BUYING GREENHOUSE INSURANCE

The Economic Costs of CO_2 Emission Limits

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The MIT Press
Cambridge, Massachusetts
London, England

This book was set in Palatino by Digital Graphics, Inc. using TEX and printed and bound in the United States of America.

Manne, Alan S. (Alan Sussmann)
Buying greenhouse insurance : the economic costs of carbon dioxide emission limits / Alan S. Manne, Richard G. Richels.
p. cm.
Includes bibliographic references and index.
ISBN 0-262-13280-X
1. Insurance, Pollution liability—United States. 2. Insurance, Pollution liability. 3. Air—Pollution—Economic aspects—United States. 4. Air—Pollution—Economic aspects. 5. Carbon Dioxide.
I. Richels, Richard G. II. Title.
HG9994.3.M36 1992
368.5—dc20 91-30865
CIP

Buying Greenhouse Insurance

For Clare, Jackie, and our offspring, who will live with the consequences of this generation's decisions.

Preface

This project, initiated in the fall of 1988, was motivated by the events of the preceding summer. A series of congressional hearings had coincided with one of the hottest and driest years on record. With caricatures of an overheated planet appearing on the covers of popular weekly magazines, the greenhouse effect was rapidly evolving from a purely scientific issue into a major public policy debate. Proposals for drastic cuts in emissions were being introduced in both the U.S. Congress and at a number of highly visible international conferences.

As is often the case with complex environmental issues, the analytical base has lagged behind the policy process. Sensible public policy requires balancing benefits and costs. Before committing to a path that would cause a major restructuring of the world's energy system, two questions need to be addressed: (1) What will reductions in emissions buy in terms of reduced environmental damages? (2) What will be the price tag? There is no straightforward answer to either question. Huge gaps remain in our understanding of the physical and biological processes that make up the climate system. Increased concentrations of greenhouse gases could lead to global warming. But by how much? Over what time frame? And what will be the impacts on different regions of the earth?

There are two broad schools of thought regarding the policy implications of these scientific uncertainties. The proponents of immediate controls acknowledge the uncertainties but contend that emissions abatement can be justified solely from an insurance perspective. They argue that low-cost alternatives to carbon-intensive fuels are readily available. Given the stakes, it would be reckless to wait for greater scientific consensus. All that is needed is the political will to engineer the transition to a low-carbon economy. If it is true that emissions can be reduced significantly at little or no cost, emission constraints make a good deal of sense. Immediate controls represent a reasonable hedge against unacceptably rapid climate change. The second school of thought consists of those who are less sanguine about the costs of emissions abatement. If economically attractive alternatives are currently in existence, what is preventing them from automatically entering the marketplace? Fossil fuels provide more than 90 percent of the world's commercial energy. Before obtaining a better understanding of what is at stake, it would be reckless to incur the costs entailed by a rapid transition away from carbon-intensive fuels.

These differing opinions present a dilemma for decision makers. Depending on one's views of control costs, a case can be made either for or against emission cuts. The issue is similar to purchasing an insurance policy. If one believes that there are great risks from global warming and that the insurance premium is negligible, there is little reason to delay. This is the attractiveness of "no regrets" strategies, such as costless conservation. The problem becomes more complex when there are price tags attached to limiting the emission of greenhouse gases. If the insurance premium is expensive, it may be worthwhile to pursue alternatives to immediate cutbacks on emissions.

This book focuses on the costs of reducing carbon dioxide emissions. CO_2 is believed to be the single largest contributor to the problem of global warming and is commanding the most attention within the international community. We examine the costs of emissions abatement from the perspective of both the technology optimist and the pessimist, and we explore the implications for policymaking.

In addition to limiting CO_2 emissions, we examine other forms of greenhouse insurance. Among the options are continuing research to reduce the uncertainties related to climate change and to develop new supply and conservation technologies. Policy makers must decide how to divide the greenhouse insurance dollar among competing needs. What portion goes to the immediate abatement of emissions? What portion goes to resolving scientific uncertainties? And what portion goes to technology development?

Although we have focused on the United States, we have also tried to take a global perspective. We calculate carbon emissions for each of five geopolitical regions under an unconstrained business-as-usual future. We explore possible ways of defining a global CO_2 agreement, compare the impacts at the regional level and estimate the size of the carbon tax required to induce consumers to reduce their dependence on carbon-based fuels. Throughout, we have concentrated on estimating the costs of CO_2 emission abatement and have not attempted to estimate the benefits of slowing the rate of climate change.

