ADVANCES IN THE ECONOMICS OF ENVIRONMENTAL RESOURCES

VOLUME 5

PERSPECTIVES ON CLIMATE CHANGE: SCIENCE, ECONOMICS, POLITICS, ETHICS

WALTER SINNOTT-ARMSTRONG
RICHARD B. HOWARTH
Editors

PERSPECTIVES ON CLIMATE CHANGE: SCIENCE, ECONOMICS, POLITICS, ETHICS

ADVANCES IN THE ECONOMICS OF ENVIRONMENTAL RESOURCES

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PERSPECTIVES ON CLIMATE CHANGE: SCIENCE, ECONOMICS, POLITICS, ETHICS

EDITED BY

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INTRODUCTION

The issue of climate change has attracted tremendous attention and increasing debate. The reason is clear: While increases in mean global temperature pose serious threats to billions of people in future generations, measures for resolving those risks would entail significant economic, political, and moral costs. The issues are sufficiently complex that they cannot be handled adequately within the framework of any single discipline. Although a number of books have approached the issue of climate change from an interdisciplinary perspective, these works have generally not emphasized the close-knit relationship between science, economics, politics, and moral reasoning in framing and responding to this emerging environmental issue. That is what our book accomplishes. We brought together top scholars from a wide variety of fields to provide their own perspectives and enable readers to gain a more comprehensive and objective view of global warming. These original essays fall into four groups.

PART 1: SCIENCE

The first group focuses on climate change science. In the opening chapter of this section, Jerry Mahlman (Senior Research Fellow at the National Center for Atmospheric Research) describes what he terms the ''global warming dilemma.'' According to Mahlman, the scientific community has reached an effective consensus that immediate and quite aggressive steps would be required to avoid climatic changes that are large in comparison with those observed in the Earth's geological record. Stabilizing atmospheric concentrations of carbon dioxide, for example, would require permanent emissions reductions of roughly 60–80%. Moreover, the long lags in the Earth's response to changes in the composition of the atmosphere suggests that even this stringent scenario would be insufficient to prevent moderate temperature increases in the coming decades. Based on his reading of the scientific literature, Mahlman concludes that deferring action until climate change has broadly recognized deleterious effects would most likely ''lock in'' quite profound environmental impacts with effects lasting for centuries and even

millennia. In terms of mechanisms, this argument appeals to the view that today's greenhouse gas emissions might use up the Earth's assimilative capacity, thus increasing the length of time that greenhouse gases remain in the atmosphere. On top of this, Mahlman notes that most scientific studies have emphasized time scales of one century or less in evaluating climate impacts. But impacts such as sea-level rise, which would be strongly affected by the melting and breakup of glacial formations such as the West Antarctic Ice Sheet, occur over much longer time horizons with a high degree of irreversibility. This makes climate change an issue of intergenerational fairness that pits present society's willingness to bear significant economic costs against the goal of protecting future generations from environmental harms that are hypothetical and yet potentially catastrophic.

The chapter by William Schlesinger (Dean of the Nicholas School of the Environment at Duke University) describes the basic science of the carbon cycle and the pathways through which human activities affect global climate. In particular, Schlesinger examines the potential for employing land-use and land-use change as techniques for removing carbon dioxide from the atmosphere, thus partially mitigating the need to reduce fossil consumption as a means of stabilizing the Earth's climate. This topic is of major importance given the emphasis placed on carbon sequestration in international negotiations. In particular, the United States has long held that emissions credits should be conferred on countries that undertake actions to store carbon dioxide in managed ecosystems. At present, fossil fuel consumption emits roughly 6 billion tons of carbon to the atmosphere on an annual basis. Schlesinger carefully traces the physical and biological processes through which carbon dioxide is transferred to the oceans, biomass, and terrestrial and marine sediments. While it is well recognized that deforestation in tropical nations is a net source of carbon dioxide emissions, the magnitude of this effect is largely offset by the regrowth of forests on abandoned farmland in North America and Eurasia. This observation has fostered hope that reforestation could substantially reduce the pace of climate change. Schlesinger, however, notes that current forecasts suggest that carbon dioxide emissions will rise to 15 billion tons per year by 2050, while even optimistic studies suggest that forest regrowth could reduce the future accumulation of carbon dioxide in the atmosphere by no more than 5–10%. While Schlesinger acknowledges the potential for technologies that capture carbon dioxide at the point of fuel consumption with subsequent geological storage, he notes that substantial uncertainties surround both the cost-effectiveness and the environmental impacts of this approach. Accordingly, he concludes that substantial and immediate reductions in fossil fuel consumption would be

required if decision-makers aimed to reduce the rate of climate change with reasonable confidence.

In the concluding chapter of this section, John Weatherly (Cold Regions Research and Environmental Laboratory) explores the notion that the Arctic may be the "canary in the coal mine" of the climate change debate. As is well known, general circulation models suggest that the temperature increases caused by greenhouse gas emissions would likely be three times higher at the poles than for the world as a whole. This prediction is matched by the observation that temperatures have already increased significantly in many polar environments and that the thickness of sea ice in the Arctic Ocean has thinned by roughly one-third since the 1960s. As Weatherly notes, changes in sea ice have been accompanied by ecological changes such as a transition from tundra vegetation to woody shrubs in northern Alaska. Perhaps most dramatically, the collapse of the Larsen B ice shelf in Antarctica released 720 billion tons of ice in March of 2002. As Weatherly notes, data from the Earth's geological record suggest that rapid climate change has in the past disrupted the Gulf Stream ocean current that is crucial in maintaining Europe's temperate climate. Accordingly, some scientists speculate that greenhouse gas emissions might ironically give rise to a human-induced "deep freeze" in Europe even as (and indeed because) the world as a whole grew warmer. In discussing the current state of scientific opinion on this issue, Weatherly concludes that a major disruption of ocean circulations patterns is unlikely but, if it occurred, would have devastating impacts.

Taken together, Mahlman, Schlesinger, and Weatherly provide a well-rounded picture of what we know about global warming and what we need to learn.

PART 2: ECONOMICS

The second group of essays brings in the perspective of economics. Michael Toman (a long-time Senior Fellow at Resources for the Future who currently worked for the Environment Division at the Inter-American Development Bank) critically examines the use of cost-benefit analysis as the basis for identifying optimal climate change policies. Toman persuasively argues that economic concepts and methods can and should play a decisive role in designing policy instruments that achieve desired levels of emissions control at the lowest cost to society. Nonetheless, he is skeptical about using cost-benefit analysis to decide on the degree to which greenhouse gas emissions should be reduced relative to projected levels. On the one hand, he

worries that cost-benefit analysis attaches insufficient weight to the interests and welfare of future generations. On the other hand is the issue of burden-sharing – how the costs of emissions reductions should be distributed between affluent and developing nations. Each of these issues embodies a moral component that is not easily addressed using cost-benefit analysis. In the final analysis, Toman recommends a two-tiered approach to policy evaluation in which: (a) decisions with relatively low stakes that play out over relatively short timescales should be based on standard cost-benefit criteria; and (b) decisions characterized by long time horizons that involve potentially catastrophic future impacts should aim to manage and mitigate the risks imposed on future generations. Since climate change is a high-stakes issue in which the potential for catastrophic costs looms large, Toman reasons that climate change policy must be based on decision makers' judgment regarding how much risk is acceptable to impose on future generations. This judgment, according to Toman, is explicitly moral in nature and cannot be reduced to the measures and calculations offered by formal policy analysis. Indeed, Toman's two-tiered approach explicitly calls for broad and open public discourse in the context of democratic political institutions.

Richard B. Howarth (Professor of Environmental Studies at Dartmouth College) echoes many of the themes raised by Toman. But, while Toman is concerned broadly with the normative dimensions of climate change policy, Howarth is concerned more narrowly with the controversies that surround the use of discounting techniques in cost-benefit analysis. In conventional cost-benefit analysis, the future benefits of greenhouse gas emissions abatement are discounted at a rate equal to the real (inflation-adjusted) return on corporate stocks, which averaged 6% per year during the 20th century. The logic for this approach holds that it would be socially inefficient to invest in environmental policies that yielded returns that were lower than those provided by typical market investments. As Howarth notes, however, a 6% discount rate implies that $1 of benefits obtained one century from the present attains a present value of less than 1 cent. Not surprisingly, conventional discounting techniques therefore imply that only modest steps toward greenhouse gas emissions are economically warranted. Howarth critiques this approach to discounting the future based on three distinct lines of reasoning. First, the use of high discount rates is inconsistent with classical utilitarianism, which holds that equal weight should be attached to the welfare of present and future generations. Second, the approach violates the principle of stewardship, which holds that it is morally unjust for present generations to engage in actions that impose uncompensated environmental costs on posterity. Third, the use of a 6% discount rate is appropriate in the

analysis of public policies that have risk characteristics that are similar to those associated with corporate stocks. Economic theory, however, suggests that discount rates of 1% or less should be used to evaluate policies that reduce future risks. Since a main objective of climate change policies is to reduce the risks faced by future society, Howarth concludes that the use of high discount rates in the analysis of climate change policies is generally inappropriate.

P.R. Shukla (Professor at the Indian Institute of Management in Ahmedabad) examines the links between equity and efficiency in achieving international cooperation to achieve long-term reductions in greenhouse gas emissions. Based on his understanding of climate change science, Shukla takes it for granted that the world community will strive to stabilize greenhouse gas concentrations to reduce the risks faced by future generations. Against this backdrop, the question is how the costs of emissions abatement should be distributed between industrialized and developing countries. According to Shukla, most economic studies have focused narrowly on minimizing the total cost of emissions reductions. This criterion suggests that relatively large emissions reductions should take place in developing countries, which disproportionately rely on inefficient, high-emission technologies. Shukla, however, argues that equity demands that emissions abatement costs be borne primarily by industrialized nations under the principle of "common but differentiated responsibilities" set forth in the Framework Convention on Climate Change. This argument rests on the observation that, in historical terms, the industrialized nations have long generated the lion's share of greenhouse gas emissions. In addition, Shukla reasons that moral considerations imply that developing countries should not and politically cannot pursue policies that jeopardize the pursuit of material prosperity. Under this argument, it follows that industrialized nations should take the lead by providing technological and financial assistance to promote the adoption of clean technologies in the developing world.

All of these considerations must be weighed by anyone who wants to decide fairly what to do about global warming.

PART 3: POLITICS

The essays in Part 3 of the book look at global warming from the perspective of politics. Daniel Bodansky (Professor of Law at the University of Georgia) opens by outlining the history of international attempts to regulate climate change since the 1980s. Bodansky divides this history into five

periods: the foundational period (as scientific concern increased during the 1980s), the agenda-setting phase (1985–1988), a prenegotiation period (1988–1990), the constitutional period (1991–1995), and a regulatory phase (1996–2001). The constitutional phase issued in the United Nations Framework Convention of Climate Change (UNFCCC) and the regulatory phase produced the Kyoto Protocol. Bodansky explains important details of the UNFCCC and the Kyoto Protocol and interprets them together as a "framework convention/protocol" approach. Bodansky also places these developments in the larger context of international law, showing how the UNFCCC reflects a "soft" approach that views international law as a means of fostering cooperation, whereas the Kyoto Protocol reflects a "harder" approach that sees international law as analogous to domestic criminal law. Overall, Bodansky's essay provides specific details and a general framework needed to understand why the Kyoto Protocol has become such a hot political issue.

Eileen Claussen (President of the Pew Center on Global Climate Change) brings the discussion up to date with a brief "insider's look" at responses to global climate change since the Kyoto Protocol. In her view, "the United States has been both a driver and a drag on the process." To move beyond the resulting impasses, Claussen provides "five keys to success." First, we must forge a response that is global, as well as effective, fair, and economically efficient. Second, we need to think and act both short- and long-term. The long-term vision is bound to include climate-friendly energy sources, which increase energy security as well as economic growth. Third, industry must be a partner by voluntarily reducing emissions and by advocating for strong government action. It is industry that will develop alternative energy sources and ultimately deliver on government requirements and goals, so they have to be involved eventually, and the sooner, the better. Fourth, government must set real mandatory goals. Voluntary guidelines won't work by themselves. Fifth, the United States must be a part of the solution and must work with other countries. If these five keys are used, Claussen is optimistic that we can succeed in making the world a better place for all. The problem is to get these keys turning.

Michele Betsill (Assistant Professor of Political Science at Colorado State University) and Harriet Bulkeley (Lecturer in Geography at the University of Durham) then explore a different level of government. Whereas traditional regime theory assumes that subnational governments follow the directions of national governments, Betsill and Bulkeley argue that cities play an important role in fighting global warming. One reason is that nations cannot meet their international commitments without local action,

especially because of the increasing urbanization of the population. Moreover, cities can take the lead in developing and implementing innovative policies. To illustrate some possibilities, Betsill and Bulkeley describe the Cities for Climate Protection program, under which various cities have adopted new initiatives in the areas of land-use planning, transportation, and energy management. Betsill and Bulkeley's study reveals varied levels of success in different cities, depending on leadership, funding, legal powers, political will, and how climate protection is framed in relation to economic objectives. Betsill and Bulkeley describe obstacles to translating rhetoric into practice, so they raise serious doubts about the extent to which climate change can be addressed at the local level. Nonetheless, they close by suggesting that we can and must seek an approach that moves beyond the traditional dichotomy of "thinking locally" and "thinking globally."

PART 4: ETHICS

The essays in Part 4 raise issues in moral philosophy. Dale Jamieson (Professor of Philosophy and Environmental Studies at New York University) traces the route that has led governments to give up significantly mitigating climate change and instead embrace a de facto policy of adaptation only. Adaptations can be conscious or unconscious, anticipatory or reactive. Some are clumsy, inefficient, inequitable, and inadequate. Still, according to Jamieson, it is inevitable that some strategies of adaptation will and should be adopted. Nonetheless, adaptation should not replace mitigation, because adaptation without mitigation creates serious practical and moral risks. One major practical risk involves catastrophic climatic surprises that happen too quickly or widely for adequate adaptation. The main moral risk is that a policy of adaptation without mitigation makes the polluted pay when it seems only fair for the polluter to pay. Adaptation-only strategies also make the poorest suffer more than the wealthy. To avoid such moral costs, Jamieson argues, wealthy countries must accept a transnational duty to mitigate climate change as well as to help poor countries adapt to the climate change that is already inevitable. Jamieson outlines a particular "modest proposal" for mitigating climate change in a way that is both fair and efficient. His proposal allows a market in permits to emit greenhouse gases but allocates those permits initially on a per capita basis. Jamieson's proposal places heavy duties across national borders, so he closes by defending his cosmopolitan moral perspective against skeptics who would deny that any

transnational duties justify or motivate action. Those who try to evade such duties, Jamieson concludes, "may one day be called to account."

Julia Driver (Professor of Philosophy at Dartmouth College) next explains why inaction (especially by the United States) cannot be justified either by failures of others to do their duties or by imperfections in international agreements. Driver argues that policy regarding global warming seems to be made on the basis of unrealistic, or idealized, assumptions. This has the effect of producing outcomes that are much worse overall. As an example she discusses the Kyoto Protocol, noting that Bush administration did not accept it for a variety of reasons (some of which may have been good ones), one of which had to do with making the mistake of holding out for ideal circumstances. Specifically, the Bush administration refused to sign on unless other countries made a similar agreement – that is, the Bush administration would not agree to comply with Kyoto unless others in the developing world (where the cost of compliance would arguably be higher) did so. Driver's argument is that, though we can agree that universal compliance is best, the United States still has an obligation to help alleviate the global warming problem even absent such compliance on the part of other nations.

Whereas others focus on mitigation and adaptation, Henry Shue (Professor of Politics and International Relations at the University of Oxford) introduces another proposal: replacement. He argues that standard mitigation policies cannot solve the real problem of global warming, since no allocation of greenhouse gas emissions is both morally tolerable and politically feasible, as long as most economies are dependent for energy on carbon-based fuels. Hence, we have political as well as moral reasons to search aggressively for alternative sources of energy. The main moral reason is to avoid the high costs of postponing "the date of technological transition," which is the year in human history when the accumulated atmospheric total of all greenhouse gases ceases to grow. The longer it takes to make the technological transition, the more carbon dioxide will have been emitted into the atmosphere and the more severe and destructive will be the climatic changes. Later technological transition also increases the risk of abrupt climate reversals and the number of species that will be driven to extinction. To reduce such dangers, Shue claims that we have a moral responsibility to bring about the technological transition as soon as is feasible. "To delay", Shue says, "is to play with fire (and ice)." It is not just that we fail to give a gift to future generations but that we make their world worse. To prevent such immoral failure, we need to work soon, hard, and fast on alternatives to fossil fuels. We need to do for non-fossil fuels what the

Manhattan Project did for the atomic bomb. If the federal government stalls, then local governments, universities, and the private sector need to provide the initiative and vision absent from Washington.

Finally, Walter Sinnott-Armstrong (Professor of Philosophy at Dartmouth College) closes by asking whether individuals have moral obligations to fight global warming in their personal lives. He focuses on a case of wasteful driving on a particular occasion and surveys many principles from a variety of moral theories, which focus on actual consequences of individual and group actions, on what would happen if everyone did it or were allowed to do it, and on virtues, intentions, and laws. Sinnott-Armstrong concludes that none of these principles is strong enough to yield an obligation not to drive wastefully on a particular occasion without becoming too strong to be plausible. He suggests that this conclusion should not be disturbing to environmentalists, because, even if individuals have no moral obligation not to drive wastefully, it can still be morally ideal and virtuous to avoid wasteful driving, it can still be legitimate to criticize individuals who drive wastefully too often, and, most important, governments can still have moral obligations to fight global warming, even by passing laws against certain kinds of wasteful driving.

These essays jointly suggest that global warming is a real problem, and we can and should take many steps to reduce its severity and impact. What will actually be done remains to be seen and will affect the lives of all humans for a long time.

DEDICATION

To our next generation: Denis, Emma, Jennifer, Kirsty, Lincoln, Marina, Matthew, Miranda, Nick, Sean, and Sophie.

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Walter Sinnott-Armstrong
Richard B. Howarth
Editors

PART I:
SCIENTIFIC PERSPECTIVES

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THE LONG TIMESCALES OF HUMAN-CAUSED CLIMATE WARMING: FURTHER CHALLENGES FOR THE GLOBAL POLICY PROCESS

Jerry D. Mahlman

ABSTRACT

In 2001, the Intergovernmental Panel on Climate Change's Third Assessment Report revealed an important increase in the level of consensus concerning the reality of human-caused climate warming. The scientific basis for global warming has thus been sufficiently established to enable meaningful planning of appropriate policy responses to address global warming. As a result, the world's policy makers, governments, industries, energy producers/planners, and individuals from many other walks of life have increased their attention toward finding acceptable solutions to the challenge of global warming. This laudable increase in worldwide attention to this global-scale challenge has not, however, led to a heightened optimism that the required substantial reductions in carbon dioxide (CO_2) emissions deemed necessary to stabilize the global climate can be achieved anytime soon. This fact is due in large part to several fundamental aspects

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of the climate system that interact to ensure that climate change is a phenomenon that will emerge over extensive timescales.

Although most of the warming observed during the 20th century is attributed to increased greenhouse gas concentrations, because of the high heat capacity of the world's oceans, further warming will lag added greenhouse gas concentrations by decades to centuries. Thus, today's enhanced atmospheric CO_2 concentrations have already "wired in" a certain amount of future warming in the climate system, independent of human actions. Furthermore, as atmospheric CO_2 concentrations increase, the world's natural CO_2 "sinks" will begin to saturate, diminishing their ability to remove CO_2 from the atmosphere. Future warming will also eventually cause melting of the Greenland and Antarctic ice sheets, which will contribute substantially to sea level rise, but only over hundreds to thousands of years. As a result, current generations have, in effect, decided to make future generations pay most of the direct and indirect costs of this major global problem. The longer the delay in reducing CO_2 and other greenhouse gas emissions, the greater the burden of climate change will be for future life on earth.

Collectively, these phenomena comprise a "global warming dilemma." On the one hand, the current level of global warming to date appears to be comparatively benign, about 0.6°C. This seemingly small warming to date has thus hardly been sufficient to spur the world to pursue aggressive CO_2 emissions reduction policies. On the other hand, the decision to delay global emissions reductions in the absence of a current crisis is essentially a commitment to accept large levels of climate warming and sea level rise for many centuries. This dilemma is a difficult obstacle for policy makers to overcome, although better education of policy makers regarding the long-term consequences of climate change may assist in policy development.

The policy challenge is further exacerbated by factors that lie outside the realm of science. There are a host of values conflicts that conspire to prevent meaningful preventative actions on the global scale. These values conflicts are deeply rooted in our very globally diverse lifestyles and our national, cultural, religious, political, economic, environmental, and personal belief systems. This vast diversity of values and priorities inevitably leads to equally diverse opinions on who or what should pay for preventing or experiencing climate change, how much they should pay, when, and in what form. Ultimately, the challenge to all is to determine the extent to which we will be able to contribute to limiting the magnitude of this problem so as to preserve the quality of life for many future generations of life on earth.

1. INTRODUCTION TO HUMAN CAUSED CLIMATE WARMING AND THE "GLOBAL WARMING DILEMMA"

This essay discusses the global implications of the very long timescales associated with human-caused climate warming (popularly termed "global warming"). This emphasis is chosen because of the major impact that these long timescales will likely have on how policy decisions concerning this problem will be determined over the 21st century.

In 2001, the Intergovernmental Panel on Climate Change's (IPCC) third assessment report, "Climate Change 2001," revealed an important increase in the level of consensus concerning the reality of human-caused climate warming during the 21st century and beyond (IPCC, 2001). In addition, at the request of U.S. President George W. Bush, the National Research Council of the U.S. National Academy of Sciences issued a special report, "Climate Change Science: An Analysis of Some Key Questions," which endorsed the key conclusions of the IPCC assessment (NRC, 2001). The scientific basis for global warming has thus now been sufficiently established to enable meaningful planning of appropriate policy responses to address global warming.

The key IPCC (2001) climate change conclusions are as follows. Atmospheric carbon dioxide (CO_2) concentrations have increased from about 280 parts per million by volume (ppmv) in the 18th century to nearly 370 ppmv in the year 2002 and are expected to at least double preindustrial concentrations before the end of the 21st century. The global average surface-air temperature has increased over the 20th century by about 0.6°C. IPCC specifically noted that "There is new and stronger evidence that most of the warming over the last 50 years is attributable to human activities." These strong conclusions have led to an increasing level of public recognition of the reality of the global warming problem. The IPCC report also stated that the global average surface-air temperature is projected to increase by an additional 1.4–5.8°C over the period 1990–2100. This range incorporates "best-guess" estimates of both the present uncertainties in climate model projections and the uncertainties in policy decisions concerning future CO_2 and other greenhouse gas emissions into the atmosphere over this century.

The IPCC and earlier national climate change assessments have described a number of likely detrimental impacts on humans and other organisms if global warming plays out consistently with the increasingly accepted international scientific consensus (IPCC, 2001; USGCRP, 2001). Listed below are some regional climate changes generally expected with a global warming

of the magnitude projected by IPCC (2001).[1] Land areas are very likely to warm more than oceanic areas. Although projected atmospheric CO_2 concentrations are very likely to increase global mean surface-air temperatures, high northern latitudes are very likely to warm more than other areas. In summer, midcontinental areas are likely to be considerably less able to sustain current levels of soil moisture. In moist subtropical areas such as the southeastern United States, the summertime heat index (a measure of the additional feeling of heat discomfort due to high atmospheric moisture concentrations) is likely to add roughly another 50% sense of warming, beyond the increased temperature warming effect (Delworth, Mahlman , & Knutson, 1999). Hurricanes are likely to become more intense, and contribute considerably more rainfall to land surfaces. Perennial Arctic sea ice is likely to virtually disappear. The overturning circulation of the Atlantic Ocean is likely to weaken noticeably, although models differ in the magnitude and timing of the weakening. Sea level is virtually certain to rise due to thermal expansion of the warming world ocean and to increasing melting of glaciers and ice sheets.

Other speculated effects of climate change are frequently discussed but are far more scientifically uncertain at this time. Examples include more extratropical storms, more frequent and more intense El Nino episodes, planet-saving negative feedbacks (natural processes that might sharply reduce the level of climate warming), a CO_2-enhanced greening of the biosphere, more frequent hurricanes and tornados, and catastrophic weather extremes. At this time, none of these often-cited potential outcomes are consistent with the current state of scientific knowledge on climate change. It is very likely, however, that we will continue to hear such assertions, often to buttress a particular point of view about policy preferences.

It is useful to point out here that the science of global warming indicates that a quadrupling of atmospheric CO_2 over preindustrial levels would essentially double the climate changes expected from the anticipated CO_2 doubling. This magnitude of global warming, under today's best estimates, is expected to lead to very substantial negative impacts on earth's life systems. Why is this relevant? To date, most assessments of future warming and the subsequent impacts are based on an assumed doubling of atmospheric CO_2. Although stabilizing CO_2 concentrations at a doubling remains achievable with the implementation of highly focused global CO_2 emissions reduction policies over the 21st century, to a reasonable approximation, quadrupling of CO_2 is where earth is headed under "business as usual" scenarios. Therefore, most assessments of global warming have not yet considered its full implications.

Because of the increasingly strong conclusions concerning the expected effects of human activities on the warming of earth's climate, the world's policy makers, governments, industries, energy producers/planners, and people from many other walks of life have increased their attention toward finding acceptable solutions to the challenge of global warming. This laudable increase in the worldwide attention given to this global-scale challenge has not, however, led to a heightened optimism that the required substantial CO_2 emissions reductions can be achieved anytime soon. The global warming problem contains many distinct facets that combine to produce what is called here as the "global warming dilemma."

The global warming dilemma can be summarized in the following manner. On the one hand, large increases in atmospheric CO_2 concentrations have occurred, with considerably more "in the pipeline." Yet, the magnitude of documented warming to date is comparatively small, about 0.6°C. This relatively benign increase is hardly enough to warrant major concerns about the viability of earth's life systems. Thus, there has been little motivation today to resort to a major effort to reduce global CO_2 emissions. On the other hand, delaying major CO_2 emissions reductions until substantial climate warming occurs would very likely "wire in" the world to globally troublesome global warming for many centuries. Thus, science tells us that major efforts will be required to restrain the final global warming to relatively benign levels. Therefore, the choices are quite daunting: we can make very large policy commitments now with little visible short-term payback, or we can delay policy action indefinitely (the de facto current strategy), with very large coping and adaptation costs decades and centuries from now. This is the global warming dilemma.

The global warming dilemma arises because of a number of separate physical effects operative in the climate system, the sum of which are almost guaranteed to shape future policy deliberations in important new ways. The global warming dilemma is due to a variety of key scientific findings. The science of global warming tells us that the phenomenon is real, its presence in the climate data is very likely consistent with model calculations, and its most serious effects will be delayed for decades to centuries. Reducing the likelihood of serious damage from climate change requires substantial emissions reduction of CO_2 and other greenhouse gases over the first half of this century, but with most of the damage-reducing benefits accruing to future generations of earth's inhabitants. This long delay in such benefits introduces many challenges to the global policy response process. These challenges will continue to produce considerable barriers to achieving

meaningful policy actions, nationally and globally. Some of the factors that combine to produce the global warming dilemma are listed below:

- The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) has been thwarted by a major difficulty in achieving timely implementation of the required social, political, technological, and infrastructure commitments on the roughly one-decade timescale outlined in the protocol. In short, the protocol requires the developed nations to achieve reductions of CO_2 emissions into the atmosphere due to burning of carbon-based fossil fuels (coal, oil, and natural gas), but without similar commitments from countries in the developing world, whose CO_2 emissions are growing at a rapid rate. Also, it is now clear that even complete implementation of the Kyoto Protocol will not come close to mitigating the projected global warming. On the contrary, full implementation of the Kyoto Protocol would imply only a relatively modest reduction in the rate of increase of global atmospheric greenhouse gas concentrations. Yet, several years after the initial UNFCCC Conference of the Parties in 1997, we still are without globally meaningful new CO_2 emissions reduction policies. Much of the blame for this is properly cast toward the inability of U.S. policy to be guided by the science of climate change that has been mainly led by U.S. scientists over the past three decades. However, even if the United States abandons its ill-advised resistance to implementation of the Kyoto Protocol, there are still major political, technological, and socioeconomic barriers to implementation of a cohesive and significant reduction of global CO_2 emissions.
- A number of policy makers worldwide have adopted the superficially reasonable position that if we can hold global CO_2 emissions constant with time, we can strongly reduce global warming to acceptable levels. This is far from the truth. The generally ignored, but invaluable, IPCC climate change special report, "Radiative Forcing of Climate Change," made it dauntingly clear that no such "comfort zone" would exist, even if this admittedly huge achievement of holding global CO_2 emissions constant with time were to be achieved (IPCC, 1994). Indeed, that report showed convincingly that it would very likely require a 60–80% reduction in today's emissions just to keep CO_2 concentrations from rising in the atmosphere. From a sociological, geopolitical, and technological perspective, such a level of global CO_2 emissions cuts over the next several decades is very unlikely, given the continued strong global growth since in CO_2 emissions. Simply put, the major policy challenge will be how to reduce growth in CO_2 emissions in the face of continued demand for more

energy in the developed nations, huge demand growth in the developing nations, and the overall demands of an increasing world population. Regardless, it is unlikely that any combination of achievable mitigation actions will produce a world in which global atmospheric CO_2 levels will always remain below a doubling of the levels at preindustrial times.

- It is fair to note that the IPCC (2001) did assert that it is technically feasible to mitigate CO_2 emissions at a rate that would eventually stabilize CO_2 concentrations at below a doubling of preindustrial levels. However, the IPCC authors were very well aware that actually achieving this would be very daunting on the global policy side. These insights led to the realization that the actual level of climate warming will have to be considerably smaller than currently projected to prevent substantial future impacts on humans and most other life forms on earth. It is fair to note that many individuals remain optimistic that major reductions of greenhouse gas emissions are achievable over the next decade or two. The burden, however, remains on them to propose clear and enforceable mechanisms by which such major global CO_2 emissions reductions would be achievable.
- Scientific studies show that if, by some unforeseen spectacular mitigation breakthrough, all CO_2 and other greenhouse gas concentrations in the atmosphere were to be held constant at current levels, the earth's surface would still warm further by about 0.5–1.5°C above today's record high levels (Wetherald, Stouffer, & Dixon, 2001). This time lag in the realized warming is caused by the expected continued absorption of much of the warming signal by the world ocean. Indeed, it may require 1,000 years to "catch up" with the warming level that would have already been observed if earth had a very shallow ocean with a very small heat storage capacity (see Section 3).
- The above points make it clear that the irreducibly high amount of minimum warming already "wired in" reveals an unplanned global strategy of relying on coping and/or adaptation to a substantial climate warming, no matter what policy makers do over the next decade or two. Thus, all anticipated benefits of future mitigation policies are much more for future humans, animals, and plants than they are for earth's current inhabitants.
- All carbon cycle models reveal a key insight: the more CO_2 that is added to the atmosphere over the next century or so, the longer newer emissions will remain in the atmosphere. This is because the relatively "fast" uptake CO_2 reservoirs (timescale of decades), such as the upper ocean and the terrestrial biosphere, will become nearly saturated with the CO_2 already added to the atmosphere (IPCC, 1994). What this reservoir saturation effect means is that the burden of the CO_2 uptake over this century

increasingly will shift to the next fastest reservoirs, such as the intermediate layers of the ocean and the deeper layers of the terrestrial biosphere, a process that requires centuries. Further removal to the deepest ocean by seafloor carbonates requires very roughly 1,000–10,000 years. Thus, as more CO_2 is added to the atmosphere, the rate at which it is removed from the atmosphere becomes progressively slower (see Section 4).

- The very slow uptake of the climate warming signal by the ocean implies a very slow, but inexorable sea level rise due to the slow warming of the ocean. This contribution to sea level rise is due to the elementary fact that warmer water occupies a larger volume than colder water. All climate models, complex and simple, show global sea level rising for more than 1,000 years due to this delayed ocean warming effect.
- The melting of the great Arctic and Antarctic ice sheets could contribute eventually to tens of meters of sea level rise, arguably most of it occurring on a timescale longer than 1,000 years. However, West Antarctic Ice Sheet (WAIS) melting could possibly add to sea level rise over the next few centuries (Oppenheimer, 1998).
- Finally, the science of global warming has become increasingly solid over the past 20 years. The essence of the problem is now rather well understood. Some key uncertainties remain, none of which are likely to change the essence of our understanding of global warming. However, much of the detailed regional information that is typically sought by policy makers will likely remain elusive, thus providing still more reasons to evade commitment to globally meaningful CO_2 emissions mitigation.

These contributors to the global warming dilemma make it very clear that addressing this problem meaningfully is likely to be far more daunting than is currently perceived by the policy makers, the press, and the world's educators. The subsequent sections in this essay will describe in more detail why the above-described contributors to the global warming dilemma are true, and why the science behind most of the sources of this dilemma is quite solid and rather widely understood. Perspectives on lessons for policy challenges and policy barriers will be offered in Section 7.

2. BASICS OF THE ATMOSPHERIC "GREENHOUSE WARMING" PHENOMENON

This section explains the basic science of human-caused climate warming.[2] It is designed to be accessible to the "educated layperson" who is not an expert

in atmospheric or climate sciences, but who has some grounding in the physical sciences. The information contained here can provide an improved understanding of the reasons why human-caused climate change is a serious issue, why it is grounded in sound scientific principles, and why this knowledge leads to the global warming dilemma. Readers who are either well versed in the science of climate change or are not particularly interested in pursuing the more difficult parts of the basic science can skip to Section 3 without significant loss of capability to understand the key points in the remaining sections.

Surprisingly, all of the physical drivers of the global warming problem are contained within the atmosphere. Despite being a region of relatively inconsequential mass, water amount, and heat capacity, it is in the atmosphere that the temperature at the earth's surface is ultimately determined. The special properties of the atmosphere define the essence of how climate warming works.

The earth is strongly heated every day by incoming radiation from the sun. This heating is offset by an equally strong infrared radiation leaving the planet. Interestingly, if the earth were without any atmosphere, and if its surface reflectivity did not change, global mean surface temperature would be roughly 33°C colder than it is today. This large difference is due to the strong atmospheric absorption of infrared radiation leaving the earth's surface. The major atmospheric infrared absorbers are clouds, water vapor, and CO_2. This strong infrared absorption (and strong re-emission) effect is extremely robust. It is readily measured in the laboratory and directly measured from earth-orbiting satellites. Simply put, adding CO_2 to the atmosphere adds another "blanket" to the planet and thus directly changes the heat balance of the earth's atmosphere.

Individuals skeptical about the reliability of global warming have correctly noted that in terms of direct trapping of outgoing infrared radiation, water vapor is by far the dominant greenhouse gas on earth. Since water vapor dominates the current radiative balance, how can it be that CO_2 is anything other than a minor contributor to earth's absorption of infrared radiation? Part of the answer comes from the well-known modeling result that net planetary radiative forcing changes roughly linearly in response to logarithmic changes in CO_2.[3] Thus, a quadrupling of CO_2 gives another roughly 1°C direct warming over the direct 1°C warming for a CO_2 doubling, valid for the extreme assumption that water vapor mixing ratios and clouds do not change.[4] Interestingly, this approximate relationship also holds for a large extended range as CO_2 is decreased.

It is thus hard to escape the conclusion that increasing atmospheric CO_2 concentrations provides a measurable direct addition to the atmospheric

trapping of the infrared radiation leaving the surface of our planet. However, a simple comparison of the relative greenhouse efficiencies of water vapor and CO_2 quickly becomes problematic because water vapor enters the climate system mostly as a ''feedback'' gas.

All models and observations currently indicate that as climate warms or cools, the observed and calculated global-mean relative humidity of water vapor remains roughly constant, whereas its mixing ratio does not.[5] Thus, as climate warms or cools, the holding capacity of atmospheric water vapor increases or decreases, respectively, exponentially. This is a powerful water vapor positive feedback mechanism – that is, a process that acts to amplify the original warming caused by increasing CO_2 levels. With this major positive feedback, the modeled ''climate sensitivity'' increases by about a factor of 3 to roughly 3°C.[6] Currently, observational evidence remains generally consistent with the modeling results that project a strong positive water vapor mixing ratio feedback under an approximate constancy of relative humidity as the climate changes (Oort & Liu, 1993; Sun & Held, 1996).

An additional, but smaller, positive feedback is the relationship between ice (or its absence) at the earth's surface and its reflectivity of solar radiation. In essence, if ice or snow cover melts, the surface left exposed (ground, vegetation, or water) is generally less reflective of incoming solar radiation. This leads to more absorption of the solar radiation, thus more warming, less ice, and so on. This feedback is expected to become important as snow lines retreat poleward and when polar ice sheets begin to melt at their lower-latitude edges.

Inclusion of this ''ice-reflectivity'' feedback process in mathematical models of the climate amplifies further the calculated warming response of the climate to increased concentrations of CO_2 and infrared absorbing gases. It would also amplify any calculated cooling if ice at the earth's surface were to increase. Other kinds of feedback, both positive and negative, result from the interaction of land-surface properties (e.g., changes of vegetation that lead to reflectivity and evaporation changes) with climate warming/cooling mechanisms or from changes in CO_2 uptake by the biosphere. Both the ice reflectivity and the vegetation feedbacks still remain somewhat uncertain, particularly in their details on the regional scale.

