the thorniest issue is allocating emissions reductions. Since greenhouse gases become uniformly distributed, emissions from anywhere in the world have the same effect. Although critical levels helped allocate emissions reductions in the acid rain case in Europe, a similar benefit is unlikely in climate change.

[jj] FCCC, Article 3, clause 1; Article 4, clause 2(a)- Article 4, clause 3, states that developed countries "shall provide new and additional financial resources to meet the agreed full costs incurred" by the developing countries.

[kk] This author is not arguing against stringent controls. The question here is how to frame the debate and the first protocol, to make progress.

Such a target requires a larger commitment than currently exists. Industrial countries are willing to commit substantial resources toward fighting climate change, but not hundreds of billions in expenditures, at least yet. Such a target would discourage a large proportion of the *high-emitting* countries to sign the first protocol. [136] As the number of parties willing to agree diminishes, so does the "market share" of the sources, sinks, and reservoirs to be controlled. Thus, while such a target might seem positive because it is aggressive, it would have a *negative* effect on reaching an agreement. An incremental approach will be more successful.

However, critical levels could contribute tremendously to the negotiation process in the long run. If scientists develop local (or regional) critical levels, they could help negotiators understand their reservation "prices." This may encourage formation of coalitions with similar desired targets. Therefore, *I recommend that the Parties should continue to develop the scientific data and theories necessary to understand, identify, and quantify critical levels, particularly on a local or country-specific basis. Furthermore, the Parties should use the critical level concept as background information and as leverage to motivate agreement.*

In conclusion, the climate change negotiations are just not ready for midstream targets, especially critical levels. Nations in favor of stringent controls will accomplish more by focusing on an incremental negotiating process, i.e., an increasing percentage reduction from a base year or an efficiency improvement approach. Levy (1993) shows how an incremental approach successfully puts pressure on resistant countries. Negotiators might be more successful invoking the precautionary principle (of acting now, despite ignorance and uncertainty), rather than the critical loads principle (of avoiding

significant damage). Quick, substantial action is likely necessary to reduce the probability of dramatic and extremely costly future impacts, but the targets should not yet be based on the critical level approach.

6.0 CONCLUSIONS

6.1 CONCLUSIONS REGARDING TARGET SELECTION

General Conclusions

The case studies show an intimate relationship between the state of the science and both policy design and negotiation dynamics. All three influence the choice of the type of policy target.

When there is less scientific support, policymakers should choose targets further "upstream." Here "less scientific support" means less scientific understanding, greater scientific disagreement, or greater uncertainty of prediction.

Where the causal links in an environmental problem are fairly well understood, "midstream" targets, such as changes in intermediate processes or intermediate material fluxes, may be used. They have distinct advantages for framing the debate, as discussed below. (In the acid rain and ozone cases, critical levels were in these categories.)

Targets may be selected at the "downstream" end of the causal taxonomy (e.g., exposures or environmental and human health consequences) only where there is a solid understanding, or at least a well-accepted view, of the causal linkages from human behavior to ultimate consequences. For example, in air toxics risk assessment, the methodology for estimating cancer risk from toxic air contaminants is well enough developed to allow targets to be set "upstream in term of cancer risk. [137] Based on air dispersion modeling and the risk assessment methodology,[138] scientists can calculate back from the desired consequences (e.g., limiting cancer risk to ten-in-one-million or less) to an emissions target.

The degrees of scientific understanding, scientific agreement, and scientific

uncertainty influence what is feasible in policy design. For pollution problems, governments typically regulate private and public entities that pollute. Therefore, for ease of implementation, states regulate activities or emissions. States must be able to measure progress toward meeting targets. Thus, in the acid rain case in Europe, while deposition is the policy goal for framing the debate, the protocols use national emissions as the actual policy targets. Similarly, in stratospheric ozone, while chlorine concentrations are the policy goal for framing the debate, the protocols use source- reduction goals by pollutants (i.e., phase-outs and bans) as the measurable policy targets.

Both science and policy design influence negotiation dynamics. States want verifiable, enforceable commitments by other states. "Upstream" targets, such as source reduction and emissions, are more verifiable and enforceable than "midstream" or "downstream" targets. In addition, whether states can agree depends less on the type of target than on the divergence or congruence of the interests of the states.

In sum, the acid rain and ozone cases demonstrate the usefulness of "midstream" targets, specifically critical levels as targets, to *inform* and *motivate* policymakers. But "midstream" and "downstream" targets are less practical than "upstream" targets as policy goals in international environmental agreements.

Results for the Acid Rain and Stratospheric Ozone Case Studies

Turning to the specific targets called critical levels, the acid rain and ozone cases are examples of using critical levels as the chosen targets within the category of intermediate materials fluxes. In the acid rain case, critical loads likely facilitated agreement in Europe, chiefly because of general consensus on the validity of the critical load concept among scientists and policymakers. But critical loads had no effect or a

negative effect with respect to the United States, where neither U.S. scientists nor U.S. policymakers could agree with their Canadian counterparts on the validity of using critical loads.

In the stratospheric ozone debate, the critical level of chlorine in the stratosphere helped achieve quicker and more aggressive action. However, the critical level target should not be given too much credit. Compared to the other cases, the ozone problem was relatively easy to solve due to fewer actors, less costs, acceptable solutions, and a more easily understood cause-and-effect linkage.

Several general conclusions arise from these two cases. In the acid rain and ozone negotiations, critical levels had a number of advantages. For designing policy strategies, critical levels focused attention on achieving the environmental objectives, and they bore close relationships to causes and negative effects. Regarding negotiations, critical levels helped to raise aspirations and to increase pressure for aggressive action.

On the other hand, critical levels in the "midstream" target categories had the disadvantage of requiring that scientists understand (or policymakers assume) the link from emissions to intermediate processes. Interest groups used scientific disagreement over critical levels to confuse the issues and to stall progress. The additional knowledge, if attainable at all, was expensive and controversial. But seeking the knowledge had the beneficial impact of building expertise and institutional capacity.

6.2 RECOMMENDATIONS FOR THE CLIMATE CHANGE NEGOTIATIONS

In the climate change case, scientists do not yet have sufficient knowledge to use critical levels for developing policy responses. Before framing the debate in terms of critical levels, scientists must better understand the relationships between greenhouse gas

emissions, greenhouse gas concentrations, changes in global climate, and effects on local climate. The increasing number of "integrated assessments" now underway may provide such understanding. But no widely shared consensus seems likely to emerge for at least several years. Furthermore, due to the high stakes involved, interest groups will emphasize what is unknown or uncertain, in order to stall the negotiations.

Critical levels will be useful in the climate change debate as a way of increasing knowledge about country-specific impacts and corresponding interests. In addition, attempts to estimate critical levels will be valuable and may later be used for framing the debate or for future protocols.

Recommendations for the Climate Change Negotiators

1) While the Parties should continue to develop the scientific data and theories necessary to understand, identify, and quantify critical levels, they should not yet attempt to base a protocol on the critical level approach. Rather, the first protocol(s) should use an alternative basis, such as emissions reductions or technological (efficiency) measures.