At the outset, we had not expected to write a book. Instead we planned to publish a series of separate papers reporting on various aspects of our work. Somewhere along the way, these reports began to take on the appearance of individual chapters, and it seemed logical to combine them into a book. Although this is the first time that our work has been published using the set of assumptions presented here, earlier versions of several of the chapters have appeared elsewhere:

"Emission Limits: An Economic Cost Analysis for the USA," *Energy Journal* 11, no. 2, April 1990.

"The Costs of Reducing U.S. CO_2 Emissions—Further Sensitivity Analyses," *Energy Journal* 11, no. 4, October 1990.

"Global CO_2 Emission Reductions—the Impacts of Rising Energy Costs," *Energy Journal* 12, no. 1, January 1991.

"International Trade in Carbon Emission Rights: A Decomposition Procedure," *American Economic Association Papers and Proceedings* 81, no. 2, May 1991.

"Global 2100: An Almost Consistent Model of CO_2 Emission Limits," *Swiss Journal of Economics and Statistics* 127, no. 2, 1991.

"Buying Greenhouse Insurance," *Energy Policy* 19, no. 6, July–August 1991.

We have received advice and encouragement from many people. We are particularly indebted to Stephen Peck, who initially suggested that we examine the greenhouse issue and has subsequently provided a number of insightful comments. William Hogan has made helpful suggestions throughout the course of this project. We have benefited from the pioneering work on global CO_2 analysis by Jae Edmonds, William Nordhaus, John Reilly, and Gary Yohe and have had profitable discussions with each of them.

Drafts of earlier chapters were reviewed by George Booras, Mark Chaitkin, Hung-po Chao, William Cline, Gregory DeCroix, Robert Dorfman, Michael Gluckman, Lawrence Goulder, Michael Grubb, James Hammitt, George Hidy, Hillard Huntington, Dale Jorgenson, Peter Laut, Lester Lave, Henry Lee, Leonard Levin, Lu Yingzhong, David Montgomery, Ronald Promboin, Scott Rogers, John Rowse, Thomas Rutherford, Lee Schipper, Leo Schrattenholzer, Daniel Segre , Chauncey Starr, John Stone, James Sweeney, Gary Vine, John Weyant, Robert Williams, and David Wood. We are most grateful to them for commenting on our material in a helpful and constructive manner.

We are much indebted to Stanley Vejtasa, who helped assemble the technology database that underlies our energy supply estimates. It was a pleasure to have had Diane Erdman, Lawrence Gallant, and Robert Luenberger as our research assistants. Lynda Clark, Tola Minkoff, and Daphna Rubin provided invaluable assistance in the production of this book.

Our deepest thanks and appreciation go to our wives, Jackie Manne and Clare Richels. They were often left to deal with the problems of the twentieth century while their spouses were speculating on those of the twenty-first. We are grateful for their patience and good cheer.

Finally, we are indebted to the Electric Power Research Institute (EPRI) for its financial support. The views presented here are solely those of the individual authors and do not necessarily represent the views of EPRI or its members.

Contents

1 Overview

The Greenhouse Debate

The greenhouse debate is short on facts and long on rhetoric. Both the activists and the skeptics play important roles in this debate. The activists—many with backgrounds in the physical sciences—point to the potential for disastrous long-term trends in the global climate. They advocate immediate action to offset the increasing accumulation of greenhouse gases in the earth's atmosphere. They argue that the costs of action are low and the potential benefits high. The skeptics—often with backgrounds in economics—counter by listing the uncertainties in climate projections. They note that limiting the emissions of greenhouse gases could be expensive. Today's consumers are being asked to change their life-styles in order to confer uncertain benefits on future generations. Typically, the skeptics recommend a wait-and-see policy, often accompanied by proposals for additional research on the physical and economic effects of greenhouse gas accumulation.

The greenhouse effect poses a serious dilemma for policy makers. The experts are deadlocked on both the likelihood and the timing of the problem. Enormous uncertainties remain in our understanding of the greenhouse effect, its likely consequences, and the possible effectiveness of various countermeasures. These uncertainties will not be resolved for decades.

The stakes are large. Waiting leads to the risk of irreversible damages. Immediate action leads to the risk that large costs will be incurred in the near future, and there is considerable disagreement on how these actions would eventually affect the world's climate. Policy makers would do well to act as though they were purchasers of greenhouse insurance. They must weigh the possible costs of delay against those of premature action, but also recognize that there are not enough resources available to purchase insurance against all conceivable downside risks.