The major source of uncertainty in determining climate feedback concerns the impact of clouds on the radiative balance of the climate system.[7] A CO_2-induced increase in low clouds would mainly act to reflect more solar radiation and would thus act to produce a negative feedback to global warming. An increase in high clouds mainly adds to the absorption of infrared radiation trying to escape the planet and would thus provide a positive

feedback. A change in cloud microphysical and optical properties could go either way. Which of these would dominate in an increasing CO_2 world? We are not sure. Our inability to answer this question with confidence is the major source of uncertainty in today's projections of how the climate would respond to increasing greenhouse gases. Furthermore, it is not likely that this cloud radiation uncertainty will be sharply reduced within the next 5 years. This is because there still remain formidable barriers in obtaining the needed cloud measurements, preparing sufficiently comprehensive cloud models, and formulating accurate theories of cloud behavior and cloud properties.

Although clouds dominate the climate modeling uncertainty, other key processes are also in need of improved understanding and modeling capability. An example is the effect of human-produced airborne particulates (aerosols) composed mostly of sulfate (from oxidation of the sulfur in fossil fuels) or carbon (from open fires). Sulfate aerosols are mostly reflective of solar radiation, producing a cooling effect, whereas carbonaceous aerosols in the lower troposphere mostly absorb solar radiation, producing a net heating effect. Efforts to reduce the current uncertainty are limited by inadequate measurements of aerosol concentrations and the sensitivity of climate to their radiative effects. Even more uncertain are the so-called indirect effects that atmospheric aerosols have on the determination of cloud amounts and their radiative properties.

Another key uncertainty lies in modeling the response of the ocean to changed greenhouse gases. This affects the calculated rate of response of the climate over the next several centuries. For details, see Section 3.

3. THE CLIMATE-REGULATING ROLE OF THE GLOBAL OCEAN

The description of the physics of global warming in Section 2 focused almost solely on the physical processes acting in the atmosphere to explain the essence of this phenomenon. Yet, as we shall see, the ocean plays a very important role in determining how the expected climate warming will evolve over this and future centuries.

Most people have experienced the mild shock of jumping into a body of water in mid to late spring when the air temperature is warm, only to find out that the water temperature is much colder, while the opposite can be experienced in the cooler days of early fall. This effect is mostly due to the much higher heat capacity of the ocean or a lake relative to that of the

overlying atmosphere. Even in moderately sized water bodies, this produces a clear "seasonal lag" of the water temperature changes relative to the march of the seasons.

Interestingly, a perceptive observer may have also noted that lakes and swimming pools tend to cool off more efficiently than they warm up. In the fall, as the weather cools, the upper water surface cools rather quickly. However, the cooling upper water becomes denser and thus sinks efficiently to lower levels, thereby transferring the cooling effect through the entire depth. As waters warm in the spring, the highest levels of a lake can feel comfortably warm, but the unwary swimmer often experiences much colder water a short distance below the surface. In this case the spring warming heats the upper layer of the water, makes it less dense, and therefore the warmed water tends to just remain at the top without appreciable downward mixing.

A similar set of processes act over long timescales when the climate is changing. A cooling climate can rather efficiently propagate the cooling signal to the interior of the ocean. A warming climate tends to concentrate the heat in the upper levels of the ocean and actually can produce an oceanic resistance to mixing the warming signal downward. This effect can produce an early atmosphere/upper ocean response to an atmospheric warming forced by increased greenhouse gases. The ultimately realized warming can become delayed for long time intervals because of the slow mixing of the warming into the deeper ocean.

This effect is amplified greatly in the world ocean because it has a far greater heat capacity than that of the atmosphere. Indeed, the heat-carrying capacity of the global ocean is over 1,000 times greater than that of the global atmosphere. This key observation carries many implications for how the atmosphere and earth's surface can respond over time to increasing atmospheric greenhouse gases.

Suppose, for example, that only, say, the top 1 m of the ocean could "feel" the atmosphere's heating and cooling effects, while the rest of the world ocean remained totally disconnected (no circulation, no mixing, no exchange with the top meter). In this case, the atmosphere/1 m ocean system would respond within a year of a CO_2-added greenhouse warming of the climate. The upper meter of the ocean would soon be in equilibrium with the current atmospheric CO_2 amount and the time lag to equilibrium would be very short. (We used to use models like this to save computer time in global warming calculations!)

Now, suppose that our "1 m lid" ocean is replaced with the real ocean, but with nearly infinitely fast mixing all the way to the bottom. In this case,

the rate of atmospheric warming due to added CO_2 would be sharply suppressed because the modest heat capacity atmosphere would be losing its added heat to the cooler ocean with its greater than 1,000 times heat capacity. In this case, one would have to wait for some time to even be able to measure the amount of atmospheric warming. Indeed, the atmospheric warming trend would be small relative to the natural variability of global mean surface temperature for a long time.

The real world lies between these hypothetical extremes. In reality, what we see from earth's climate measuring systems is a lower atmosphere that is warming considerably slower than an almost "atmosphere-only" planet would, but noticeably faster than it would in the "infinitely fast mixing" ocean case.

A bottom line constraint is still applicable, however. The new climate cannot be in equilibrium until the ocean is no longer warming up, all the way to the bottom. Indeed, the last degree or two of warming could take well over a 100 years beyond the time that greenhouse gas atmospheric concentrations have been stabilized, while the last few tenths of a degree of warming could require over a 1,000 years.

Most state-of-the-art climate models of global warming suggest a slowing down of the ocean's overturning circulation, and thus less mixing of excess CO_2 into the ocean. That same slowing down phenomenon would also act to slow down the mixing of heat into the deeper layers of the ocean. This effect acts to produce an earlier warming, but a delay of the "end game" warming due to this suppression of mixing of the added heat into the interior of the ocean.

Levitus et al. (2001) demonstrated that most of the heat storage due to the warming of the 20th century is in the ocean, and not in the atmosphere, soil, or land glaciers. This observational result is fully consistent with theoretical and modeling expectations. It is fair to note, however, that the rate of the oceanic mixing that eventually fills up the huge ocean heat reservoir is a source of significant uncertainty in itself.

Oceanic mixing is also a factor in evaluating the observed 20th century warming in the context of climate change science. The amount of global warming that has accumulated to date is primarily determined by the amount of greenhouse gases added to the atmosphere, minus "offset" negative forcing caused by factors such as sulfate particles. However, the rate at which such warming occurs is strongly dependent on the rate at which the warmer atmosphere loses some of its added heat through mixing it into the ocean. Also, the apparent warming or cooling effects due to decade-to-century-scale natural variability and data imperfections must be

considered. Obviously, the climate model calculations are also imperfect. However, the very point of these types of studies is to evaluate the credibility of the theory-based climate models.

These difficulties explain why the level of scientific confidence about the match between the observed 20th century warming and retrospective model calculations still has to be expressed in probabilistic terms. The author has stated that there is a greater than 90% chance that the observed warming to date is directly attributable to the greenhouse gases added over the 20th century (Mahlman, 1997; IPCC, 2001). The remaining "messiness" in this key calculation would be lowered by more precise climate warming measurements and more accurate modeling of cloud-feedback processes and of the mixing of the warming signal into the ocean. The confidence in this still-imperfect model-data "match" has been elevated to this 90 percent level partly because of the still-remaining lack of any alternative hypothesis that is either consistent with observations, a self-consistent theoretical framework, or a quantitative model simulation.

The multiple layers of the ocean thus will play a key role in how global warming will unfold over the next century or two. If ocean mixing does become strongly suppressed, then the atmospheric warming rate with be temporally enhanced, but the long-term delay in the final magnitude of warming will be extended even further in time.

4. NATURAL RESERVOIRS FOR ATMOSPHERIC CO_2

The perceptive reader might question why scientists and policy makers are so focused on CO_2 when it is well known that other powerful greenhouse gases such as methane, nitrous oxide, lower-atmospheric ozone, chlorofluorocarbons, and other manufactured molecules, in combination, are currently adding nearly as much a greenhouse warming forcing contribution as does CO_2. Indeed, this understanding is already being used as a policy tool for near-term priority setting: keep the powerful, long-lived greenhouse gases out of the atmosphere now, because it is effective and comparatively inexpensive to do so. This is a very appropriate mitigation strategy for the next decade or so. On timescales of decades and longer, however, atmospheric CO_2 concentrations will have grown further and the "easy-mitigation" gases will be gradually exiting the atmosphere. In the long run, however, CO_2 dominates everything, including the effects of the cooling sulfate particles, the substance that makes acid rain. The reason CO_2 warming overwhelms sulfate cooling is that sulfate lasts about a week in the

atmosphere, while added CO_2 remains for roughly a century. Because of this difference, at today's emission rates of sulfur and CO_2, sulfur concentrations will not grow further, while CO_2 concentrations will continue to grow for centuries. The reason CO_2 levels would continue to grow for centuries at today's emission levels is that, for every unit of CO_2 emitted, about half of it is removed from the atmosphere and half stays, thus adding systematically to the atmosphere's CO_2 concentrations. As a result, the current rate of atmospheric CO_2 increase is about 0.5% per year, roughly 50% of the annual global CO_2 emissions.

Superficially, a CO_2 "piling-on" rate of 0.5% per year seems pretty small. However, this current rate compounded gives a doubling of CO_2 levels over preindustrial levels by the year 2100. This is actually quite significant, because all model calculations indicate that a doubling of CO_2 would produce a substantial climate change with likely significant impacts on human lives as well as most other life on earth (IPCC, 2001). This observation seriously understates the challenge for two reasons. First, the current "business as usual" growth rate of CO_2 emissions projects a tripling over today's emissions by 2100 (IPCC, 2001). Second, as subsequent paragraphs will demonstrate, the percentage of CO_2 emissions remaining in the atmosphere is expected to increase steadily with time as CO_2 concentrations continue to grow. Thus, we expect that a progressively higher fraction of CO_2 will stay in the atmosphere as time progresses. Disconcertingly, even constant CO_2 emissions would progressively result in much more CO_2 in the atmosphere. Surprisingly, to get the same 0.5% per year net CO_2 increase we see today, we would eventually have to emit progressively less CO_2 than we do today.

Why is this the case? As known for over a decade (IPCC, 1994, 2001), the key so-called "CO_2 sinks" become progressively less efficient as more CO_2 is added to the atmosphere. The scientific argument for this assertion is actually quite straightforward. When extra CO_2 first began to be added to the atmosphere through biomass and fossil fuel burning, the "unburdened reservoirs" of the upper levels of the oceans and the terrestrial biosphere were able to absorb a relatively large fraction of the "new" CO_2. However, over the 20th century, more and more CO_2 has been deposited in these two "fast" reservoirs. As these fast reservoirs eventually become nearly saturated, their ability to absorb newly added CO_2 will become progressively less efficient.

Added atmospheric CO_2 acts to increase the concentration gradient of CO_2 between the atmosphere and the upper ocean, thus producing a relatively efficient exchange, at least until the upper ocean becomes nearly saturated with the added CO_2. Then, the exchange of CO_2 between the atmosphere and the ocean becomes less efficient. This decreased efficiency

becomes important on timescales of decades to a century. Once this occurs, the transfer of CO_2 from atmosphere to ocean becomes limited by the exchange rate of the upper ocean to the intermediate layers of the ocean, a process that is measured in centuries. With further CO_2 intrusions into the ocean on these century timescales, the intermediate layers also would become saturated, thus limiting the oceanic "escape" of CO_2 from the atmosphere to even longer times, nearly 1,000 years. Finally, the excess CO_2 can only be slowly removed by dissolving seafloor carbonates (roughly 10,000 years). This very slow process governs how atmospheric and oceanic CO_2 are changed on geologic timescales, probably not applicable to the global warming problem.

There are a number of other calculated climate feedback processes that may be applicable to the oceanic uptake efficiency of excess atmospheric CO_2. It is well known, for example, that CO_2 is considerably more soluble in cold water than it is in warm water. Consider, for example, the difference in your experience of opening a slightly agitated cold carbonated beverage versus that of opening a similarly agitated warm one. Thus, warmer oceans are more resistant to dissolving atmospheric CO_2 than are colder ones. Surprisingly, this effect is not thought to be a very important one in the CO_2 ocean uptake context, due to the comparatively weak dependence of CO_2 solubility on temperature.

Another feedback process now calculated in most of today's climate models is that as climate warming occurs, the large-scale overturning of the global ocean is likely to be inhibited, thus reducing the efficiency of the overturning/mixing process that transports the excess atmospheric CO_2 into the interior of the ocean (Stouffer, Manabe, & Bryan, 1989). This process may inhibit the downward oceanic mixing of CO_2 by roughly 10–40%. The uncertainty in this effect remains substantial, due to a number of complicating factors that limit our understanding of oceanic overturning.

There are a number of other speculated biological mechanisms that possibly could either accelerate or decelerate the process of oceanic drawing down of the excess atmospheric CO_2. Most of these are not considered likely to change our thinking substantially on this problem. The role of the terrestrial biosphere in the uptake of atmospheric CO_2 remains somewhat problematic. It is clear that added CO_2 is a "fertilizer" for many plant species, increasing their growth rates (and thus their CO_2 uptake rates), assuming the requisite water and nutrients are readily available. In unmanaged ecosystems, this is often not true because the availability of water and nutrients is frequently limited. Nevertheless, CO_2 fertilization is still likely to be an important mechanism for accelerated uptake of CO_2. It has been argued, however,

that net carbon storage in soils and plants can be inhibited by accelerated biomass decomposition rates in the future warmer, wetter climate, particularly so in biologically productive regions that are already warm and moist.

One place where the terrestrial biosphere is projected to be a strong candidate for acting to draw down higher levels of atmospheric CO_2 is in formerly productive regions that have been heavily deforested or cleared. In those regions, one would expect that the tendency to "rebuild" lost carbon would dominate over other processes. Finally, the ultimate sink for excess CO_2 is in the weathering of terrestrial silicate rocks, a process requiring on the order of 100,000 years.

This section can be summarized by simply noting that the earth's scientific "deck" is stacked to make atmospheric CO_2 last in the future atmosphere considerably longer than it does today. Thus, the higher the levels of CO_2 in the atmosphere, the more difficult it will be to remove it if we begin to experience a climate that we no longer wish to "live" with.

5. THE INERTIA OF THE ICE SHEETS OF GREENLAND AND ANTARCTICA

One of the anticipated outcomes of global warming is a tendency to produce melting of the great ice sheets of Greenland and Antarctica. An attention-grabbing, but misleading, statistic is that these ice sheets, if completely melted, would raise sea level by roughly 70 m.

It is clear from the geological record that ice sheets have melted and have grown. It is also clear that these ice sheet advances and declines can require tens of thousands of years to be completed. In fact, the ice sheet melting from the most recent ice age has led to a roughly 100–120 m sea level rise from 15,000 to 6,000 years ago (roughly 1 m per century). Interestingly, this "recent" sea level rise occurred as a rebound effect of the recovery from the last ice age. The effect of the ice sheet growth, sea level decline, and CO_2 draw down (to 190 ppmv) at the last glacial maximum has been calculated to have produced a negative (cooling) global climate forcing of about 4–6 W/m^2. Interestingly, a positive (warming) 4–6 W/m^2 forcing of the climate is roughly what we expect for a doubling to a tripling of atmospheric CO_2. This suggests that future sea level rise due to ice sheet melting is likely to be a very lengthy, but substantial, and inexorable process.

This slow melting of the ice sheets could be sped up substantially if the long-speculated "collapse" of the WAIS were actually to occur (Oppenheimer,

1998). The basis for the concern is that part of the WAIS is grounded on land that is below sea level and part is in the form of floating ice shelves. If the grounded part were to become detached for any reason, this could carry the potential for up to a 7 m addition to sea level. IPCC (2001) argues that it is very unlikely that a large sea level rise due to collapse of the WAIS could occur in the 21st century. It is useful to note, however, that collapse of the WAIS, if it were to occur, would require roughly 1,000 years to carry itself to completion. From this perspective, the word "collapse" is quite misleading when heard by the nonspecialist. "Slow detachment" might be a more appropriate phrase.

The Greenland ice sheet is expected to melt at a much faster relative rate than would the WAIS. This is because essentially all of the highlands of Greenland would be exposed to summertime melting if, say, a 5°C-high northern latitude warming were to occur within the next century or so. However, because of the greater than 3 km elevation of much of Antarctica, it is expected that the warmer climate would produce greater continental snowfall, thus producing a regional net ice accumulation over the Antarctic Continent. Again, all of these processes act to produce large changes only on timescales considerably longer than a century. Thus, analogous to the warming of the world ocean, the inertia of the great ice sheets of Greenland and Antarctica slows down, and greatly extends, the sea level response to increasing concentrations of greenhouse gases.

It is important to point out, however, that the IPCC (2001) report only considered detailed sea level rise projections out to the year 2100, thus inadvertently deflecting attention away from the real concerns about this problem. Yet, the body of the 2001 report did make a special effort to point out that sea level rise has the potential to continue for hundreds to thousands of years in response to increased greenhouse gases in the atmosphere.

6. IMPLICATIONS FOR MILLENNIAL-SCALE TRENDS IN SEA LEVEL

In Section 4, we learned that emissions of CO_2 into the atmosphere, if sustained at today's high levels for much of the 21st century, have the potential to remain in the atmosphere for multiple centuries. Thus, at these high CO_2 levels, even a rapid draw down in CO_2 emissions is not accompanied by a rapid draw down of atmospheric CO_2 concentrations. Elevated atmospheric CO_2 concentrations are thus very likely to lead to elevated

global temperatures for at least the centuries required to draw down the excessive CO_2 concentrations back to preindustrial levels, plus the added centuries required for the oceans to give most of their accumulated heat back to space, roughly another 500 years (as noted in Section 3).

Also, it was noted in Section 5 that the great ice sheets of Greenland and Antarctica can only melt substantially on timescales ranging from centuries to millennia. However, it is thought that the Greenland ice sheet is likely to respond within centuries, at least at its lower-elevation edges. On the shorter timescale of the 21st century, Greenland is expected to add to sea level rise, while Antarctica is expected to produce a small net negative contribution. This is because negligible ice melting is expected at Antarctica's ice edges, while the warmer, wetter atmosphere is expected to cause a small net accumulation of snow in the continental interior.

So, what do these various facts and circumstances tell us about the expected sea level rise in response to global warming? First, it is important to note that IPCC (2001) chose to emphasize only climate change up to the year 2100. If there actually is a large reduction of global CO_2 emissions throughout the 21st century, it is reasonable to assume that large future changes in global mean surface air temperature would be increasingly unlikely after 2100 (even though the oceans would continue to warm for further centuries).

Note also that IPCC (2001) chose not to project sea level rise amounts beyond the year 2100, even though its Chapter 11, "Changes in Sea Level," does discuss the inevitability of sea level rise for many centuries beyond 2100. They mention that, after 500 years, sea level rise could range between 0.5 and 2 m for a doubling of CO_2 and twice that if we were to reach a quadrupling of CO_2, just due to the effects of thermal expansion of the warmed seawater.

IPCC (2001) also recognized that "ice sheets will continue to react to climate change, even if the climate is stabilized." They note that a sustained 5.5°C climate warming over Greenland would melt enough of its ice sheet in 1,000 years to lead, by itself, to a 3 m sea level rise. Note that a 5.5°C warming over Greenland is about what midrange climate models project for a stabilization at a doubling of atmospheric CO_2, a level generally acknowledged to be difficult to stay below.

These sea level rise projections suggest very strongly that the sea level issue has been substantially overlooked in greenhouse gas emissions mitigation negotiations to date. The policy goal of eventual stabilization of CO_2 concentrations is important, but still shortsighted, simply because it incorrectly assumes that climate would then be stabilized. This is not true. Such a major and laudable global policy achievement would still commit earth to a

continually rising sea level for the next millennium, a huge and continuing challenge for humankind and the biosphere in coastal zones everywhere. This inexorable sea level rise would be driven by the millennium-scale increases in global ocean temperature and the resultant inescapable thermal expansion of the oceans. It would also be driven by the likely tendency of the Greenland ice sheet to melt in the presence of the sustained higher temperatures, as explained above.

The bottom line is that sea level rise is very likely to begin innocently enough at a very slow rate, pick up its rate of increase as the earth's climate system warms up, and then sustain it indefinitely, due to the intrinsically long timescales of atmospheric CO_2, the global ocean warming rate, and the ice sheet response of Greenland and Antarctica. Thus, even a very successful greenhouse gas emissions policy may be setting up a sea level rise "end game" that is well over 10 times longer than the roughly 150-year "setup time" we will have spent getting into this situation.

7. IMPLICATIONS OF THE "GLOBAL WARMING DILEMMA" FOR CLIMATE CHANGE POLICY

In Section 1, it was noted that the current scientific knowledge base creates multiple challenges for global warming policy makers to overcome before truly meaningful mitigation policies can be accomplished. In Section 1, it is called the global warming dilemma. The factors leading to the global warming dilemma are briefly restated here to provide a setting for examining new policy possibilities and potential policy dead ends.

- Implementation of the 1997 Kyoto Protocol agreement has been thwarted on all sides by major political and national self-interest barriers from achieving even modest levels of net global CO_2 emissions mitigation.
- Even perfect implementation of the important Kyoto Protocol will still only be a small step toward the solution of the global warming problem.
- Even if the near-term daunting policy goal of holding global CO_2 emissions constant through time were achieved, it would not come close to stopping further global warming.
- It is now widely recognized that it will be very difficult to prevent an eventual doubling of atmospheric CO_2 concentrations over the preindustrial amounts.
- The above point shows that an "already-committed" irreducibly high warming amount has exposed an unplanned "strategy" of substantial

coping/adaptation to significant climate change, almost independent of what politically and technologically acceptable mitigation strategies are established.

- Modeling studies have shown that, even with a spectacular mitigation breakthrough of holding atmospheric CO_2 concentrations at their current levels, another 0.5–1.5°C of climate warming is expected.
- Carbon cycle models reveal that the more CO_2 we add to the atmosphere, the longer it takes for natural processes to get it back out of the atmosphere over the next several hundred years.
- The very slow oceanic uptake of the added heat due to global warming will produce a sea level rise that is "wired in" for the next 1,000 years and beyond.
- Polar ice sheet melting is likely to produce substantial sea level rise, which would likely take considerably longer than would the contribution due to ocean warming.
- The science of global warming has become increasingly solid over the past 20 years. A small, but effective, minority disputes these facts, mainly by pointing out that significant details remain uncertain. Indeed, significant uncertainties do remain. The harsh reality, however, is that no viable alternative hypotheses to current global warming knowledge exist, in spite of major efforts to construct them. The likelihood of finding a planet-saving, substantially overestimating flaw in the climate change science now appears to be exceptionally low – less than a 1% chance.

It is not difficult to see why the sum of these well-understood truths inevitably lead to the harsh reality of the global warming dilemma. Consider the policy makers' sincere question: "What can we do in a mitigation context to keep global warming from happening?" The blunt answer is almost nothing; climate change is well under way and it carries a huge momentum. Clearly, the question needs to be restated: "What are the options available for us to manage this dauntingly difficult problem in the most globally responsible way?" In this form, the question is quite reasonable because it allows avenues for finding rational approaches for dealing with the real problem.

8. PERSONAL COMMENTS

It has been clearly beyond the province of climate scientists to offer policy "solutions" to this problem. After all, our expertise is in climate science, not

technology, sociology, economics, policy, or ethics. Yet, a number of climate scientists over the past 20 years have assisted in framing out the questions, answers, and insights that science and scientists can offer to assist the difficult policy-making process. For example, widespread recognition of the hard science that has led to the daunting global warming dilemma should eventually lead to a maturation of global policy deliberations, well beyond the almost Lilliputian political stances and frequently incorrect characterizations of the problem that still remain typical. In that spirit, a number of observations are offered below that may contribute to the maturation of these very difficult policy challenges.

Consider, for example, the kinds of arguments today that still dominate policy makers' exchanges and press coverage of the problem. "If we do anything meaningful now on CO_2 emissions, we will damage our economy!" "If the problem is this daunting, the science must be flawed!" "We must act now to keep global warming from advancing any further!" "Science has surely underestimated the magnitude of the terrible effects that will occur." "Science has surely underestimated the magnitude of the benign effects that will occur!" Let's focus on scientific and political controversies; it sells newspapers and raises ratings!" Most people reading this will almost surely have heard, and maybe even have agreed with, some of these perspectives. In my view all of these arguments will be eventually exposed as being wrong, flawed, or emotional, simply because they contain only partial and self-serving "truths."

So, how much do the scientific facts comprising the global warming dilemma provide guidance to the world on how to respond? Quite a lot, in my opinion. Consider the following science-based, policy-relevant observations:

- There are no quick policy fixes, nationally or globally.
- If we do not begin to chip away at the problem soon, it is very likely that serious consequences will be wired in for the world of our great-grandchildren and for their great-grandchildren, etc.
- The previous item is only invalidated if essentially all of the current scientific knowledge about climate change is completely wrong.
- The odds against all of the science being so wrong as to make the problem nearly go away are now very small, less than a 1% chance.
- The long timescales of the problem highlighted above will inevitably change the policy debates in ways that we probably cannot yet foresee.
- The long timescales and robustness of the problem almost guarantees that our descendants in the 22nd century will, with historical perspective, see that we were actually confronted with a major planet-scale stewardship/management problem.

- They will most assuredly note how we responded, or how we did not respond to the problem.
- They will also be aware of how our decisions or nondecisions today are still affecting most aspects of their lives and their own continuing responses to the evolving challenge of human-caused climate warming.

With this clearer framing of the policy challenges, is the path to rational and sensible policy choices on CO_2 mitigation sufficiently clarified? Are we now ready to make real and binding commitments that all can agree to and adhere to? Probably not. Not yet, anyway. It does seem clear, however, that policy makers could make far more substantive progress if they were to be more thoroughly informed on how and why this problem is both seriously important and seriously daunting, as outlined in the previous sections. However, if policy makers were to be well grounded in these issues, would they then be able to respond much more effectively? Still, probably not. Numerous barriers to legitimate action still lurk in arenas far broader than thorough grounding in climate science, far broader than economic science, and far broader than innovative technological approaches. This next set of challenges appears to be within the realm of, for lack of a better all-encompassing term, global "values conflicts." It is within this realm that we can see more clearly why intelligent humans can perceive very different realities in the face of what physical scientists might label as clear and objective facts. We do not need to focus on distant or alien cultures to observe this phenomenon. We can see it in the high-minded disagreements between Republicans and Democrats, 5/4 Supreme Court decisions, and negotiations on any number of international nonclimate issues, say biological warfare or international fishing rights. We can see it in the sharply divergent assertions from highly respected religious leaders. We can see it almost everywhere we look in the sacrifice of long-term goals for short-term interests and needs.

In the context of this essay, it might be helpful to frame this new set of challenges in terms of these conflicts of deeply held values. Ultimately, it will be these values conflicts that must be reconciled at levels that objective science can partially guide, but certainly cannot and should not control. Simply put, scientific knowledge ordinarily does not change deeply held belief systems.

These values conflicts are an all encompassing label for the ubiquitous looming presence of sharply differing perspectives on what is important, what is treasured, and what we believe, based on our national, cultural, religious, political, economic, environmental, and personal value systems. In

short, our perceptions of ''right,'' ''appropriate,'' or ''good'' are very much influenced by our personal and group value systems. Many of us, personally and collectively, have often experienced having our most deeply held values being perceived by others as odd, wrong, or hostile, often to our bafflement.

Why are values conflicts being raised here as major challenges in dealing with the consequences of the objective science of global warming? It is because values conflicts lurk as impediments in a surprising number of possible approaches to address the challenges of global warming. For example, the economic costs of CO_2 mitigation policies are now more frequently being weighed against the future economic costs of coping and adaptation to climate change. Yet, mitigation costs will likely be paid mostly by the technologically advanced wealthy nations, while coping and adaptation costs will likely be paid mostly nonfinancially by the poorest and most vulnerable nations. How will the world decide on a fair division of these very different costs? This is a very challenging task, made even more so by these two different costs being levied against two separate human generations. It is even more challenging when one considers that these two contrasting costs deal with very different currencies: economic costs for wealthy nations and viability-of-life costs for the climate-impacted poorer nations. Clearly, such radically different measures of cost must be evaluated in very different ways from those to which we are currently accustomed.

Already values conflicts are evident between those who view human life as inherently special relative to all other life forms (anthropocentric values) and those who view humans as having a major ethical obligation as stewards of earth''s environmental health (environmental values). It is clear that adherents of both of these viewpoints often regard their thinking and perspectives as being ''morally sound'' or ''religiously correct,'' or even ''self- evident.'' These differing values positions also have led to very different viewpoints on who ''pays'' for the preservation of species and ecosystems – the humans that created the threat or the species and ecosystems that may become nonviable in the future? Clearly, these kinds of values conflicts cannot be easily reconciled on economic grounds alone.

The above conflicts are expanded in scope when global population growth is considered. The anthropocentric viewpoint sees human population growth as either being benign or in terms of its possible impacts on the quality of human life. The environmental viewpoint sees it as a major and growing threat to all nonhuman life forms. The economic viewpoint uses very different definitions of cost in the context of this problem. Again, these differing ''logically correct'' and ''morally correct'' viewpoints are not readily reconciled.

As the global warming policy debates continue to develop, with increasing recognition of the multiple ways that values conflicts can inhibit real progress toward reducing the impact of climate change, it will become increasingly clear that global policy negotiations must mature to levels well beyond today's largely ineffective efforts. Will this happen? Who knows? It does seem, however, that it is almost inevitable that the deliberations on global warming mitigation will eventually be far more oriented toward recognizing and reconciling national-scale and global-scale values conflicts than is evident today. The key question, given the momentum of the global warming problem, is "when"?

I assert that progress can be greatly advanced through widespread recognition of the harsh, but true, science-based message of the global warming dilemma. This, by itself, can force the policy-making process to be far more grounded in reality than is evident from today's halting efforts, both in the United States and globally. Progress can be advanced considerably further when the global-scale "values conflicts" are recognized and respected, and are also seen as a basis for beginning the very difficult process of finding values compromises that are productive and meaningful in the long run. This will likely prove to be dauntingly difficult. However, given the importance of this century-scale global challenge, future historians will be evaluating our level of success, or lack thereof, in resolving our global values conflicts and in achieving meaningful progress on the global warming problem.

NOTES

1. The following phrases are used to describe judgmental estimates of confidence: virtually certain (greater than a 99% chance that a result is true), very likely (90–99% chance), likely (66–90% chance) (from Mahlman, 1997; IPCC, 2001).

2. Parts of this section were taken from a previous essay by the author (Mahlman, 1998).

3. It is straightforward to perform simple one-dimensional radiative/convective model calculations of the climate effects of reducing CO_2. The log-linear relationship has been found to hold down CO_2 concentrations to as low as 1/64 of preindustrial levels. As CO_2 is decreased, the atmosphere's ability to hold water vapor collapses and the global temperatures drop sharply, leaving CO_2 as the clearly dominant greenhouse gas.

4. Relative humidity is the ratio (in percentage) of the vapor pressure of air to its saturation vapor pressure. The saturation vapor pressure of air, determined from the Clausius–Claperon equation of classical thermodynamics, is a strong exponential function of temperature, roughly doubling for each 10°C. Water vapor mixing ratio is the mass of water vapor of air divided by the mass of dry air; it is generally conserved for a few days following an air parcel when no condensation is present.

5. Relative humidity (see Note 4) is determined in the troposphere by the interplay among evaporation at the earth's surface; upward transfer of water vapor (by small-scale turbulence, thunderstorm-scale moist convection, large-scale rising motion); and net removal by precipitation. Equally important is the local lowering of relative humidity in the troposphere due to adiabatic warming in regions of descending air under approximate conservation of water vapor mixing ratio. Any appeal to a sharp change in mean relative humidity in a warming climate thus implicitly hypothesizes a substantial change in the dynamical behavior of the troposphere, in this case a large change in the motions of the troposphere in response to a comparatively small perturbation to the thermodynamics of the climate system.

6. The term "climate sensitivity" typically refers to the level of equilibrium global mean surface air temperature increase that the climate system would experience in response to a doubling of atmospheric CO_2 concentrations. Each model has its own climate sensitivity, almost guaranteed to be somewhat different from the unknown value for the real climate.

7. Clouds are effective absorbers and reflectors of solar (visible plus ultraviolet) and absorbers/re-emitters of infrared radiation. Their net effect is to cool the planet, but the effect is very small relative to the 33°C "atmosphere/no atmosphere" difference noted above. However, for projecting the smaller human-caused climate changes examined here, the effect of clouds becomes crucially important.

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THE GLOBAL CARBON CYCLE AND CLIMATE CHANGE

William H. Schlesinger

INTRODUCTION

A variety of gases, including water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), add to the radiative forcing of Earth's atmosphere, meaning that they absorb certain wavelengths of infrared radiation (heat) that is leaving the Earth and thus raise the temperature of its atmosphere. Since glass has the same effect on the loss of heat from a greenhouse, these gases are known as "greenhouse" gases. It is fortunate that these gases are found in the atmosphere; without its natural greenhouse effect, Earth's temperature would be below the freezing point, and all waters on its surface would be ice. However, for the past 100 years or so, the concentrations of CO_2, CH_4, and N_2O in the atmosphere have been rising as a result of human activities. An increase in the radiative forcing of Earth's atmosphere is destined to cause global warming, superimposed on the natural climate cycles that have characterized Earth's history.

Relative to a molecule of CO_2, the greenhouse warming potential of each molecule of CH_4 and N_2O added to Earth's atmosphere is about 25 and 200 times greater, respectively. Nonetheless, most attention has focused on CO_2 because it will contribute more than half of the increase in radiative forcing during the next 100 years; it has a long residence time in the atmosphere–ocean system on Earth; and the major cause of its increase in the atmosphere,

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fossil fuel combustion, is well known and potentially subject to regulation (Reilly et al., 1999).

In an attempt to understand the changing chemistry of Earth's surface – that is, its biogeochemistry – scientists try to understand what controls the movements of gases in and out of the atmosphere and to estimate the amount of each gas that cycles through the atmosphere each year (Schlesinger, 1997). For the carbon cycle, biogeochemists assess the emissions of CO_2 to Earth's atmosphere relative to the natural processes that add or remove CO_2 to and from that reservoir, allowing us to forecast atmospheric CO_2 concentrations and the human impact on future climate. In this, our job is far from complete: while biogeochemists have a good estimate of worldwide fossil fuel emissions, we have conflicting views about how the terrestrial biosphere – especially its forests and soils – affects the rising levels of atmospheric CO_2.

The most recent budgets for atmospheric CO_2 contain an unknown sink (or fate) for CO_2 that amounts to about 30% of estimated annual emissions (Table 1). Although far from certain, the assumption is that this carbon is accumulated on land, largely in forests of the temperate zone (Houghton, 2003a). In this role, forests perform a great service to society. If it were not for forest uptake, more CO_2 would accumulate in the atmosphere, leading to the societal costs of global warming. Thus, growing forests, which remove CO_2 from the atmosphere, convey economic value to the natural biosphere.

It is essential to know how the terms in this equation will change in the future. What will happen, for instance, if fossil fuel combustion increases from today's level (>6 PgC/year) to more than 15 Pg C/year[1] that is projected for 2050? How will forest growth respond to higher concentrations of CO_2 and a warmer climate? If CO_2 is now accumulating in forests that are regrowing on abandoned agricultural land, the storage of carbon will diminish as these forests age (Hurtt et al., 2002). If existing forests are growing faster as a result of CO_2 and nitrogen (N) fertilization, then we might expect the rate of growth and carbon uptake to accelerate in the future. Studies of

Table 1. Atmospheric Budget for Carbon Dioxide for the 1990s, in Units of PgC/yr (Houghton, 2003a).

Fossil Fuel	Deforestation Increase		Atmospheric Uptake	Ocean	Residual
6.3	+2.2	=	3.2	+2.4	+2.9

Source: Houghton, 2003a.

forest growth are now intimately tied to questions of public policy and global biogeochemistry.

THE NATURAL CARBON CYCLE

The concentration of CO_2 is controlled by a variety of processes that add and subtract CO_2 to and from the atmosphere. Nearly all of these processes are cyclic – for example, the removal of CO_2 by plant photosynthesis,

$$CO_2 + H_2O \rightarrow CH_2O + O_2, \quad (1)$$

is balanced by the return of CO_2 and the consumption of oxygen (O_2) when plant tissues burn or decompose:

$$CH_2O + O_2 \rightarrow CO_2 + H_2O. \quad (2)$$

The global carbon cycle consists of a variety of such balanced processes operating at different rates and different timescales. The cycles are overlaid on one another, each contributing to the overall, global biogeochemical cycle of carbon.

The most basic cycle, often called the carbonate-silicate subcycle, is driven by the reaction of atmospheric CO_2 with the Earth's crust, causing the chemical breakdown of rocks, known as rock weathering. Since this reaction would occur even on a lifeless Earth, it is a component of the *abiotic* carbon cycle on Earth (Fig. 1). Rock weathering transfers CO_2 to the world's oceans, via rivers, in the form of bicarbonate (HCO_3^-). Bicarbonate is eventually removed from seawater by the deposition of calcium carbonate (limestone, or $CaCO_3$), which is added to Earth's oceanic crust. When the oceanic crust undergoes subduction and heating under great pressure (i.e., metamorphism), CO_2 is returned to the atmosphere in volcanic emanations. The presence of life on Earth has increased the rate of some of these processes (e.g., witness the deposition of marine carbonate by oysters), but the carbonate-silicate cycle appears to have turned slowly for nearly all of geologic time. Very few marine sediments are more than 150,000,000 years old (Smith & Sandwell, 1997). Presumably, the carbon content of older sediments has been returned to the atmosphere.