2) The Parties should steer research efforts under the Framework Convention on Climate Change[ll] toward local and country-specific impact assessment. Such critical levels should include physical and biological indicators. Local and countryspecific impacts assessments should identify critical levels, such as the amount of sea-level change that would inundate populated areas, the amount of agricultural land susceptible to drought, and so on.

As a first step, the Parties should request the various research bodies

(ll) See Article 4, clause 1 (g); Article 5; and Article 7, clause (2) (e).

discussed in the FCCC to set aside a portion of their research funding and efforts to develop country-specific impact assessments for all Parties. Where multi-country assessments would be possible and more cost-efficient, impact assessments should be conducted for groups of countries.

3) The Parties should keep critical levels in mind as background information and use the potentially drastic impacts of climate change induced by anthropogenic greenhouse gas emissions as motivating leverage in the negotiations.

4) As linkages between anthropogenic greenhouse gas emissions and climatic effects are better understood, negotiators and scientists should focus first on critical levels based on GHG concentrations, rather than measures of climate change.

FIGURE 1
SIMPLIFIED CAUSAL TAXONOMY
FOR ACIDIFYING DEPOSITION, STRATOSPHERIC OZONE DEPLETION, AND CLIMATE CHANGE

	Human Activities	Emissions -- (Chg Material Fluxes)	Intermediate Processes & Mat. Fluxes	Impact Mechanisms	Changes in Valued Env. Components	Exposure Variables	Env. and Human Consequences
ACIDIFYING DEPOSITION	Electricity generation; autos	SO_2; NO_x	transport of SO_2, NO_x, → **acid deposition**↑	Deposition & acidification	pH↓ in rain, lakes, forest soil	Lake location	Fish kills
STRATO-SPHERIC OZONE	Refrig./ cooling	Chlorofluoro-carbons	Increased **chlorine conc.** in stratosphere	Cl↑ → O_3↓ → decr. ultraviolet absorption	Stratos. O_3↓; ultraviolet absorption↓	Latitude	Skin cancer
CLIMATE CHANGE	Fossil-fuel burning; agriculture	CO_2; methane	CO_2 conc.↑; CH_4 conc↑	TRF↑ → temp.↑ & sea level↑	Temperature↑; sea level↑	Location; elevation	Drought; flooding

Shaded cells contain possible critical levels/loads measures.
Boldface terms in shaded cells are the selected critical levels/loads measures.

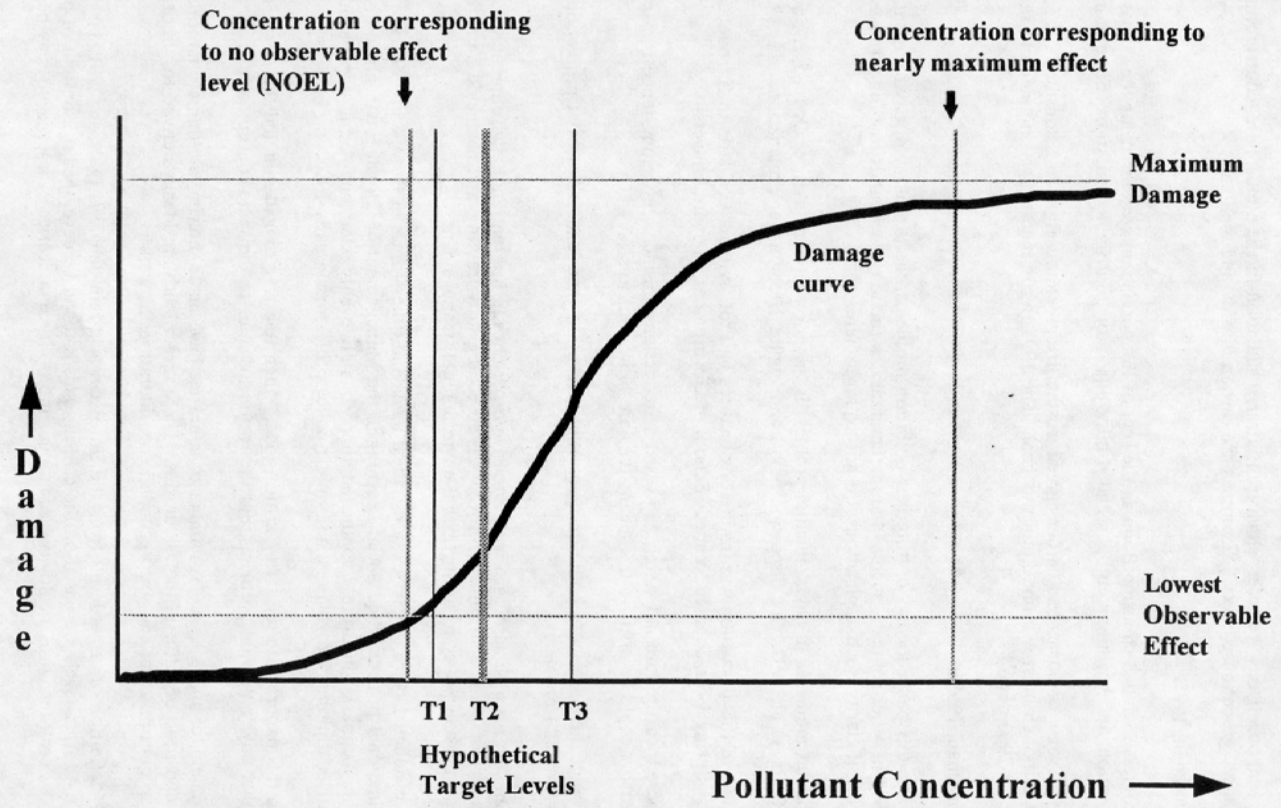
Abbreviations:

SO_2	= sulfur dioxide	CH_4	= methane
NO_x	= oxides of nitrogen	TRF	= total radiative forcing
CFCs	= chlorofluorocarbons	conc.	= concentration
Cl	= chlorine		
O_3	= ozone		
CO_2	= carbon dioxide		

Matrix inspired by: Hohenemser et al, 1985, 69;
Norberg-Bohm and Clark, et al, 1992.

U.S. (C) 1994 W.F. Dietrich

Figure 2
Typical Environmental Damage Curve



Notes: T2 = hypothetical critical level corresponding to threshold of significance
T2 - T1 = an example margin of safety

U.S. (C) 1994 W.F. Dietrich

ENDNOTES

1. Greenhouse gases are gases which trap infrared radiation in the atmosphere, contributing to the "enhanced greenhouse effect." Examples are carbon dioxide and methane.

2. Simonian, 1995b.

3. Progress included choosing Bonn as the seat or the permanent secretariat for the climate change convention, and beginning an open-ended pilot phase for joint implementation. Simonian, 1995a.