Uncertainty is but one factor that confounds the debate. The greenhouse problem is a global issue. Many countries are taking the position that if significant efforts are required to reduce emissions, these efforts should be undertaken only in the context of an international agreement. As the climate debate moves toward the consideration of specific legislative initiatives and policy options, international negotiations will become increasingly important.

The negotiation of a greenhouse gas agreement would be extraordinarily complex. Major reductions in emissions could be expensive. Some nations might incur high costs in order to achieve modest reductions, and the converse might hold for others. Each country's leaders need to weigh the benefits and the costs of proposed actions in order to arrive at an overall judgment.

The Costs of Limiting CO_2 Emissions

It is believed that carbon dioxide (CO_2) emissions are currently responsible for more than 50 percent of the human contributions to the greenhouse effect. Accordingly, the energy sector plays an important role in strategies to delay climate change. Over the next few decades, most strategies call for a push toward greater energy efficiency and—to whatever extent is feasible—moving away from coal and oil toward natural gas with its lower carbon emissions per unit of energy. Over the longer term, energy could be supplied by carbon-free alternatives such as solar (in several different forms), nuclear energy, and fusion.

Estimates of the costs of a CO_2 limit vary widely. For a given abatement target, the exact amount will depend on the severity of the carbon limit, the rate of energy conservation, and the supply technologies available for meeting energy demands. Differences in abatement cost estimates arise primarily from alternative views about the potential for innovations in the energy sector. Technology optimists describe an energy future with abundant low-cost, carbon-free supply alternatives and low overall demands for energy. In such a world, carbon-free substitutes would be economically attractive. Highly efficient end-use technologies would virtually eliminate any growth in fossil fuel consumption. Technology pessimists visualize a very different energy future. Coal would be used as the principal source of electric power and of liquid fuels for transportation. The lack of carbon-free substitutes, combined with rapidly rising energy demands, would make it difficult for consumers to reduce their dependence on carbon-intensive fuels.

This book outlines a way to think about greenhouse decisions under uncertainty. It provides region-by-region estimates of the costs that would underlie an international agreement. We focus on just one aspect of the greenhouse debate: the costs of limiting the carbon dioxide emissions produced by burning fossil fuels: coal, oil, and gas. Our work is based on a computer model known as Global 2100. The name emphasizes the global nature of the problem and the need for a long-term perspective.

We analyze the economic impacts of limiting CO_2 emissions under alternative supply and conservation scenarios. Global 2100 is employed to indicate how emissions are likely to evolve in the absence of carbon limits and how regional patterns might shift during the next century. The model provides a consistent way to examine alternative strategies for limiting global emissions and to calculate the impact of higher energy prices on gross domestic product (GDP). It enables us to estimate the size of the tax required to induce consumers to reduce carbon emissions. We also analyze the possibility of significant interregional differences in carbon taxes that would lead to opportunities for international trade in emission rights.

The costs of abatement are only part of the story, but they are an essential part. They enable us to assess the feasibility of alternative proposals and to determine which measures are cost-effective. Moreover, a reduction in emissions is not the sole policy response that is available. There is a point at which further reductions could become so expensive that it would be preferable to shift to other options, such as adaptation to climate change. Without careful analysis, it is difficult to know where that point might be.

We do not attempt to estimate the benefits of slowing the rate of climate change through a reduction in worldwide CO_2 emissions. Our analysis is confined to the direct impacts of carbon limits upon the cost of energy and the resulting effects on the economy as a whole. It is a far more formidable task to estimate the benefits from reducing emissions, and is well beyond the scope of this book. Clearly, policy makers will need information on both costs and benefits in order to make a balanced decision. (For imaginative approaches to integrated benefit-cost analysis, see Nordhaus 1991 and Peck and Teisberg 1991.)

The Greenhouse Effect: Likely Causes and Possible Consequences

Before turning to the central focus of this book—the costs of CO_2 emissions abatement—we summarize some general background on the greenhouse effect, its likely causes, and possible consequences. There is a broad consensus on many of these issues, but disagreement on others. In order to follow the debate over the role of carbon dioxide and the energy sector, it is essential to understand the points of contention.

The earth's climate is determined by the balance between energy received from the sun and energy radiated back into space. Slightly more than half of the solar energy entering the atmosphere is absorbed by clouds and particles in the air or is reflected back into space. The remainder is absorbed at the earth's surface and then radiated outward in the form of heat. Rather than escaping directly into space, some of this heat is trapped by traces of atmospheric water vapor, carbon dioxide, and other infrared absorbing gases and re-emitted back to earth. This is the phenomenon termed the greenhouse effect.