Each year, the amount of carbon moving in the carbonate-silicate cycle is relatively small: volcanic emissions are currently estimated between 0.02 and 0.05 Pg C/year (Bickle, 1994; Williams, Schaefer, Calvache, & Lopez, 1992), annual river flow of HCO_3^- is 0.40 Pg C/year (Suchet & Probst, 1995), and the formation of $CaCO_3$ carries about 0.38 Pg C/year to ocean sediments

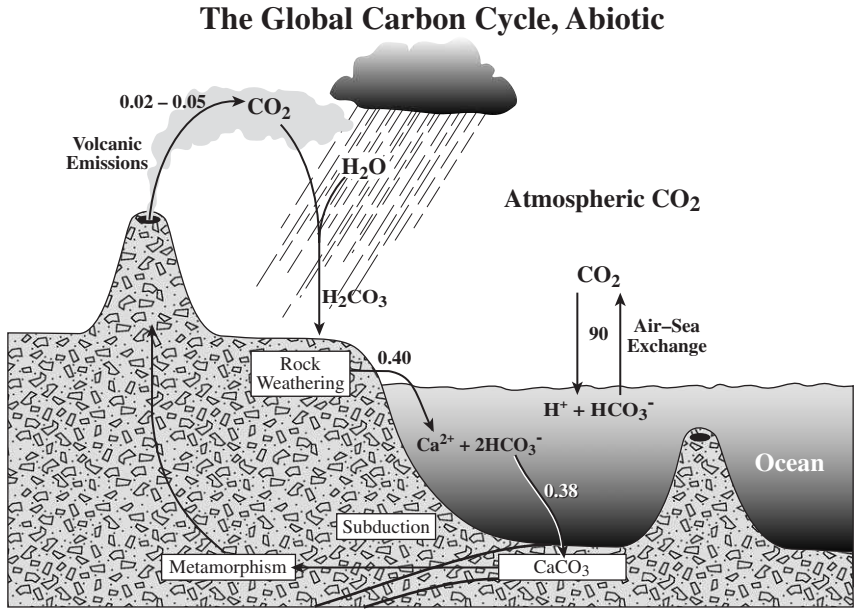

Fig. 1. Abiotic Processes Contributing to the Global Carbon Cycle of the Present-Day Earth. *Source:* Modified from Schlesinger, 1997.

(Milliman, 1993). It would take nearly 3,000 years for rock weathering to remove the current pool of CO_2 from the atmosphere in the absence of emissions from other sources. The geologic record shows periods when volcanic emissions greatly exceeded the rate at which CO_2 could react with the Earth's crust, so high levels of CO_2 built up in the atmosphere (Owen & Rea, 1985). However, for all intents and purposes, this subcycle now appears reasonably well balanced, and there is no credible evidence that the current buildup of CO_2 in Earth's atmosphere can be attributed to recent, unusually high levels of volcanic activity or to lower rates of rock weathering. Indeed, there is observational and experimental evidence that chemical weathering has increased in recent years, perhaps removing an additional 0.1–0.2 Pg C/year of CO_2 from the atmosphere (Andrews & Schlesinger, 2001; Raymond & Cole, 2003).

Another component of the abiotic cycle of carbon derives from the presence of liquid water at the Earth's surface. Any time CO_2 rises in Earth's atmosphere, a greater amount will dissolve in water, as shown as in the

following reaction:

$$CO_2 + H_2O \rightarrow H^+ + HCO_3^- \rightarrow H_2CO_3. \quad (3)$$

The reaction is mediated by Henry's Law, which describes the distribution of any gas, with significant solubility, between the gaseous and liquid phases in a closed system. Played out at the global level, Henry's Law means that the oceans act to buffer changes in atmospheric CO_2 concentration. As the concentration has risen owing to industrial emissions during the past 150 years, a significant fraction of the CO_2 that might otherwise be in the atmosphere has dissolved in ocean waters (Sabine et al., 2004). Indeed, we can document the oceanic uptake of CO_2 by comparing sequential measurements taken at the same locale during the past few decades (Peng, Wanninkhof, Bullister, Feely, & Takahashi, 1998; Quay, Tilbrook, & Wong, 1992; Quay, Sonnerup, Westby, Stutsman, & McNichol, 2003). The total uptake of CO_2 by the oceans is determined by the downward mixing of surface waters into the deep sea, in a global pattern known as the thermohaline circulation (Broecker, 1997). Marine biogeochemists are fairly confident that, as a result of rising CO_2 concentrations in Earth's atmosphere, the net uptake of CO_2 by the world's oceans is about 2 Pg C/year (Sabine et al., 2004) – about 20 times more than estimates of enhanced consumption of atmospheric CO_2 by rock weathering (Andrews & Schlesinger, 2001). However, they are also fairly certain that the uptake of CO_2 by the oceans will not increase in proportion to the future anticipated increase of CO_2 in the atmosphere (Archer, 1995; Houghton, 2003b). Indeed, it is possible that the oceanic uptake of CO_2 might decline if the Earth's thermohaline circulation stopped (Alley et al., 2003).

In contrast to the abiotic cycle, the *biotic* carbon cycle stems directly from the presence of life on Earth and its biogeochemistry (Fig. 2). Photosynthesis [Eq. (1)] and respiration [Eq. (2)] have stimulated the movement of CO_2 to and from the atmosphere. On land and in the sea, photosynthetic organisms remove CO_2 from the atmosphere, using it to form organic matter [Eq. (1)]. Globally, the annual production of new plant tissues is known as *net primary production* (NPP), which is estimated to capture 105 Pg C/year – with 54% occurring on land and the rest in the sea (Field, Behrenfeld, Randerson, & Falkowski, 1998). As a result of uptake of CO_2 by marine phytoplankton, seawater is undersaturated in CO_2 concentration at the ocean's surface, which enhances the marine uptake of CO_2 from the atmosphere. About 20% of marine NPP sinks to the deep sea, acting as a "biotic pump" that transfers CO_2 from the atmosphere into deep ocean waters (Falkowski, 2003).

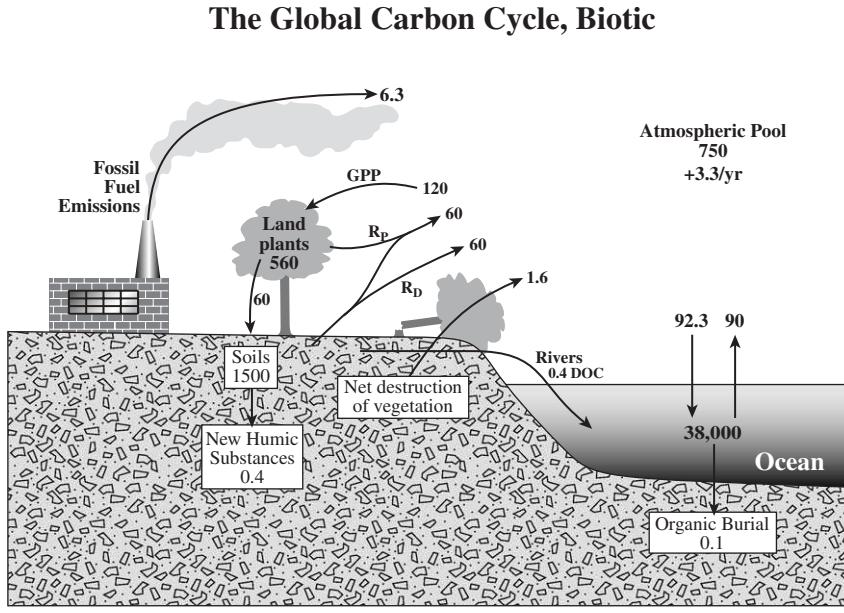

Fig. 2. Biotic and Anthropogenic Processes Contributing to the Global Carbon Cycle of the Present-Day Earth. *Source:* Modified from Schlesinger, 1997.

The mean residence time for a molecule of CO_2 in Earth's atmosphere – about 5 years[2] – is largely determined by the uptake of carbon in photosynthesis. The well-known annual oscillations of CO_2 concentration in Earth's atmosphere occur because a large fraction of global photosynthesis occurs in regions with seasonal climate – i.e., where plants grow only during the summer. Annual oscillations of atmospheric O_2 are a mirror image to those of CO_2, supporting the role of photosynthesis as a major factor affecting the presence of these gases in Earth's atmosphere (Keeling & Shertz, 1992).

Most of the CO_2 removed from the atmosphere by photosynthesis is not captured for long, because dead organic matter decomposes rapidly in soils and seawater. The long-term accumulation of carbon in undecomposed materials in soils is about 0.4 Pg C/year (Schlesinger, 1990), while the storage of carbon in marine sediments is only about 0.1 Pg C/year (Berner, 1982).[3] The low rate of carbon burial in sediments today is not unlike the rates through most of Earth's history (Garrels & Lerman, 1981); however,

over millions of years of geologic time, a huge amount of organic matter has accumulated in the Earth's crust ($\approx$15,600,000 PgC).

PAST VARIATIONS IN ATMOSPHERIC CO_2

One way to gain perspective about the potential future trajectory for atmospheric CO_2 is to examine the geologic record of its concentration in the past. How high has the CO_2 concentration been in the past? How fast did it reach past high levels? Do past fluctuations offer any insight about how effective the various subcycles of the global carbon cycle would be in buffering future increases in atmospheric CO_2? Is there a relationship between past levels of atmospheric CO_2 and past fluctuations in Earth's climate?

There is good reason to believe and some supporting geologic evidence indicating that the concentration of CO_2 in Earth's atmosphere in its very distant past was much higher than it is today. Persistent high concentrations of CO_2 are likely to have characterized Earth's history before the evolution of land plants, which subsequently greatly increased the consumption of CO_2 by rock weathering (Berner, 1998; Moulton, West, & Berner, 2000). High concentrations of CO_2 and other greenhouse gases in Earth's early history may have been instrumental in maintaining Earth's temperature above the freezing point of water at a time when the Sun's luminosity was significantly lower than today.

While the Earth may have experienced very high levels of CO_2 in its "deep" geologic history, studies of marine sediments indicate that atmospheric CO_2 has remained in a narrow range between 100 and 400 ppm[4] over the past 20,000,000 years (Pearson & Palmer, 2000). Bubbles of air trapped in layers of the Antarctic ice pack show concentrations in the range of 180–290 ppm over the past 420,000 years (Petit et al., 1999), with low values associated with glacial epochs and higher values during warmer, interglacial periods. Small variations, between 230 and 290 ppm, since the end of the last glacial epoch (10,000 years ago), suggest short-term temporal imbalances in the global carbon cycle (Indermuhle et al., 1999), with fluctuations in the amount of forest biomass partially responsible for changes in atmospheric CO_2. During the past 2,000 years, concentrations of CO_2 have remained between 270 and 290 ppm, except since the Industrial Revolution (Barnola et al., 1995). The rise in CO_2 during the past 150 years appears to be associated with global warming (Crowley, 2000; Mann, Bradley, & Hughes, 1998), and the most recent Intergovernmental Panel on Climate Change

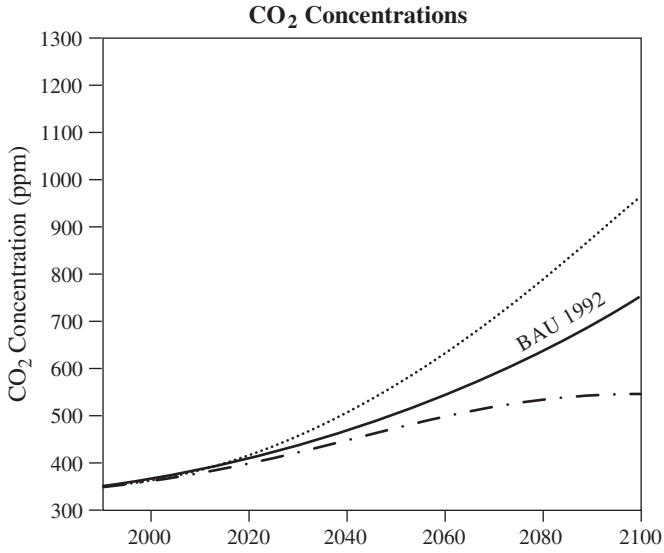

Fig. 3. CO_2 Emissions Projected from Fossil Fuel Combustion, Showing High, Low, and Business-as-Usual (BAU) Scenarios. *Source:* IPCC, 2001.

(IPCC) (2001) projections are for levels reaching 550 ppm in 2050 and exceeding 700 ppm by 2100 (Fig. 3).

HUMAN PERTURBATIONS OF THE GLOBAL CARBON CYCLE

Each year, humans extract more than 6 PgC of fossil fuels from the Earth's crust (oil, coal, and natural gas) and convert these to CO_2 that is added to the atmosphere. The "business as usual" scenario of the IPCC (2001) predicts that CO_2 emissions will rise to 15 Pg C/year by the year 2050, largely due to increases in fossil fuel combustion (Fig. 4). Our impact on the global carbon cycle may appear small compared to some of the natural transfers, such as decomposition, that also add (or subtract) CO_2 to (of from) the atmosphere (Fig. 2), but it is important to recognize that photosynthesis and decomposition are naturally occurring, counter-balancing processes that produce no large net source or sink of atmospheric CO_2 on an annual basis. As a result, before the Industrial Revolution, the concentration of atmospheric CO_2 was roughly constant for centuries (Barnola et al., 1995). In

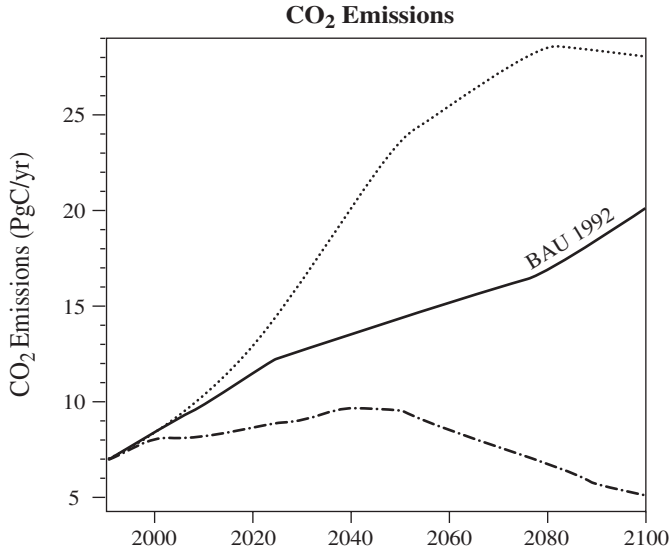

Fig. 4. Atmospheric CO_2 Concentrations Resulting from Emissions Scenarios Outlined in Fig. 3. *Source:* IPCC, 2001.

contrast, with fossil fuel combustion, humans remove organic carbon from the Earth's crust at an annual rate of more than 100 times greater than the storage of organic carbon in newly formed marine sediments. We have made no equivalent counterbalancing change to stimulate carbon storage in the crust, such as burying large amounts of carbon in geologic sediments (Smith, Renwick, Buddemeier, & Crossland, 2001), so we must count on Henry's Law and changes in the activity of the biosphere to buffer any changes in atmospheric CO_2 concentration.

Forest destruction, largely deforestation in the tropics, is also thought to be a net source of atmospheric CO_2, although its exact magnitude is most uncertain. Melillo, Houghton, Kicklighter, and McGuire (1996) estimated a release of 1.2–2.3 Pg C/year as CO_2 from global tropical deforestation in the early 1990s. Considering the rates of regrowth on harvested land, Houghton (2003a) affirms a net loss of 2.2 Pg C/year from tropical forests during the 1990s (Table 1). However, two recent studies suggest that the rate of deforestation in the tropics may be much less than previously estimated (Achard et al., 2002; Defries et al., 2002), and that the net loss of carbon from these regions may be only 0.9–1.3 Pg C/year (Houghton, 2003a). Some recent modeling studies also indicate lower-net emissions of CO_2 from

tropical deforestation (Ciais, Peylin, & Bousquet, 2000). Lower estimates of CO_2 emission from the tropics would require only modest CO_2 uptake in other forests to balance the budget for atmospheric CO_2 (Table 1).

Using an inverse model[5] of atmospheric CO_2 concentrations, Tans, Fung, and Takahashi (1990) suggested that the northern temperate latitudes were a net sink for carbon (2–3.4 Pg C/year), largely as a result of the regrowth of forests on abandoned agricultural lands. Similar conclusions have derived from other inverse modeling studies (Ciais, Tans, Trolier, White, & Francey, 1995; Denning, Fung, & Randall, 1995), and Fan et al. (1998) indicated that the sink in North America was as large as 1.7 ± 0.5 Pg C/year between 1988 and 1992. Satellite observations confirm an increase in forest production (NPP) in North America between 1982 and 1998 (Hicke et al., 2002). Battle et al. (2000) postulate a net global uptake of carbon by forests at 1.4 ± 0.8 Pg C/year in the mid-1990s – i.e., the uptake in the northern latitudes more than compensated for all the losses from tropical deforestation. Their results are consistent with other studies of changes in atmospheric O_2 (Bopp, Le Quere, Heimann, Manning, & Monfray, 2002; Keeling, Piper, & Heimann, 1996; Plattner, Joos, & Stocker, 2002).

Direct measurements from forest inventory confirm that temperate forests are a sink for carbon, and atmospheric CO_2 concentrations would be rising more rapidly without them. Houghton, Hackler, and Lawrence (1999) found an accumulation of 0.037 Pg C/year in U.S. forests during the 1980s, postulating a maximal upper limit for carbon storage at 0.35 Pg C/year if a variety of other processes, including greater carbon storage in soils, are included. Other workers have reported a net accumulation of 0.17 Pg C/year in eastern U.S. forests (Brown & Schroeder, 1999). Alternative estimates of 0.08 (Turner, Koerper, Harmon, & Lee, 1995), 0.2 (Birdsey, Plantinga, & Heath, 1993), and 0.28 Pg C/year (Goodale et al., 2002) for net carbon uptake in all U.S. forests; and 0.2–0.5 (Chen, Chen, Liu, Cihlar, & Gray, 2000) to 0.6–0.7 Pg C/year (Goodale et al., 2002) for all North American forests are similar to the North American sink determined by inverse modeling (Ciais et al., 2000). Participants in a recent workshop convened to reconcile the inverse modeling and inventory studies agreed that there was a sink of 0.30–0.58 Pg C/year in the United States during the 1980s (Pacala et al., 2001). European forests are also estimated to accumulate 0.135–0.205 Pg C/year – between 7 and 12% of that region's CO_2 emissions (Janssens et al., 2003; cf. Ciais et al., 2000).

In the face of large losses of carbon from tropical forests and only small recognized sinks in the temperate zone, we must postulate huge, recent, and unmeasured increases in the carbon uptake and storage in Siberian forests,

for which the causes are unclear. Kolchugina and Vinton (1993) estimate a net sink of 0.49 Pg C/year in forests and their soils in the former Soviet Union, and Ciais et al. (2000) suggest a sink as large as 1.3 Pg C/year over Siberia based on inverse modeling of atmospheric CO_2 concentrations. It is possible that carbon storage has increased in northern Eurasian forests in response to warmer climate and a longer growing season (Myneni et al., 2001; Zhou et al., 2001). Balancing tropical deforestation against temperate reforestation, it seems likely that the world's forests are roughly neutral with respect to the atmospheric CO_2 budget.

PROSPECTS FOR THE FUTURE

Changes in forest biomass and soil carbon storage have certainly affected atmospheric CO_2 concentrations in the past, and there is some indication that year-to-year variability in the accumulation of CO_2 in the atmosphere is affected by changes in the activity of the terrestrial biosphere (Bousquet et al., 2000; Houghton, 2000). Despite the disparity between inverse-model and inventory estimates of forest carbon storage, there is no doubt that the increase of atmospheric CO_2 concentrations would be even greater if it were not for forest regrowth in the temperate zone. Nevertheless, while these forests grow, CO_2 concentrations continue to rise. Can we expect, or orchestrate, more uptake by terrestrial ecosystems in the future?

The carbon uptake by forests is determined by their total area, as well as by factors that affect the rate of carbon accumulation per unit of area, including forest age. Total area is affected by land-management decisions and by increases in the spatial extent of forests, as determined by a warmer climate (Myneni, Keeling, Tucker, Astar, & Nemani, 1997). Changes in local carbon uptake are determined by climate, CO_2 fertilization, and the enhanced deposition of N from regional air pollution. Young forests show the most rapid carbon uptake, and the rate of carbon sequestration normally decreases with time (Law, Sun, Campbell, van Tuyl, & Thornton, 2003; Schiffman & Johnson, 1989). Separate studies using biogeochemical modeling (Schimel et al., 2000) and an analysis of historical forest inventory (Caspersen et al., 2000) agree that changes in land use have the greatest impact on the current net uptake of carbon by U.S. forests. However, Nemani et al. (2003) report that changes in climate have increased global net primary productivity by 3.4 Pg C/year during the past 18 years, largely in the tropics.

Keeling (1993) notes that the increasing amplitude of the annual seasonal fluctuation of atmospheric CO_2 means that some process has stimulated the biosphere – presumably by increasing rates of photosynthesis. However, there are several indications that the stimulation of photosynthesis by CO_2 fertilization, while widely observed in short-term experiments (Curtis & Wang, 1998), does not result in large increases in plant mass when the exposure is long-term and plants can acclimate to the higher CO_2 levels (Hattenschwiler, Miglietta, Raschi, & Korner, 1997; Idso, 1999). Subjected to Free-Air CO_2 Enrichment (FACE),[6] both loblolly pine and sweetgum forests showed greater than 15–25% increases in tree growth (Hamilton, De Lucia, George, Naidu, Finzi, & Schlesinger, 2002; Norby et al., 2002). In several CO_2-enrichment experiments, increases in the turnover of soil organic matter preclude large increases in the pool of carbon in the soil, despite greater inputs of dead plant materials (Hagedorn, Spinnler, Bundt, Blaser, & Stegwolf, 2003; Lichter et al., 2005; Schlesinger & Lichter, 2001; cf. Van Kessel et al., 2000a; Van Kessel, Horwath, Hartwig, Harris, & Luscher, 2000b). Thus, the early results of long-term field CO_2-enrichment experiments tell us to exercise caution in expecting a large enhanced carbon sink in terrestrial ecosystems as a result of rising CO_2 in Earth's atmosphere.

Increased deposition of N from the atmosphere might also stimulate the growth and carbon content of forests (Holland et al., 1997). However, the growth enhancement from N deposition may simply allow forests to attain maximum biomass more rapidly, rather than at higher final values. Excessive N deposition is often a cause of acid rain, leading to soil acidifications that can reduce forest growth. Simultaneous exposure to other air pollutants, such as ozone, may explain the relatively low-growth enhancements in forests of the eastern U.S. exposed to elevated N deposition (Caspersen et al., 2000).

Estimates of the N-derived sink need to be discounted to the extent that emitted N falls on non-forested lands (Asner, Seastedt, & Townsend, 1997; Townsend, Braswell, Holland, & Penner, 1996). Furthermore, only a fraction of the added N input accumulates in vegetation, where carbon-to-nitrogen (C/N) ratios are high and carbon storage is most efficient (Nadelhoffer et al., 1999; Schlesinger & Andrews, 2000). Nitrogen can be adsorbed to soil organic matter, lowering its C/N ratio without adding significantly to soil carbon storage (Johnson, Cheng, & Burke, 2000). Accounting for many of these effects, Townsend et al. (1996) estimate the N-derived carbon sink at 0.44–0.74 Pg C/year.

With reasons to suspect rather minor responses of forests to rising CO_2 and enhanced atmospheric N deposition, we must suspect that the regrowth

of trees on abandoned agricultural land is the most plausible cause of a carbon sink in the terrestrial biosphere of the temperate zone. A large amount of land in the eastern U.S. has reverted to forest since agricultural abandonment in the past century (Delcourt & Harris, 1980; Hart, 1968). These lands now support growing forests, which are accumulating CO_2 from the atmosphere. While reforestation of these lands may be helpful in mediating the rise of atmospheric CO_2 concentrations, it offers no long-term solution to the greenhouse-warming problem. It would require reforestation of all the once-forested land on Earth, including all the land that is now used for agriculture or covered by urban areas, to store 6 Pg C/year – the amount emitted each year from fossil fuel combustion (Vitousek, 1991). House, Prentice, and Le Quere (2002) conclude that the "maximum feasible reforestation and afforestation activities over the next 50 years would result in a reduction in CO_2 concentration of 15–30 ppm by the end of the century," when the global concentration will have risen to 700 ppm (Fig. 3).

MANAGING THE CARBON CYCLE

The IPCC (2000) panel on *Land Use, Land-Use Change, and Forestry* evaluated the potential for direct human intervention to enhance the storage of carbon in forests and soils, concluding that a significant potential exists to mediate the rise of CO_2 in Earth's atmosphere. However, many of the recommended management procedures, including afforestation and intensification of agricultural management, need careful scrutiny to ensure that the costs associated with the practice do not exceed the credits paid for increased carbon storage. The afforestation of marginal lands is likely to involve especially large uses of fossil fuel in planting, irrigation, and fertilization of young trees (Dixon, Winjum, Andrasko, Lee, & Schroede, 1994). Turhollow and Perlack (1991) calculate an energy ratio (i.e., energy in biomass grown/energy used) of 16 for hybrid poplar grown for fuel wood in Tennessee. Amortizing the initial cost to establish forestry plantations over a 50-year rotation, the cost of carbon sequestration ranges from $1 to $69 per metric ton, with a median value of $13 (Dixon et al., 1994). The rate of carbon storage in forests declines as they mature, so "the only way by which reforestation programs can continue to sequester carbon over the long term is if they transition into programs that produce commercial biomass fuels" (Edmonds & Sands, 2003) – that is, we must replace fossil fuel with biomass energy.

Implementation of reduced and conservation-oriented tillage practices in agriculture appears to offer a consistent net benefit by enhancing soil carbon storage (Kern & Johnson, 1993; Robertson, Paul, & Harwood, 2000; West & Marland, 2002); however, greater use of N fertilizer often does not (Schlesinger, 2000; but see West & Marland, 2003). The release of CO_2 by using fossil fuels to pump irrigation water also greatly exceeds the enhanced carbon storage found in irrigated agricultural soils (Schlesinger, 2000). Wildly positive forecasts (e.g., 0.4–0.8 Pg C/year) have been made for the potential to increase carbon storage in agricultural soils (Lal, 2001), but reality is not nearly so sanguine. Pacala et al. (2001) estimate that the carbon storage in cropland soils of the U.S. was only 0–0.04 Pg C/year during the 1980s. Ogle, Bredt, Eve, Paustian (2003) suggest a net increase of 0.0013 Pg C/year in agricultural soils due to land use change and improved management between 1982 and 1997. Kern and Johnson (1993) estimated that immediate implementation of conservation tillage on all U.S. farmland with this potential would provide a sink (less than 0.015 Pg C/year) accounting for only about 1% of the fossil fuel emissions in the U.S. at today's levels. Substantial areas are already in conservation tillage regimes (Uri, 1999), for which the net carbon sequestration potential is estimated at 0.0003 Pg C/year (Uri, 2000). Moreover, in a manner similar to the pattern of carbon storage during forest regrowth, storage in soils is finite, and the rate will diminish with time (Schlesinger, 1990).

More aggressive carbon sequestration projects seek to capture emissions from power plants and store this CO_2 in geological formations or the deep ocean. These projects will need careful cost/benefit evaluation, but they offer attractive near-term CO_2 mitigation alternatives while maintaining existing power-plant infrastructure (Lackner, 2002). Deep geological sequestration is a particularly attractive option because, unlike trees, geologic deposits store carbon in a form that will not return to the atmosphere for millennia (Holloway, 2001; Lackner, 2002). Proposals to store carbon in the oceans, either through direct injection or by using iron additions to stimulate marine productivity, will need careful evaluation to assess potential inadvertent impacts to the marine biosphere (Buesseler & Boyd, 2003; Chisholm, Falkowski, & Cullen, 2001).

CLIMATE CHANGE

If the Earth's temperature rises due to the greenhouse effect, we can expect soils to be warmer, especially at high latitudes. Except in some deserts, the

rate of decomposition in soils increases with increasing temperature – as seen both in compilations of literature values (Raich & Schlesinger, 1992) and nearly all studies that have imposed experimental warming (Rustad et al., 2001). The rate of soil respiration[7] [(Eq. 2)] doubles with a 10°C rise in temperature – that is, the Q_{10} of the relationship is about 2.0 (Kätterer, Reichstein, Andren, & Lomander, 1998; Kirschbaum, 1995; Palmer-Winkler, Cherry, & Schlesinger, 1996). The greatest response is found in samples of surface plant debris and in soils from cold climates (Lloyd & Taylor, 1994). Nearly all models of global climate change predict a loss of carbon from soils as a result of global warming (McGuire, Melillo, Kicklighter, & Joyce, 1995; Schimel et al., 1994). However, Melillo et al. (2002) suggest that the liberation of N during enhanced decomposition of soil organic matter may also stimulate plant growth and carbon uptake, partially compensating for the carbon losses from soils.

As a result of cold, water-logged conditions, large quantities of organic matter accumulate in boreal forest and tundra soils (Harden, O'Neill, Trumbore, Veldhuis, & Stocks, 1997; Trumbore & Harden, 1997). Radiocarbon measurements indicate limited turnover, but nearly all the organic matter is found in labile fractions that will be easily decomposed should the climate warm (Chapman & Thurlow, 1998; Lindroth, Grelle, & Moren, 1998). In the tundra, melting of permafrost and concomitant lowering of the water table may lead to a large increase in decomposition (Billings, Luken, Mortensen, & Peterson, 1983; Moore & Knowles, 1989). Indeed, Oechel et al. (1993), Oechel, Vourlitis, Hastings, and Bochkarev (1995) found evidence of a large loss of soil organic matter in tundra habitats as a result of recent climatic warming in Alaska, and Goulden et al. (1998) found a significant loss of carbon from soils during several warm years that caused an early spring thaw in a boreal forest of Manitoba. Recent measurements of European forests show greater respiration, and lower net carbon uptake, by forests at high latitudes, perhaps as a result of climatic warming during the past several decades (Valentini et al., 2000). In response to global warming, large losses of CO_2 from boreal forest and tundra soils could reinforce the greenhouse warming of Earth's atmosphere (Woodwell, 1995).

CONCLUSIONS

The IPCC (2001) offers a number of scenarios that predict the future course of atmospheric CO_2 concentrations (Fig. 3). The business-as-usual scenario shows emissions rising to 15 Pg C/year and atmospheric concentrations

rising to 550 ppm by the year 2050. Even the most rigorous abatement scenarios show concentrations of greater than 500 ppm in the year 2100, and nearly all scenarios show emissions in excess of 10 Pg C/year in the year 2050 (Fig. 4), dwarfing even the most optimistic scenarios for enhanced carbon storage in the terrestrial biosphere. Thus, if we are serious about preventing climate change, I see no alternative but to cut emissions, substantially and immediately. Alternative suggestions simply divert our attention from this problem, and precious time is lost in our attempt to control the emissions of this gas, which will otherwise take centuries for natural processes to remove from Earth's atmosphere.

NOTES

1. $1\,\text{Pg} = 10^{15}\,\text{g} = 1$ gigaton (Gt) = 1 billion metric tons of carbon.
2. The mean residence time is calculated as the mass of CO_2 in the atmosphere divided by the sum of the inputs (or outputs) to the atmosphere each year (Schlesinger, 1997).
3. It is curious to note that the annual storage of carbon in marine sediments is less than the carbon delivered to the oceans by rivers (Schlesinger & Melack, 1981), so that decomposition in the oceans appears to consume all marine production, plus a large fraction of the annual riverine transport. Thus, the oceans act as a net heterotrophic system (Smith & MacKenzie, 1987).
4. $1\,\text{ppm} = 1$ part per million $= 1\,\mu\text{l/l}^{-1} = 0.0001\%$.
5. Inverse models predict the atmospheric CO_2 concentration based on the latitudinal distribution of fossil fuel emissions and ocean uptake. Any difference between the predicted and observed concentrations is taken to result from sources or sinks in the land biosphere.
6. In FACE experiments, large plots of forest are surrounded by towers that emit CO_2, so that predetermined, elevated experimental levels are maintained 24 h/day, 365 days/year, allowing investigators to study forest growth under hypothetical future global conditions (Hendrey, Ellsworth, Lewin, & Nagy, 1999).
7. Soil respiration is the release of CO_2 from the soil surface, which is an index of decomposition (Schlesinger, 1977).

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WATCHING THE CANARY: CLIMATE CHANGE IN THE ARCTIC

John Weatherly

1. THE ARCTIC AND THE GLOBAL CLIMATE SYSTEM

The Arctic has been called the "canary in the coal mine" of the Earth's climate because of its sensitivity to climatic warming caused by increasing greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4). Evidence of a warming global climate is expected to appear earlier in the Arctic than elsewhere. At present, this evidence includes:

- Shrinking of the area extent of sea ice covering the Arctic Ocean and adjacent seas by approximately 1 million km^2 between 1975 and 2002, or about 10% of the average sea ice-covered area in the Arctic. This is similar to the U.S. losing an area the size of Texas.
- In September 2002, the sea ice-covered area of the Arctic Ocean reached the lowest recorded value since satellites began retrieving polar images.
- Changes in air temperatures over the Arctic that vary regionally from warming 1 °C per decade over Siberia and Alaska to cooling 1 °C per decade over southern Greenland.
- An increase in temperatures in permafrost (see description below) in Alaska and Siberia, and melting of permafrost in some locations.
- Thinning of up to 40% of the sea ice in the Arctic Ocean between 1958 and the 1990s that is coincident with warmer air and ocean temperatures.

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- A transition in northern Alaska from tundra vegetation to the woody shrubs typical of temperate climates.
- A decrease in the snow-covered area in the northern hemisphere in the winter.

Many of these changes associated with recent warming trends are seen as changes in the cryosphere, the part of the Earth comprising ice in different forms (and analogous to the Earth's atmosphere and biosphere). The cryosphere includes:

- Sea ice – frozen seawater (comprising ice floes usually 1–3 m thick) that floats on the surface of the Arctic Ocean and its adjacent northern seas and the oceans surrounding the Antarctic continent.
- Ice sheets – the largest masses of ice that cover most of the Greenland and Antarctica land masses, created by snow accumulating over 500,000 years. Ice cores collected by drilling into these ice sheets have provided valuable information about past climate changes.
- Glaciers – masses of accumulated snow in mountains or high-altitude plateaus, which can slowly flow down mountains in ice streams.
- Ice shelves – the portions of ice sheets and glaciers that extend over oceans and actually float in the ocean. Where ice shelves and glaciers flow into the ocean, they usually create icebergs, glacial (fresh) ice floating in the ocean, but different from (partly saline) sea ice floes.
- Snow cover – the seasonal snow over continental land areas.
- Permafrost – layers of soil that remain frozen year-round, underlying the surface soil layer that seasonally melts and refreezes.

In the southern hemisphere, the Antarctic continent is also experiencing a net loss in ice from the extensive glaciers and ice sheets that cover it. However, the connection between changes in Antarctic ice sheets and the global warming trend are much more uncertain than in the Arctic. The complex of changes in the Antarctic climate and the ice sheets are described in a later section of this chapter.

The decreasing areas of sea ice and snow cover in the Arctic are considered to be important early indicators of global climate change. Predictions made using global climate models show that the area covered by sea ice and snow is likely to decrease with increasing greenhouse gases. In addition, sea ice and snow produce several "feedbacks" on the climate, which can amplify the effect of increasing greenhouse gases. These feedbacks show how changes in the Arctic and the Antarctic can affect the rest of the globe.

To understand these feedbacks, consider that the obvious visible quality of the sea ice and snow is that they are white; fresh snow reflects up to 90%

of the incoming sunlight. This fraction of reflected sunlight is called the albedo, and ice and snow have the highest albedos of any naturally occurring surface on Earth. By reflecting most of the incoming sunlight, the ice albedo helps maintain cold temperatures in the Arctic. By contrast, the ocean around the ice has a very low albedo, and reflects only 5–10% of sunlight, so it absorbs up to 95% of the sunlight.

One feedback on the climate, called the ice albedo feedback, works like this: if air temperatures in the Arctic increase, some of the sea ice cover will melt. This exposes more of the ocean to absorb the incoming sunlight, which will warm the ocean (and the air over it) further, and cause an additional melting of the ice cover. At first glance, this feedback would seem able to continue indefinitely until all the ice disappears. In reality, given a warmer air temperature, the sea ice would melt and retreat farther north to where the ocean temperatures still reach the freezing point. This albedo feedback works in a similar fashion for snow cover on land: as temperatures rise, the snow cover is reduced, and the exposed land (which is darker) will warm up faster, and causes a greater increase in temperatures.

A less-obvious feedback, the "heat transport feedback," illustrates how warming in the Arctic and the Antarctic can contribute to warming for the rest of the globe. The Polar Regions act as a "heat sink" for the globe, by absorbing the excess energy that is absorbed in the tropics. Warming in the Polar Regions can weaken the transfer of heat between the heat source (tropics) and the heat sink (Polar Regions). This feedback can trap excess heat in the tropics and middle latitudes, adding to the climatic warming there. Studies with climate models suggest that warming in Polar Regions could cause as much as one third of the warming caused by the doubling of CO_2 over the rest of the globe.