4. Ibid. Some countries had earlier agreed to stabilize greenhouse gas emissions at 1990 levels by the year 2000, although most will not attain this goal. The 1995 Berlin meeting was intended to make deeper cuts for the post-2000 period.

5. Simonian, 1995a.

6. While this paper focuses on three air pollution problems, the taxonomy of environmental hazards may also he used in other contexts, such as the incremental destruction of wetlands by filling for development. In the interest of clarity, such applications are not explored here.

7. This taxonomy of an environmental problem is based on Hohenemser, et al, 1985, 69, and Norbert-Bohm and Clark, et al, 1992- See discussion below and Figure 1 for further explanation.

8. Much of this discussion was inspired by lectures by Prof. William C. Clark, in Introduction to Environmental Policy, Spring 1992, John F. Kennedy School of Government, Harvard University.

9. These measures are not simply expressed as reductions; an increase in long-range transport of ozone precursors could be positive if it means they are blown out to sea.

10. I limit this analysis to pollution-type problems, rather than land use, habitat protection, or other types of environmental problems.

11. Dr. Jager is a climatologist with extensive experience in international environmental issues, including climate change and acid rain. Prof. Clark is an ecologist by training, and has made numerous contributions to research and policy regarding global environmental management.

12. I conducted eleven interviews on critical loads and other topics in Europe in 1992, as part of the multinational project called Social Learning in the Management of Global Environmental Risks. In my work for the Wuppertal Institute, I conducted approximately twenty telephone and in-person interviews with scientists, diplomats, regulators, and public policy professors in early 1994.

13. In this paper, I use the term, "critical load,"when referring to acid rain and the term, "critical level," for all other environmental problems, but the two terms refer to the same concept.

14. Amann, et al., 1992, 6. "A number of countries have made interim, preliminary national target loads for the deposition of sulfur in their countries. These target loads are ideally derived from critical loads but take into account political and socio-economic considerations as well."

15. A definition of target levels from the European acid rain debate is (Nilsson, 1991, 1):

> Target levels are based on the critical loads and will be developed in the light of possible legal, technical, ecological, economic, and political concerns. Target levels may be set lower

or higher than the critical loads depending upon actual conditions. The basic idea in setting target levels is that they will form the basis for negotiating internationally accepted emissions reduction strategies.

16. Due to the difficulty of achieving critical loads for acid rain in Europe (discussed in Chapter 3), participants in the debate created the "target loads" concept. Brodin and Kuylensnerna, 1992, 337.

17. Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions, 33 *International Legal Materials* 1540, 1549, Annex II (1994).

18. To create Figure 1, I modified the causal taxonomy for environmental hazards presented by Hohenemser, Kates, and Slovic, 1985. 1 also drew from Figures 2, 3, 4, and 5 and the analysis in Norbcrg-Bohm and Clark, et al., 1992.

Hohenemser, et al. (1985, 69) identify six stages of causal sequence: human needs, human wants, choice of technology, release of materials or energy, exposure to materials or energy, and human and biological consequences.

19. Beanlands and Duinker, 1983, as cited by Norberg-Bohm and Clark, et al., 1992, 5.

20. The causal taxonomy's other advantages include its comprehensive and systematic approach, its focus on outcomes as changes in material or energy fluxes, and its attention to upstream behavioral changes. Hohenemser, Kasperson, and Kates, 1985, 31.

21. A corresponding action would be increasing GHG sinks. Greenhouse gas "sinks" are processes that absorb GHGs from the atmosphere.

22. The curve could describe damage to cells, individual organisms, a population of one species, groups of populations in an ecosystem, or even groups of ecosystems.

In toxicology, this sigmoid shape describes the effect on an individual. The curve is known as a dose-response curve. Gets, 1992, 43.

In ecological risk estimation, the sigmoid shape describes the effect on populations of organisms. The curve is called a concentration-response function. Bartell, et al., 1992, 66.

23. Environmental impact assessments commonly use the phrase "significant adverse effect." For example, a "significant" impact for a threatened species might be defined as a loss of ten percent of the population. For an endangered species, *any* loss of individuals or habitat is significant. Debates rage over defining what is "significant." For one approach, sec the California Environmental Quality Act's definition of significance. California Public Resources Code § 21068 (Deering 1987).

24. Setting and pursuing a target is equivalent to assuming the that damage curve rises almost vertically. After the target is set, regulators turn their attention to implementation.

25. Brickman, Jasanoff, and Ilgen, 1985, 207-08.

26. My illustration in Figure 2 differs from Bull (1990, 108, 119), who portrays the critical level as the zero (percentage) effect level in his theoretical dose-response curve. Figure 2 differs by recognizing the concept of significance, (After years of preparing environmental impact assessments, I cannot ignore the distinction between insignificant and significant impacts.) My description and Bull's description can be reconciled by interpreting Bull's "effects" as "significant effects."

27. See Collingridge and Reeve, 1986, 2.

28. For example, commenting on the 1995 climate change negotiation session in Berlin, an editorial posited: While it would be encouraging to see such a large number of governments agree on the existence of a problem, it would be equally disturbing if costly measures on a global scale were adopted to combat a threat where the margin of uncertainty is still so large.

Financial Times. 1995. *Cool Air at Berlin Summit* (editorial). (March 27, p. 17).

29. If an environmental problem is relatively simple, the causal chain may be thoroughly understood. But this is the exceptional case. Typically, the causal links are difficult to fathom, and years of research result in a murky understanding at best. For example, while it is well established that volatile organic compounds and oxides of nitrogen react in the presence of sunlight to form ozone, whether the more effective policy response is to reduce emissions of both sets of compounds or just one set remains in dispute.

For example, for years, the San Francisco Bay Area Air Quality Management District ("BAAQMD") followed a strategy of reducing only VOCs. At the spurring of the 1989 California Clean Air Act, the BAAQMD conducted air quality modeling to demonstrate that additional emission control measures could meet the more stringent standards. Unfortunately, the modeling counterintuitively indicated that neither the VOC-only strategy nor the VOC/NO_X strategy could accomplish the desired ozone reductions. This indicated a possible flaw in the scientific foundation for the models. (The author managed the preparation of the Draft Environmental Impact Report for the BAAQMD's 1991 Clean Air Plan.)

30. Lindblom, 1968, 34.

31. Ibid., 34-35.

32. I leave it to the reader to examine Collingridge and Reeve's case studies and reasoning.

33. Ibid., ix-x.

34. Ibid., 31-32.

35. Ibid., x.

36. Ibid., 32.

37. Ibid., x.

38. Ibid.

39. Ibid., 15.

40. *Cf.* Jasanoff, 1990, 12.