The naturally occurring greenhouse effect has warmed the earth for billions of years, and it is essential to life on our planet. Without greenhouse gases, the average temperature of the earth would be about 34° C colder, well below freezing. The extremely cold temperatures on the surface of Mars and the oven-hot surface of Venus can be explained primarily by differing atmospheric levels of CO_2. By contrast, the composition of the earth's atmosphere is ideal for supporting life.

Climate scientists are concerned that human activities are increasing the atmospheric concentrations of the naturally occurring greenhouse gases and that we are compounding the difficulties by adding potent new gases such as the chlorofluorocarbons (CFCs). If recent trends continue, the buildup of these gases will enhance the greenhouse effect and could cause significant warming within the next century. Enormous uncertainty surrounds virtually every aspect of climate change. How much warming will occur? How quickly? What will be the region-by-region consequences?

Figure 1.1 and table 1.1 summarize what is known about the key greenhouse gases. Ice core studies show that there have been major increases in these gases since the Industrial Revolution. Many observers believe that human activities account for much of the 0.6° C

Table 1.1
Summary of Key Greenhouse Gases Influenced by Human Activities

Parameter	CO_2	CH_4	CFC-11	CFC-12	N_2O
Preindustrial atmospheric concentration (1750–1800)	280 ppmv[a]	0.8 ppmv	0	0	288 ppbv[a]
Current atmospheric concentration (1990)[b]	353 ppmv	1.72 ppmv	280 pptv[a]	484 pptv	310 ppbv
Current rate of annual atmospheric accumulation	1.8 ppmv (0.5%)	0.015 ppmv (0.9%)	9.5 pptv (4%)	17 pptv (4%)	0.8 pptv (0.25%)
Atmospheric lifetime[c] (years)	(50-200)	10	65	130	150

Source: Houghton et al. (1990).

Note: Ozone has not been included in the table because of lack of precise data.

a. ppmv-parts per million by volume; ppbv-parts per billion by volume; pptv-parts per trillion by volume.

b. The current concentrations have been estimated based on an extrapolation of measurements reported for earlier years, assuming that the recent trends remained approximately constant.

c. For each gas in the table except CO_2, "lifetime" is defined as the ratio of the atmospheric content to the total rate of removal. This time scale also characterizes the rate of adjustment of the atmospheric concentrations if the emission rates are changed abruptly. CO_2 is a special case since it has no real sinks, but is merely circulated between various reservoirs (atmosphere, ocean, biota). The lifetime of CO_2 given in the table is a rough indication of the time it would take for the CO_2 concentration to adjust to changes in the emissions.

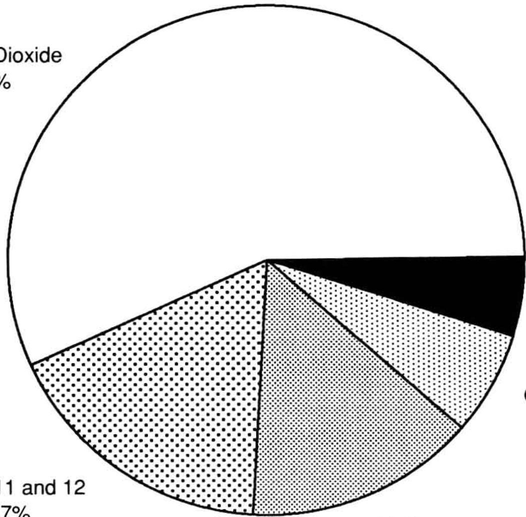

Figure 1.1 Human contributions to the greenhouse effect. Source: Houghton et al. (1990).

rise in average global temperature observed over the last century. Although the recorded temperature increase is consistent with the predicted effects of CO_2 and other greenhouse gases, there is a plausible alternative explanation: chance variations within the normal range of temperature trends.

Atmospheric scientists rely on computer models to predict how key climate variables (temperature, rainfall, wind speed, humidity) might change as a result of increases in the major greenhouse gases. The atmospheric models, originally developed for long-term weather forecasting, have a number of limitations (World Resources Institute 1990). The shortcomings include poor spatial resolution, inadequate accounting for various feedback mechanisms that could exacerbate or counteract the greenhouse effect, and insufficient treatment of such important factors as variations in solar output, volcanic activity, and the earth's reflectivity.

These limitations lead to inaccuracies in the projections of mean global temperature. Nevertheless, the best evidence suggests that a doubling of greenhouse gas concentrations from their pre–Industrial Revolution levels would increase average global temperatures from 1.5 to 4.5° C, and that the doubling of concentrations could take place well