The following section describes how the global ocean – the Earth's oceans and the system of currents that flow through them – might behave in a warming climate, and how that behavior also affects the Arctic. Later sections describe how the Arctic sea ice and the Antarctic ice sheets are shrinking, and examine whether computer models of global climate can prove whether these changes are caused by human activities or by other natural causes.

2. RAPID CLIMATE CHANGES AND THE "FLICKERING SWITCH"

The global ocean plays a significant role in determining the climate around the world. Because of its greater heat capacity, the ocean stores over 1,000

times more heat than the atmosphere. This heat capacity acts to moderate the seasonal temperature changes in the ocean and in the coastal regions with cooler summers and warmer winters than those observed farther inland. The ocean will generally act to dampen (or slow down) any rapid changes in temperatures caused by increasing greenhouse gases. However, it appears that some rapid changes in temperatures occurred in the past, and may have been caused by changes in the ocean circulation.

The circulation of ocean currents takes the heat absorbed by the ocean at low latitudes and moves it to higher latitudes. The warm water of the Gulf Stream, originating in the Gulf of Mexico, travels across the North Atlantic and ends up along the coast of Norway. This makes the climate of northern Europe considerably milder than Canada and southern Greenland, which are located at similar latitudes. When warm Gulf Stream water reaches the fringes of the Arctic it encounters the edge of the floating sea ice cover and near-freezing water flowing south from the Arctic Ocean. As the water cools, it sinks to the ocean floor and recirculates through the global ocean as deepwater. Eventually, this deepwater returns to the surface, forming what has been called the global ocean conveyor. The movement of deepwater is also called the thermohaline circulation, as it is produced by differences of heat (thermo-) and salt (-haline) in the ocean.

The warming of the global climate, in particular, the warming and melting of the Arctic ice pack, would reduce the cooling and sinking of water in the North Atlantic. This could potentially cause the global ocean conveyor to slow down or cease, in what has been called the ''thermohaline catastrophe.'' One theory is that slowing the thermohaline circulation will reduce the heat provided by the Gulf Stream to the North Atlantic, and cause this region, including northern Europe, to become significantly colder. A colder climate in Europe would have impacts, such as reducing access to economically vital ports in winter, reducing the growing season and increasing the energy usage for millions of people. It has also been suggested that a dramatic change in climate from a thermohaline catastrophe could happen within a span of 20 years. This theory was described in a National Academy of Sciences report by Alley (2002).

Evidence shows that, in the past, there were several rapid climatic changes in the North Atlantic. Ice cores from Greenland contain changes in their chemical composition over ice layers from a few decades that indicate changing temperatures.[1] Analyses of ocean sediments, pollen found in lake sediments, and the composition of seashells suggest a similar scenario: when the Earth was emerging from the last ice age (about 15,000 years ago), the warming trend reversed and returned to a colder climate for another 1,000

years, in what is called the Younger Dryas period. The chemical composition of microscopic shells in ocean sediments suggests that the deepwater temperatures and thermohaline circulation changed dramatically during this time, which may have triggered this rapid change in climate. The trigger for this change is thought to have been the release of freshwater into the North Atlantic from the melting of the North American (Laurentide) ice sheet. This cold, freshwater could have prevented the warmer, saltier Gulf Stream water from sinking, and caused the shutdown of the thermohaline circulation.

In light of this evidence, we might ask whether an abrupt climate shift is likely to happen in the future because of changes in the global ocean circulation. Although the evidence shows that rapid climate changes have occurred, the probability of similar changes occurring in the next 100–200 years is rather small. In terms of overall risk, the probability of such an event is small, but the consequences would be substantial. The trigger for a thermohaline shutdown would presumably be a rapid melting of the Greenland ice sheet. At present, Greenland is increasingly experiencing surface melt, but a rapid loss in Greenland ice mass has neither been observed to date nor been predicted by climate models for the next 100–200 years.

Could other triggers cause a shutdown of the global ocean conveyor, such as melting Arctic sea ice? Since the Arctic sea ice already drifts out of the Arctic Ocean and melts in the northern North Atlantic, melting the sea ice will not make the ocean fresher overall. However, as the global climate warms, the Arctic Ocean is expected to become fresher, because an increase in precipitation is expected to create greater river flows into the Arctic, which already receives about 10% of the global river runoff.

Proponents of the flickering switch theory in the ocean suggest that, even without melting the Greenland ice sheet, the thermohaline circulation may be in a quasi-stable state, balanced close to a transition to another state of thermohaline shutdown. Gradual increases in temperature and precipitation, like gradual pressure on a light switch, may cause an abrupt shift into a thermohaline shutdown. We cannot reliably predict with climate models whether such a sudden transition could happen in the near future; our present understanding of the ocean circulation, and our ability to accurately model it, is too limited.

Recent climate models that include global ocean circulations have predicted a decrease in the thermohaline circulation in the North Atlantic caused by increased CO_2 and a warming climate. This change is produced gradually with the change in climate, and not as an abrupt switch. Previous model studies have produced thermohaline shutdown by imposing very

different climatic conditions from the present. No models have produced a realistic simulation of an abrupt climate shift using climatic conditions from the present day to that expected in the next 200 years.

3. RECENT OBSERVATIONS OF CHANGES IN THE POLAR REGIONS

While there is a continuing scientific debate over the likelihood of a thermohaline shutdown, which might cool the North Atlantic and Europe, there are numerous observations of unusual phenomena in the Arctic and the Antarctic reported, which suggest that greenhouse warming is occurring. Some of these phenomena appear to be related to climate change, while some may simply reflect short-term weather extremes or the natural year-to-year (and decade-to-decade) variability of climate. In this section, we look at changes occurring in both the Arctic and the Antarctic that appear to be connected to climate warming and increasing greenhouse gases.

3.1. Thinning and Shrinking of the Arctic Sea Ice

The New York Times reported in August 2000 that two marine biologists accompanying a tourist cruise to the North Pole on a Russian icebreaking ship encountered an expanse of open (ice-free) water on reaching the pole. In their reports, the scientists described this advance as the evidence of climatic warming in the Arctic. Other Arctic scientists were not so convinced. This phenomenon occurred in midsummer, when the Arctic ice would normally include about 10% ice-free area, so the chances of having open water at the pole are approximately 1 in 10. The sea ice floes also drift with the ocean currents and winds, so the open water directly at the pole could have been covered with sea ice within a few hours of the biologists' observation.

What appeared more significant, however, was the fact that the icebreaker had reported thinner-than-usual sea ice on the transit to the pole. This observation is consistent with the more widespread thinning of sea ice across the Arctic Ocean, as shown by measurements of ice thickness obtained by sonar from submarine cruises under the ice. The ice thickness in the Arctic decreased from an average of 3 m (over the period from 1958 to 1976) to an average 2 m (in the 1990s), or by about 33% (Rothrock, Yu, & Maykut 1999). While individual ice floes in the Arctic can vary in thickness from less

than 1 to over 5 m, a decrease in the average thickness of Arctic floes from 3 to 2 m appears to be a significant change.

Could this thinning-ice trend be attributed to climate warming? It is possible, as the observations span several decades and cover a wide area of the Arctic Ocean. However, these submarine observations of ice draft are not continuous records through time; they are cruises separated by 20–30 years. The ice thickness over any one submarine cruise ranges from less than 1 m (for newly formed ice floes) to over 5 m (for older ice floes), and over 10 m for ice ridges. Additional submarine cruises show that sea ice north of Alaska also thinned by 1 m in the shorter interval between 1987 and 1991 (Tucker, Weatherly, Eppler, Farmer, & Bentley, 2001). This interval is coincident with the observed shift in the Arctic climate patterns called the Arctic Oscillation. The Arctic Oscillation shifted to a prolonged warm phase in winter 1987–1988, which lasted through the 1990s. This phase is associated with warmer air temperatures, lower air pressures, and a shift in ice motion across the Arctic, which can all contribute to thinner ice and a reduction in ice cover.

The Arctic Oscillation seems to be a natural pattern of variability in the Arctic climate, although the processes that control it are not yet understood. The warm phase from 1987 to 2000 is the longest warm period in the last 50 years of Arctic climate data, but it is not known whether similarly long periods occurred earlier than 1950. It is also possible that the warm phase of the Arctic Oscillation was caused by warmer global temperatures and increasing greenhouse gases. However, climate models do not show a consistent picture of how the Arctic Oscillation might behave as the climate changes.

While the data suggest that the Arctic ice has thinned by about one third over a period of 30 years, we cannot say unequivocally that the only cause of the thinning trend is increasing temperatures. The natural variations in the thickness of ice floes, and those variations produced by the Arctic Oscillation, are likely as large as the observed thinning trend. We can, however, compare these observed trends to simulations made by general circulation models (GCMs). In Section 4, we compare different scenarios of climate change with a GCM to assess whether the observed trends can be attributed to human activities, natural phenomena, or a combination of these.

3.2. Collapse of Ice Shelves on the Antarctic Peninsula

Between January 31 and March 5, 2002, satellite photos from the National Aeronautics & Space Administration and the National Oceanic & Atmospheric

Administration showed the rapid disintegration of part of the Larsen B ice shelf attached to the Antarctic Peninsula. Approximately 3,250 km^2 of the Larsen B ice shelf released 720 billion tons of ice into the Weddell Sea, in what may have been the largest ice release in the last 12,000 years. Ice shelves, such as the Larsen B, float on (or more accurately in) the ocean, extending from ice sheets and glaciers on land. While the volume of ice lost by the Larsen ice shelf is a small fraction of the total volume of ice in the Antarctic, scientists are concerned that these ice sheets are beginning to be impacted by rising global temperatures.

The polar ice sheets (both Greenland and Antarctica) have the potential to affect global sea levels through changes in the total volume of ice they contain. If the Greenland and Antarctic ice sheets were to melt, global sea level would rise by about 70 m, which would cover the most populated regions of the Earth. While the complete melting of either Greenland or Antarctica due to greenhouse warming in the next 100 years is extremely unlikely, the loss of ice from the polar ice sheets can still contribute to the acceleration of global sea level rise. The West Antarctic ice sheet (WAIS) is a "marine ice sheet" whose bedrock is well below sea level, which causes concerns that both rising temperatures and rising sea level could cause the WAIS to become unstable and to rapidly lose ice mass. The Antarctic Peninsula contains enough ice to raise global sea level by 0.3 m. In recent years, global sea level has been rising at approximately 1.8 mm/year. This rise is due to both long-term geologic processes (such as plate tectonic movement and gradual uplifting of continental areas rebounding from the last glacial period) and observed melting of alpine (mountain) glaciers. Losses in ice from the polar ice sheets may also be contributing to this sea level rise. Floating ice shelves, such as the Larsen ice shelf, already displace water, so the collapse of the ice shelves into the ocean does not directly contribute to the rise in sea level.

The changing heights of the Antarctic ice sheet have been measured in the last 20 years through a variety of techniques, including global positioning system stations, aircraft- and satellite-based radar, and laser altimetry. These studies suggest that the WAIS is likely thinning, and losing ice at a rate that adds 0.16 mm/year to the global sea level (Rignot & Thomas, 2002). The larger portion of Antarctica, the East Antarctic ice sheet, appears not to be gaining or losing much ice mass. The Antarctic Peninsula overall is losing ice mass at a significant rate through the observed disintegration of several ice shelves.

The recent observations of climate change in the Antarctic are quite different from those seen in the Arctic. Air temperatures over most of the Antarctic continent have not been warming, but, rather, have cooled in

several places. At observing stations along the Antarctic Peninsula, however, there has been a warming trend of as much as 1 °C per decade since the 1960s, as large as the trend in the Arctic. Since this region of greatest warming is also where the Larsen ice shelf and other nearby ice shelves have been breaking up, there appears to be some connection between the two phenomena. Glaciologists studying this region, however, do not know whether warmer air temperatures alone over the last 30 years could make these ice sheets disintegrate. Changes in these ice sheets often occur on geologic timescales of 10,000 years or more; little is known about whether rapid changes could translate into short-term changes in climate.

Also, in contrast to the Arctic, the sea ice surrounding the Antarctica has not significantly decreased in area since the 1970s. This suggests that air temperatures over the ice-covered Southern Ocean have not changed significantly over this period, except, perhaps, in the region surrounding the Antarctic Peninsula. The Peninsula region appears to be more susceptible to changing temperatures than the Antarctic interior because of its lower altitude and proximity to the equator.

Also complicating this picture is the theory that, as global climate warms, the atmosphere will contain more water vapor, and will transport more precipitation onto Antarctica. A warmer climate will likely produce an increase in accumulation of snow on the Antarctic ice sheet. Ice cores from both Antarctica and Greenland show that periods of warmer temperatures correspond to higher snow accumulation. However, as the climate warms, ice may be melting and thinning at a faster rate at the edges of Antarctica. There can be no reliable estimates as to whether the total amount of Antarctic ice will increase or decrease in the next 50–100 years, as the climate warms until scientists have a clearer picture of how fast the ice sheet is changing in response to warmer temperatures.

4. WHAT ARE GLOBAL CLIMATE MODELS?

The scientific assessment that the global climate will continue to become warmer due to increasing greenhouse gases is based on studies using global climate models, also called GCMs. What are global climate models, and how are they used in this assessment of greenhouse gas-induced warming? GCMs are large computer programs that produce a mathematical representation of the physical climate system, including:

a. Equations of motion of the atmosphere, i.e., winds, pressure, temperature, and air density.

b. Equations of heat and energy transfer in the atmosphere, including sunlight (solar radiation), infrared (thermal) radiation, and their effects on air, land, and water temperatures.
c. Equations for water in the atmosphere – water vapor, cloud formation (condensation), precipitation, and evaporation from the surface.

Many global climate models also include equations for the currents, temperature, and salinity of the world's oceans, as well as sea ice in the Polar Regions, hydrology, and other terrestrial processes. Since all of these components of the system interact, these models are also called coupled atmosphere–ocean–ice GCMs.

The temperatures, winds, and other variables in the equations are computed at every point on a spherical grid of the Earth, and at multiple heights (and depths) in the atmosphere and the ocean. The resolution of this grid, i.e., the distance between grid points, defines the spatial detail that the climate model can represent, just as a high-resolution photo or image can capture small-scale features that cannot be seen at lower resolution. At their present resolution of about 300 km between grid points, GCMs can capture large-scale weather patterns on Earth, as well as some of the day-to-day variations in weather. They cannot resolve smaller-scale weather features, such as hurricanes (though still large), severe storms, flash floods, or the details of narrow mountain ranges like the Andes or Cascades. Scientists have been improving the resolution of GCMs as the size and speed of supercomputers have increased. General circulation models are now able to simulate important phenomena, such as El Niño in the Pacific Ocean and its global-scale effects.

The equilibrium temperature of the Earth's climate – the temperature at which the incoming energy absorbed from the Sun balances the outgoing energy from the Earth in the form of infrared radiation – depends on the concentrations of greenhouse gases in the atmosphere. Increasing concentrations of the greenhouse gases can absorb more of the outgoing infrared radiation from the surface and increase air temperatures. Greenhouse gases that are included in recent GCMs include water vapor (the most abundant greenhouse gas), carbon dioxide, methane, ozone, nitrogen oxides, and chlorofluorocarbons (CFCs). The sensitivity of the Earth's climate to changes in greenhouse gases has been studied by comparing climate model simulations using different gas concentrations. These simulations show, in general, that doubling the present-day values of CO_2 concentration would produce a global average warming between 3 (1.5 °C) and 9°F (5 °C). The range of warming reflects the results of climate models that feature different assessments of the atmosphere, ocean, and sea ice, and different model grid resolutions.

5. ARE RECENT TRENDS IN THE ARCTIC CLIMATE AND SEA ICE CAUSED BY INCREASING GREENHOUSE GASES?

To address this question using a climate model, we have to examine several kinds of climate simulations. A climate simulation with increasing greenhouse gases can exhibit a shrinking ice cover. But can other natural or man-made factors likewise cause the ice cover to shrink? The Arctic Oscillation appears to have a strong influence on the Arctic climate. The energy and brightness of the sun has also increased slightly over the last 100 years, and this might explain most of the warmer temperatures. Also, changes in land use, such as deforestation and expanded farming, might also have an impact on climate. Using a climate model, we can test several of these possibilities, both individually and in groups, to see which factors might have the most impact on the climate and the Arctic ice.

An atmosphere–ocean–ice model was used to test these different factors by simulating the climate of a 120-year period from 1880 to 2000. One simulation included the known increase in CO_2 and other greenhouse gases. The second simulation kept the greenhouse gases fixed as a constant, but included the changes in solar energy over these years. A third simulation contained both the greenhouse gases and the solar energy changes. Furthermore, each of these three simulations was performed at least four times, so that the natural, random variations in climate were also included in this experiment.

A few details of these experiments: for the increasing-CO_2 simulation, the CO_2 concentration in the GCM was set as increasing from 280 parts per million (ppm) in 1880 (as suggested by ice cores) to 360 ppm in 2000 (from modern data). Other active greenhouse gases, such as methane, nitrous oxides, ozone, and CFCs, were also set according to the past observations, as was the coverage of sulfate aerosol pollution, which scatters sunlight and slightly cools the Earth's surface. For the simulation with natural (non-man-made) changes and constant greenhouse gases, the input of solar radiation was varied according to the estimated changes in the Sun's brightness over the last 100 years based on numbers of sunspots.[2]

The solar radiation is estimated to have increased by 0.2% between 1890 and 1960, decreased slightly in the 1970s, and increased again during the 1980s. In addition, aerosol amounts increased at periods following notable volcanic eruptions over the period from 1880 to 2000, which cooled the climate at irregular intervals.

The global average temperature is shown in Fig. 1 for the simulation with only natural forcing (sunlight and volcanoes) (lower panel), and for the simulations with the CO_2, greenhouse gases, and natural changes together (upper panel). Temperatures in the CO_2 simulation increase by about 0.8 °C over the period from 1890 to 2000, similar to the observed global average temperature data. The timing of the warming is also similar, with one-half occurring from 1900 to 1950, a level (or slight cooling) period between 1950 and 1980, and warming occurring from 1980 to 2000. The most recent 20 years show the most rapid warming, which results (in the model) directly from human-induced greenhouse gases. The simulation with only the natural forcing (solar and volcanic signals) shows warming only until 1950 from solar radiation. The solar radiation trend contributes notably to the overall warming before 1960.

The impact of greenhouse warming on the Arctic ice cover is shown in Fig. 2. In the simulation with increasing CO_2 (solid line), the Arctic ice area begins to decrease around 1970, and loses approximately 1 million km^2 by 2000. This downward trend is also notable because it falls below the range of natural year-to-year changes in the ice area (the gray band). This decrease does not occur when only the solar and volcanic forcings are included (dotted line). The observations of sea ice area also show a decrease in ice area of 1 million km^2 in the late 20th century. The ice areas in the model are, in both cases, larger than observed, because of the difficulty of making the global model simulate the ice cover perfectly.

The average thickness of the Arctic sea ice (Fig. 2, lower panel, solid line) in the CO_2 simulation shows thinning of about 5% in response to increasing CO_2 and warmer temperatures. However, the thinning ice in the CO_2 simulation is not as distinctly different from the natural forcing simulation (dotted line), and only drops below the natural year-to-year range of the simulations by the year 2000. Similar to the real Arctic, the climate model shows a large amount of natural variation in the ice thickness, and so reflects the difficulty of detecting a thinning trend in the Arctic ice. It does, however, show that the greenhouse gases in the climate simulation have produced a noticeable thinning trend. We do not have enough observations to plot the average thickness trend over the entire Arctic Ocean, but the data suggest that the ice has thinned by about 33%. This drop is significantly larger than the 5% reduction shown in the model, so it suggests that other factors, such as the Arctic Oscillation and solar forcing, are also adding to the thinning trend.

Overall, these simulations support the hypothesis that increasing greenhouse gases have produced the warming trend of the last 20 years. Increasing

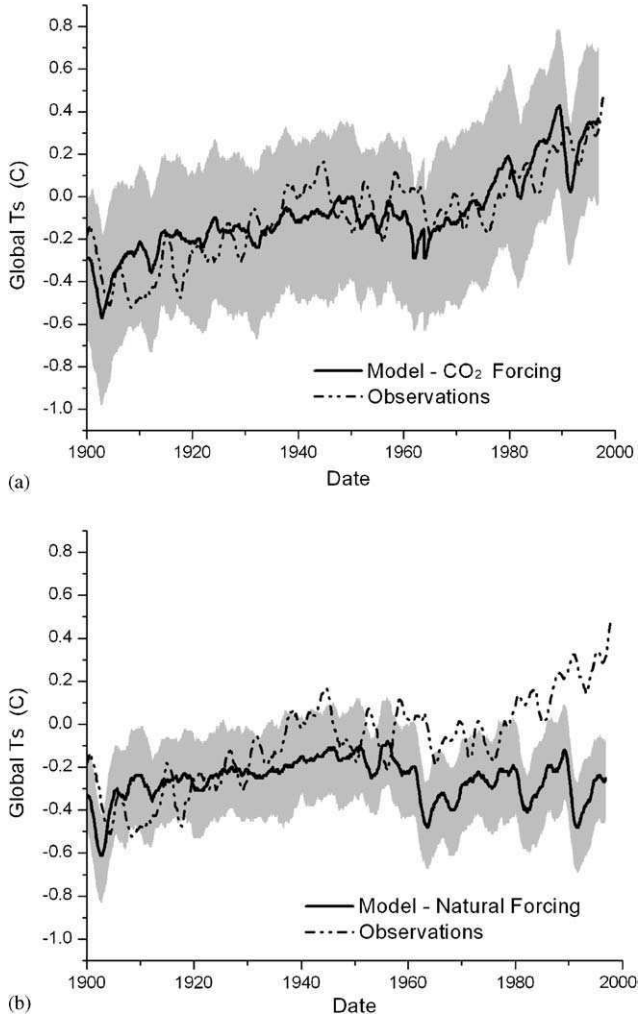

Fig. 1. (a) Global average surface temperature anomaly from the GCM simulation with increasing greenhouse gases (solid line) for 1900–2000, the observed temperature anomaly from the Intergovernmental Panel on Climate Change (IPCC) (dashed line), and the range of year-to-year variations in temperature from the GCM (gray band). (b) The temperature anomaly from the GCM simulation with only natural forcing (solid), the observed temperatures from the IPCC (dashed line), and the range of year-to-year variations in temperature from the GCM (gray band).

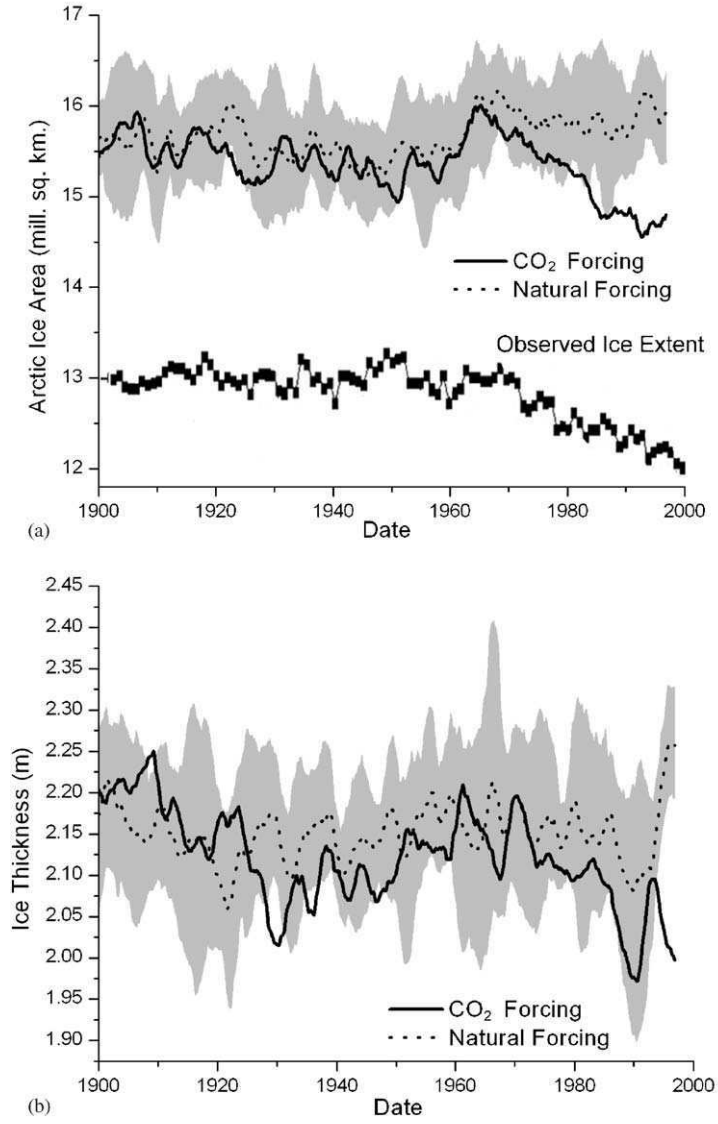

Fig. 2. (a) Arctic sea ice area from the GCM simulations with increasing greenhouse gases (solid line) and with only natural forcing (dotted line), and the range of natural year-to-year variations (gray band). The observed ice extent is shown for 1900–2000 (black boxes). (b) Arctic average ice thickness from the GCM simulations with increasing greenhouse gases (solid line) and with only natural forcing (dotted line).

greenhouse gases have also caused the shrinking and thinning of the Arctic sea ice, although natural changes like the Arctic Oscillation have contributed to the short-term changes in the ice pack in the last 20 years. These trends in the Arctic are only recently becoming clearly greater than the background "noise" of natural changes. However, the climate model simulations also show that the Arctic sea ice will continue to disappear with continued increases in greenhouse gases.

6. ARCTIC SEA ICE IN THE NEXT 100 YEARS

Carbon dioxide and other greenhouse gas concentrations are expected to continue increasing with the increased consumption of fossil fuels for power generation and transportation. While the rate of CO_2 increase is not always constant, it has effectively been 1% per year when the effects of different gases (methane, CFCs, nitrous oxides, and ozone) are accounted for. At this rate, the amount of CO_2 in the atmosphere will effectively double in about 70 years, to 720 ppm.

Scientists have run global climate model simulations with this 1% per year CO_2 trend for the years 2000 to 2100. The global mean temperature in the simulation increases by 3.2°F (1.8 °C) over the years 2000–2100, while temperatures in the Arctic increase by 9°F (5 °C). This polar amplification of the greenhouse effect, caused by the loss of sea ice and the ice albedo feedback, is one of the more consistent features of different climate model simulations.

The area of the Arctic sea ice shows a steady decrease in the future simulation, losing about 3 million km^2 (or about 30%) by the year 2100. Both the maximum ice area in the winter and the minimum ice cover in the summer are reduced by about 30%, meaning that, under these conditions, the Arctic would not (on average) become completely free of ice in the summer. However, when the range of natural year-to-year variations in the ice cover is considered in addition to the downward trend, the likelihood of ice-free periods in the Arctic increases substantially.

The remaining ice cover would also behave quite differently from the present-day ice because the remaining ice would be significantly thinner. The model shows that the thickness of the Arctic sea ice continues to decrease in the future simulation, losing about 25% of its present thickness by the year 2100. The simulation also shows short periods in which the ice thickness could increase. These short-term periods, which are a part of the natural climate oscillations like the Arctic Oscillation, demonstrate the difficulty in identifying

long-term trends from our limited measurements of the Arctic ice cover. Any 10-year period may exhibit a positive trend in ice thickness, while the long-term trend may be negative. These limited measurements also present a problem in terms of determining either long-term thickening or thinning in the future, if any steps are taken to stabilize or reduce greenhouse emissions.

7. THE IMPACT OF DISAPPEARING ICE ON ECOSYSTEMS AND PEOPLE

The continuing thinning and shrinking of the Arctic sea ice cover has numerous possible impacts on the Arctic ecosystem and the people who live within it. Many Arctic residents (human and nonhuman animals) depend on the natural resources on the land and in the oceans for food, shelter, and livelihood. Warming the Arctic climate impacts these resources at all levels. Residents have begun to encounter conditions with which they have no experience, and they have fewer resources to adapt than residents in the less extreme climates.

Nonhuman animals would likely be adversely impacted. For instance, the thinning of the Arctic ice presents a problem for polar bears at the top of the Arctic food chain. Polar bears spend much of their time on the ice hunting for seals. Thinning ice degrades their natural habitat by reducing the stable platform on which they live. The reduction of ice cover next to the coastlines in the summer also creates a larger barrier for bears to cross in search of food. Concern about the health of polar bears has increased in the recent years as biologists have noticed a large number of thin, young adult bears in search of food.

Caribou herds are also likely to feel the impacts of a warmer climate. Changes in the vegetation from typical tundra types to woody shrubs have been documented on the north slope of Alaska over the last 50 years. This indicates the degree of change in the habitat in the Arctic, and the sources of food that inhabit this ecosystem. The northward expansion of pests, such as mosquitoes, also suggests greater stresses on caribou and other animals, as well as potential insect-borne diseases.

Since many Arctic residents live in coastal communities, they are also sensitive to changes in the ice cover and ocean. In recent years, the thinner ice cover has presented an increasing hazard to Alaskan native whalers who camp on the ice to access the ocean. They have encountered the ice breaking up earlier in the season, before the normal migration of whales, and have on occasion needed to be rescued from breakaway ice floes. Travel on land has

also become more difficult with the warming and melting of permafrost and a longer summer season in which the ground is thawed.

The reduction of ice cover along the coastline also increases the coast's exposure to storm-driven waves and, in turn, contributes to the coastal erosion. In spring and fall, the ice cover that can protect the coast from large waves retreats. Combined with the trend of rising sea levels and the warming of the soil layers, this retreat is likely to give rise to an accelerated trend in the coastal erosion. The impacts on coastal communities include the costs of relocating and rebuilding critical infrastructure farther inland.

Both the economy and the environment may be impacted by the need to expand shipping along a more ice-free route in the Arctic. The potential for increased shipping activity along this Northern Trade Route along the Siberian coast, with a direct route between the North Atlantic and the North Pacific, may drive the development of northern ports and economic expansion to these regions. Similar to the past development initiatives, such as the Alaska Pipeline, this shift in trade route would provide a boost to the Arctic economies, but also adversely impact the environment and increase social pressures on the residents. The potential for greater contamination of these fragile regions also increases with expanded shipping, particularly with regard to oil transport. Since the Arctic is a region that encompasses many national boundaries, protecting this environment will require that international environmental protection efforts be expanded.

8. SUMMARY

The Arctic is a unique region that experiences extremes in climate, habitat, natural resources, and human adaptation to the environment. Numerous observations indicate that the Arctic is changing at an unprecedented rate. The most visible change is the loss, since the 1970s, of 10% of the sea ice cover, or an area about the size of the state of Texas. The Antarctic has also exhibited recent changes, including the dramatic collapse of several floating ice shelves and the warming trend over the Antarctic Peninsula. Although the loss of ice mass over regions of Greenland and Antarctica is contributing to the global sea level rise, the melting of alpine glaciers has made the largest contribution.

Climate models show that the loss of Arctic sea ice has most likely been produced by warming from increasing carbon dioxide and other greenhouse gases; these changes are likely to continue. Natural cycles of wind and ocean circulation and solar energy also affect the climate, but human-produced changes have become distinctly more significant in the last 20 years.

While the canary in the coal mine that is the early warning for the Earth's climate has become rather ill, it has not yet expired. However, based on climate model predictions, this canary will not likely recover to its previous size or condition if the concentrations of greenhouse gases in the atmosphere are not stabilized.

NOTES

1. Layers of ice (H_2O) in the Greenland and the Antarctic ice sheets contain different amounts of O^{16} and O^{18} isotopes. The heavier isotope O^{18} evaporates from the ocean at a slower rate than O^{16}. Snow accumulating on Greenland during warmer periods contains less O^{18} than in colder periods.
2. While sunspots appear darker on the Sun's surface, they are produced by solar flares and greater solar energy output. Sunspot abundance has an approximate 11-year cycle, which peaked recently in 1991 and 2002. The sunspot abundance in this cycle has been shown to vary by small amounts with estimates of varying solar energy toward Earth of $\pm 0.2\%$.

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PART 2:
ECONOMIC PERSPECTIVES

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CLIMATE CHANGE MITIGATION: PASSING THROUGH THE EYE OF THE NEEDLE?

Michael A. Toman*

INTRODUCTION

Anyone who follows climate change policy debates even casually knows that these debates are shot through with controversy about what ought to be done and who ought to be doing it. What sometimes get lost in these debates, however, are much deeper differences over the nature of the climate change problem itself. That is my focus in this chapter. I will take climate change as a prime example of broader debates over what constitutes ''sustainable development'' and draw upon different strands of the sustainability literature to show how these disagreements play out in the climate change context.

What are the elements of the ''climate change problem?'' Some of them involve scientific facts or judgments: the implications of rising greenhouse gas (GHG) concentrations for climatic conditions, and the implications of changes in climatic conditions for attributes of the biosphere that affect the

*I am grateful for the wisdom and advice of many colleagues with whom I have discussed and written about climate change and sustainable development. I alone am responsible for the ideas expressed here.

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nature of human existence. Some of these involve social and behavioral scientific judgments: how changes in energy prices, or various market ''barriers,'' might affect energy choices. But no less important are what Howarth (2000) has called the normative criteria for climate change policy analysis.

What makes climate change a ''problem?'' People approach this question with a variety of beliefs and sentiments and therefore with different emphases placed on various parts of the scientific and behavioral backdrop, including the large continuing uncertainties in that backdrop. If there were broad agreement on what makes climate change a problem, there would still be policy debate over the means for addressing it. For example, economists and technologists would still debate the extent to which regulations and energy prices can and should be relied upon to stimulate reductions in GHG emissions. But the debate would be more muted and more technocratic than today's debate over ends, which often remains loud and incoherent.

In this view of the issue, increased scientific understanding of the problem may be useful but it is hardly sufficient for achieving greater coherence. A fundamentally moral problem cannot be settled primarily through scientific investigation. Partisans on many sides of the debate over climate policy (the means) point to uncertainties about the risks and consequences of climate change to help support their positions. But perhaps what we do not yet understand well about ourselves is just as important as what we do not yet understand about the climate.

With these observations as backdrop, I turn first to a discussion of different ways in which the climate change mitigation problem has been characterized. The most familiar approach to economists is applied cost–benefit analysis. The economics literature is replete with such analysis, but the approach nonetheless is misunderstood on a number of occasions by both its detractors and its supporters. I then discuss what economics can tell us about the design of climate change policy and the linkages between means and ends.[1]

The conclusions I reach are inherently, and I believe unavoidably, somewhat contradictory. Consideration of costs and benefits of mitigating climate change, as well as of taking proactive steps to encourage adaptation to future climate change, is not just unavoidable but desirable. But how benefits of mitigation and adaptation are defined and measured (and, to a lesser extent, mitigation costs as well) is difficult and ambiguous. The moral dimension of climate change is unavoidable in the discussion of climate change policy. Economists and others who would rely on cost–benefit analysis as a tool for evaluating the climate change policy need to recognize this

complication in the definition as well as measurement of preferences for more or less mitigation (or adaptation). The lessons of economics for the design of climate change policy are less cloudy, I believe, and need to be brought forward more forcefully in current policy debates – with due regard for the underlying moral ambiguity surrounding the ends.

IDENTIFYING GOALS FOR CLIMATE CHANGE MITIGATION POLICY: AN ECONOMIC FRAMEWORK

As already noted, the standard framework for identifying the goals of climate change mitigation policy in an economics framework is applied cost–benefit analysis. As typically implemented, cost–benefit analysis compares costs of expected future adverse impacts from changes in climatic conditions – "damage costs" – and costs of taking actions to reduce these climatic changes, mainly through abating GHG emissions – "mitigation costs." The costs of adverse impacts as well as of mitigation are expressed in monetary terms. The "monetization" of damage costs is difficult, but it is accomplished in principle by trying to infer what a hypothetical "representative individual" would be willing to give up in terms of material consumption possibilities as part of a collective effort to achieve less adverse impacts. In practice, monetization of damage costs often involves piecemeal efforts to ascertain losses in productivity or direct effects on personal well-being, such as increased costs for avoiding or treating illness (see Tol, 1999, for an excellent example of such a synthesis effort). In some cases, it is possible also to adjust estimates of damages to account for prospective adaptation that individuals can be expected to undertake as they foresee and react to the consequences of climate change.

Mitigation costs largely derive from changes in energy systems to abate CO_2 emissions (fuel switching, conservation, improved efficiency), though cost–benefit models are increasingly looking at a broader (and therefore less costly) array of response options including control of methane emissions from decomposition of organic material in landfills, reforestation, and others. Here again there is uncertainty, though perhaps less so than with damage costs. The costs of achieving a particular degree of CO_2 mitigation can be substantial or moderate, depending on what is assumed about distortions in energy markets (like energy subsidies that encourage CO_2 emissions) and the costs of overcoming them, and the degree to which energy use can be reduced without cutting back economic activity through substitution of

other inputs (including knowledge that facilitates cleaner production processes). The costs rise, the more ambitious the mitigation target. This is an important consideration since stabilization of atmospheric GHG concentrations will require very significant global GHG reductions (or very low-cost and safe methods for collecting and storing emitted CO_2, which do not yet exist). The costs also depend critically on what is assumed regarding both baseline trends in energy efficiency that reduce CO_2 emissions per unit of economic activity, and the possibility that even modest policies to limit CO_2 emissions might engender substantial increases in GHG-saving innovation activity.