41. Collingridge and Reeve, 1986, 16.

42. Ibid., 19.

43. Ibid., 21.

44. Ibid., 21-22.

45. Ibid., 12.

46. Ibid., 24-25.

47. Ibid., 26-27.

48. Ibid., viii-ix.

49. Ibid., ix.

50. Ibid., 42.

51. Here Collingridge and Reeve rely upon Lindblom. Ibid., 27.

52. Collingridge and Reeve mention the role of science in agenda setting very briefly. Ibid., 155.

53. Ezrahi, 1990, 17.

54. Of course, vehicle manufacturers will strive to pass the costs onto consumers, but in various contexts the ability of a producer to pass on such costs depends upon the elasticity of demand.

55. Lax and Sebenius, 1986, 30. 56. Ibid., 32.

57. Zartman, 1984, 2.

58. Lax and Sebenius, 1986, 126.

59. Ibid., 48.

60. Ibid.

61. Ibid., 131.

62. Zartman, 1978, 134-35.

63. Ibid., 135.

64. Zartman, 1978, 135.

65. Parson, Edward. 1994. Personal interview with author. March 9. Professor Parson teaches negotiation at the John F. Kennedy School *of* Government, Harvard University.

66. Nilsson, et al., 1988, 8.

67. This definition is attributed to the definition agreed by the UN-ECE Working Group on Nitrogen Oxides at its Eighth Session in February 1988. Nilsson and Grennfelt, 1988, 8.

68. Hettelingh, et al., 1991.

69. An Executive Body of member states governs LRTAP. Under the Executive Body, various Working Groups oversee various cooperative research programs and task tortes. They are also the central fora for the discussion of scientific and policy issues, and arc consequently central players in research on critical loads.

In addition, other institutions, play key roles. One is the Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP). EMEP measures pollutant levels throughout Europe and created the "transfer-matrices" that show how pollution moves over

long distances. These transfer-matrices are fundamental to determining where emissions reductions should be made in order to meet critical loads.

Another key organization is the International Institute for Applied Systems Analysis (IIASA), a non-governmental research institution sponsored by East and West. IIASA developed the RAINS model, a model that integrates emissions, transport, deposition and cost information. RAINS provides the Working Group on Strategies, the Executive Body, and the LRTAP member governments with simulations of various emission reduction scenarios. IIASA has prepared numerous simulations of critical load-based policies for decision makers.

70. The monitoring program is called EMEP, which stands for the Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe.

71. Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions, 33 *International Legal Materials* 1540 (1994).

72. This protocol may deal with NO_x, NO_x and ammonia, or a set of transportation or other measures.

73. Shaw, 1990, 27.

74. Cf. Dovland, 1992.

75. As discussed above, the Canadians proposed that the Canada and the U.S. adopt a 50 percent emissions reduction from the baseline of 1980 levels. However, this proposal did not stem from scientific ignorance or uncertainty, rather, it was based on a critical loads approach.

76. Cf. Amann, et al., 1992a.

77. Hordijk, 1992.

78. In 1994, scientists and policy analysts within the U.S. EPA and the U.S. National Acid Precipitation Assessment Program were still debating the advantages and disadvantages of critical loads. For example, EPA policy analysts objected to Europe's use of a static measure. Leaf, 1994.

79. As scientists began to explore the possibilities of using critical loads, new data and analysis needs became obvious. If one was going to estimate the emission reductions and costs for countries, the following data and estimates would be needed:

- Determination of the critical loads, through field measurements, calculations, and modeling,
- Emissions forecasts,
- Estimation of long-range source-receptor relationships,
- Costs of reductions.

Finally, an integrated model would be needed to put all of this together by either simulating different assumptions in scenarios and/or optimizing to reduce costs.

80. Hettelingh, 1991.

81. Ågren, 1992, 1993. Ågren directs the Swedish NCO Secretariat on Acid Rain, an umbrella environmental group for other Swedish environmental organizations. He points out that for practical reasons, the RAINS model includes only a few technical options. He contends that introducing fuel-substitution, increased energy efficiency, alternative energy and transport systems, and other options could change the conclusion that critical loads cannot be met.

82. Confidential interviews with U.S. officials, 1994.

83. But a corollary problem is that meeting critical loads in most locations in Europe would be so costly that sharing the burden of these costs may be too difficult politically (Dovland, 1992).

84. Amann, et al., 1991, 16.

85. Sebenius, 1984.

86. Hordijk, 1992, 1994.

87. A downside to widespread acceptance of critical loads-defined targets *for acid rain,* is the lack of a single policy solution. Because acidifying compounds are not *uniformly mired,* there is not a unique relationship between target loads and the measures to be taken in certain countries. In other words, many solutions are possible. Much horse-trading could occur and probably has occurred regarding specific reductions needed to meet certain critical loads in particular locations. The exception to this drawback is that an optimized solution in economic terms (i.e., the cost-effective solution), such as an optimized scenario from the RAINS model, is unique.

In other words, bargaining over emission reductions is to be expected. But the drawback of critical loads in this case is a vast multiplication of the number of things to be traded (specific source-receptor relationships), thus potentially complicating the negotiating process tremendously.

88. Although not objecting any longer to the concept, the United Kingdom did object to the stringency of the Second Sulfur Protocol. Specifically, the United Kingdom objected to the stringency of the proposed 80 percent "gap closure" target. The U.K later agreed to a roughly 70 percent target.

89. Leaf, 1994.

90. Confidential source. Telephone interview with author. October 1993. Eastern European countries arc, quite understandably, striving for security, economic, and technical gains. Looking for such gains, they are highly motivated to comply at least a bit, so they can get into the fold.

91. Levy, 1994.

92. In 1985 British scientists in Antarctica published their findings that springtime ozone levels dropped to about 50 percent lower than in the 1960s. However, it was not clear that this drop was due to CFCs. Other candidate causes were polar winds, volcanoes, and sunspots. Benedick, 1991, 18-19.

93. Benedick, 1991, 110-111.

94. Benedick. 1991, 121.

95. Although bromine also depleted ozone, the chemistry was not well understood. Chlorine loading became the benchmark. (The halons contain bromine.) (Benedick, 1991, 121)

96. Benedick, 1991, 124.

97. For example, over 80 nations, compared to 25 to 30 nations participated. (Benedick, 1991, 124).

98. Benedick, 1991, 125.

99. Benedick, 1991, 129-30.

100. The weakest part of the London Amendments was only agreeing to report on, rather than to restrict, HCFCs. (Benedick, 1991).

101. Benedick, 1991, 106-07.

102. Some of these factors were observed by Chaves (1993). Cf. Parson and Zeckhauser, 1993, 19.

103. Du Pont initiated the change in industry position in September 1986. Soon after, the Alliance for Responsible CFC Policy, a consortium of CFCC producers, changed its position to favor controls.

104. For a definition of focussing events, see Kingdon (1984, 99-100).

105. *International Legal Materials* 31 (July 1992): 849.

106. Wigley and Barnett, 1990, 243.

107. Oppenheimer, 1994.

108. Jager, 1988, 22.

109. [bid.

110. According to one noted climatologist, these targets were sensible and appropriate efforts, but the scientific work behind them was insufficient (Mintzer, 1994).