Good "integrated assessment models" containing modules describing the links among economic activity, GHG emissions, climatic consequences, and impacts of climate change acknowledge the incompleteness and uncertainty of damage cost and mitigation cost estimates. A key finding in many integrated assessment studies is that the level of damages may be less important vis-à-vis policy than the rate at which damages might rise over time as the climate undergoes more and more change (the "nonlinearity" of the risk). As illustrated by other chapters in this volume (see also Roughgarden & Schneider, 1999), scientists and policy analysts do have growing concerns about these nonlinearities. However, these nonlinearities are much more likely to arise over a longer period of time as accumulated GHGs in the atmosphere grow. In a shorter period of time, the threat of a highly nonlinear destructive response by the natural system seems rather remote.

It is easy to get caught up in a potentially technocratic debate over how well economic cost–benefit models do their cost and benefit measurements, following along the lines suggested by the preceding paragraphs. But this may not be the most important avenue for debate. It is necessary also to look more deeply at how the applied economic cost–benefit framework on which these models rests defines the climate change problem. To evaluate the severity of a particular climate change scenario, the models calculate the present value of the stream of future monetized damage costs using a particular "intertemporal rate of discount." Discounting of future costs and benefits in economic analysis is a well-established practice that reflects the common observation that people generally prefer current benefits over future benefits (and future costs in lieu of present costs). The discount rates assumed in the analysis affect the results as much or more than any other aspect of the cost–benefit approach.

This is sharply illustrated by the comparison of integrated assessment models undertaken by Manne (1996). Manne showed that even when damages from climate change were made both larger and more nonlinear,

integrated assessment models generally would determine an "optimal" trajectory of GHG emissions (or of mitigation effort) that allowed for slower but continued rise of emissions for many decades, if not indefinitely. This kind of outcome would hardly be seen as "sustainable" by most noneconomists who argue in climate policy debates for the need to rapidly arrest and reverse the trend of global GHG emissions growth. The exception to this general finding with the models occurs when the models assume a near-zero rate of discount. In this case the weight of accumulating damages over a very long period of time does cause the models to generate more aggressive GHG mitigation trajectories.

Discounting is among the most complex and least understood aspects of the integrated assessment framework and of cost–benefit analysis applied to long-term problems more generally. One line of argument on the right way to handle discounting in this context concerns the need for discounting to reasonably reflect the alternative return on capital that is redirected to GHG mitigation from other uses, in order to ensure that society gets the best value for its money. ("Society" in this sentence is a slippery term, as indicated below.)[2] However, the choice of a long-term discount rate in the models based on a typical individual's impatience for current over future benefits treats the evaluation of societal interests in climate change as if they were the interests of a fictitious individual who lives forever. This in turn defines a critical moral aspect of the climate change problem: a consideration by people today of the potential impacts and opportunities experienced by people in a climate-changed future. A question of intergenerational distribution is wrongly subsumed in a conventional present value analysis into hypotheses about intertemporal time preference.

This important distinction between intertemporal economic efficiency and intergenerational distribution was brought out clearly over a decade ago in the work by Howarth (see Howarth, 1996, 1998, and the chapter by Howarth in this volume for further discussion), and it applies with particular force to the climate change issue. Some scholars such as Schelling (1997) are not greatly perturbed by this observation, largely because they believe that adaptation to a changing climate will not pose a great difficulty, especially as the world keeps getting richer, and that there are many other greater problems competing for attention today, especially in poorer parts of the world. The emphasis in this perspective is on both the opportunity cost of capital to avert what is seen to be a lower-scale risk and the seemingly illogical focus on such a risk while revealing greater indifference to current problems of development and environment. This argument is greatly annoying to many advocates of more aggressive GHG mitigation policies, but it is valuable

because it forces those who advocate such policies to keep their eye on the ball.

A sharply contrasting view can be inferred from the "Faustian bargain" perspective that Kneese (1999) brought to the debate over nuclear power.[3] This perspective easily maps over to climate change. Kneese observed that it would be virtually impossible for human beings to design today containment systems for high-level radioactive waste that would survive the tens of thousands of years necessary for such wastes to become acceptably "cool" in terms of their risks to humanity. Therefore, Kneese argued that expanding nuclear power use today necessarily confers on long-term future generations a risk whose mitigation we cannot fathom today, given our current knowledge and technology. We can go ahead with the inflicting of that risk, professing confidence that over such a long period of time, human ingenuity will find a way to deal with it. For Kneese and others following in his footsteps, however, such actions give rise to deep ethical concerns. These concerns are echoed today in work by people in many disciplines on different aspects of stewardship, sustainability, and climate change.[4]

My concern here is not with the rightness of any of the views sketched in the previous paragraph. These different perspectives simply serve to highlight a moral dimension of climate change that can be lost in a simple aggregate cost–benefit approach. While it is possible that a more discriminating approach could be found just by reducing scientific uncertainty (for example, some persuasive demonstration that climate change is a lot less risky than previously thought), it seems more likely that we need to look at other perspectives to glean and weigh the moral implications.[5]

Before proceeding, we should note that the focus here and elsewhere in the debate on intergenerational consequences of climate change obscures some important intragenerational issues that should not be neglected. It is now widely perceived that climate change damages will fall disproportionately on the future poor. These individuals would put a higher relative value than would the rich on additional material consumption opportunities they would have in the future if there were less adverse impacts from climate change. Therefore, to reflect this distributional feature of the problem, long-term discounting of climate change damage and mitigation costs should be at a lower rate than might otherwise be used if one simply took the average time preference of all persons, rich and poor (Azar & Sterner, 1996).

Much of the current international debate over mitigation policy targets stumbles on distributional issues as well. The United Nations Framework

Convention on Climate Change (UNFCCC, 1999a) in effect expresses the view that ability to pay should be a key influence on what people of different standards of living are asked to do. For many poor people, the challenge is an improved standard of living that may demand increases in GHG emissions. If we start with some target for long-term GHG concentrations in the atmosphere (based on aggregate economic cost–benefit considerations or other normative criteria), and the view that developing countries deserve a growing share of a shrinking emissions pie, then the developed countries must do that much more to reduce their own emissions and finance initiatives to slow emissions growth in poor countries. This in turn leads to a kind of retroactive liability argument for past GHG emissions that developed countries have stoutly resisted.

IDENTIFYING GOALS FOR CLIMATE POLICY: A PLURALISTIC APPROACH

One way to address the seeming moral incompleteness of standard cost–benefit analysis for describing the climate change problem is to work within some kind of intergenerational rights framework, with reciprocal duties on the part of people today to respect those rights. A rights approach can be defined in a variety of distinct ways. Here, I want to focus first on approaches that see the current generation as having obligations to protect the potential well-being of persons who will come into existence in the future. This approach in principle can retain much if not all of the integrated assessment approach to climate change cost–benefit analysis, while taking a different view of how costs and benefits should be distributed over time. The focus remains on the impacts and opportunities experienced by people today and those who may be living in the future.

Reference in the rights-based literature is often made to Rawls' (1971) system of justice, though it implies concern for the least well-off and can be interpreted in an economic context to imply a constraint of nondecreasing well-being (or potential well-being) over time. Economists have further addressed the issue by noting that changes in the utility of successive generations can in principle be affected by changes in intergenerational wealth endowments, in that greater intergenerational concern in the face of climate change can be expressed by bequeathing to the future some mixture of lower GHG concentrations in the atmosphere, the capital stock necessary for maintaining such low concentrations (like renewable energy systems), and greater capital accumulated for adaptation.[6]

"Stewardship" is a popular word in some of this literature. Legal scholars like Weiss (1989) have argued for a moral as well as a legal obligation to keep the potential for future well-being intact over generations; and given the uncertainties about the ability to do so with a radically changed climate, they add a corollary obligation to maintain tight limits on the size and speed of climate change. An older focus of stewardship in various theological literatures (the need to protect God's creation, not just have dominion over it) also has come to the fore in many modern writings. See the work of Daly and Cobb (1989) or Brown's (1998) argument for a stewardship economics, though neither of these works are driven exclusively by theological arguments.

Various constructs of the "precautionary principle" similarly are invoked in discussions of sustainability, intergenerational allocation, and fairness. The principle is rooted, at least implicitly, in the prospect that large and discontinuous adverse effects of climate change could occur, and that a degree of risk aversion on the part of the current generation of actors and decision makers is appropriate to mitigate the risks of setting in motion such effects.

Stewardship ideas and the precautionary principle can be used to define criteria based relatively directly on the physical world. One can imagine these approaches being implemented with a set of physical indicators describing what are or are not acceptable changes in the climatic system. An example is the "safe corridors" approach to defining targets for GHG mitigation: one compares various scenarios for various ways that GHG emissions and the natural world could evolve, excluding all those that involve GHG concentrations that grow beyond a pre-determined level or grow too fast. Then, and only then, does one consider the economic consequences of different paths.

As with the cost–benefit approach, a number of important technical issues can be raised here. One can argue in principle for the idea of protective intergenerational resource transfers from the present to its descendants as described above, and then confront the practical difficulty of how to actually arrange this institutionally. The composition of the intergenerational transfer also can be debated. Advocates of "weak sustainability" argue that so long as aggregate wealth is maintained, an intergenerational transfer can allow substantial modification of the climatic system provided other forms of social investment are made (including adaptation to climate change as well as other socially beneficial activities). The "strong sustainability" approach would rely instead on more stringent climate protection through more aggressive GHG mitigation.

Notwithstanding these kinds of questions, many people seem to embrace ideas of stewardship and the precautionary principle, in their hearts if not always with their pocketbooks. These ideas strike a deep emotional chord. Moreover, they seem to define obligations in ways that are relatively straightforward to apply. So why do these approaches not rule the roost?

As with the cost–benefit approach, we can address this question partly by asking some more fundamental questions about how well this kind of intergenerational contracts or obligations approach seems to capture the climate change problem. Can we make sense out of obligations to potential future beings? It is easy to say this is only a metaphor; but it becomes more than a metaphor when we start to think about how large the intergenerational transfers ought to be. The identities of these potential future people obviously cannot be known to us in advance, and our degree of kinship with these people may exist at varying levels and for varying reasons. A number of philosophers writing about what has come to be called the "identity problem" have wrestled with the extent to which it is possible to meaningfully define moral obligations to potential persons.[7] Moreover, at least some rights-based intergenerational contracts are hard to reconcile with the idea of intertemporal preference consistency. If we care as much for the future as we do for ourselves, why do we not act even more aggressively for the greater good of our descendants in lieu of ourselves? And if we do not, are we not led back to some kind of intergenerational discounting that seems to confound the moral compass with cost–benefit analysis?

One key difficulty is in determining what level of stewardship or risk avoidance is morally appropriate. Individuals may believe deeply that we should leave the world better than we find it and take steps to avoid peril to the earth, but there is still some limit to what people will commit to such actions. In practice, safe corridors for the evolution of the climate system incorporate limits on the cost to be borne in carrying out mitigation.

Once cost considerations enter the picture, one is not so far from the balancing envisaged in cost–benefit analysis – though the way costs and benefits are weighed may be far different from a simple present value criterion. I believe that consideration of benefits and costs is unavoidable. How their impacts are assessed is what differentiates one approach from another. The conclusion that benefits and costs must be "considered" when judging climate change policies does not mean I advocate a simple, one-dimensional benefit–cost test for climate change policies. In practice, decision makers can, will, and should bring to the fore important considerations about the equity and fairness of climate change policies across space and time. Decision makers also will bring their own judgments about the relevance,

credibility, and robustness of benefit and cost information and about the appropriate degree of climate change and other risks that society should bear. The argument in favor of considering both benefits and costs in part is that policy deliberations will be better informed if good economic analysis is provided. But there is a need also for a methodological pluralism in addressing the definition of the climate change problem in a way that combines both logic and passion, the dual forces that figure in any other important human question.

In assessing mitigation costs that the current generation will experience, it is important to consider carefully all the relevant opportunity costs, including the foregone returns from other uses of capital (and any ancillary benefits that can be registered as negative costs, like local air pollution reductions). Damage costs (the benefits of mitigation actions), on the other hand, need to be assessed in a way that gives full voice to the concerns we may feel for the future, whether that future is sensed in terms of descendants or ecological conditions.

Here, we run into a number of additional complications that further strengthen the case for methodological pluralism in defining normative criteria for climate change policy analysis. The impacts being assessed are extraordinarily complex in terms of their nature and timing, compared even to other environmental concerns and certainly in comparison to more conventional consumption-savings decisions. They involve interpersonal and collective evaluations of several types that will be seen very differently by different people. Moreover, it seems likely that what people want to do vis-à-vis protection of future beings and ecological conditions (whether we call these wants preferences or moral sentiments) will change over time with changes in experience and interaction with others. The elucidation of such wants inherently is a social process, one moreover that can at least somewhat reshape the very wants being investigated.

It is easy to imagine this somewhat amorphous approach becoming a refuge for scoundrels. The passion that people bring to debates over the climate problem and potential solutions can be uplifting or oppressive. Many disciplines, most especially economics, can help propel the debates in productive directions by pointing out clear errors or inconsistencies in valuation. But at the end, I see no alternative to complicated and possibly ambiguous social processes for passing through the eye of the needle on this issue.

"Two-tier" conceptual frameworks provide one conceptual basis for structuring a pluralistic approach, though there are still serious operational problems to be overcome in using them (see Toman, 1994; Norton &

Toman, 1997 for discussions).[8] In this sort of framework, decision makers must first consider what criteria and management tools to apply to a particular issue. It is presumed in the framework that human impacts on the environment that are larger in scale and longer in duration give rise to greater concerns about the opportunities for well-being available to future generations (as well as to ourselves), and about the opportunities for amelioration of adverse effects through resource substitution and innovation. Impacts that are smaller in scale and shorter in duration give rise to less concern and thus are more amenable to being treated through conventional cost–benefit tools, supplemented with information about nonmonetizable impacts and distributional consequences. In other cases, standard economic calculations are more likely to need supplementing with information about the physical robustness of underlying ecological systems and the potential consequences over time, and by information about social norms (e.g., basic presumptions about fairness to existing communities and future generations) that might be affected.

We can briefly illustrate these ideas in the context of climate change. Climate policies undertaken by the current generation will impose costs (and generate some ancillary benefits, like local air quality improvements) for the current generation. These costs should be assessed to the extent possible using the best state of the art in economic analysis, including procedures for intragenerational discounting that reflect the opportunity costs of changes in consumption and investment streams. The benefits of action or the costs of inaction, on the other hand, are more complex to assess since they involve significant redistributions of income between current and future generations; they will accrue globally, not just to our own heirs; they are difficult to estimate; and they will depend on the actions taken – for example, actions to reduce future risks by limiting GHG emissions versus actions to promote adaptability to future climate change that can also provide more immediate economic development benefits. Simply calculating the present value of these effects as they appear to the current generation does not provide an adequate basis for evaluating different outcomes. An alternative is to provide a description of the effects (monetary and otherwise) and their timing, and allow decision makers to weigh these effects and their costs against a variety of ethical criteria and the expressed wishes of various stakeholders.

This approach uses multiple normative perspectives in the first tier to assess how an issue should be judged, and then in the second tier in evaluating the issue and decisions (with a mix of perspectives that varies depending on the first-tier outcome). This is not just an application of "scientific" policy analysis, as is underscored by the fact that value judgments will permeate the

first-tier categorization decision making as well as guide the second-tier evaluation. The process thus can operate only if it is superimposed on a mature ongoing social discussion about which values matter in which contexts. This superimposition enables an interaction between science, on the one hand, and the process of values formation and education, on the other.

To go further along these lines, we can envision an approach to considering and determining climate change policy goals that is not only pluralistic and multitier but also iterative, to reflect the processes of learning and value formation. The process might take the following general form:

1. Prior assessment of what criteria and evaluation tools should apply to the issue. In the two-tier model sketched above, this amounts to assessing where the issue lies on a continuum between a simple analysis of economic trade-offs and an analysis more circumscribed by physical limits on substitution and the operation of broader social norms, which themselves must be identified.
2. Assessment of physical impacts from different courses of action to the extent possible, with particular attention to their scale, the identification of impacts that are difficult to evaluate in monetary terms, and distributional issues across space and time.
3. Assessment of economic benefits and costs from different courses of action to the extent possible, as well as their incidence in space and time.
4. Further identification of whether and how social values or norms beyond the quantified benefits and costs may be affected by a decision.
5. Engagement of public discourse about both the consequences of different actions and the applicable social values, especially where operable norms are not clear-cut or are conflicting. This is a step in explicitly acknowledging that the decision process cannot be purely scientific. The public engagement can take various forms, from educational programs to multiple-stakeholder negotiations to interagency debates characterized by disclosure and electoral accountability.
6. Decision making based on the pluralistic approach and criteria outlined above.
7. Using the results of the decision process to consider what new information and uncertainties have been revealed about both science and social values, and plugging these insights back into both the values discourse and scientific research agendas.

Discussion of climate change and of sustainability more generally rests on a wide range of different conceptions, emphasizing substantive economic,

ecological, and social concerns as well as procedural issues. These various conceptions are based in turn on various sets of values, i.e., perceived differences in the importance of economic well-being, ecological integrity, and social legitimacy. This underscores again that debate on sustainability cannot be resolved solely by recourse to scientific inquiry. For example, substantial progress in resolving uncertainties about the effects of GHGs on the world's climate system, and the effects of climatic changes on ecological systems and human well-being, will not in itself address basic disagreements about the importance of humans versus nature.

Governments and other decision makers continually seek to reduce factual uncertainties in order to support "better" decisions. This can be seen in the attention paid to the quality of science underlying major regulatory and other policy decisions in debates within the United States on environmental issues generally, not just climate change. Efforts to improve scientific understanding are important contributions to better decision making. However, such efforts also can mask deeper and more complex disagreements about social values.

Even in the domain of scientific inquiry, moreover, value judgments are not absent. Prior assumptions about what is important implicitly guide the structuring of scientific inquiry. For example, if one takes the view that ecological systems are organized hierarchically according to scale, the study of these systems at the micro-scale (the function of a single leaf) will differ from the study of these systems at a macro-scale (the biome), and there is no scientific basis for preferring one level of inquiry over another (Norton, 1992).

The fact that science is not and cannot be entirely value-free does not imply that science must be subservient to values in sustainability, or that established measures to test and validate scientific hypotheses must be discarded. Instead, I would argue that science and values need to be seen as two sides of a recurring process in which increased information about the natural world and human impacts leads to a reconsideration of values, which in turn leads to a refocusing of science as needed to address emerging policy issues. This recursive process ensures not only that scientific inquiry is focused on issues that need to be addressed in forming policies, but also that new scientific insights find their way into the policy debate and stimulate constructive reevaluations of existing positions.

DESIGNING CLIMATE POLICY INSTRUMENTS

Climate change policies need to reflect, among other factors, inherent tradeoffs between the stringency of a target (however defined) and the flexibility

offered by policy to meet the goal. Different policy tools can inflate or attenuate the costs of hitting any given target. Inflexible, inefficient policies will inflate costs without additional reductions in climate risk. Well-designed policies will lower the cost of achieving any particular targets and thereby make more stringent targets affordable. One of the principal contributions of the economic approach to GHG mitigation policy is the attention it has drawn to economic policy tools that work cost-effectively, in tandem with clear standards and adequate monitoring and enforcement capacity, to create incentives for GHG mitigation while maintaining flexibility in the means used.

Economic tools help cut the costs of achieving a GHG emissions target because they generate a market price for GHG emissions, which are otherwise treated as having no social cost. This price creates tangible financial reasons to reduce carbon emissions while providing flexible means to do so at a lower cost. Emissions taxes and rights to emit GHGs that can be bought and sold are economists' favorite incentive tools. Consumers respond to the price signals that these policies represent by switching to less carbon-intensive fuels (for example, natural gas for coal); increasing energy efficiency per unit of output by using less energy-intensive technologies; adopting technologies to reduce the emissions of other GHGs (assuming they are covered in the policy program); reducing the production of what have become high-cost, carbon-intensive goods; increasing the sequestration of carbon through reforestation; and developing and refining new technologies (for example, renewable energy resources) for avoiding GHG emissions.

Carbon can be taxed indirectly by taxing fossil fuels. Taxing fossil fuels works because their carbon content is easily ascertained, and no viable option for end-of-pipe carbon abatement (for example, scrubbing) currently exists (though this could change in the future). A fossil fuel tax could be collected in several ways: as a severance tax on domestic fossil fuel output, plus an equal tax on imports; a tax on primary energy inputs levied on refineries, gas transportation systems, and coal shippers; or a tax downstream, on consumers of fossil fuels. However, the farther upstream the tax is levied (that is, closer to the producers of fossil fuels), the less the amount of carbon that might leak out through uncovered activities such as oil field processing. Implementing such a tax would be relatively straightforward in the United States and most other developed countries, given the existing tax collection systems, but more challenging in developing countries that have less effective institutions for levying taxes and monitoring behavior.

Carbon trading is somewhat more complicated than a carbon tax. One has to decide where to assign property rights for carbon: downstream, upstream,

or some combination of the two. In principle, a downstream approach encompasses all emissions. In practice, however, all people in the United States who heat their homes with fossil fuel and/or drive a car would be required to buy and sell carbon permits. Operating and overseeing such a market would be an administrative nightmare. In contrast, an upstream system would be easier to administer because the number of market actors is smaller. Comprehensive policy would have to account for imported refined products as well as domestic fossil energy supplies and to address noncombustion uses of fossil fuels (for example, chemical feedstocks). One possibility is a system in which emissions of large sources are regulated directly and small sources are regulated through limits on their fossil fuel supplies. Or, a carbon tax could be levied on the energy used by smaller sources.

Questions about how to distribute permits also complicate carbon trading. A government could sell permits to the highest bidders in an auction-style system, hand them out gratis according to some formula such as grandfathering (that is, the government assigns permits to existing emitters relative to a historical base year), or combine the two approaches somehow. The choice would force policy makers to address trade-offs among goals of economic efficiency, distributional equity, and political feasibility. Efficiency increases with greater auctioning (or with recycling of carbon tax revenues) because the revenues can be used to offset existing distortionary taxes (Parry, Roberton, & Goulder, 1999). Gratis permit allocation can target the distribution of a valued commodity toward the people most adversely affected by the policy (for example, low-income households and coal miners) or to those wielding the greatest political influence over the distribution of trading profits and losses. This option no doubt could increase the political feasibility of a trading policy. Bovenberg and Goulder (2000) provide some simulation analyses that suggest that the cost of compensating fossil fuel-producing companies and their shareholders for losses resulting from reduced sales under a carbon-trading system is not very large. The cost increases, of course, if policy also seeks to compensate fossil fuel-intensive industries and the affected workers.

Which GHGs to address beyond CO_2 is another issue that both trading and taxation policies can address. For instance, the appropriate tax on natural gas entering the pipeline system could account for leakage and the greater relative global warming potency of methane. Levies also could be placed on methane releases from coal mines and landfills and on human-manufactured gases on the basis of their expected venting to the atmosphere through sources such as automobile air conditioners. Some gases will be more difficult and costly than others to measure and control. A prime example is

the capture of decentralized sources of agricultural methane that would be costly to measure.

Tax or trading systems also could be extended to carbon sequestration activities such as reforestation programs, in which participants could earn tax credits or garner additional emissions permits. The challenge is to define a credible baseline to measure the amount of carbon sequestered by the forest. For example, one does not want a system that rewards carbon sequestration that would have occurred any way as part of forest rotation practices, or a system that encourages deforestation so that landowners could then claim credit for replanting trees.[9]

GHG trading can be extended around the globe. Economic theory says that global trading can generate mutual gains by allowing low-cost abaters to profit from selling permits to grateful high-cost abaters. The 1997 Kyoto Protocol (UNFCCC, 1999b) allows for both formal GHG trading among developed countries and bilateral trading between developed and developing countries through the Clean Development Mechanism (CDM). Under the CDM, emissions reduction activities in developing nations without national limits on GHGs can generate emission reduction credits for developed nations. These endeavors could be organized and financed by developed country GHG emitters, the developing countries themselves, and international third parties.

The CDM could generate both low-cost emissions reductions for developed countries and tangible benefits to the host country through the transfer of efficient, low-carbon technology. However, many obstacles remain. The key immediate question is how to design a credible monitoring and enforcement system that does not impose such high transaction costs that it chokes off CDM trades. People will not start a project if the time, effort, and financial outlays needed to search out, negotiate, and obtain governmental approvals are too onerous. The economics perspective emphasizes the importance of considering such ''transaction costs'' in the design and evaluation of the policy regime.

Rules for ''banking'' and ''borrowing'' carbon permits are another key component of a trading system. Banking lowers costs by allowing traders to hedge against risks in emissions patterns (for example, a colder-than-average winter), and to smooth out fluctuations in abatement costs over time. With borrowing, traders have more flexibility to respond to unexpected short-term increases in abatement costs, thereby spreading the economic risk of compliance across time. Intertemporal flexibility lets private actors reach a target more cost-effectively by adjusting their abatement strategies to minimize costs over time (Kosobud, Daly, South, & Quinn, 1994).

Banking and especially borrowing flexibility raise the more fundamental issue of how to set credible long-term targets while facilitating short-term adjustments. Critics doubt the credibility of processes that focus only on longer-term targets. They argue, for example, that a firm's natural tendency to delay emissions control to the future could impose unacceptable future climate change costs and make targets unenforceable.

This issue may be subsumed into a larger question where there is a crossover in the discussion between means and ends of climate policy: when should GHG reduction take place – now or later? Costs of GHG control depend on the speed of control as well as its scale. Wigley, Richels, & Edmonds (1996) showed (as have many studies thereafter) that most long-term target GHG concentrations could be achieved at substantially lower present value costs if abatement were increased gradually over time, rather than rapidly, as envisaged under the Kyoto Protocol.[10] These cost savings come about not only because costs that come later are discounted more, but also because less of the existing capital stock becomes obsolete prematurely. In addition, the unit cost of GHG control in the future may be lower than in the present, as a consequence of presumed continuation in trends toward greater energy efficiency in developed and developing countries (as well as some increased scarcity of fossil fuels). These trends will be enhanced by policies that provide economic incentives for GHG-reducing innovation.

Other analysts have argued, however, that without early action to reduce GHG emissions, markets for low-emission technologies would not develop and societies would lock into continued use of fossil fuel-intensive energy systems (Grubb 1997; Ha-Duong, Grubb, & Hourcade, 1997). When knowledge is gained through basic research and development (R&D), the optimal time path moves in the direction of maintaining current emissions levels and increasing future reductions to take advantage of accumulated knowledge (Goulder & Mathai, 2000). However, when knowledge is gained through "learning by doing" there is a stronger case for earlier action.[11] Moreover, earlier action provides more of a hedge against the possibility of an unwelcome and irreversible surprise in assessments of climate change damages – the current generation can offer more insurance to their descendants against such risks.

Another important crossover between means and ends arises in evaluating the different risks created by tax and emissions trading policies. Taxes fix the price and allow the emissions levels to vary, putting the risk on the environment (the firm knows the cost of emission reduction), whereas permits fix the emission target and allow the price to vary, putting the risk on the regulated firm (the firm no longer knows the cost of a permit with certainty).

As such, a permit system fits more naturally into the Kyoto Protocol, which focuses on fixed emissions targets and timetables.

However, with GHG trading society does not know what the actual abatement cost will be for a fixed quantity of emissions. When costs are uncertain and potentially severe, society may be better off with a tax-based approach that caps the cost of emissions control but does not ensure hitting a specific emissions target (Pizer, 2002; Newell & Pizer, 2003b). This approach may make good economic sense with GHG emissions over the shorter term. But if there were a strong reason to limit GHG concentrations below a certain limit in the short-term because of the risk of catastrophic damages, the case for permit trading would be stronger.[12]

Incentive-based policies such as taxing and GHG trading work to encourage the diffusion of existing low-carbon technology and the development of new technology. This leaves open the question of whether additional nonprice policies are necessary to promote climate-friendly technology advances and investment. Proponents of such policies argue that economic incentives are inadequate to change behavior to a degree sufficient to reduce climate risk. They advocate public education and demonstration programs; institutional reforms, such as changes in building codes and utility regulations; and technology mandates, such as fuel economy standards for automobiles and the use of renewable energy sources for power generation.

No one doubts that such approaches eventually can reduce GHG emissions. At issue is the cost-effectiveness of such programs. Advocates of technology mandates often argue that the subsequent costs are negligible because the realized energy cost savings more than offset the initial investment costs. An important factor in assessing the costs of CO_2 control is the capacity and willingness of consumers and firms to substitute alternatives for existing high-carbon technologies. Substitution undertaken depends partly on the technological ease of substituting capital and technological inputs for energy inputs and partly on the cost of lower-carbon alternatives. Some engineering-oriented studies suggest that 20–25% of existing carbon emissions could be eliminated at low or negligible cost if people switched to new technologies such as compact fluorescent light bulbs, improved thermal insulation, efficient heating and cooling systems, and energy-efficient appliances (see NAS, 1991; OTA, 1991; Interlaboratory Working Group, 1997).

The economics perspective emphasizes searching for inefficiencies that impede low-cost choices as opposed to barriers that reflect unavoidable direct or hidden costs. Most economic analysis recognizes that energy use suffers from inefficiencies but remains skeptical that large no-regret gains

actually exist. Economists counter that even if new or better technologies are available, many people are unwilling to experiment with new devices at current prices. Factors other than energy efficiency also matter to consumers, such as quality, features, and the time and effort required to learn about a new technology. People behave as if their time horizons are short, perhaps reflecting their uncertainty about future energy prices and the reliability of the technology.

Economic analyses incorporate a clear role for government when consumers have inadequate access to information or if existing regulatory institutions are poorly designed. This role can include subsidies to basic R&D to compensate for an imperfect patent system; reform of energy sector regulation, and reduction of subsidies that encourage uneconomic energy use; and provision of information about new technological opportunities (compare with Geller & Nadel, 1994; Jaffe, Newell, & Stavins, 2001). Moreover, barriers in the energy sector and other sectors (including financial markets and human capital), especially in developing countries, can stall the diffusion of cost-effective technology. Where barriers to technology diffusion exist, the most effective solution typically is not found in regulatory mandates or ill-focused rules for technology adoption. Rather, solutions are found in institutional or broader market reforms, such as greater availability of information, expansion of financing opportunities, and reforms in energy sector pricing and other areas. How large the ''cheap lunch'' is for energy efficiency and how it can best be realized remain topics of hot debate.

CONCLUDING REMARKS

As emphasized at the outset, my conclusions about both climate policy and economic analysis are somewhat mixed. I believe the kind of pluralistic approach to goal setting that I have outlined is a critical element of engendering social awareness and mature social debate about the risks of climate change and the options for mitigating it. At the same time, I believe that economic analysis needs to be included at the center of that debate, in providing information about potential costs and benefits and especially in designing innovative policies for GHG mitigation.

Environmental advocates by and large have accepted in principle the use of economic instruments for GHG mitigation, as have business people. The concern for environmentalists is the potential of the proposed policy mechanisms to produce real and verifiable reductions. The concern for business, on the other hand, focuses on the costs.

Often a proxy war between these two perspectives seems to be fought through arguments about the soundness of climate science. Other contributions in this volume from esteemed scientists should help put much of this debate to rest. We do know persuasively at this point that climate change is occurring, that human activity is behind it, and that it poses real risks. At the same time, how severe the risks will be, when they will be realized, and by whom, all remain uncertain.

I have argued that climate science cannot settle issues of climate policy, which are ultimately moral issues. This calls into question the usefulness of the proxy war referred to above, quite apart from any conclusion one might reach about the state of the science. A mature social debate about climate policy would focus more on the choices to be made and their potential consequences. In that context, I believe there is a real middle ground for pursuing active but not excessive climate policy once public will for doing so becomes stronger.

In my view, the key precepts for beginning to sketch out the middle ground are that we need to act, but we do not have to act precipitously, and we need to act fairly. Both cost–benefit analysis and other perspectives conclusively demonstrate the need to start taking some GHG mitigation measures as well as promoting greater adaptation capacity. Such action is needed in part because investments in GHG-producing capacity in the economy are long-lived (highways as well as cars, power plants as well as gas fields, and windmills). The expectation that gradually more aggressive limits on GHG emissions over time will be forthcoming (in the absence of a large and safe breakthrough in GHG sequestration technology) will gradually but inexorably steer longer-term investment planning toward a less GHG-intensive energy and economic system, as well as curbing the flow of emissions in the shorter term.

This approach is based not on precipitous and costly action, but on deliberate and inexorable action. There are many important details about the design and stringency of policies to be worked out in implementing such an approach. A more direct and at least partly economics-based focus in this debate might help catalyze middle-ground action in the United States and further action in other developed countries.

Acting fairly as well as purposefully in mitigating GHGs (and promoting adaptation) means not only recognizing some intergenerational obligation, but also working through current caustic debates around how to integrate actions by rich and poor countries (or groups within countries). The CDM is one mechanism for seeking to more fairly and cost-effectively distribute the costs and ancillary benefits of GHG mitigation. GHG mitigation activities

in developed countries that stimulated further development of cost-effective and lower GHG energy technologies would have larger impacts on the long-term well-being of people in poor countries and on their own GHG trajectories.

Eventually the countries of the world also will need to work beyond the Kyoto Protocol to strive toward more universal participation in GHG targets. The chapter by Shukla in this volume lucidly lays out the challenges to be encountered on this road and the imperative to focus on sustainable development in poor countries, not just GHG abatement. It is impossible at this point to have that clear a perception of how global participation in GHG mitigation may unfold – for example, what kinds of "graduation rules" might be used to move developing countries toward more formal commitments as their per capita incomes rose. In the meantime, strong emphasis on gradual and deliberate actions in rich countries, and aggressive pursuit of win–win energy and economic reforms in poor countries that generate GHG reductions and other benefits, are a starting point. The United States should be integral to this process, not sitting on the sidelines as it is today.

NOTES

1. The discussions that follow draw heavily on parts of Shogren and Toman (2000).

2. However, with long-term uncertainty about economic productivity with climate change, it can be shown that long-term discount rates should be lower than a simple extrapolation of short-term financial costs would indicate (see, e.g., Weitzman, 1998; Newell & Pizer, 2003a).

3. This reference is to the republication of an article written over 40 years ago and therefore quite prescient in its concern for sustainability issues.

4. See, for example, Weiss (1989), Brown (1998), and Pezzey and Toman (2002).

5. Economic analyses of climate change policy goals have taken note of the fact that there will be learning about both risks and response costs over time. As might be expected, in situations where the most important learning opportunities are with respect to future response options, the emphasis is on a somewhat slower approach to abating GHGs in order to allow better options to be developed and diffused (Kolstad, 1996). From this perspective, climate change may be found to be riskier than anticipated but there is likely to be time to accelerate mitigation if that is discerned; the slowness of prior mitigation is not irreversible. If instead the greater concern is with the discovery of unanticipated and irreversible effects of GHG accumulation, then a more aggressive mitigation program is warranted (Fisher & Narain, 2003).

6. Pezzey and Toman (2002) provide a general review of this line of reasoning, as does the chapter by Howarth in this volume.

7. For further discussion of these issues see, for example, Norton and Toman (1997).
8. The discussion that follows draws heavily on Toman (1999).
9. For additional discussion about carbon sequestration, see Sedjo, Sampson, and Wisniewski (1997).
10. See Manne and Richels (1997) and, for a review, Toman, Morgenstern, and Anderson (1999).
11. Goulder and Schneider (1999) note that opportunity costs may be associated with inducing more technical innovation in GHG mitigation. To the extent that fewer research and development resources are made available in the economy as a whole for other innovation activities, productivity growth in the economy as a whole would be lower than it would be otherwise.
12. It is also possible to adopt a hybrid policy based on emissions trading but with a safety valve in case costs go too high. In practice, this policy would involve the government issuing additional permits if the price went beyond some predetermined level (which could change over time). A version of this idea is sketched in Pizer (2002). If permits are internationally traded, regulations would have to prevent entities in one country from exploiting a "safety valve" in another country.

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AGAINST HIGH DISCOUNT RATES

Richard B. Howarth

INTRODUCTION

The theory of discounting is based on the assumption that people's observed behavior in markets for savings and investment reveals their subjective preferences regarding trade-offs between present and future economic benefits. A person who borrows money at the annual interest rate r, for example, shows a willingness to pay $(1+r)^t$ dollars t years in the future to obtain one dollar in the present. On the other side of this transaction, the lender demands $(1+r)^t$ future dollars in exchange for each dollar loaned out today. In the logic of this situation, both borrowers and lenders behave as if one dollar of future currency has a "present value" of just $1/(1+r)^t$. In this expression, the interest rate, r, is interpreted as the prevailing "discount rate" or time value of money.

According to economists, people discount the future for a variety of reasons (Lind, 1982; Pearce, 1994). First is the concept of impatience or pure time preference – the desire (all else equal) to obtain benefits in the short run while deferring costs until the future. There is good evidence that this is a basic aspect of human psychology that arose in the course of human evolution (Rogers, 1994); in any event, the reality of impatience seems intuitive to most people. A second factor that supports discounting is the observation that, in a world of rising incomes and consumption levels, one dollar of future expenditure would deliver less satisfaction than a dollar spent in the present. Third, people discount the future because of uncertainty – the

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risk that expected benefits may fail to materialize in a world of imperfect foresight. Finally, discount rates are linked to the productivity of capital investment. In sum, discount rates reflect both people's subjective attitudes toward trade-offs between present and future benefits and the objective benefits that arise when income is invested in assets such as new homes and production facilities.