111. Mintzer, 1994.

112. The adopted language stayed very similar to the original formulation proposed by the EC, drawing upon an earlier Ministerial Declaration from a conference in Noordwijk in Nov. 1989. (Grubh, et al., 1993, 63, n.l).

113. *International Legal Materials* 31 (July 1992): 849.

114. Usher, 1994.

115. Since Article 2 does not provide a refined objective, the INC has requested the IPCC to study how to make Article 2 operational. The IPCC held a meeting in Brazil in April, 1994, to further discuss the scientific research necessary to determine "dangerous anthropogenic interference" means and what the critical levels might be. (Vellinga, 1994). At the time of this writing, the results of this meeting were not available.

116. See IPCC, 1991, xxxiv-xlvii.

117. United Nations Environment Programme and the Beijer Institute, 1989, 151.

118. Cf. Mintzer, 1994.

119. IPCC, 1990, mvii, 317-321.

120. Ibid., xxvii.

121. Ibid., xxvii; Rijsberman and Swart, 1990, x.

122. Alcamo, 1994.

123. CL Zeckhauser, 1994; Haites, 1994.

124. IPCC, 1990,157-58.

125. For example, climate modelers using high resolution simulations have forecasted that "the warming over North America in winter is about 4°C, rising to 8°C in the northeast of the continent ... Similarly over Europe and northern Asia, the warming is of order 4°C, with some areas of much larger warming as for example in eastern Siberia." IPCC, 1990, 140.

126. See Parson and Zeckhauser, 1994.

127. Ibid., 339.

128. Usher, 1994.

129. Simonian, 1995a, 6.

130. Sebenius, 1993.

131. Ibid.

132. Sebenius' "opportunism" label is too harsh.

133. Brenton, 1994.

134. IPCC, 1991, xxv. "The long-lived [greenhouse] gases would require immediate reductions in emissions from human activities of over 60 percent to stabilize their concentrations at today's levels." As alluded to in this chapter, substantial uncertainties attach to this estimate.

135. Cf. Usher, 1994.

136. It would be better to have a protocol that will result in actions than just a goal statement. (Sebenius, 1993).

137. See California Air Pollution Control Officers Association ("CAPCOA") risk assessment methodology.

138. See e.g., Dietrich and Atwood, 1989.

BIBLIOGRAPHY

Ågren, Christer. 1992. Interview with author. Gothenburg, Sweden. 3 June. (Agren directs the Swedish NGO Secretariat for Acid Rain and is the Editor of Acid News).

Ågren, Christer. 1993. Letter to author, 13 April 1993.

Alcamo, Joe M., 1994. Telephone interview with author. 4 February. (Alcamo is at the National Institute of Public Health and Environmental Protection (RIVM), Bilthoven, The Netherlands).

Alcamo, J., R. Shaw and L. Hordijk. 1992. *The RAINS model of acidification. Science and strategies in Europe.* Dordrecht: Kluwer Academic Publishers.

Albritton, Daniel L. Telephone interview with author. February. (Albritton directs the NOAA Aeronomy Lab at the U.S. National Center for Atmospheric Research.)

Amann, Markus. 1992. Interview with author. Laxenburg, Austria. 2 July. (Amann is leader of Transboundary Air Pollution Project at the International Institute for Applied Systems Analysis).

Amann, M. and G. Klaasen. 1992. *Trading of emission reduction commitments for sulfur dioxide in Europe.* Status Report 92-03. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Amann, M. et al, 1992a (I. Bertok, J. Cofala, G. Klaassen, W. Schopp). *Strategies for reducing sulfur dioxide emissions in Europe.* Unpublished Working Paper WP-92-XX [sic] Laxenburg, Austria: International Institute for Applied Systems Analysis.

Amann, M., G. Klaasen, and W. Schöpp. 1991. *UNIECE workshop on exploring European sulfur abatement strategies.* Status Report WP-91-03. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Anderssen, B.; Dicksson, W.; Eriksson, E.; Henriksen, H.; Kaman, Nilsson, I.; and Nilsson, J.. *Critical loads for sulphur and nitrogen.* Miljorapport 1986:11. Nordic Council of Ministers, 1986. Nordisk Ministerrad.

Bakkan, P. 1992. Interview with author. Oslo, Norway. 10 June. (Bakkan is Head Negotiator, Norwegian Ministry of the Environment).

Batterman, S. 1990. *Optimized abatement strategies using critical loads: Suggested deposition criteria and results.* Working Paper 90-67. Laxenburg, Austria: IIASA.

Batterman, S., M. Aniann, J-P. Hettelingh, L. Hordijk, G. Kornai. 1988. Optimal SO2 abatement policies in Europe. In *Systems analysis -- Modeling -- Simulations.* 533-559.

Beanlands, Gordon E. and Peter N. Duinker. 1983. *An ecological framework for environmental impact assessment.* Quebec, Canada: Institute for Resource and Environmental Studies, Dalhousie University, in cooperation with the Federal Environmental Assessment Review Office.

Bendahmane, Diane B. and John W. McDonald, Jr. 1984. *International negotiation: Art and science.* Report of a conference on international negotiation, June 9-10, 1983. Washington, D.C.: U.S. Dept- of State, Foreign Service Institute, Center for Study of Foreign Affairs.

Benedick, Richard E. 1991. *Ozone diplomacy: New directions in safeguarding the planer.* Cambridge, Mass.: Harvard University Press.

Berlin climate delegates agree to negotiate post-2000 emission pact. 1995. *BNA International Environment Daily*. (Apr. 10).

Bodansky, Daniel. 1993. The United Nations Framework Convention on Climate Change: A Commentary. *Yale journal of environmental law.* 18:451-558.

Brenton, Tony. 1994. Telephone interview with author. 1 February. (Brenton was head of the British Foreign Office Dept. that conducted the climate change negotiating up to the UNCED Conference).

Brickman, Ronald, Sheila Jasanoff, and Thomas Ilgen. 1985. *Controlling chemicals: The politics of regulation in Europe and the United States.* Ithaca, New York: Cornell University Press.

Bull, KR. 1991. The critical loads/levels approach to gaseous pollutant emission control. *Environmental pollution.* 69:105-123.

Burtraw, Dallas. 1991. *Equity and international agreements for CO_2 containment.* Washington, D.C.:Resources for the Future.

Cairncross, Frances. *Costing the Earth: The challenge for governments, the opportunities for business.* Boston, Mass.: Harvard Business School Press.

Chayes, Ahram. 1993. Lecture at the Harvard Law School, fall 1993.

Clinton, William J. and Albert Gore, Jr. 1993. *The Climate change action plan.* Washington, D.C.: The White House.

Collingridge, David and Colin Reeve. 1986. *Science speaks to power. The role of experts in policy making.* London: Frances Pinter.

Cool air at Berlin summit (editorial). 1995. *Financial times.* 27 March, 17.