As is well known, discounting procedures play a key role in the economics of climate change. According to standard estimates, stabilizing greenhouse gas emissions at current levels would reduce short-run economic output by 0.2–2.0% in industrialized nations such as the United States (IPCC, 2001b; Weyant, 1999). Emissions abatement is a means of reducing the future costs of climate change, which – although uncertain – would likely amount to several percent of world economic output given the 1.4–5.8 °C temperature increase that is projected to occur during this century (IPCC, 2001a). Since climate change response strategies involve short-run costs and long-run benefits, the identification of optimal policies depends strongly on the relative weight decision-makers attach to the interests of present and future society.

Although there are competing approaches to answering this question (see Howarth, 2001), one prominent approach is the application of conventional cost–benefit analysis. In this approach, the costs (C_t) and benefits (B_t) of public policies are measured in monetary units for each year $t = 0, 1, 2, \ldots$ with the initial date ($t = 0$) defined as the present. Policies are then chosen to maximize the discounted value of net benefits as summarized by the "net present value" criterion:

$$NPV = (B_0 - C_0) + (B_1 - C_1)/(1 + r) + (B_2 - C_2)/(1 + r)^2 + \cdots$$
$$= \sum_{t=0}^{\infty} (B_t - C_t)/(1 + r)^t. \quad (1)$$

For the reasons outlined above, the discount rate, r, is chosen based on observed interest rates and returns to capital investment.

Based on historical returns in real-world financial markets, analysts such as Nordhaus (1994b; see also Manne, 1995) argue that the discount rate should be set equal to a real (inflation-corrected) value of 6% per year. The use of real discount rates is standard practice in this literature and is theoretically appropriate when costs and benefits are expressed in inflation-adjusted terms so that the purchasing power of one dollar is constant over time. Given current estimates concerning the anticipated costs and benefits of climate change, discount rates of this magnitude suggest that only modest steps toward climate stabilization should be undertaken (Howarth, 1998;

Nordhaus, 1994b). With a 6% discount rate, one dollar of benefits obtained one century in the future attains a present value of less than one cent. Unsurprisingly, this assumption implies that it is better to bear the future costs of climate change than the short-run costs of stringent emissions reductions.

The purpose of this chapter is to critically evaluate the use of this standard (or "high") discount rate in the economics of climate change. The analysis sets forth three logically distinct lines of reasoning. First, I shall argue that the fact that *individuals* discount the future in private market decisions does not imply that policy makers should discount future costs and benefits that accrue to *future generations* (Parfit, 1983b). On moral grounds, authors such as Broome (1992) and Cline (1992) argue that equal weight should be attached to the welfare of present and future generations in environmental policy analysis. As we shall see, this value judgment implies that quite aggressive steps toward climate stabilization might be morally justified.

Second, I shall argue that the net present value criterion, when implemented using high discount rates, supports an outcome in which short-run greenhouse gas emissions reduce the welfare of future generations in comparison to a path where emissions are stabilized one-third below current levels. This result runs afoul of Brown's (1998) notion of "stewardship" – the principle that future generations hold a moral right to inherit an undiminished natural environment unless they are duly compensated for environmental harms.

Finally, I shall argue that the use of high discount rates is unjustified based on considerations of risk and uncertainty. While market decisions show that people demand a 6% annual return on risky investments such as corporate stocks, they also show that people accept much lower returns on safe investments such as U.S. Treasury Bills and corporate bonds. According to the Framework Convention on Climate Change, a key purpose of climate change response policies is to reduce the risk that climate change will impose catastrophic impacts on future generations. Since the economic theory of decision-making under uncertainty implies that public investments that reduce future risks should be evaluated using low discount rates (see Sandmo, 1972; Starrett, 1988), the use of high discount rates may be unwarranted in the context of climate change.

THE ARGUMENT FROM UTILITARIANISM

The basic argument that supports the use of high discount rates is described in the preceding paragraphs. Since private individuals demand a 6% annual

return on investments in standard financial assets, public decision-makers should discount the future benefits of climate change policies at that same 6% rate in the context of monetary cost–benefit analysis. Proponents of this view argue that the use of lower discount rates would violate the principle of consumer sovereignty – the notion that people are the best judge of their individual welfare and that policy-makers should respect the preferences people reveal in their market decisions. This reasoning assumes that market decisions are based on a rational assessment of the consequences of one's actions for one's experienced utility – an assumption that is called into question by analysts such as Norton, Costanza, and Bishop (1998). The notion of consumer sovereignty, however, has significant intuitive appeal, emphasizing as it does the importance of individual freedom.

In the discounting literature, however, this line of reasoning runs up against a powerful critique. While rational *individuals* may discount future benefits that accrue to them personally, it does not logically follow that policy-makers should discount costs and benefits that fall on members of *future generations* (Parfit, 1983b). From this perspective, issues of personal time preference are simply not relevant to the moral problem of adjudicating conflicts between the interests of present and future society. Instead, discount rates should be chosen based on explicit principles of intergenerational fairness.

Defenders of high discount rates have a well-articulated response to this critique. Although individual persons have finite life spans, they assert, savings and investment decisions are managed by *households* or "dynasties" with preferences that stretch from the present into the indefinite future (Barro, 1974). From this perspective, market decisions reflect the altruistic concern that parents may feel for their children and more distant descendants. Accordingly, market rates of return reveal the preferences that present society holds regarding intergenerational trade-offs, thus justifying the use of conventional discounting procedures.

Critics, however, have identified at least two potential flaws in this line of reasoning. On the one hand, empirical evidence does not unambiguously support the hypothesis that investment decisions are premised on a desire to transfer wealth to one's children and grandchildren. An empirical study by Hurd (1987), for example, suggests that investment behavior is best described in terms of individuals' desire to enjoy financial security in old age. Bequests to one's children – although a real phenomenon – play a minor role in explaining people's economic behavior. More deeply, Chichilnisky (1997) argues that the notion that discount rates should be based on the altruistic preferences that present society holds toward posterity constitutes

a "dictatorship of the present" that denies full moral standing to members of future generations. This point mirrors the general ethical principle that moral obligations – for example, the duty to alleviate the suffering of the poor and infirm – are conceptually independent of individual preferences, altruistic or otherwise.

An alternative approach to the analysis of climate change response strategies is based on the theory of Classical Utilitarianism, a moral framework that traces its roots to the works of Bentham (1823) and Mill (1863). According to Utilitarians, social decisions (and hence climate change policies) should seek to maximize the total level of well-being (or "utility") experienced by all present and future persons (Broome, 1992; Cline, 1992). Although this framework is analogous to cost–benefit analysis in the sense that it aims to maximize a formal conception of the good, it differs from cost–benefit analysis in two crucial respects. First, gains and losses are measured in terms of utility as opposed to monetary units. Second, Utilitarianism holds that equal weight should be attached to the welfare of present and future generations.

The implications of this debate for climate change policy are illustrated in Figs. 1–4. These figures, which are based on Howarth's (1998) model of interactions between climate change and the world economy, compare the climate change policies that emerge under four alternative social choice rules:

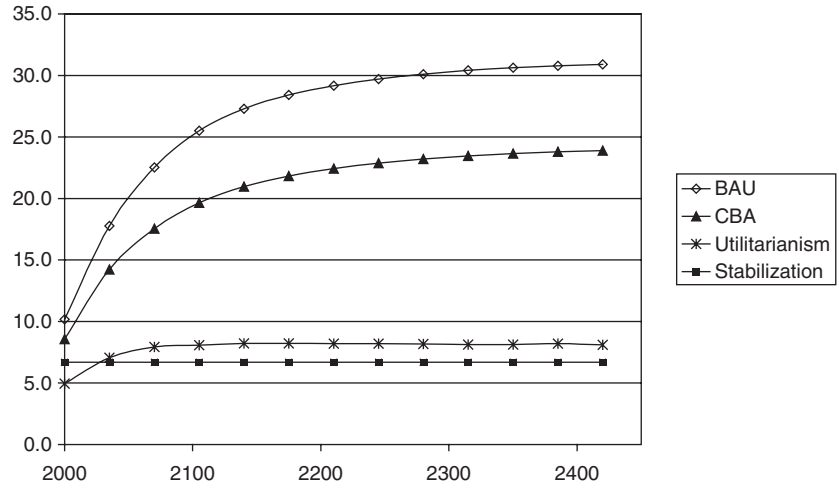

Fig. 1. Greenhouse Gas Emissions (Billion tce/Year).

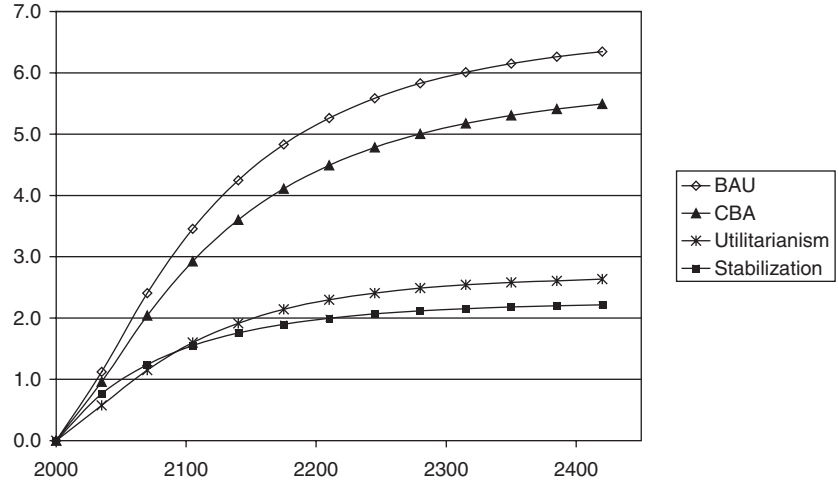

Fig. 2. Temperature Increase (°C).

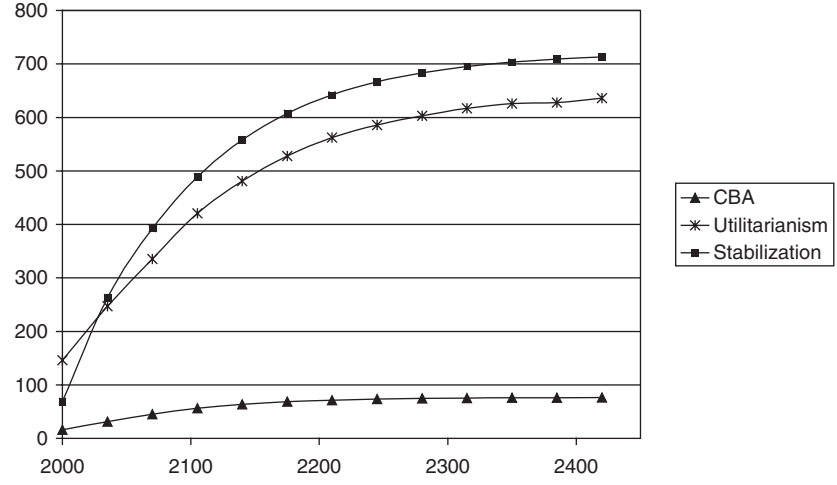

Fig. 3. Emissions Tax ($/tce).

1. *Business-as-usual* (BAU), which assumes that greenhouse gas emissions remain unregulated both in the present and at all future dates.
2. *Cost–benefit analysis* (CBA), which discounts the future at a rate equal to the market return on capital investment.

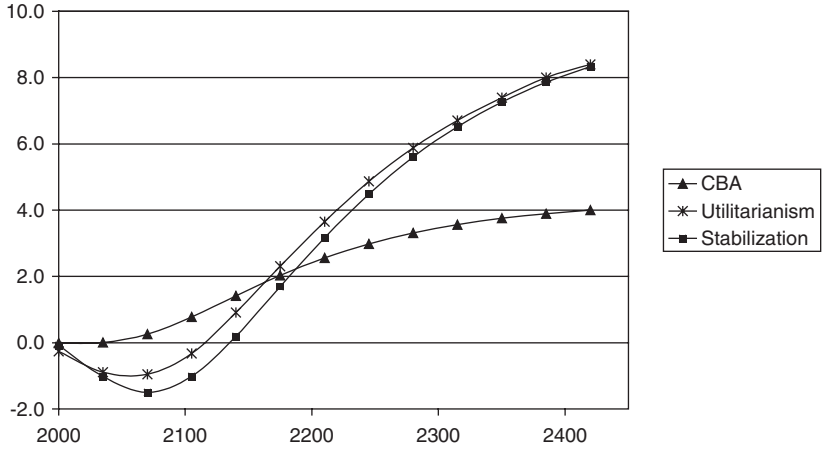

Fig. 4. Net Benefits – Change Relative to BAU (Trillion $/Year).

3. *Classical Utilitarianism.*
4. *Climate stabilization*, in which emissions are maintained at a fixed level that limits long-term greenhouse gas concentrations to a doubling relative to preindustrial levels.

In this model, decisions concerning consumption, investment, and economic production are managed by private households and businesses in the context of competitive markets. The role of public policy is limited to defining a tax on greenhouse gas emissions that strikes an optimal balance between the short-run costs and long-run benefits of climate mitigation measures. The revenues raised by the emissions tax at each date are returned to private individuals in equal payments. A further description of the model is presented in the appendix.

As the figures show, greenhouse gas emissions grow quite substantially over time in the business-as-usual scenario. In this case, emissions rise from 10 billion tonnes of carbon equivalent (tce) in the year 2000 to 31 billion tce per year in the long-term future. Most of this increase occurs during the 21st century. This emissions path leads mean global temperature to increase by 6.3°C over the next four centuries. Although this increase in temperature is small when compared to seasonal fluctuations or differences between geographic regions, it is large in comparison with the changes have occurred during the Earth's geological history (IPCC, 2001c). In the context of this model, this temperature change leads to costs equivalent to 10% of long-term

economic output. This figure accounts for the impacts of climate change on both market activities (such as agriculture, energy use, water supply, and real estate) and nonmarket goods (such as human health and the functioning and integrity of natural ecosystems).

In this model, cost–benefit analysis gives rise to optimal policies that involve relatively modest rates of emissions control. In comparison with business-as-usual, emissions are reduced by 16% in the short run and by 23% in the long run. These reductions are achieved through a greenhouse gas emissions tax that rises from \$16/tce in the present to \$76/tce in 2420. (Throughout this discussion, monetary values are measured in inflation-adjusted 1989 US dollars.) Although this scenario leads to a relatively small reduction in the rate and magnitude of climate change, it confers quite substantial economic benefits on members of future generations. In the year 2105, for example, society experiences a net benefit of \$0.8 trillion in comparison with the business-as-usual case, while net benefits rise to \$4.0 trillion in the year 2420. Interestingly, however, this policy has almost no impact on short-run economic welfare. By way of comparison, the optimal emissions tax in the year 2000 is equivalent to a gasoline tax of just 4 cents per gallon – a figure that would allow producers and consumers to respond at a relatively low economic cost.

Classical Utilitarianism, in contrast, gives rise to substantially more aggressive policies. Under Utilitarianism, greenhouse gas emissions are reduced by 51% relative to business-as-usual in the year 2000. Although emissions rise gradually during the 21st century, they are stabilized at a level of 8.1 billion tce per year, a figure that is significantly below the year 2000 level under business-as-usual. This emissions path, which limits the long-run rise in mean global temperature to 2.6 °C, is supported by an emissions tax that rises from \$146/tce to \$636/tce over the next four centuries. Relative to business-as-usual, greenhouse gas emissions abatement imposes net economic costs of \$0.3 trillion in the year 2000 and \$1.0 trillion in the year 2070. These short-term costs, however, give rise to future net benefits that rise to \$8.4 trillion in the year 2420. These net benefits are more than twice as large as those that arise under conventional cost–benefit analysis.

These particular numerical results depend of course on empirical assumptions that are open to critical examination (Howarth & Monahan, 1996). Nonetheless, the analysis reveals the sensitivity of optimal climate change policies to changes in the discount rate. Although Utilitarianism attaches equal weight to changes in present and future well-being, the Utilitarian optimum described is consistent with the results that arise when a small positive discount rate is used in monetary cost–benefit analysis. Given

anticipated growth in income and consumption, Cline (1992) gauges that the satisfaction provided by an incremental unit of expenditure will decline at a 1% annual rate over the course of the next century. Hence, the Utilitarian social choice rule may be operationalized through the use of a 1% discount rate in monetary cost–benefit analysis (IPCC, 1996).

Authors such as Manne (1995) argue that the Utilitarian approach to climate change policy is "unrealistic" because, in a world of economic growth, it requires sacrifice on the part of relatively poor people (living in the present) to provide benefits to people with much higher incomes (future generations). While this argument seems plausible on its face, it overlooks an important dimension of climate change policy that is emphasized by Schelling (2000). As Schelling notes, emissions control costs would fall principally on affluent people living in industrialized nations, while the impacts of climate change would fall hardest on future peasant farmers living in developing countries who lacked the resources required to adapt to altered environmental conditions. This issue is obscured in aggregate models of climate–economy interactions that abstract away from issues of uneven development and economic inequality. This observation, however, generally reinforces Utilitarian arguments that favor relatively stringent steps toward climate stabilization.

THE ARGUMENT FROM STEWARDSHIP

Despite their differences, cost–benefit analysis and Utilitarianism share a common characteristic: both frameworks are based on a consequentialist approach to social decision-making, according to which public policies should be designed to balance the interests of different members of society. Consequentialism, however, is viewed skeptically by advocates of "deontological" or rights-based ethics. Philosophers such as Locke (1690), Kant (1963), and Rawls (1971), for example, set forth theories in which government actions are justified to the extent that they protect the rights or freedoms of individuals. In debates over long-term environmental management, the notion of *stewardship* offers a distinctive moral outlook that is based on the perceived rights of future generations.

The logic of stewardship is nicely summarized by Thomas Jefferson's aphorism that "the earth belongs in usufruct to the living" (see Ball, 2000). From this perspective, environmental resources are the shared patrimony of present and future generations. While individuals living in today's society hold a *right* to enjoy the benefits provided by environmental systems, they also hold a *duty* to protect and conserve environmental quality for the

benefit of future generations. This view is embodied in the definition of "sustainable development" described by the World Commission on Environment and Development (1987, p. 43), according to which natural resources should be managed to meet "the needs of the present without compromising the ability of future generations to meet their own needs."

The moral foundations of the stewardship ethic are explored by Howarth (1997), who argues that a commitment to the principle of equal opportunity between contemporaries implies that present decision-makers hold a duty to ensure that human life opportunities are maintained or improved from generation to generation. At each point in time, parents and their living offspring are contemporaries who are entitled to meaningful equality. From this perspective, actions that conferred short-term benefits but that reduced future opportunities would constitute an unfair use of the power that adults hold in relation to children. Since this position is grounded on an appeal to duties between actual living persons, it is not vulnerable to Parfit's (1983a) argument that the rights of future generations are sharply limited by their hypothetical or contingent status. Part of what present society owes young people, however, is the capacity to provide suitable opportunities to their own children and grandchildren. In this way, direct duties between one generation and the next define a "chain of obligation" (Howarth, 1992) between the present and more distant future generations.

As Page (1983) points out, protecting the life opportunities of future generations requires attention to several factors that provide the basis for achieving a favorable quality of life – natural resources, environmental quality, manufactured capital, social institutions, and technological capacity. In principle, the depletion of one valued asset (such as environmental quality) might be compensated by another (manufactured capital or new technologies) that offered commensurate contributions to human welfare. But in a world of uncertainty regarding the needs and interests of future generations, the only sure way of maintaining life opportunities is by passing on a "structured bequest package" (Norton & Toman, 1997) that includes continued access to environmental resources. This point is strengthened by evidence that many people view the substitution of manufactured goods for unique natural environments as morally inappropriate (Sagoff, 1988). In this view, reductions in environmental quality would be permissible only in the face of compelling evidence that future generations would share in the benefits or receive just compensation as judged from their own vantage point (Barry, 1983).

Brown (1998) reasons that the stewardship ethic entails a moral obligation to stabilize the global climate as one component of environmental

quality. If future generations hold a right to enjoy the benefits of climatic stability, then policies that allowed unrestrained greenhouse gas emissions might inflict uncompensated harms that were morally unjustified. This line of argument conforms to the principal objective of the United Nations Framework Convention on Climate Change, which calls for the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." This language is important because the Framework Convention is a binding treaty that has been signed and ratified by 188 nations including the United States.

Although the Framework Convention does not specify the concentration levels that should be considered "dangerous," scientific efforts to support this agreement have explored the prospects for limiting carbon dioxide concentrations to levels no more than 60–260% above the pre-industrial norm (IPCC, 2001c). This range is based on evidence that (a) small changes in climate would yield relatively modest impacts to which future society could successfully adapt, while (b) large changes in climate would impose a risk of irreversible, catastrophic harms. According to the IPCC (2001c), climate change could produce catastrophic impacts via several plausible mechanisms:

1. The disruption of ocean circulation patterns, which ironically could plunge the European continent into a deep freeze even as the planet as a whole became warmer.
2. The release of greenhouse gases from terrestrial and marine sediments, which could greatly amplify the direct climate change induced by human activities.
3. The possible collapse of the West Antarctic ice sheet, which would lead to a sea-level rise of several meters.

Although none of these scenarios is particularly likely, scientists emphasize that environmental systems are complex, nonlinear, and only partially understood. As a result, it is reasonable to expect "surprises" (Faber, Manstetten, & Proops, 1992) – the occurrence of outcomes that were unforeseen and indeed unforeseeable.

The problem of catastrophic risk is illustrated by an expert opinion survey conducted by Nordhaus (1994a), who asked a group of economists and scientists with expertise on climate change to estimate the probability that a doubling of greenhouse gas concentrations would impose costs equivalent to 25% of world economic output. In Nordhaus' sample, the mean probability estimate was 5%, indicating a significant potential for catastrophic impacts.

Since this figure is based on the subjective judgment of technical experts, its scientific reliability is of course limited. On the other hand, this study points to important doubts amongst expert analysts regarding the hypothesis that climate change will have limited or acceptable consequences.

Critics of stewardship and the approach taken by the Framework Convention argue that taking steps to stabilize climate would impose large economic costs that would ultimately harm both present and future generations. From this perspective, high levels of greenhouse gas emissions abatement might reduce the rate of long-term economic growth. Hence, both present and future generations might be better off if climate change policies were based on conventional cost–benefit analysis, which aims to achieve an efficient balance between the interests of present and future generations.

This argument, however, is not as clear-cut it as might seem. Consider, for example, the ''climate stabilization'' scenario depicted in Figs. 1–4. In Howarth's (1998) model of climate–economy interactions, greenhouse gas concentrations may be stabilized at a level that is twice the pre-industrial value if emissions are held constant at 6.7 billion tce per year. This goal could be achieved through the use of an emissions tax that rose from \$69/tce to \$713/tce over the course of the next four centuries. Relative to the business-as-usual (no policy) baseline, this scenario imposes a net cost that rises from \$0.1 trillion to \$1.5 trillion per year between 2000 and 2070. After 2140, however, the policy yields positive net benefits that rise to a level of \$8.3 trillion per year in the long-run future. These long-term benefits are more than twice as large as those that arise when climate change policies are based on the use of conventional cost–benefit analysis. Interestingly, this scenario corresponds closely to the policies that emerge under Classical Utilitarianism.

Viewed somewhat differently, switching from the climate stabilization scenario to the cost–benefit criterion provides short-term benefits of \$0.1 trillion in the year 2000 while imposing uncompensated costs of \$4.3 trillion in the year 2420. An advocate of stewardship would view this as an unjustified invasion of the rights of future generations.

There are several points to bear in mind about these calculations. First, the particular stabilization target considered in this analysis – limiting greenhouse gas concentrations to a doubling relative to preindustrial levels – is in some sense arbitrary. While this target is in the range of possibilities currently under discussion, higher or lower targets might ultimately be justified based on the scientific evidence and policy-makers' considered judgment regarding how much climate change would be ''dangerous.'' Second,

these simulations assume that climate change would have negative but relatively modest impacts. In particular, they assume that a doubling of greenhouse gas concentrations would impose costs equivalent to 1.3% of world economic output. While this number is plausible as a central estimate, it does not account for the risk that climate change might impose catastrophic costs. As we saw above, the literature suggests a small but significant probability that climate change would impose damages almost 20 times as large.

To illustrate the importance of this point, Fig. 5 depicts the net benefits of the climate stabilization case when the damage coefficient is increased by a factor of 10 – an arbitrary figure that is nonetheless inside the range of plausible possibilities – so that a doubling of greenhouse gas concentrations would impose costs equivalent to 13% of economic output. In this event, net benefits become positive by the middle of the 21st century and rise to a value of $18.4 trillion by the year 2105. In the long-term future, net benefits increase $50 trillion per year. This policy imposes net costs only in the short term, and those costs are limited to $0.1 trillion per year.

Alternative interpretations of the stewardship ethic are available in the literature. Gerlagh and Keyzer (2001; see also Barnes, 2001), for example, consider a formal model in which polluters must compensate victims for the costs imposed by climate change. In this approach, optimal rates of greenhouse gas emissions control are determined using conventional cost–benefit

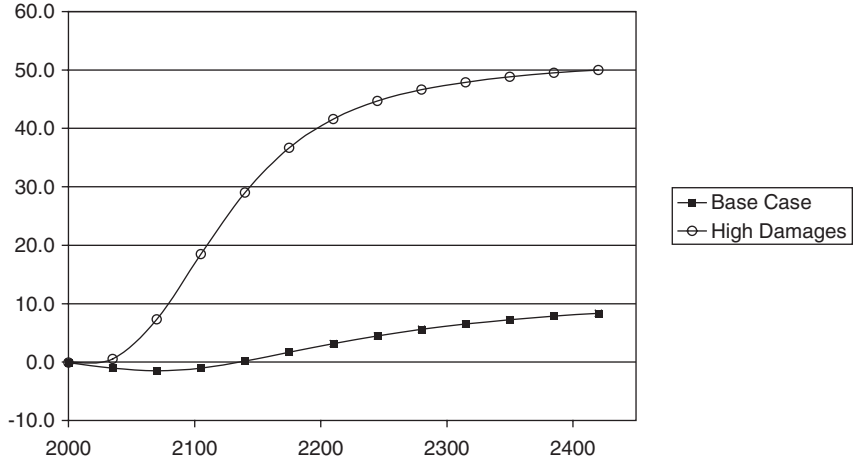

Fig. 5. Net Benefits of Emissions Stabilization – Change Relative to BAU (Trillion $/Year).

analysis, which ensures that resources are allocated in a manner that is economically efficient. In this setup, polluters make payments to an intergenerational trust fund that pays compensation to members of future society who bear the costs of climate change. Since the assets held by the trust fund are invested the market rate of return (r), one dollar of environmental costs that occur t years from the present can be financed through an investment of just $1/(1+r)^t$ today. In theory, this approach yields an outcome that both present and future generations would prefer to the case in which greenhouse gas concentrations are stabilized in the neighborhood of current levels.

Although the Gerlagh–Keyzer approach is conceptually elegant, it runs up against two types of practical difficulties. First, if the future impacts of climate change are uncertain, then the level of investment required to compensate future generations for climate change damages cannot be operationally defined. This point is highlighted by the comparison of the "base case" and "high damage" scenarios depicted in Fig. 5. As Bromley (1989) notes, compensation mechanisms are a problematic means of protecting rights when potential environmental costs are unknown and possibly catastrophic. In such instances, legal systems commonly employ property rules designed to prevent harm before it occurs with strict punishments for violations.

Second, the Gerlagh–Keyzer model requires the creation of a financial institution (the trust fund) that would function effectively over the course of many decades or indeed centuries. As Lind (1995) notes, this task would pose daunting practical challenges; it is easy to imagine scenarios in which governments would raid the trust fund to finance short-term expenditures, or in which a financial crisis would effectively wipe out the assets held in trust for future generations. Together, these arguments suggest why advocates of stewardship focus on stabilizing greenhouse gas concentrations to protect the rights of posterity.

THE ARGUMENT FROM RISK

In an important sense, the arguments from Utilitarianism and stewardship critique the moral foundations of conventional cost–benefit analysis, not the use of high discount rates *per se*. In contrast with these moral critiques, the third line of reasoning explored in this chapter – the argument from risk – accepts the premise that climate change policies should be analyzed based on the private preferences that people reveal through their market behavior. But while conventional discounting procedures rest on the assertion that

individuals exhibit a high degree of impatience – and hence an unwillingness to exchange short-term costs for long-term benefits – the argument from risk holds that the use of high discount rates is in fact inconsistent with the empirical evidence.

To understand this point, it is useful to note that financial markets involve the purchase and sale of a large number of assets characterized by varying degrees of risk. Risky assets such as corporate stocks pay average long-run returns of roughly 6% per year in real (inflation-adjusted) terms (IPCC, 1996, chap. 5). As I noted in the introduction, authors such as Nordhaus (1994b) and Manne (1995) argue that public policies should be evaluated at a discount rate that reflects the typical returns investors demand of corporate stocks. In this view, the use of low discount rates might lead policymakers to approve low-return public projects that crowded out private investment that yielded higher returns to society.

Although this claim is intuitive, it runs up against an important body of theory and evidence from the finance literature. In particular, safe forms of investment such as U.S. Treasury Bills generated long-term yields of less than 1% per year between 1926 and 2000 (Ibbotson Associates, 2001). In financial economics, Treasury Bills are generally viewed as a risk-free asset since their returns are remarkably stable over time. In this respect, they resemble money market accounts and short-term certificates of deposit. By way of comparison, corporate bonds, which are characterized by an intermediate degree of risk, yield long-term returns of roughly 3% per year. In explaining observations of this nature, financial economists work with models in which the expected (or average) rate of return on a risky asset ($\bar{r}_r$) is determined by the return available on safe assets (r_s) plus a risk premium (RP_r) according to the equation:

$$\bar{r}_r = r_s + RP_r \tag{2}$$

In simplified terms, this equation captures the idea that people will invest in risky forms of wealth only if they expect to receive a rate of return that is higher than that available on safe investment options. The risk premium measures the effective reward an investor demands in exchange for accepting uncertainty.

Various formulae exist for determining the risk premium that investors demand based on the uncertainties that surround the potential returns achieved by a given investment (Cochran, 2001). In general, these formulae are derived from theoretical models in which people allocate investments between available assets to optimally balance the goals of maximizing returns and minimizing risks. These methods both indicate, however, that the

risk premium is positive for investments that increase the degree of uncertainty surrounding an investor's overall economic welfare. Corporate stocks fall into this category because investors' incomes rise and fall with the market. On the other hand, insurance policies yield payoffs that – although uncertain – serve to reduce the risks that surround an investor's overall financial position. Since insurance policies protect buyers from the risk of incurring large (sometimes catastrophic) losses, people purchase them despite the fact that these policies will (on average) return less cash than money deposited in the bank. In terms of Eq. (2), this implies that insurance policies have a negative risk premium.

As I noted in the preceding section, climate change policies are designed to reduce the environmental risks faced by future generations. This is illustrated in Fig. 5, which shows that climate stabilization can forestall the risk that climate change will impose irreversible, catastrophic costs with a significant (though poorly measured) probability. More formally, Tol (2003) presents a quantitative analysis in which climate change completely devastates the economies of Eastern Europe and the former Soviet Union with a probability of 0.1%. This result occurs because of shifts in precipitation patterns that deprive this region of needed water resources. Less ominous catastrophes occur in Tol's model with greater levels of probability. Tol's study is important because it represents a serious attempt to integrate the scientific, technological, and economic uncertainties that surround global warming using a fully specified mathematical model.

What are the implications of these points for the choice of discount rates in cost–benefit analysis? One approach to answering this question is provided by Sandmo (1972) and Starrett (1988), who explore theoretical models in which public policies should be evaluated using discount rates that reflect the risks those policies impose on future society. According to these authors:

1. If a policy would involve risks that are similar to those posed by private investments, then it would be appropriate to discount its future net benefits based on the returns paid by corporate stocks.
2. If a policy were risk-free, then its net benefits should be discounted at the risk-free rate of return.
3. For policies that provide insurance benefits – i.e., that reduce the overall uncertainties faced by future society – the use of discount rates below the risk-free rate would be theoretically appropriate.

For the reasons described above, it is reasonable to presume that climate stabilization measures fall into this last category.

Alternatively, the general framework employed by Sandmo and Starrett implies that cost–benefit analysts may address questions of risk by (a) adjusting a standard measure of net benefits to account for the value of risk reduction; and (b) discounting adjusted net benefits at the risk-free rate of return (see Howarth, 2003). This approach is illustrated by Cline's (1992) analysis of the costs and benefits of climate change, which supports stabilizing greenhouse gas emissions at roughly half the year 2000 level under business-as-usual – a target that is even stricter than the climate stabilization scenario described above. Although Cline defends his use of a 1.3% annual discount rate based on Utilitarian moral reasoning, this discount is in line with the rates of return paid by safe investments.

It is important to note that this "argument from risk" does not assert that policy-makers should adopt ad hoc or ethically based discount rates that are below the returns paid by private-sector investments. Instead, the point is that climate change policies have risk characteristics that are quite unlike those pertaining to corporate stocks. According to economic theory, the choice of discount rates should reflect the risk characteristics of the policy or project under examination. The use of low discount rates is appropriate when evaluating policies that reduce risk.

SUMMARY AND CONCLUSIONS

The economics of climate change emphasizes an approach in which the future benefits of greenhouse gas emissions reduction are discounted at a rate equal to the long-run return on corporate stocks. Since stocks generate real (inflation-adjusted) returns of roughly 6% per year, and since a 6% discount rate implies that one dollar of benefits obtained one century from the present attains a present value of less than one cent, this method implies that only modest steps toward greenhouse gas emissions are economically warranted.

This chapter has critiqued this approach through appeals to three independent lines of reasoning. First, a Classical Utilitarian would reject conventional discounting in favor of an approach that attached equal weight to the welfare of present and future generations. Because the prospect of economic growth implies that the utility provided by an extra dollar of expenditure should fall over time, Classical Utilitarianism is possibly consistent with the use of a low (but positive) monetary discount rate. Nonetheless, a Utilitarian would view the use of a 6% discount rate of morally unfair.

Second, the concept of stewardship, according to which future generations are entitled to enjoy the benefits of an undiminished natural

environment, implies that it is morally unjust for present generations to engage in actions that impose uncompensated environmental costs on posterity. Yet the use of conventional discount rates gives rise to an "optimum" in which greenhouse gas emissions impose major costs on future generations, including a real potential for low-probability, catastrophic impacts.

Third, the use of a 6% discount rate is appropriate in the analysis of public policies that have risk characteristics that are similar to those associated with corporate stocks. Economic theory, however, suggests that discount rates of 1% or less should be used to evaluate policies that reduce future risks. Of course, a key objective of climate change policies is to reduce the risks faced by future society.

Significantly, these arguments rest on quite different judgments regarding the principles that should be employed in balancing the interests of present and future generations. All three, however, suggest that there are good reasons for stabilizing greenhouse gas emissions significantly below the level current generated by human activities. One would need to reject each of these arguments to justify the use of conventional discounting procedures in the economics of climate change.

APPENDIX: MODEL DESCRIPTION[1]

The numerical results described in Figs. 1–5 are based on a simplified model of the links between climate change and the world economy that was developed by Howarth (1998). The model's empirical assumptions are derived from the previous work of Nordhaus (1994b), who provides a concise representation of climate dynamics and the technical determinants of economic growth. Nordhaus' analysis, however, focuses on an "optimal growth" model in which decisions regarding consumption, investment, and greenhouse gas emissions are made by a hypothetical central planner to maximize a measure of long-term social welfare. Howarth's model, in contrast, makes use of an alternative specification in which routine economic decisions are made by individual households and businesses. In this model, the role of government is limited to the definition of environmental policies.

The model considers a market economy in which goods and services are produced using inputs of capital and labor. Economic output is divided between consumption and investment, and production is carried out by competitive firms that seek to maximize their profits given the prevailing prices of inputs and outputs. In the model, wages and salaries account for three-quarters of the value of economic output while capital accounts for the

remainder. In addition, the model assumes that technological change augments the level of output at an initial rate of 1.4% per year. In line with standard demographic projections, the human population rises from its present level of about 6.0 billion persons to 10.5 billion in the long-run future. Population growth is concentrated in the next 100 years, during which four-fifths of the total increase occurs. The model assumes that the supply of labor is proportional to the total population. Individuals earn wage income by providing labor services to employers in the production sector.

Decisions regarding savings and investment are made by private individuals. A typical person lives for 70 years, investing part of the income she earns during her working years to provide for her retirement in old age. Savings are invested in capital goods at the prevailing interest rate, which reflects the incremental contribution that increased wealth makes to future economic activity. The model's assumptions about consumer preferences are chosen to match expected rates of economic growth.

The model assumes that greenhouse gas emissions – which include carbon dioxide, chlorofluorocarbons (CFCs), and CFC substitutes – increase in proportion to economic output. In the absence of emissions abatement policies, emissions in the year 2000 amount to some 0.37 kg of carbon equivalent per dollar of output. Due to technological innovations, the ratio of emissions per unit output falls at an initial rate of 0.55% per year. The model assumes that emissions abatement, although technologically feasible, is economically costly. A 50% reduction in greenhouse emissions requires a 0.93% reduction in economic output. Abatement costs rise to 6.86% of economic activity when emissions are fully controlled.