Dietrich, William F. and Carolyn J. Atwood. 1989. *Application for authority to construct and permit to operate for vapor degreaser in Building 071, Phase II, LMSC Plant No. 1, including risk screening analysis.* Prepared for Lockheed Missiles and Space Company, Inc. (LMSC), Sunnyvale, California. (Berkeley, CA: TENERA, L.P.)

Dovland, H. 1992. Interview with author. Lillestrøm, Norway. 9 June. (Dovland is Director of the Norwegian Institute for Air Research (NILU)).

Ezrahi, Yaron. 1990. *The descent of Icarus: Science and the transformation of contemporary democracy.* Cambridge, Mass.: Harvard University Press.

Fisher, Roger and William Ury. 1981. *Getting to yes: Negotiating agreement without giving in.* Ed., Bruce Patton. New York: Penguin Books.

Free Transport and Pedal Power. 1995. *Financial times.* 28 March, 6.

Graham, John D. 1985. The failure of agency-forcing: The regulation of airborne carcinogens under section 112 of the Clean Air Act. *Duke law journal* vol. 1985: 100 ff.

Grubb, Michael. 1989. *The Greenhouse e pct: Negotiating targets.* London: Energy and Environmental Programme, Royal Institute of International Affairs.

Grubb, Michael, et al, 1993. Koch, Matthias; Thomson, Koy; Munson, Abby; Su. United Nations Framework Convention on Climate Change in *The Earth Summit' agreements: A guide and assessment: an analysis of the Rio '92 UN Conference on Environment and Development.* London: Earthscan Publications, Inc.

Haas, Peter M. 1990. *Saving the Mediterranean: The politics of international environmental cooperation.* New York: Columbia University Press.

Haas, Peter M., Robert O. Keohane, and Marc A. Levy. 1993 *Institutions for the Earth: Sources of effective international environmental protection.* Cambridge, Mass.: MIT Press

Haites, Erik F. 1994. Telephone interview with author. February. (Haites is the Head of the Technical Support Unit for Working Group III of the Intergovernmental Panel on Climate Change.

Hettelingh, J., R.J. Downing and P.A..M. de Smet, eds. 1991. *Mapping critical loads for Europe: CCE technical report no. 1* (RIVM Report No. 259101001). Bilthoven, The Netherlands: LRTAP Coordinating Center for Effects, Netherlands National Institute of Public Health and Environmental Protection.

Hohencmser, Christoph, Roger E. Kasperson, and Robert W. Kates. 1985. *Causal structure.* In Kates, Robert W., Christoph

Hohenemser, and Jeanne X. Kasperson, eds. *Perilous progress: Managing the hazards of technology.* Boulder, Colorado: Westview Press

Hohenemser, Christoph, Robert W. Kates, and Paul Slovic. 1985. *A causal taxonomy.* In Kates, Robert W., Christoph Hohencmser, and Jeanne X. Kasperson, eds. *Perilous progress: Managing the hazards of technology.* Boulder, Colorado: Westview Press.

Hordijk, L. 1992. Interview with author. Laenburg, Austria. July. (Hordijk was formerly the Leader of the Acid Rain Project at the International Institute for Applied Systems Analysis).

Hordijk, L. 1994. Interview with Ms. Nancy Dickson of the Center for Science and International Affairs, Harvard University. Washington, D.C. February. (Hordijk participates in the acid rain negotiations as a leading voice in LRTAP's Working Group on Strategies.)

Hordijk, L., J. Alcamo, J. Kämäri, P. Kauppi, M. Posch, and E. Runca. 1985. Integrated analysis of acidification in Europe. *Journal of Environmental Management.* 21:47-61.

Jäger, Jill. 1988. *Developing policies for responding to climate change: A summary of the discussions and recommendations of the workshops held in Villach (28 Sept - 2 Oct 1987) and Bellagio (9-13 Nov. 1987) under the auspices of the Beijer Institute, Stockholm.* WMO and UNEP.

Jasanoff, Sheila. 1990. *The fifth branch: Science advisers as policymakers.* Cambridge, Mass.: Harvard University Press.

Kayo, Y. et al. 1993. *Costs, impacts, and benefits of CO_2 mitigation*- Proceedings of a workshop held on 28-30 September 1992 at IIASA, taxenburg, Austria. IIASA Report CP-93-2. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Kingdon, John W. 1984. *Agendas, alternatives, and public policies.* Harper Collins.

Iklé, F. C. and N. Leites. (1962) Political negotiation as a process of modifying utilities. *Journal of conflict resolution.* 6:19-28.

IPCC (World Meteorological Organization/United Nations Environment Programme Intergovernmental Panel on Climate Change). 1990 *Climate change: The IPCC scientific assessment.* Edited by J.T. Houghton; G.J. Jenkins, J.J. Ephraums. Cambridge, England: University Press.

IPCC. 1991. *Climate change: The IPCC response strategies.* Washington, D.C.: Island Press.

Latin, Howard. 1988. Good science, bad regulation, and toxic risk assessment. *Yale Journal on Regulation.* vol 5: 1, 89.

Lax, David A- and James K Sebenius. 1986. *The manager as negotiator.* New York: Free Press (Macmillan).

Leaf, Dennis. 1993. Telephone interview with author. 19 October; 20 October. (Leaf is a policy analyst at the U.S. Environmental Protection Agency).

Levy, Marc A. 1993. European acid rain: The power of tote-board diplomacy. In Haas, Peter M., Robert O. Keohane, and Marc A. Levy, eds. *Institutions for the Earth: Sources of effective international environmental protection.* Cambridge, Mass.: MIT Press.

Lindblom, Charles, E. 1968. *The decision making process.* Englewood Cliffs, NJ: Prentice Hall.

Lindblom, Charles, E. 1959. The Science of Muddling Through. *Public administration review.* 19 (Spring), 7988.

Lunde, Leiv. 1990. *The north/south dimension in global greenhouse politics: conflicts, dilemmas, solutions. Oslo:* Fridtjof Nansen Institute.

Midgaard, Knut and Arild Underdal. 1977. Multiparty conferences. In *Negotiations: Social-psychological perspectives.* 329-345. Ed. by Daniel Druckman. Beverly Hills, California: Sage Publications.

Mintzer, Irving. 1994. Telephone interview with author. 4 February. (Mintzer holds joint appointments at the Center for Global Change, University of Maryland and the Stockholm Environment Institute).

Nilsson, J. and P. Grennfelt. 1988. *Critical loads for sulphur and nitrogen.* Workshop report from the workshop at Skokloster, Sweden, 1988, organized by UN-ECE and the Nordic Council of Ministers, 19-24 March 1988. (Miljørapport 1988:16, NORD 1988:98). Copenhagen: Nordic Council of Ministers.

Norberg-Bohm, Vicki and William C. Clark, et al. 1992. *International comparisons of environmental hazards: Development and evaluation of a method for linking environmental data with the strategic debate management priorities for risk management*. Center for Science and International Affairs Discussion Paper 92-09. Cambridge, Mass.: Harvard University, CSIA, Environment and Natural Resources Program.

Norwegian Ministry of the Environment. 1991. *Critical loads/levels.* Oslo: Norwegian Ministry of the Environment.

Oberthuer, Sebastian. 1994. Telephone interview with author. 10 March.

Oppenheimer, Michael. 1984. Developing policies for responding to climatic change; an editorial. *Climatic change.* 15 (October, no, 1-2).

Oppenheimer, Michael. 1994. Telephone interview with author. 4 February. (Oppenheimer is a chief *scientist* with the Environmental Defense Fund).

Oppenheimer, Michael and Robert H. Boyle. 1990. Dead heat The race against the greenhouse effect. New

York: Basic Books, Inc.

Parson, Edward AL and Richard J. Zeckhauser. 1993. *Equal measures or fair burdens: Negotiating environmental treaties in an unequal world* Unpublished manuscript.

Parson, Edward A- and Richard J. Zeckhauser. 1994. Cooperation in the unbalanced commons. In Arrow, K-, et al, eds. *Barriers to the negotiated resolution of conflict*- Norton. In press.

Pershing, Jonathan C. 1994. Telephone interview with author. February. (Pershing is a chief scientist with U.S. Department of State, Office of Global Change).

Ramberg, Bennett. Tactical advantages of opening positioning strategies: Lessons from the seabed arms control talks, 1967-1970. In Zartman, William I., ed. 1978. *The negotiation process: Theories and applications.* Beverly Hills, California: Sage Publications.

Raiffa, Howard. 1982. *The an and science of negotiation.* Cambridge, Mass.: Harvard University Press.

Reitze, Arnold W., Jr. 1991. A century of air pollution control law: What's worked; what's failed; what might work. *Environmental law.* 21:1549-1646. No. 4:11.

Rijsberman, F.R. and R.J. Swart, eds. 1990. *Targets and indicators of climatic change.* Stockholm: Stockholm Environment Institute.

Riordan, Courtney. Telephone interview with author. February. (Riordan directs the U.S. EPA Office of Environmental Processes and Effects Research).

Schelling, Thomas C. 1992. Some economics of global warming. *American economic review.* 82/1 [1-14 check]. Schelling, Thomas C. 1960. *The strategy of conflict.* Cambridge, Massachusetts: Harvard University.

Schöpp, W. 1991. *Modeling of critical loads for acid deposition in Austria.* Status Report 91-04. Laxenburg, Austria: IIASA.

Schöpp, W. and S.P. Uryas'ev. 1990. *On the optimization model for acid loads on forest soils. IIASA* Working Paper 90-37. Laxenburg, Austria: IIASA.

Sebenius, James K. 1993. *Towards a winning climate coalition.* Unpublished manuscript.

Sebenius, James K. 1984. *Negotiating the law of the sea.* Cambridge, Mass.: Harvard University Press.

Shaw, R.W. 1992. Interview with author. Laxenhurg, Austria. 9 July. (Shaw was the leader of Transboundary Air Pollution Project at IIASA 1987-1990).

Shaw, R. W. 1990. *A study in contrasts: Acid rain negotiations in North America and in Europe.* Unpublished manuscript.

Simonian, Haig. 1995a. Climate change talks seen as modest success. *Financial Times.* 8 April, 2.

Simonian, Haig. 1995b. Deadlock over key issues at climate change conference. *Financial Times. 3* April, 16.

Simonian, Haig. 1995c. Determined to force the pace. *Financial times.* 28 March, 6.

Simonian, Haig. 1995d. Opposing theorists go into battle for the world. *Financial times.* 28 March, 6.

Simonian, Haig. 1995e. US left exposed in chill of climate talks. *Financial Times.* 7 April, 5.

Staaf, HAkan. 1993- Telephone interview with author. October. (Staaf is Head of acid rain research, Sverige Naturvdrdsverket (Swedish Environmental Protection Agency)).

Staaf, Hdkan. 1992. Interview with author. Solna, Sweden. 2 June.

Subak, Susan, and William C. Clark. 1990[?]. *Accounts for greenhouse gases: towards the design of fair assessments.*

Svensson, Karin. 1993. *The greenhouse effect: The negotiation process toward global policy.* Unpublished manuscript, University of Lund, Sweden.

Sverdrup, II., W. de Vries, and A. Henriksen. 1989. *Mapping critical loads: Criteria, calculation methods, input data, and calculation examples for mapping critical loads and areas were they have been exceeded.* Prepared as a background document for the Workshop and Task Force on mapping critical loads and levels, at Bad Harzburg Nov. 6-9, 1989, organized by the Secretariat of the UNECE and the Nordic Council of Ministers (NMR).

Swart, Robert J. and Pier Vellinga. 1993. *The "ultimate objective" of the Framework Convention on Climate Change requires a new approach in climate change research.*

Swart, R., H. de Boois, and P. Vellinga. 1989. Targets for climatic change, in United Nations Environment Programme and the Beijer Institute, *The full range of responses to anticipated climatic change.* April. pp. 137-159.

Tobin, Richard J. 1979. *The social gamble: Determining acceptable levels of air quality.* Lexington, Mass.: Lexington Books.

UN-ECE. 1988. *ECE critical levels.* Workshop report for meeting at Bad Hartzberg, Federal Republic of Germany.

UN-ECE. 1979a. *Convention on long-range transboundary air pollution.*

United Nations Environment Programme and the Beijer Institute. 1989. *The full range of responses to anticipated climatic change.* April.

Usher. Peter. 1994. Telephone interview with author. February. (Usher works at the United Nations Environmental Programme.)

Vellinga, Pier. 1994. Telephone interview with author. February. (Vellinga is at the Free University of Amsterdam, The Netherlands).

Walker, Richard and Michael Storper. 1978. Erosion of the Clean Air Act of 1970: A study in the failure of government regulation and planning. *Boston college journal of environmental affairs.* 7:189.

Walton, Richard E. and Robert B. McKersie. 1965. *A behavioral theory of labor relations: An analysis of a social interaction system.* New York: McGraw-Hill.

Wigley, T.M.L. and T.P. Barnett. Detection of the greenhouse effect in the observations. In IPCC 1990.

Winstanley, Derek. 1994. Telephone interview with author. February. (Winstanley is at the U.S National Oceanic and Atmospheric Administration).

Zeckhauser, Richard. 1994. Interview with author. February. (Zeckhauser is a professor at the John F. Kennedy School of Government at Harvard University).

Zartman, I. William, ed. 1978. *The negotiation process: Theories and applications.* Beverly Hills, California: Sage Publications

Zartman, I. William. 1984. *Negotiation: Theory and reality* in Bendahmane, Diane B. and John W. McDonald, Jr. *International negotiation: Art and science.* Report of a conference on international negotiation, June 9-10, 1983. Washington, D.C.: U.S. Dept. of State, Foreign Service Institute, Center for Study of Foreign Affairs.

APPENDIX A

NEGOTIATION THEORY

This appendix provides an overview of the negotiation theory relevant to international environmental negotiations considered above.