The model rests on a simple, but analytically tractable, representation of climate dynamics. Approximately two-thirds of greenhouse gas emissions go into the atmosphere, while the remaining third is absorbed by ecosystems and the surface waters of the oceans. Once in the atmosphere, a typical greenhouse gas molecule remains airborne for 120 years. Thus, anthropogenic emissions of greenhouse gases are removed from the atmosphere to the deep ocean at an effective rate of 0.833% per year. The model assumes that mean global temperature increases with the level of total greenhouse gas concentrations, measured in terms of carbon equivalent. A doubling of greenhouse gas concentrations relative to the pre-industrial norm (i.e., the prevailing conditions of the late 19th century) causes a net temperature increase of 2.91°C. The climate impacts of methane and nitrous oxide (which are small in comparison with those caused by carbon dioxide, CFCs, and CFC substitutes) follow a fixed time path that is not affected by public policies.

A critical aspect of the model is regarding its assumptions about the damage imposed by climate change. Following Nordhaus (1994b), the model assumes that a 3.0°C temperature increase imposes environmental costs equivalent to a 1.33% reduction in economic output, while a 6.0°C temperature increase leads to a 5.32% output loss. The level of damage is proportional to the economic activity.

NOTES

1. This appendix is adapted from Howarth (2000).

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ALIGNING JUSTICE AND EFFICIENCY IN THE GLOBAL CLIMATE CHANGE REGIME: A DEVELOPING COUNTRY PERSPECTIVE

P. R. Shukla

MINIMIZING AND SHARING THE BURDEN

Fairness is central to any multilateral regime, that is, any agreement between multiple nation-states to address and resolve a common problem. Climate change mitigation is among the key global environmental concerns that will require a common agenda, approach, and set of actions by the community of nations. To that end, global climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC, 1992) are centered on establishing a multilateral framework to control greenhouse gas (GHG) emissions from all nations and to help those who would be affected by climate change.

Although intertwined with issues (e.g., energy, transport, water, food, and forests) that are fundamental to the economic interests of all nations, the international effort to address climate change has hitherto met only with limited success. Negotiations have been confined to the limited goal of

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controlling emissions from industrialized countries that are historically and currently the largest emitters. Even proposals for limited actions, such as the Kyoto protocol (UNFCCC, 1997), have met with significant opposition from the largest emitters – the United States and the owners of fossil fuel resources.

Meanwhile, scientific information (IPCC, 2001a,b,c) is increasingly indicating the rising threats that climate change poses to human and natural systems. Scientific and economic assessments (IPCC, 2001d) show that the burden from efforts to address climate change would be significant. This burden includes costs of GHG emissions mitigation, adaptations, impacts, and risks (Chichilnisky & Heal, 1993). In this context, the key questions are first, how to minimize the total burden, and second, how nations would share the burden fairly. The first concerns efficiency and the second concerns justice.

Principles laid out in the UNFCCC refer to both questions. Economic efficiency is urged in Article 3.3: "policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost." On burden sharing, Article 3.2 exhorts that "Parties, that would have to bear a disproportionate or abnormal burden under the Convention, should be given full consideration."

EFFICIENCY IN THE CLIMATE CONTEXT

Efficiency in the context of climate change means minimizing the extent of the climate change burden and is synonymous with cost-effectiveness. The climate change burden has two dimensions: first, the cost of mitigating emissions to reach the desired GHG concentration stabilization target and second, the cost of adaptation to and impacts of climate change. Costs and benefits of climate actions vary across nations and activities. For instance, sizable emissions reductions could be feasible in developing countries (that is, countries with a comparatively low material standard of living) at relatively lower costs compared to reductions carried out in industrialized nations. Thus, the global cost-effectiveness would mandate sizable mitigation in the developing world. Efficiency alone would thus transfer the mitigation burden to developing countries. The mitigation analysts, whose models are structured on neoclassical economics (which assumes that market outcomes are shaped by the rational and well-informed decisions of households and businesses), most often only go this far. The sharing of mitigation cost is left out as a separate problem, merely a secondary

side-payment issue. Similarly, cost of adaptation and impacts are also low in developing countries. The impacts analysts, using a similar economic paradigm, also arrive at the conclusion that most cost-minimizing actions need to be carried out in developing countries.

However, I hold that GHG emissions are global public goods with negative external effects. Their mitigation produces global benefits. This entails that the adoption of efficiency or cost-effectiveness as a stand-alone criterion would have the rich nations "free riding" on efforts whose costs are borne by poor countries. This claim is based on the notion that climate impacts most often incur local and private costs. Adaptation actions, on this line of reasoning, would produce local benefits. The costs of adaptation, however, arise from unmitigated emissions. Even the most cost-effective adaptation actions are externally imposed by emitters, who are historically and currently the richest nations. Under the exclusive cost-effectiveness criterion, these nations would, I argue, "free ride" by imposing costs on poor nations.

An efficient regime could be quite inequitable. Yet, paradoxically, this kind of regime requires universal participation – both for the good of others in emissions mitigation and for the good of those nations when they adapt to the harmful effects of others' actions. In the case of climate change, the irony is stark since the poor would bear the consequences of the actions or inactions of the rich. A global regime cannot be constructed on such a weak foundation. "Justice," as Rawls (1971) has pointed out, "is the first virtue of social institutions." A robust climate change regime can be built only on the foundation of fair and equitable burden-sharing arrangements. Here, justice would be not only its virtue, but also the engine for ensuring universal cooperation – the necessary condition for efficiency.

JUSTICE IN THE CLIMATE CONTEXT

Climate change arises from accumulation in the atmosphere of GHGs emitted in and through human activities. The complexity of the issue of justice in the climate context arises from the global and long-term character of the problem and the asymmetry of emitters and impacted groups – spatially and temporally. Limiting emissions would impose costs on emitters, but would reduce costs borne by those affected by emissions. Underlying climate mitigation arrangements, such as emissions limitations, are justice issues, such as how much does a particular nation have the right to emit based on principles of fair distribution?

Emissions mitigation is but one dimension of the justice problem; adaptation to impacts and compensation to affected parties pose other questions of justice. Impacts of climate change have two characteristics that add to the complexity of the climate question. First, for a given global emissions trajectory, the distribution of impacts across nations is independent of the emissions profile of each nation. Second, the impacts would span a long duration due to the long life of GHGs in the atmosphere (see Houghton et al., 1996).

Thus, central to the justice issues are both intragenerational and intergenerational equity concerns, this chapter focuses on intragenerational distributive justice, that is, distribution of emissions entitlements among nations in the time period beyond 2012 (the term of the Kyoto Protocol). Immediate global negotiations and actions are centered on this issue. In time, though, intergenerational equity will become increasingly important in multilateral negotiations.

EQUITY PRINCIPLES AND PERSPECTIVES

Diverse equity principles and perspectives underlie the climate change debate (see Banuri, Goran-Maler, Grubb, Jacobson, & Yamin, 1996; Rose, 1990; Rose & Stevens, 1993). The central ones are: (i) per capita entitlements (see Agarwal & Narain, 1991; Grubb, 1989) or the egalitarian principle (see Rose, 1990), (ii) historical responsibilities (see Hyder, 1992), (iii) basic needs, (iv) obligation to pay – a composite criteria that combines historical responsibility and basic needs (see Hayes, 1993), (v) Rawlsian criteria (see Benestad, 1994), (vi) ability to pay (see Smith, Swisher, & Ahuja, 1993), (vii) ''grandfathered'' emissions (see Bodansky, 1993), and (viii) utility maximization (see Chichilnisky & Heal, 1994).

Apart from the direct equity-based approaches, various indirect but practical approaches have been proposed in the literature. A few prominent ones include:

1. *Income-based graduation to emissions commitment* (see Edmonds & Wise, 1997): This approach proposes differentiated timings for graduation of each country into binding emissions limitation commitments-based criteria like per capita income exceeding a pre-specified level.
2. *Contraction and convergence* (see Global Commons Institute, 1996): This approach proposes a long-term pathway for evolution of future emissions for each country, resting on the principle that national emissions of

CO_2 should converge at a common per capita level. The implementation involves specifying the global emissions pathway and convergence by all nations to the per capita emissions level so as to achieve CO_2 concentration stabilization in the long term, such as by the year 2100.

3. *Soft-landing in emissions growth* (see Blanchard, Criqui, Trommetter, & Viguier, 2001): this approach differentiates countries by categories based on criteria like their emissions and income. For each category of emission reduction, targets are proposed in stages to achieve a gradual transition to low-emissions path.
4. *The ''development and climate'' paradigm* (see Heller & Shukla, 2003): this approach offers a practical solution to equity via sustainability. Its premise rests on the strong evidence that strategies driven by core-development priorities in developing countries can simultaneously produce climate benefits. The approach advocates adherence to climate strategies that explicitly address the fundamental needs of developing countries, if they are to be constructively and seriously engaged in common efforts toward climate protection.

Equity is vital for avoiding conflicts in that it can reconcile multiple interests, perspectives, needs, and diversity – a precondition for constructing a robust multilateral framework. Emissions profiles of developed and developing countries, however, reflect very different histories. To accommodate this diversity, emissions limitations negotiations have followed a two-track approach, as described in the Kyoto Protocol. The emissions rights of developed nations are ''grandfathered'' in proportion to their emissions at an agreed time. Developing countries are excluded from binding commitments, keeping in view their low emissions history and compromised ability to pay. Critics have argued that the ''grandfathered'' emissions distribute higher entitlements to present polluters. On this line of reasoning, past dated ''grandfathering'' would disfavor developing countries since their emissions are historically low and would only rise in the future. Since the Kyoto Protocol excludes developing countries from binding commitments, the ''grandfathering'' is not contested. On the other hand, discarding ''grandfathering'' and allocating emissions rights on an equal per capita principle is proposed by those who argue for the equal right of each person to the global commons, akin to the right to vote. A compromise between ''grandfathering'' and per capita emissions rights is the ''contraction and convergence'' framework, which accepts ''grandfathered'' allocations at the beginning but then requires convergence in the future with equal per capita entitlements that could match the desired stabilization trajectory. The convergence limit

and the timing of convergence are, then, the key equity parameters for transition to equal emission rights.

A practical, though indirect, approach is based on a graduation threshold that differentiates the timing of the entry of a country into the binding emissions limitations regime. For instance, Edmonds and Wise (1997) propose an "income-based graduation" for the entry of developing countries into a technology-based protocol for emissions limitations. When the per capita income of a country reaches the agreed-upon threshold level, it graduates to the protocol. The technology protocol then mandates the country to agree to technology standards, such as compulsory use of carbon capture and storage technology, with any fossil-based new electricity capacity. Variants of the graduation approach exist, which are based on a set of complex graduation indices (Michaelowa, Butzengeiger, & Jung, 2003; Nordhaus, 2001) that direct the entry of a nation into a specific protocol. For example, "soft-landing," a variant of the graduation approach, proposes entry for developing countries into the protocol based on criteria like their ability to pay and per capita emissions contributions (Blanchard et al., 2001).

A practical solution to equity via sustainability is proposed under the "development and climate" paradigm (Heller & Shukla, 2003). Its premise rests on the strong evidence that strategies driven by core development priorities in developing countries can simultaneously produce climate benefits. This approach advocates adherence to climate strategies that explicitly address the fundamental needs of developing countries if they are to be constructively and seriously engaged in common efforts toward climate protection.

EQUITY IN THE UNFCCC

The principles of the UN Framework Convention on Climate Change explicitly refer to varied equity criteria. The principle of "common but differentiated responsibilities" (Article 3.1) exhorts industrialized nations to accept a leadership role and bear greater burden. Equity concerns are similarly reflected in the special attention and considerations proposed for developing country parties, which are particularly "vulnerable to the adverse effects of climate change" and have "to bear disproportionate or abnormal burden under the convention" (Article 3.2). The fact that developing countries are excused from binding emissions limitation commitments in the Kyoto Protocol reflects the Convention's equity commitments.

EQUITY – PROCEDURAL AND CONSEQUENTIAL

Two types of equity (Banuri et al., 1996) underlie the multilateral frameworks that have been discussed so far – procedural and consequential. Procedural equity refers to the "impartiality and fairness" in the process of delivering and administering justice. Principles like inclusive participation of affected parties in justice proceedings or equal treatment of all before the law reflect the notion of procedural equity. In multilateral processes, procedural equity concerns on the part of developing countries often arise not from their formal exclusion from multilateral negotiations but, rather, from their inability to influence the process due to a poor information base and weak bargaining power.

In contrast, consequential equity relates to assessing and remedying the consequences arising from climate change and mitigation actions; it addresses the sharing of the climate change burden. Despite the existence of various approaches to consequential equity, such as parity, proportionality, priority, utilitarianism, and distributive justice (see Banuri et al., 1996), there is no consensus on the superiority of a single approach. Concerns relating to consequential equity from the developing country perspective arise from countries that can be categorized as follows:

1. Low historical contribution to the existing stock of GHGs in the atmosphere.
2. Very low per capita emissions that are only a fraction of those in the developed countries (see Banuri et al., 1996).
3. Risk from climate change impacts (e.g., on small island nations) in proportion to the size of their economy.
4. Lack of resources, technologies, and capabilities to mitigate the impacts.

In short, agreements that draw on consequential equity involve determining the share of the burden for each party; procedural equity ensures that the decisions were arrived at in a free and fair manner. Both types of equity are essential to creating a robust multilateral regime.

"UNKIND" HISTORY

History leaves its own equity imprint; considerations of justice to redress any inequities left by history are a separate issue. The background conditions (the end product of history) have profound implications for future

equity arrangements. In the case of climate change, history has been ''unkind'' to developing countries in two types of background conditions. The first is the uneven bargaining power among nations, wherein developing countries are in an inferior position. Developed countries control finance, political power, and resources – these are the conditions that would distort free bargaining. In a free world, in theory, the distribution of emissions rights, for instance, is a bargaining problem with multiple players wherein the players reach a voluntary agreement that makes none worse off and some better off compared to the status quo (Kverndokk, 1995). However, when this bargaining power is unequally distributed, the agreement may not be Pareto-optimal, i.e., it may leave room for further improvements that serve to advance the interests of all parties.

The second unkind background condition is the timing of the occurrence of any climate phenomenon. Industrialized countries developed when the phenomenon of climate change was not yet manifested. Their emissions were, therefore, not constrained, though these emissions continue to occupy the atmosphere. In contrast, climate change has coincided with a period in which many developing countries are set for rapid economic growth. These major developing countries like China and India are endowed with coal, the most carbon-intensive fuel. Proposed emissions limitations agreements now would transfer the mitigation burden to developing countries, despite their lower per capita emissions and ability to pay compared to industrialized nations.

These initial conditions could distort climate negotiations, enhance inequity, and exacerbate contradictions among the nations and thereby hamper full, unreserved participation of nations, the main condition for success of the regime (Kverndokk, 1995).

ASYMMETRY OF EMISSIONS AND IMPACTS

Emissions cause impacts; this is the fundamental causal relation in the climate change phenomenon. GHGs are long-lived and well-mixed gases. Geographical distribution of impacts is, therefore, independent of the origin of emissions. This means that the causality of emissions and impacts is geographically asymmetric – in fact unfavorably so for developing countries. This asymmetry further distorts the already unfair background conditions. Compared to low emitters, like small islands, affluent nations emit more but have higher adaptive capacities and suffer lower welfare losses (experience fewer burdens) from climate change. Since climate change impacts are

uncertain and inadequately understood, the future generations of poor nations would face greater risks. Receiving due compensation for impacts would not be feasible – not only because the insurance markets are underdeveloped in developing countries but also because valuations remain plagued by controversies about the value of life, future purchasing power parity, and discount rates (see Shukla, 1996b). Rich emitters could, therefore, "free ride" at the expense of the poor impacted populace in developing countries, notwithstanding the fact that the future generations of present developing countries could be richer and more capable than their current ancestors.

EFFICIENCY ALONE – THE NEOCLASSICAL PERSPECTIVE

A principal objective of the multilateral negotiations is to determine the norms for using the atmosphere, a global common. In a celebrated paper, Coase (1960) cogently argued that, in the absence of transaction costs, the market exchange would lead to efficient resource allocation regardless of the distribution of rights. The neoclassical economic interpretation of Coase's argument, theoretically articulated as the "Coase theorem," leads to the conclusion that free markets would minimize total costs, including economic and social costs. The corollary of the "proof" is that equity is immaterial to socially optimal arrangements (or, alternatively, that market efficiency and equity are separate issues). To neoclassical economics, then, market efficiency alone is relevant and equity is irrelevant.

This perspective gained ground over the past decade with emergence of the new world economic order. Under its influence, the climate debate remained restricted to the agenda to develop a cost-minimizing mitigation regime. Market tautologies, such as equalization of marginal costs across nations, sectors, and time periods, gained ascendance as the sole criterion for determining the level of participation of each nation in the regime. Climate negotiations remained confined to defining and refining flexible market instruments like tradable emissions rights. In climate negotiations, as in the world trade negotiations, the "efficiency-alone" perspective was well suited to the interests of industrialized countries, since cost-efficiency suggested locating most mitigation actions in "technologically backward and inefficient" developing countries. Furthermore, the absence of equity sidelined the issue of who should pay for these actions.

EQUITY FOR EFFICIENCY – THE DEVELOPING COUNTRY PERSPECTIVE

Limitations of the neoclassical perspective are, however, exposed when one realizes that free markets with no transaction costs do not exist. This global real-politik rests on foundations of power (not freedoms), abilities (not needs), and capacities (not vulnerabilities). Climate negotiations to date are confined to the mitigation efficiency agenda, as it suits the interest of powerful developed countries. Climate mitigation actions, however, require universal cooperation. Those who are outside the agreement could benefit in situations involving competition, as their emissions are not penalized. The nations facing impacts would cooperate only if fairly compensated. The parties, thus, not only have cooperative needs to minimize the global burden but competing needs to minimize their own share of the burden.

The market efficiency-oriented global mitigation assessments arrive at the obvious conclusion that the cheapest mitigation actions can only be carried out in developing countries (see IPCC, 2001c; Richels, Edmonds, Gruenspecht, & Wigley, 1996) due to prevailing market inefficiencies and inadequacies. However, a cost-effective analysis of this kind has two major deficiencies: First, it assumes the existence of efficient markets in a developing country and, second, it ignores equity in burden sharing (see Shukla, 1996a). In other words, such analysis suffers from the neoclassical pitfall of separating efficiency and equity. If there were no transaction costs and if cost-effectiveness was the sole criteria, the negotiations would have been needless – and, as per the Coase theorem, the trivial solution would have been to agree on a market instrument like emissions trading; cost-effectiveness would have automatically materialized.

In the real world, however, there are transaction costs. The developing country view suggested by the Coase theorem duly recognizes this, and hence differs from the neoclassical view. In situations involving multiple players with conflicting interests, there are high transaction costs that render market instruments inefficient. Low transaction costs are necessary for market efficiency. This point is particularly important in the context of the climate change issue – where stakes are high, interests of parties are in conflict, and perceptions of what justice means vary widely – the transaction cost of reaching an agreement could, in fact, be very high. The primary challenge global negotiators face is to minimize transaction costs, which will automatically lead to efficiency, à la Coase theorem. The transactions in a long-term multilateral agreement would be frictionless only if players were convinced that the negotiation process was just and fair and the end results

equitable. Equity is central to minimizing transaction cost and should be the raison d'être of negotiations; if it is, efficiency will follow. Climate negotiations have, to date, been tardy and wayward; they will progress only if equity is given primacy.

EMISSIONS STATUS

At the turn of the millennium, in the year 2001, carbon dioxide emissions from human activities worldwide amounted to 6.57 billion tons of carbon equivalent. Emissions grew at an annual rate of 1.1%, despite the recognition of climate change as the major global environmental threat. North America, with 5% of the global population, contributed 30% of the global emissions. In contrast, developing countries, with two thirds of the world's population, contributed only one third of the global emissions. The stark difference in per capita emissions among developed and developing countries is demonstrated in Fig. 1.

Atmosphere is a global common resource; at present, it is used inequitably. A sink of GHGs and atmosphere was not thought of as a scarce resource until the discovery of the climate change phenomenon. The use of atmosphere as a sink of GHGs needed to be restricted; consequently, defining the right to use or occupy the atmosphere emerged as central to climate negotiations. Since GHGs have a long life in the atmosphere – the

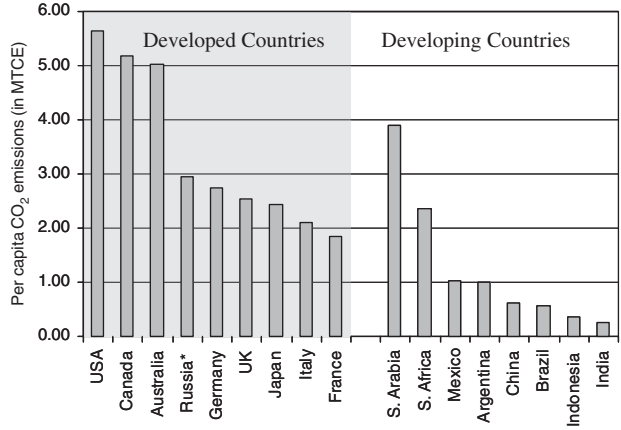

Fig. 1. Per Capita CO_2 Emissions of Representative Developed and Developing Countries (Year 2000).

average life of carbon dioxide (CO_2) in the atmosphere is over 100 years (IPCC, 2001a) – their occupation of atmosphere is a cumulative or stock problem as opposed to local pollutants like particulates or sulfur dioxide, which have a short life span and do not accumulate. As a result, historical emissions of GHGs would continue to occupy the atmosphere for a relatively long period of time. This situation sustains and exacerbates inequity in the occupation of the atmosphere by developed and developing nations, and rich and poor individuals, globally. The principal equity issue in this context is the equitable allocation of rights to occupy the atmosphere.

FUTURE EMISSIONS

Whereas, historically and presently industrialized countries have been the chief contributors to GHG emissions, future emissions scenario assessments (SRES, 2000) show that emissions from developing countries may grow faster compared to those from the developed world. However, while total emissions from the developing countries will likely surpass those of the developed countries within two decades (SRES, 2000), the per capita emissions from developing countries will remain far below those of developed countries well into the future. On average, a person living in a developing country would, therefore, occupy less atmosphere throughout the century. This inequity in the use of atmosphere would persist for an extended period of time.

What is a fair solution to this inequitable access to the global common resource? This is a crucial, complex issue that has invited attention from divergent perspectives and approaches, and that has led to controversy and disagreement. The defining and assigning of emissions rights of individuals and nations has been central to the emissions mitigation agenda in the climate negotiations.

EMISSIONS MITIGATION AND DEVELOPING COUNTRIES

Most of the plausible emission scenarios suggest that, even with strong emissions mitigation in developed countries, developing country emissions must fall below business-as-usual projections if atmospheric GHG concentrations are to be stabilized by 2100 (IPCC, 2001a). On this scenario,

economic growth, a key driver of emissions, would nonetheless remain the utmost priority of developing nations in the long run. Economic growth has a dual relationship to emissions. Globally, economic growth, energy use, and GHG emissions have remained linked through modern history. In developing countries, particularly those with low per capita energy use, sustained growth will require an absolute increase in the total energy production and consumption. However, growth also raises the demand for environmental quality and, through improved technology, creates new opportunities to produce and use energy more cleanly and efficiently.

The emission scenarios (SRES, 2000) described by the Intergovernmental Panel on Climate highlight the potential importance of technology innovation and diffusion in weakening the historical linkages between growth, energy intensity, and carbon output. Certain scenarios project both lower emissions and higher economic growth relative to alternative scenarios with technology choice among the critical underlying variables. Technology patterns, and the organizational and institutional arrangements that encourage and maintain them, emerge as the key determinants of future emissions paths – regardless of the rate of economic growth. Such de-linking of emissions with economic growth has been observed in the past. For instance, the carbon intensity of the gross domestic products (GDPs) of the United States, Japan, and France was similar in 1970. Intensities have declined in all three countries, though at different rates. By 2000, French intensity (following the growth of nuclear electricity and high-speed rail) was 60%; Japanese intensity (judged on the basis of efficiency and structural investments) was 80% of US intensity.

To date, however, the international climate regime has been largely ineffective in delinking economic, energy, and emissions growth, providing neither the incentive nor the means for developing countries to pursue alternative paths. As a result, emissions mitigation is imposed as an external constraint and as a barrier to development; the conflict lies therein.

ENGAGING DEVELOPING COUNTRIES: ALTERNATE APPROACHES

Ample arguments exist from developing countries' viewpoints for why not to actively engage in emissions mitigation (Shukla, 1999). The climate regime to date has ignored the concerns underlying these arguments. Notwithstanding this fact, developing countries have enthusiastically participated in the

climate regime since its inception. The vital questions before the climate negotiators are not whether developing countries should mitigate or how much they should mitigate but, rather, who would pay for mitigation actions and how to ensure that mitigation actions would not hamper the achievement of development goals. The former questions belong to the domain of efficiency and the latter to that of equity.

Myriad approaches have been proposed officially by nations, such as Brazil (Brazilian Ministry of Science and Technology, 2000), or by various researchers (Barrett, 2003; Cooper, 1998; Edmonds & Wise, 1997; Global Commons Institute, 1996; Heller & Shukla, 2003; McKibbin & Wilcoxen, 2002; Müller, 1999; Nordhaus, 2001; Schelling, 2002; Victor, 2001). These proposals are diverse in terms of approach, measures, and mechanisms. Two broad trends emerge among the proposals: one is results oriented and the other is process- or conduct-oriented. A brief discussion of these two types of proposals for engaging developing countries in mitigation actions follows.

The first is the "contraction and convergence" proposal (Global Commons Institute, 1996), which proposes contraction (reduction) of per capita emissions of each nation to a convergence limit at an agreed-upon future time. This approach provides room for increasing emissions for those countries, mainly developing countries, whose per capita emissions are below the agreed-upon convergence limit, and mandates contraction from those nations whose per capita emissions are above this limit. The second is the so-called "development and climate" paradigm (Heller & Shukla, 2003), which purports to construct an agreement for making development the driving force for addressing climate change challenges. This approach proposes alignment of the climate actions with national projects and programs that are already crafted for achieving sustainable development goals. Its key proposition is to align the concerns of the Climate convention with universally agreed-upon development goals, such as those exhorted by the Millennium Declaration and the Johannesburg Declaration from the World Summit on Sustainable Development (United Nations, 2002).

CONTRACTION AND CONVERGENCE

The "contraction and convergence" framework proposes to bridge the gap in per capita emissions between developed and developing nations within a few decades. Its main aim is to specify the long-term pathway for evolution of national emissions of CO_2 that would converge at a common per capita

level. The proposal typically involves two steps. The first specifies a global emissions pathway for each year, corresponding to a stabilization target for a long-term CO_2 concentration level such as 550 ppmv (parts per million volume) by the year 2100. The second allocates annual emissions limits among nations for per capita emissions to converge at an agreed-upon date in the first half of the century. This proposal reflects ''grandfathering'' and ''equal per capita emissions entitlement'' principles.

Prima facie, the compromise reflected in this proposal appears practical and acceptable, since ''grandfathering'' suits the present needs of developed nations and ''equal per capita emissions entitlements'' fit well with the demands made by developing countries (Agarwal & Narain, 1991). Fairness is not the natural outcome of the framework; it is, rather, a function of the parameters of the framework: the convergence limit and the rate of convergence. Thus, the equity conflict is pushed to another domain, that of agreeing to these parameters. Unless these parameters are agreed on in a fair manner, the result could contravene accepted equity principles like the obligation to pay, Rawlsian (Rawls, 1971) criteria, and welfare maximization.

The per capita emissions gap between the developed and developing nations today is very high (see Fig. 1). Under the business-as-usual approach, in a few decades, the per capita emissions of a developing country could cross the emission limit, and from then on that nation would be a net buyer of emissions entitlements. Early entry of a developing country into such a binding commitment, which is likely to happen under the conventional conception of convergence (Jepma & Munasinghe, 1998), could be doubly inequitable if convergence pathways are constructed presuming that the per capita emissions trajectories of developed and developing nations will converge without crossing the target (Fig. 2a). Such convergence would make developed nations the net gainers of emissions entitlements (Fig. 2a, Area A) and developing countries the net contributors (Fig. 2a, Area B) for all times – past and future.

The income effect (see Kuznets, 1955) is likely to cause the per capita emissions from the developed countries to transition to a declining trajectory earlier than in the developing countries. In later periods, developing countries will experience a rising burden associated with buying entitlements or incurring mitigation costs. For instance, the present per capita carbon emissions from China are 0.7 tons of carbon, and these emissions are rising rapidly. The enforcement of a stabilization requirement, such as 550 ppmv (Wigley et al., 1997), would require the convergence limit to be below this trajectory later in the century. Even if the limit were set in the earlier period at a higher level, say at around 1 ton of carbon per capita, China would

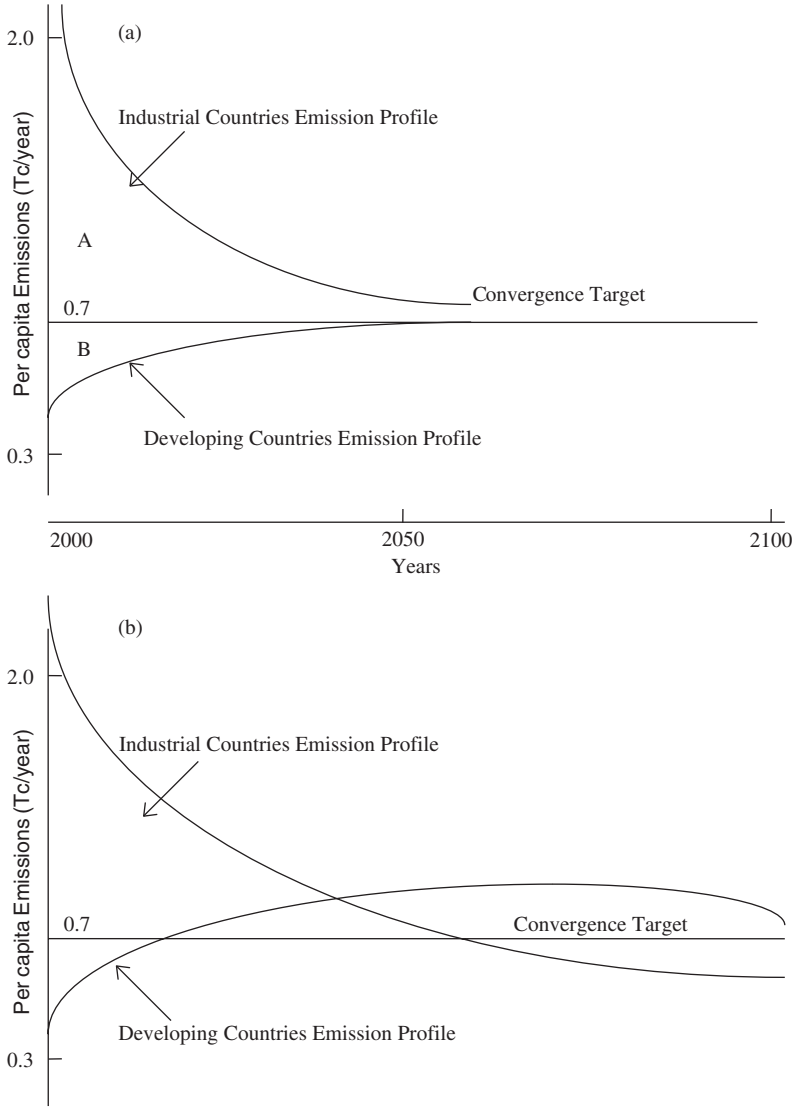

Fig. 2. Convergence Pathways of per Capita Emissions (Stylized Representation). (a) Conventional Convergence Concept. (b) Just and Equitable Convergence Profiles.

become a net buyer of entitlements within this decade or would have to incur significant emissions mitigation costs for transitioning to a lower carbon emissions trajectory. This situation could be unfair from the perspectives of both historical responsibility and ability to pay, given China's low historical per capita emissions and income.

A more equitable convergence scheme (Shukla, 1999), from the perspective of developing countries, may follow the trajectories shown in Fig. 2(b). The developing country per capita emissions can first cross and then converge to the target level, while remaining on a downward path that follows an environmental Kuznets curve. (The reference to Kuznets curves is linked to Kuznets' empirical observation that income inequality tends to first rise and then fall in the course of economic development, yielding an inverted U-shaped curve between per capita income and inequality or, by extension, environmental performance.) Alternatively, fairness would require dynamic targets that at first allow rising and then declining trajectories for developing countries so that they earn and bank entitlements for later use.

The contraction and convergence framework is useful for reconciling the divergent interests and views of nations on the basis of their diverse per capita emissions profiles. This framework limits equity measurements to two simple parameters and can, therefore, facilitate comparison of alternate equity formulations. However, it is neither an instrument for cooperation nor a mechanism for creating equitable solutions.

THE DEVELOPMENT AND CLIMATE PARADIGM

Climate change interfaces with various societal and natural processes and, consequently, with development processes. Development and climate intersect along two broad dimensions. First, the localized impacts of climate change like water shortages, agricultural disruption, and coastal flooding pose serious long-term threats to development. These impacts will be felt disproportionately in developing countries. Second, development activities emit GHGs, which are driving forces of climate change. Developing countries, particularly those that are least developed, have expressed considerable concern about their vulnerability to climate impacts. Since the impacts are considered a future problem, climate negotiations have concentrated on emissions mitigation. Balance in emphasis between mitigation and adaptation must be restored. Aligning development and climate actions in developing countries is the most practical and effective way to restore the balance and ensure the participation of developing countries.

Conventionally, global policymakers have viewed climate change as a barrier to development, and development as a threat to climate change. Most conflicts in climate debates and negotiations can be traced to this perspective. The current impasse in negotiations and progressively divergent views among nations now demand alternate perspectives. One alternate approach is the development and climate paradigm, which views development, i.e., the building of capacities, institutions, and human capital in developing countries, as the key driving force for enhancing the capacity to adapt to or mitigate the climate change. This paradigm holds that innovations and cooperation can support the simultaneous improvement of development and climate.

To this end, the development paradigm proposes a myriad of climate-friendly economic and social activities. Since national sustainable development goals tend not to require aggressive advances in the climate change arena, the achievement of these goals accrues a "double dividend" in terms of added climate change benefits. The cascading effects of sustainable development would reduce emissions, moderate the costs of adverse impacts of climate change, and enhance welfare. In recent years, many developing countries have attempted to align national goals with globally agreed-upon sustainable development priorities (Shukla, Sharma, Ravindranath, Bhattacharyya, & Garg, 2003). As a result, the conventional paradigm of economic development that was woven around the optimal resource allocation is now extended to include participative processes, local initiatives, and global interfaces. From this emergent perspective, while efficiency is addressed by market mechanisms, institutions are given primacy in the nation's capacity to use resources optimally.

Most development targets address climate change concerns effectively, if indirectly. For instance, poverty reduction and elimination of hunger would enhance the adaptive capacity of the poor due to improved food security and health, while also enhancing their resilience to cope with risks from uncertain and extreme events. Increased use of hydro and renewable energy resources would reduce GHG and local pollutant emissions, enhance energy security, and provide access to water resources from additional hydro projects. Many actions for climate adaptation and mitigation can then be integrated with projects that are already under way – and could, alternatively, be designed as incremental or adjunct to projects that are justified for economic development purposes (Heller & Shukla, 2003). Climate-friendly development and national sustainable development goals, like conservation of resources and enhancements of human capacity, are complementary. In fact, cascading effects of development along a sustainable pathway could

reduce emissions and also moderate the costs of adverse impacts of climate change.

CONCLUSIONS

The complexity of the climate change problem arises from three important attributes: its long time horizon, its global scope, and the fact that universal participation is necessary to address it. The progress in regime building to date has been slow and fragmented. However, robust foundations of a long-term and universally inclusive regime can be built (see Toman & Burtraw, 1991; Kverndokk, 1995, Rayner & Malone, 1997) on the pillars of equity and efficiency. This chapter is based on the premise that, while efficiency concerns are eminently represented in climate negotiations, equity has received meager attention. This error in misplaced priorities is making the climate regime both inequitable and inefficient. Giving priority to equity would support efficiency goals, too, since fair dealings reduce transaction costs, the fundamental condition for economic efficiency.

This chapter has focused primarily on the mitigation aspect of the climate regime. Its central claim is that the key issue is not ''where or when'' mitigation actions should occur, but, rather, how the mitigation burden could be distributed fairly among the nations. This is a justice issue that is not well appreciated in current climate negotiations. The unfavorable bargaining position of developing countries, refusal of developed nations to take leadership, and high stakes have heightened apprehensions, hampered cooperation, and increased risks and transaction costs.

Founding new institutions to take on the responsibility of climate change mitigation requires accepting fair principles and associated gains and losses. Studies show that stakes in climate mitigation are very high: several trillion dollars over a century (IPCC, 2001c). The gains or losses associated with accepting alternative entitlement schemes are very high for any nation. For instance, in the case of India, ''grandfathered'' or ''equal per capita'' entitlement schemes would lead to substantial losses or gains, respectively, amounting to several percent of India's GDP (see Shukla, 1996; Fisher-Vanden, Shukla, Edmonds, Kim, & Pitcher et al., 1997). Equity is, thus, potentially very costly, and is not a trivial achievement.