A.1 COLLECTIVE ACTION VERSUS BARGAINING

Most analyses on negotiations focus on *bargaining,* which can be defined as negotiations over the allocation of scarce resources, such as money. Typical situations include purchase of a used car or labor-management contracts. Somewhat closer to this paper's topic is the literature on the Law of the Sea negotiations concerning access and rights to mining manganese nodules on the ocean floor (among other things).

This literature is of limited value, because the acid rain, stratospheric ozone, and climate change cases involve *collective action problems,* not dividing scarce resources. The goal in each case is to decide what pollution-control burdens should he borne by whom. Since each case involves common-property resources, "free-riding" is an issue. Even though the literature provides less guidance on these types of negotiations, it can shed some light.

A.2 OVERVIEW OF RELEVANT NEGOTIATION THEORY

Value Creating and Value Claiming

Advances in negotiation theory have stepped beyond the analysis of win-lose bargaining situations (i.e., zero-sum games) to more complex mixtures of win-lose and win-win situations. Lax and Sehenius (1986) provide a good analytical model integrating two key themes of negotiations: creating joint gains and dividing these gains. They refer to creating joint gains as "creating value." Negotiators work to devise an agreement that

yields considerable gains to each party, relative to no agreement.[1] Other writers variously refer to creating value as problem solving and integrative bargaining.[2] In the common-property cases examined herein, parties strive to protect common environmental resources through collective action.

Lax and Sebenius call dividing up the gains "claiming value." Value claimers strive to attain more of the benefits of the bargain than their opponents, through such tactics as starting high, exaggerating the value of concessions, concealing information, and pretending they have lots of time.[3]

One tactic for claiming value is using moral-sounding language; "my request is [morally, scientifically, socially] right." [4] In the cases examined here, value claiming focuses on getting other countries to agree to sacrifice (in terms of cost, effort, reduced opportunities) to reduce pollutant emissions. This includes getting the other parties to assume either a proportionate ("fair") burden or a disproportionate burden. Because rejecting the norms of the group may be costly, normative argument may limit the realm of possible agreements. [5]

A key contribution of Lax and Sebenius is highlighting the intertwining of value creating and value claiming. Creative problem solving enlarges the pie to be divided, but it must still be divided. If not enlarged, there is less pie to divide.[6]

Principles versus Positions

Fisher and Ury (1981, 83) distinguish positional bargaining from principled bargaining.[7] When negotiators focus on positions, they generally stake out an initial position, try to defend it with reasons, attack the opponent's position, and concede only gradually from their own initial position. Alternatively, negotiators may identify some

principle, objective standard, or social norm for making the agreement. Ideally, after agreeing on a "fair" principle, negotiators apply the principle to the situation at hand. The details flows from application of the principle.[8] The solution will seem more legitimate to an opponent if the opponent agrees with the principle from which the solution was derived.[9] In negotiations of long duration, principles may also set powerful precedents.[10]

Focal Points

People seem to be attracted to "round numbers"[11] or numerical values in tens (since we primordially count with our fingers and even toes). Thus in acid rain, there was the "30 percent club" (explained below). Norms, such as "equal division," also serve as focal points. Therefore, as norms, equal percentage reductions and critical levels could be focal points.

The Zone of Agreement, Aspirations and Anchoring

Another key concept is the perceived bargaining set or "zone of agreement." This is the range of agreements to which all parties would agree (with more or less benefit to each party).[12] In two-party bargaining over the price of a car, it is a spectrum extending from the maximum acceptable price for the buyer to the minimum acceptable price for the seller. Each end-point is a "reservation price." Each party's alternatives to agreement limit the bargaining range.[13] For example, the seller's reservation price is a hid from a second buyer. The buyer's reservation price is the price of an equivalent car.

A negotiator's "aspirations" increase or decrease with what she thinks is possible.[14] Thus aspirations influence the perceived zone of agreement. Influencing

aspirations, for example, by deflating the opponent's aspirations, can shift the zone of agreement.

A related concept is "anchoring." When one party makes an opening bid or an initial reference to what must be a fair result, the stated bid tends to affect the expectations of other parties. They may infer that only bids somewhat close to the initial bid will be acceptable to the first party. Thus, the first party can "anchor" the debate around an outcome more beneficial to himself. Anchoring may shift the perceived zone of agreement.

A negotiator can use a maximum opening bid as an anchor for several purposes:[15] 1) to get information by noting the opponent's response, 2) to modify an opponent's minimum preferences,[16] 3) to provide something to give up or swap,[17] and 4) to make it difficult for an opponent to estimate one's minimum preferences. Bargaining studies show that "anchoring" the opponents with a high target, may result in a higher final result.

In this sense, a critical level could be an "anchor." A critical level could expand the zone of possible agreement toward the high end, i.e., more action. Unfortunately, little work has been done on how anchoring functions in a collective action negotiation.[18]

Special Attributes of International Negotiations

Without belaboring the obvious, the sovereignty of the parties plays an important role in international environmental negotiations. Nations only sign agreements if they view signing as in their interests. Arbitration is seldom available. Enforcement is typically weak.

The large number of parties presents special problems. Other things being equal, the larger the number of parties, the harder it is to find a solution that is acceptable to everyone.[19] In addition, as the number of parties increases, the probability increases that an agreement (if attained at all) will be "partial" in at least one of three ways: 1) it will cover only some of the agenda items; 2) it will leave some disagreement latent in an ambiguous text; or 3) it will be signed and accepted by only some of the parties.[20]

Negotiations based on principles can reduce the difficulties of multi-party negotiations. The normative pressure of the principle can help pressure more parties to sign an agreement. In contrast to positional bargaining, the need to build and maintain coalitions decreases.[21]

ENDNOTES FOR APPENDIX A

1. Lax and Sebenius, 1986, 30.

2. Walton (1965, 144) uses the term integrative bargaining, but the essence is joint problem solving.

3. Lax and Sehenius. 1986, 32.

4. Lax and Sebenius. 1986, 141.

5. Ibid., 142.

6. Lax and Sehenius. 1986, 33.

7. Lax and Sebenius (1986, 69) disagree with Fisher and Ury's focus on interests rather than positions. Lax and Sehenius recognize the value and role of each in their integrative scheme.

8. Zartman, 1984, 2

9. Fisher, 1984, 65.

10. Lax and Sebenius. 1986, 73.

11. Lax and Sebenius, 1986, 126.

12. Lax and Sebenius. 1986, 48.

13. Ibid.

14. Lax and Sehenius, 1986, 131.

15. Zartman, 1978, 134-35.

16. Zartman, 1978, 135.

17. Zartman, 1984, 135.

18. Parson, Edward. 1994. Personal interview with author. March 9. Professor Parson teaches negotiation at the John F. Kennedy School of Government, Harvard University.

19. Midgaard and Underdal, 1977, 336.

20. Ibid., 339.

21. Fisher and Ury. 1981, 83.