Justice, as the first virtue of social institutions (Rawls, 1971), should be the primary concern driving climate negotiations. Equity, again, is necessary for efficiency. This is the fundamental difference between developing countries' perception of the climate change debate, on the one hand, and the

neoclassical vision of equity and efficiency as disjoint spheres, on the other. The profound observation of Rawls (1971) warns against the dangers of constructing the climate regime on an incorrect neoclassical theory and an unjust political order; as he puts it, "A theory however elegant and economical must be rejected or revised if it is untrue; likewise laws and institutions no matter how efficient and well-arranged must be reformed or abolished if they are unjust."

The rapid rise in developing country emissions is driven by development imperatives – in particular, the need for energy and economic growth – and is encouraged by the movement of investment and technology that supports conventional paths of development. By advocating the development and climate paradigm, this chapter suggests that future climate strategies must explicitly address fundamental needs on the part of developing countries if they are to be constructively and seriously engaged in common efforts toward climate protection. These observations point to a vital nexus between development and climate change. Conventionally, vulnerability assessments and searches for adaptation solutions have been confined to climate change science and policy. Development concerns are then viewed as exogenous to the assessment, at best offering some ancillary benefits. In contrast, this chapter supports the synergizing of climate strategies with development actions, which are the key contributors to the capacity to mitigate and adapt to climate change.

There is strong evidence that strategies driven by core development priorities can produce climate benefits. For instance, China's rapid improvements in energy efficiency, while motivated principally by economic goals, have significantly slowed down the growth of its GHG emissions. Recent analyses identify similar experiences and opportunities in major developing countries. However, to the extent that developing nations regard climate concerns as no more than potential barriers to their ability to reduce poverty and increase income levels, climate issues will not command the attention of core political actors. Since constraining economic growth is not an option for these policy makers, the only politically viable approach to climate mitigation is to devise development strategies that can produce climate benefits ancillary to sustained economic expansion. A principal aim of climate policy must be to build the capacities of developing nations to recognize and meet this challenge. This strategy requires shifting the frontier that binds the climate actions and economic growth (Fig. 3), through innovations and transfers of technology and investments to developing countries.

In the context of continued uncertainty about the future of the Kyoto Protocol and the prospect of new climate negotiations starting in 2005,

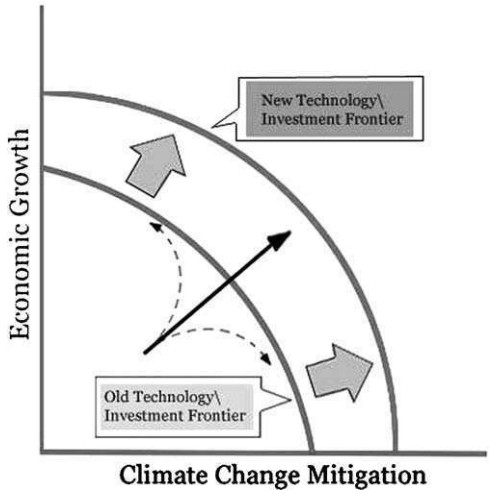

Fig. 3. Innovation and Expansion of Development and Climate Frontier.

experts, stakeholders, and governments have begun to assess a range of options for advancing the international climate change effort beyond 2012. If future mitigation efforts are to succeed, I have argued, they must align with the development priorities of developing countries, and must provide incentives for and mechanisms to redirect investment and technology flows from conventional to more climate-friendly pathways. Put simply, effective climate action must be "mainstreamed" to re-orient development paths toward those that are most climate friendly. Solutions to complex questions often do not lie where they could be obviously found. Climate negotiations would do well to shift from climate-centric to development-oriented solutions.

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PART 3:
POLITICAL PERSPECTIVES

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THE INTERNATIONAL CLIMATE CHANGE REGIME ☆

Daniel Bodansky

INTRODUCTION

Although the general theory of greenhouse warming has been understood by scientists since the end of the nineteenth century, an international regime to address the problem of climate change began to develop only in the late 1980s.[1] In the decade and a half since then, the regime has undergone a remarkable evolution. In 1992, states adopted the UN Framework Convention on Climate Change (UNFCCC), which took effect in 1994 and serves as the "constitution" for the international climate change regime.[2] In 1997, the UNFCCC was supplemented by the Kyoto Protocol, which requires industrialized countries to reduce their emissions of carbon dioxide

☆The present chapter incorporates portions of the following articles: The United Nations Framework Convention on Climate Change: A commentary. (1993). *Yale Journal of International Law. L., 18*, 451–558; Managing climate change. (1993). *Yearbook of International Environmental Law – 1992* (Vol. 3, pp. 60–74). London: Graham & Trotman; Prologue to the climate change convention. (1993). In: I. Mintzer & J.A. Leonard (Eds.), *Negotiating climate change: The inside story of the Rio Convention* (pp. 45–74). Cambridge, UK: Cambridge University Press; The emerging climate change regime. (1995). *Annual Review of Energy and Environment, 20*, 415–461; This history of the climate change regime. (2001). In: U. Luterbacher, & D.F. Sprinz (Eds.), *International relations* and *global climate change*. Cambridge, MA: MIT Press; International law and the design of a climate change regime. In *idem.*; Bonn voyage. (2001, Fall). *The National Interest, 65*, 4.

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and five other gases that contribute to the greenhouse effect (so-called "greenhouse gases" or GHGs for short). And the 2001 Marrakesh Accords further elaborate the Kyoto Protocol's regulatory regime, setting forth detailed rules for how the Kyoto Protocol will operate.

Several general features of the emerging climate change regime are noteworthy. First, the regime has aimed, thus far, at the widest participation possible, due to the global nature of the greenhouse effect and the recognition that human-induced ("anthropogenic") climate change is the "common concern of humankind."[3] This aim has been severely undermined by the withdrawal of the United States from the Kyoto Protocol in 2001, and the reluctance of developing countries to accept quantified limitations on their GHG emissions. Currently, the United States contributes more than one-fifth of global CO_2 emissions and all OECD (Organization for Economic Co-operation and Development) countries roughly one half.[4] Moreover, although emissions from developing countries are comparatively low at present, particularly in per capita terms, they are growing rapidly and are projected to surpass industrialized country emissions in the next 20–30 years. Although some have argued that a regime comprising only the dozen largest industrialized and developing countries (which together account for more than three-fourths of global GHG emissions) could potentially be effective, such a regime would be difficult to negotiate, given fears that it would provide a competitive advantage to non-participants and would lack the international legitimacy of a regime representing a true global consensus.

Second, the climate change regime exemplifies the "framework convention/protocol" approach to international environmental law – an approach used successfully to address such problems as acid rain in Europe and depletion of the stratospheric ozone layer. As its title indicates, the UNFCCC established the basic framework for the climate change regime.[5] The 1997 Kyoto Protocol then built on that framework by setting forth specific obligations and mechanisms to control the GHG emissions of industrialized countries.[6]

Third, the climate change regime has an exceptionally broad scope, encompassing not simply environmental protection as traditionally conceived (that is, limiting emissions of pollutants), but economic and development policies more generally. Virtually the entire range of human activities contribute to GHG emissions. GHG emission scenarios, for example, are highly sensitive to population growth assumptions. (According to one scenario, population growth will account for half of the increase in global CO_2 emissions from fossil fuels over the next 60 years.[7]) Thus, population policy could conceivably play a prominent role in the climate change regime.

Fourth, the climate change regime is largely neutral regarding policy options. Although climate change is primarily a problem of carbon dioxide (which accounts for about 70% of the enhanced greenhouse effect to date),[8] fossil fuels (which account for 65–90% of CO_2 emissions and 30% of methane emissions),[9] and ultimately coal (which represents more than 90% of the carbon in estimated fossil fuel reservoirs), neither the UNFCCC nor the Kyoto Protocol singles out any particular greenhouse gas or economic sector for special attention. Indeed, while attention has tended to focus thus far on mitigation – an emphasis reflected in the Kyoto Protocol – the UNFCCC addresses adaptation as well. As a result, states have significant flexibility in designing strategies to respond to climate change.

This chapter provides an introduction to the international climate change regime. The first section reviews the development of the regime, from the emergence of the climate change issue in the 1980s through the adoption of the 1997 Kyoto Protocol and the 2001 Marrakesh Accords. The subsequent section then outlines the principal elements of the regime, including:

- the objective and guiding principles set forth in the UNFCCC;
- the regime's governing institutions such as the Conference of the Parties (COP) and financial mechanism;
- the emissions limitation commitments set forth in the Kyoto Protocol, and
- innovative mechanisms such as emissions trading and the Clean Development Mechanism (CDM).

THE DEVELOPMENT OF THE GLOBAL CLIMATE CHANGE REGIME

The development of the climate change regime in the late 1980s and 1990s rode a wave of environmental activity that began in 1987 with the discovery of the ozone hole and the publication of the Brundtland Commission report, *Our Common Future*,[10] and crested at the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro.[11] An earlier wave of international environmental activity, culminating in the 1972 Stockholm Conference and the establishment several years later of the United Nations Environment Programme (UNEP), had tended to focus on local, acute, and relatively reversible forms of pollution – for example, oil spills and dumping of hazardous wastes at sea. The more recent cycle of environmental activity in the 1990s has concerned longer-term, irreversible,

global threats, such as depletion of the stratospheric ozone layer, loss of biological diversity, and greenhouse warming, and has focused not merely on environmental protection *per se*, but on the more general economic and social policies needed to achieve sustainable development.[12]

The development of the climate change regime can usefully be divided into five periods: the *foundational period*, during which scientific concern about global warming developed; the *agenda-setting phase*, from 1985 to 1988, when climate change was transformed from a scientific into a policy issue; a *pre-negotiation period* from 1988 to 1990, when governments became heavily involved in the process; the *constitutional period* from 1991 to 1995, leading to the adoption and entry into force of the UNFCCC; and a *regulatory phase*, focusing on the negotiation and elaboration of the Kyoto Protocol from 1996 to 2001.

The Emergence of Scientific Concern[13]

Although the greenhouse warming theory was put forward almost a century ago by the Swedish chemist Svante Arrhenius,[14] climate change did not emerge as a *political* issue until the last decade. As late as 1979, efforts by the organizers of the First World Climate Conference to attract participation by policymakers proved unsuccessful, and even in 1985, when a major workshop on climate change was held in Villach, Austria, the US government officials who participated did so without specific instructions. By the late 1980s, the US Congress was holding frequent hearings on global warming; the issue was raised and discussed in the UN General Assembly; and international meetings such as the 1988 Toronto Conference, the 1989 Hague and Noordwijk Conferences, and the 1990 Second World Climate Conference attracted numerous ministers and even some heads of government.

The development of the climate change issue initially took place in the scientific arena, as understanding of the climate change problem improved. Through careful measurements at remote observatories such as Mauna Loa, Hawaii, scientists established in the early 1960s that atmospheric concentrations of CO_2 (the primary greenhouse gas) were, in fact, increasing. The so-called "Keeling curve," which shows this rise, is one of the few undisputed facts in the climate change controversy and led to the initial growth of scientific concern in the late 1960s and early 1970s. During the 1970s and 1980s, improvements in computing power allowed scientists to develop much more sophisticated computer models of the atmosphere, which, while still subject to considerable uncertainty, led to increased confidence in global

warming predictions. Based on a review of these models, a 1979 report of the US National Academy of Sciences concluded that, if CO_2 in the atmosphere continued to increase, "there is no reason to doubt that climate change will result and no reason to believe that these changes will be negligible."[15] Moreover, in the mid-1980s, scientists recognized that emissions by humans of other trace gases such as methane and nitrous oxide also contribute to the greenhouse effect, making the problem even more serious than previously believed. Finally, careful reassessments of the historical temperature record in the 1980s indicated that global average temperature had indeed been increasing since the middle of the twentieth century.

Agenda-Setting, 1985–1988[16]

Despite these advances, whether improved scientific knowledge would have been enough to spur political action is doubtful, particularly given the scientific uncertainties about climate change that persist even now. Although the growth of scientific knowledge was significant in laying a foundation for the development of public and political interest, three additional factors acted as the direct catalysts for governmental action. First, a small group of environmentally-oriented Western scientists – including Bert Bolin of Sweden, who would later become the first Chair of the Inter-governmental Panel on Climate Change (IPCC) – worked to promote the climate change issue on the international agenda. As major figures in the international science establishment, with close ties to the World Meteorological Organization (WMO) and UNEP, these scientists acted as "knowledge-brokers" and entrepreneurs, helping to translate and publicize the emerging scientific knowledge about the greenhouse effect through workshops and conferences, articles in non-specialist journals such as *Scientific American*, and personal contacts with policymakers. The 1985 and 1987 Villach meetings, the establishment of the Advisory Group on Greenhouse Gases under the joint auspices of WMO and UNEP, the report of the Enquete Commission in Germany, the testimony of climate modelers such as James Hansen of NASA before US Congressional committees in 1987 and 1988 – all of these developments helped to familiarize policymakers with climate change and to convert it from a speculative theory into a real-world possibility.

Second, as noted above, the latter half of the 1980s was a period of increased concern about global environmental issues generally – including depletion of the stratospheric ozone layer, deforestation, loss of biological diversity, pollution of the oceans, and international trade in hazardous

wastes. The discovery of the so-called Antarctic "ozone hole," followed by the confirmation that it resulted from emissions of chlorofluorocarbons (CFCs), dramatically demonstrated that human activities can indeed affect the global atmosphere and raised the prominence of atmospheric issues generally. Initially, public concern about global warming rode on the coattails of the ozone issue.

Finally, the North American heat wave and drought of the summer of 1988 gave an enormous popular boost to global warming concerns, particularly in the United States and Canada. By the end of 1988, global environmental issues were so prominent that *Time* magazine named endangered Earth "Planet of the Year." A conference organized by the Canadian government in June 1988 called for global emissions of CO_2 to be reduced by 20% by the year 2005; the development of a global framework convention to protect the atmosphere; and establishment of a world atmosphere fund financed in part by a tax on fossil fuels.[17]

Early International Responses, 1988–1990

The year 1988 marked a watershed, with the emergence of the climate change regime as an intergovernmental issue. During the agenda-setting stage, the distinction between governmental and non-governmental actors had been blurred. The climate change issue had been dominated essentially by non-governmental actors – primarily environmentally oriented scientists. Although some were government employees, their actions did not reflect official national positions. Moreover, the series of quasi-official meetings that they helped organize – which were influential in communicating an ostensible scientific consensus about climate change and articulating a set of initial policy responses – were *non*-governmental rather than *inter*-governmental in character.[18]

The period from 1988 to 1990 was transitional: Governments began to play a greater role, but non-governmental actors still had considerable influence. The IPCC reflected this ambivalence. Established by WMO and UNEP in 1988 at the instigation of governments, in part as a means of reasserting governmental control over the climate change issue, the IPCC's most influential output was its 1990 scientific assessment of global warming (IPCC 1990) – a product much more of the international scientific community than of governments. Cognizant of this fact, Brazil insisted on including a statement in the report that it reflected "the technical assessment of experts rather than government positions" – thus at least temporarily reading the "I" out of IPCC.

Among the landmarks of the pre-negotiation phase of the climate change issue were (Table 1):

- the 1988 General Assembly resolution on climate change, characterizing the climate as the "common concern of mankind"[19];
- the 1989 Hague Summit, attended by seventeen heads of state, which called for the development of a "new institutional authority" to preserve the earth's atmosphere and combat global warming[20];
- the 1989 Noordwijk ministerial meeting, the first high-level intergovernmental meeting focusing specifically on the climate change issue[21];

Table 1. Landmarks in the Emergence of the Climate Change Regime.

Conference	Date	Organizer	Conclusions and Principal Recommendations
Villach Conference	1985	WMO and UNEP	Significant climate change highly probable Countries should begin considering the development of a global climate convention
Toronto Conference	1988	Canada	Global CO_2 emissions should be cut by 20% by 2005 States should develop comprehensive framework convention on the law of the atmosphere
UN General Assembly	1988	UN	Climate change a "common concern of mankind"
Hague Summit	1989	Netherlands	Signatories will promote new institutional authority to combat global warming, involving non-unanimous decision making
IPCC First Assessment Report	1990	WMO and UNEP	Global mean temperature likely to increase by ca. 0.3°C per decade, under business-as-usual emissions scenario
Second World Climate Conference	1990	WMO and UNEP	Countries need to stabilize GHG emissions Developed countries should establish emissions targets and/or national programs or strategies
UN General Assembly	1990	UN	Establishment of INC
UNCED Conference	1992	UNCED	UNFCCC opened for signature
COP-1	1995	UNFCCC	Berlin Mandate authorizing negotiations to strengthen UNFCCC commitments
COP-2	1996	UNFCCC	Geneva Ministerial Declaration calling for binding targets and timetables
COP-3	1997	UNFCCC	Kyoto Protocol
COP-4	1998	UNFCCC	Buenos Aires Plan of Action
COP-6	2000	UNFCCC	Breakdown of US–EU negotiations
COP-7	2001	UNFCCC	Marrakesh Accords

Source: Adapted from Bodansky (2001a).

- the November 1990 Second World Climate Conference (SWCC),[22] which in contrast to its forerunner a decade earlier, was a major political event, held at the ministerial level.

By the end of 1990, when the Second World Climate Conference met, the three basic dynamics in the climate change negotiations had already begun to manifest themselves – dynamics that persist to this day:

- First, a split within the industrialized country group between supporters and opponents of binding, quantitative limits on greenhouse gas emissions.
- Second, a split between industrialized and developing countries over their respective responsibilities for addressing climate change.
- Finally, a split among developing countries between those worried more about climate change and those worried more about economic development.

The split among Western developed countries was the first dynamic to emerge. Western countries conducted the bulk of the scientific research on climate change, had the most active environmental constituencies and ministries and, as a result, were the first countries to become seriously concerned about the climate change problem. At the 1989 Noordwijk meeting, the divergence among them became apparent. On the one hand, most European countries, joined to some degree by Canada, Australia, and New Zealand (the so-called CANZ group), supported adopting the approach that had been used to address the acid rain and ozone depletion problems, namely, establishing quantitative limitations on national emission levels of greenhouse gases (''targets and timetables''). On the other hand, the United States – supported at Noordwijk by Japan and the Soviet Union – challenged this approach – the US quite adamantly, Japan and the Soviet Union less consistently – on the grounds that targets and timetables were too rigid, did not take account of differing national circumstances, and would be largely symbolic. Instead, the US argued that emphasis should be placed on further scientific research and on developing national rather than international strategies and programs.[23] The differences between the US and other Western states deepened at the SWCC, with the US insisting on a recommendation that was neutral between targets and timetables on the one hand and national strategies on the other.

The SWCC also saw the emergence of a second fault-line in the climate change negotiations: the divide between developed countries (often referred to as the ''North'') and developing countries (the ''South'').[24] Earlier that

year, at the London Ozone Conference, developing countries had successfully pressed for the establishment of a special fund to help them implement the Montreal Protocol on Substances that Deplete the Ozone Layer, and, in the UN General Assembly, had insisted that the environmental conference scheduled to be held in Rio de Janeiro in 1992 give equal weight to environment and development. In the climate change context, they sought greater representation and argued that climate change be viewed not simply as an environmental issue but as a development issue as well. For both reasons, they sought to move the negotiations from the comparatively technical, narrow confines of the IPCC, in which they found it difficult to participate on an equal basis with industrialized countries, to the UN General Assembly. Their efforts proved successful, and the December 1990 resolution authorizing the initiation of negotiations[25] placed the negotiations under the auspices of the General Assembly rather than the IPCC, UNEP, or WMO, as developed countries would have preferred.

As early as 1990, however, the split among developing countries had also become apparent. Developing countries agreed on the need for financial assistance and technology transfer, but on little else. At one extreme, the small island developing countries, fearing inundation from sea level rise, supported strong commitments to limit emissions. At the SWCC, they organized themselves into the Alliance of Small Island States (AOSIS), which played a major role in the subsequent UNFCCC negotiations in pushing for CO_2 emissions reductions. At the other pole, the oil-producing countries questioned the science of climate change and argued for a "go slow" approach. In the middle, the big industrializing countries such as Brazil, India, and China tended to insist that measures to combat climate change not infringe on their sovereignty – in particular, their right to develop economically. They argued that, since the North was historically responsible for creating the climate change problem, the North should also be responsible for solving it. This position has prevailed among developing countries to this day, leading them to categorically reject proposals by developed countries – for many years, led by the United States – that they consider accepting emissions limitation targets.

Constitutional Phase: Negotiation and Entry into Force of the UNFCCC[26]

Although international environmental law has undergone impressive growth over the past 30 years,[27] when the climate change issue emerged in the late 1980s, international environmental law had little to say about it.[28] The only existing air pollution conventions addressed transboundary air pollution in

Europe[29] and depletion of the stratospheric ozone layer.[30] While customary international law articulates general principles relevant to atmospheric pollution,[31] these principles do not have the specificity and certainty needed to address the climate change problem effectively.[32] Therefore, when calls began to be made to take international action to address climate change, the unquestioned assumption was that this would require negotiation of a new treaty.

Initially, two alternative models were considered: (1) a general framework agreement on the "law of the atmosphere," modeled on the 1982 UN Law of the Sea Convention, which would recognize the interdependence of atmospheric problems and address them in a comprehensive manner; and (2) a convention specifically focused on climate change, modeled on the Vienna Ozone Convention.[33] Despite initial Canadian support for the former, the second approach quickly prevailed. The unwieldiness of the law of the sea negotiations compared unfavorably with the step-by-step approach used with great success in the ozone regime.[34]

The total time for the formal treaty-making process, from the commencement of negotiations to the entry into force of the UNFCCC, amounted to little more than 3 years, a comparatively short period for international environmental negotiations.[35] The process began in December 1990, when the UN General Assembly established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCCC), with the mandate to negotiate a convention containing "appropriate commitments," in time for signature in June 1992 at UNCED.[36] Between February 1991 and May 1992, the INC/FCCC held five sessions. It adopted the UNFCCC on May 9, 1992, and the Convention entered into force less than 2 years later on March 21, 1994 as a result of its ratification by 50 countries.

In understanding the INC process, four factors are critical. First, the June 1992 UNCED deadline exerted substantial pressure on governments. Given the public visibility of the UNCED process, most countries wished to have a convention ready for signature in Rio. Second, in contrast to the agenda-setting and pre-negotiation phases, governments were very much in control and non-governmental actors played a quite limited role. Even the IPCC did not have a substantial effect on the actual negotiations.[37] Third, although many of the principal issues in the UNFCCC negotiations were real issues with potentially substantial implications for national interests, the negotiations were often more semantic than substantive in character. Words were debated and selected as much for their political as for their legal significance. Proposed formulations took on a symbolic and even talismanic quality, only distantly connected to the actual meaning of the words. Linguistic debates became a proxy for political confrontation, with success or failure measured

not just by the substantive outcomes but by the inclusion or exclusion of particular terms. Fourth, the desire for consensus decision-making gave individual countries (in particular, the United States) substantial leverage – if not a complete veto – over the final outcome.

The negotiation of the UNFCCC (and later the Kyoto Protocol and Marrakesh Accords) followed a pattern common to international environmental negotiations. At first, little progress was apparent, as countries debated procedural issues and endlessly repeated their positions rather than seeking compromise formulations. But, while frustrating to those hoping for rapid progress, this sparring process allowed countries to voice their views and concerns, to learn about and gauge the strength of other states' views, and to send up trial balloons. Real negotiations, however, began only in the final months (or even hours) before the negotiations were scheduled to conclude, when governments realized that they would need to compromise if they wished to avoid failure. Agreement was facilitated by the preparation of a compromise text by the chairperson, which cleared away many of the incrustations of alternative formulations proposed during the course of the negotiations. Even so, countries did not reach agreement until the last possible moment, following several late night sessions involving a small group of key delegations (generally referred to as the "friends of the chair").

The initial baseline for the negotiations was the "framework agreement" model used in the preceding decade to address the acid rain and ozone issues: the 1979 Convention on Long-Range Transboundary Air Pollution (LRTAP) and the 1985 Vienna Convention for the Protection of the Ozone Layer.[38] Both of these conventions are largely procedural in nature. Their only obligations are very general – for example, to cooperate in scientific research and to exchange information. Rather than establishing strict obligations, their main purpose is to establish a legal and institutional framework for future work through regular meetings of the parties and the possible adoption of more substantive protocols.

Virtually all countries agreed that the UNFCCC should include, at a minimum, the basic elements of a framework convention – except for the oil-producing countries, which would have preferred not to have a convention at all. The main question was whether to include additional provisions. As a whole, the UNFCCC reflects the US preference for what might be called a "framework convention plus." It does not contain legally binding emission targets, as the European Union and AOSIS wished. But it goes beyond previous framework conventions by establishing a financial mechanism and comparatively strong implementation machinery, including detailed reporting requirements and international review.

To a significant degree, however, the provisions of the UNFCCC did not resolve differences so much as paper them over, either through formulations that preserved the positions of all sides,[39] that were deliberately ambiguous,[40] or that deferred issues until later.[41] From this perspective, the convention represented not an end point, but rather a punctuation mark in an ongoing process of negotiation that continues to this day.

REGULATORY PHASE: NEGOTIATION AND ELABORATION OF THE KYOTO PROTOCOL[42]

Recognizing the substantial delays that can occur between the adoption of a treaty and its entry into force, the INC/FCCC decided to continue meeting prior to the first meeting of the Conference of the Parties (COP-1) in order to elaborate and implement the UNFCCC's reporting and review procedure, to address unresolved issues such as the relations between the COP and the financial mechanism, and to begin consideration of the next steps beyond the UNFCCC. This "prompt start" to the UNFCCC process helped speed the development of the climate change regime by allowing multilateral negotiations to continue during the interim period before the UNFCCC's entry into force.[43] In addition, during this interim period, most industrialized country parties submitted national reports and the international review process began. As part of this process, the Secretariat compiled a synthesis report analyzing the overall progress by industrialized countries in implementing their commitments and initiated in-depth reviews by experts of individual national reports.

The UNFCCC entered into force on March 21, 1994, less than 2 years after its adoption. The ink had barely dried on the convention, however, when most countries (including the United States, under the newly elected administration of President Clinton) agreed that its commitments were inadequate and needed to be supplemented by more specific emission limitation objectives. In 1995, the first Conference of the Parties (COP-1) adopted the so-called "Berlin Mandate," which established an ad hoc committee[44] charged with negotiating a new agreement that would set forth additional commitments for industrialized countries for the post-2000 period. The Clinton Administration reluctantly accepted the Berlin Mandate, despite its complete rejection of US efforts to leave open the possibility of new mitigation commitments for developing countries.

The negotiations continued for 2 years, ending in the adoption of the Kyoto Protocol in December 1997. Following the pattern of the UNFCCC

negotiations, little progress was made initially, as some countries questioned the need for legally binding commitments. Until the very final stage, negotiations remained stalemated over three issues: first, what the emissions limitation targets should be for developed countries; second, whether the protocol should include "flexibility mechanisms" to allow countries to meet their targets in a cost-effective manner; and third, whether the protocol should include any emission objectives for developing countries. With regard to the first issue, the European Union proposed a comparatively strong target, requiring a 10% cut in greenhouse gas emissions below 1990 levels by the year 2010, while other industrialized countries such as the United States and Australia proposed much weaker targets, with Japan somewhere in the middle. The debate about flexibility was equally, if not more, divisive. The United States sought mechanisms to allow developed countries to achieve their emissions targets in the most flexible, cost-effective manner possible, through mechanisms that would, among other things, allow countries to receive credit for emissions reductions in other countries as well as for forest and agricultural activities ("sink activities") that remove carbon dioxide from the atmosphere. The European Union (generally supported by developing countries) tended to oppose these flexibility mechanisms on the ground that industrialized countries should meet their emissions targets primarily through reductions in carbon dioxide emissions at home. Finally, on the third issue, the United States pressed for the inclusion of a mechanism to allow developing countries to "voluntarily" assume emission limitation objectives. Not surprisingly, most developing countries strongly opposed such an approach, arguing that they were not responsible for creating the climate change problem and had other more pressing priorities.

In essence, the Kyoto Protocol represents a trade-off between EU victory on the first issue (namely, the stringency of the emission targets), US victory on the second issue (the flexibility mechanisms) and developing country victory on the third issue. The United States accepted a much stronger target than it had wanted, but succeeded in incorporating significant flexibility into the protocol. Most importantly, as detailed below, the protocol provided for the development of an international emissions trading system; created the Clean Development Mechanism (CDM), by which industrialized countries can receive credit for emission reduction projects in developing countries; and allowed for the possibility of credits for certain sink activities. Developing countries, however, successfully resisted strong US pressure to establish a process by which they could assume quantitative emission limitation goals.

While a tremendous achievement, the Kyoto Protocol deferred to future negotiations, most of the detailed issues about how the various flexibility

mechanisms would work. That was the subject of the post-Kyoto negotiations that concluded in Marrakesh in Fall 2001. The scope of these post-Kyoto negotiations was agreed upon at COP-4 in Buenos Aires, where the parties adopted a comprehensive plan for the completion of work on the Kyoto Protocol rules (the "Buenos Aires Plan of Action"). Initially, negotiations were scheduled to conclude in November 2000 at COP-6 in The Hague. But when negotiations broke down at the eleventh hour, principally over the issue of credits for sink activities, the parties agreed to reconvene the following summer to make one final effort to reach agreement. At first, it looked like this effort would be fruitless. The rejection of the Kyoto Protocol by the newly elected Bush Administration in early 2001 led many to predict the protocol's demise. But, ironically, the peremptory nature of the Bush Administration's action had the opposite effect. It galvanized other countries into action – in particular, the European Union – and led them to make the necessary compromises for adoption of the Marrakesh Accords, which set forth detailed rules fleshing out the Kyoto Protocol's often skeletal provisions. As a result of Russia's ratification, the Kyoto Protocol entered into force in February 2005.

PRINCIPAL ELEMENTS OF THE INTERNATIONAL CLIMATE CHANGE REGIME

Legal scholarship on the climate change problem reflects two contrasting approaches to international law – what might be called a "hard" and a "soft" approach. The hard approach views international law essentially in domestic criminal law terms, as a command backed by the threat of sanctions, while the soft approach views international law in facilitative terms, as a means of fostering greater cooperation among countries. At the risk of oversimplification, the UNFCCC reflects a soft approach to the climate change problem, while the Kyoto Protocol reflects a much harder approach. Despite early hopes that the UNFCCC would include a clear commitment to stabilize or even reduce GHG emissions, it does not impose strong substantive commitments on countries – for example, targets and timetables on GHG emissions or common response measures such as carbon taxes or energy efficiency standards. Instead, it puts in place a long-term, evolutionary process to address the climate change problem that: (1) enunciates the regime's ultimate objective and guiding principles; (2) establishes an infrastructure of institutions and decision-making mechanisms; (3) promotes the systematic collection and review of data; and (4) encourages national action (Table 2).

Table 2. Key Provisions of the UNFCCC.

Objective	Stabilize atmospheric greenhouse gas (GHG) concentrations at a level that would prevent dangerous anthropogenic interference with the climate system, within a time-frame sufficient to: (a) allow ecosystems to adapt naturally, (b) protect food production, and (c) allow sustainable economic development (Article 2)
Principles	Intra- and inter-generational equity; differentiated responsibilities and respective capabilities; special needs of developing country parties; right to sustainable development; precaution; cost-effectiveness; comprehensiveness; and a supportive and open economic system (Article 3)
Commitments	All countries – General commitments to: develop national GHG inventories; formulate national mitigation and adaptation programs; promote and cooperate in scientific research, education, training, and public awareness (Articles 4(1), 5, and 6)
	Developed countries (listed in Annex I) – Recognize that a return to earlier emission levels of CO_2 and other GHGs by the end of the decade would contribute to modifying long-term emission trends, and aim to return to 1990 emission levels (Article 4(2))
	OECD countries (listed in Annex II) – Commitments to fully fund developing country inventories and reports; to fund the incremental costs of agreed upon mitigation measures; to provide assistance for adaptation; and to facilitate, promote and finance technology transfer (Article 4(3)–(5))
Institutions	Conference of the Parties (COP) (Article 7), secretariat (Article 8), Subsidiary Body for Scientific and Technological Advice (SBSTA) (Article 9), Subsidiary Body for Implementation (SBI) (Article 10), financial mechanism (Article 11)
Reporting (“communication of information”)	All countries – National GHG inventories; steps taken to implement the convention (Article 12(1))
	Developed countries (Annex I) – Detailed description of policies and measures to limit GHG emissions and enhance sinks, and a specific estimate of their effects on emissions (Article 12(2))
	OECD countries (Annex II) – Details of financial and technological assistance measures (Article 12(3))
Adjustment procedure	Reassessments of the adequacy of commitments every 3 years, based on the best available scientific information (Article 4(2)(d)). First reassessment at COP-1 (Berlin, 1995)

Source: Bodansky (2001b).

The Kyoto Protocol represents a progression in the climate change regime towards a much harder approach, including quantified emissions limitation targets. Its provisions include:

- Specific emissions targets for each developed country party for the 2008 to 2012 "commitment period," aimed at reducing overall developed country emissions by 5% from 1990 levels.
- Various mechanisms to allow countries to achieve these targets in a flexible manner, including international emissions trading and the Clean Development Mechanism (CDM).

Basic Goals and Principles

Objective

The UNFCCC defines the regime's ultimate objective as the stabilization of atmospheric concentrations of GHGs at safe levels (i.e., levels that would "prevent dangerous anthropogenic interference with the climate system"). Stabilization should be achieved within a time frame that: (1) allows ecosystems to adapt naturally; (2) ensures that food production is not threatened; and (3) enables sustainable economic development.[45]

Two features of this objective are noteworthy. First, it focuses on atmospheric *concentrations* of GHGs rather than *emissions*. Second, it addresses not only concentration *levels*, but also *rates of change*.

In large part, the regime's evolution will involve spelling out what this objective means: in particular, (1) what concentration levels and rates of change are "safe"? and (2) what emission reductions are necessary to achieve these levels and in what time frame? While science can provide guidance on these questions (for example, about the effect of concentration levels on the climate system and ultimately on ecosystems), in the final analysis they will require political answers.

Principles

In addition to defining the regime's ultimate objective, the UNFCCC enunciates several guiding principles.[46] These include:

- *Equity* – Countries should protect the climate system for the benefit of present and future generations, in accordance with their common but differentiated responsibilities and respective capabilities. Developed countries should take the lead in combating climate change and its adverse effects.

- *Special needs* – The special needs of developing countries, especially those that are particularly vulnerable or that would bear a disproportionate burden under the UNFCCC, should be given full consideration.
- *Precaution* – Lack of full scientific certainty should not be used as a reason for postponing action.
- *Cost-effectiveness and comprehensiveness* – Measures should ensure global benefits at the lowest cost; cover all relevant sources, sinks, and reservoirs of GHGs; and comprise all economic sectors.
- *Sustainable development* – Countries have a right to sustainable development. Policies and measures to protect the climate system should be appropriate for the specific conditions of each party and should be integrated into national development programs.
- *International economic system* – Countries should promote a supportive and open international economic system, and should not take measures that constitute arbitrary, unjustifiable, or disguised barriers to trade.

Most of these principles reflect more general principles of international law – for example, the principles of common but differentiated responsibilities, intra- and inter-generational equity, and precaution. The principle of common but differentiated responsibility and the right to sustainable development address developing countries' concern that the climate change issue might be used as a basis to limit their economic development. The UNFCCC specifically acknowledges that the GHG emissions of developing countries will need to grow.[47] Similarly, precautionary measures are appropriate given the time lags in the climate system (by the time we unambiguously detect climate change, we may have already committed ourselves to substantial warming) and the possibility of non-linear responses and catastrophic harm.

The principles in the UNFCCC establish the general framework for the development of the climate change regime. They provide benchmarks against which to evaluate proposals such as targets and timetables and tradable emission allowances. But while the principles set the terms of debate for future discussions and negotiations, they do not determine directly what measures should or should not be taken. The precautionary principle, for example, does not specify the appropriate level of precaution or how much certainty is needed before taking action. Nor does the principle of common but differentiated responsibilities specify the basis or degree of differentiation. In practice, resolution of these difficult issues depends on a process of negotiation rather than on abstract principles.

Commitments

The climate change regime includes three categories of commitments, which are applicable to different categories of countries:

General Commitments

The UNFCCC's general commitments apply to all parties, both developed and developing, and are intended to promote long-term national planning and international review. Without question, the most significant general commitment is to develop a national inventory of emissions by sources and removals by sinks of GHGs. These national inventories not only provide better information about countries' contribution to the climate change problem, but can help promote an internal process of learning. Other general commitments include provisions to formulate and implement national programs to mitigate and adapt to climate change, and to promote and cooperate in scientific research, exchange of information, education, training, and public awareness related to climate change.[48] These commitments are general not only in their applicability to all countries but also in their content. They do not compel particular actions; rather, they reflect a "bottom-up" approach, encouraging countries to undertake a more comprehensive and systematic review of existing policies, to better coordinate the activities of different national agencies, and to implement their own national programs to address climate change.

Targets and Timetables

In the 1980s, targets and timetables emerged as the preferred international method for controlling atmospheric pollution. While they constrain countries, they give each country flexibility to choose how it will meet its national target, whether by means of direct regulation, market mechanisms, or taxes. This flexibility has made them more politically acceptable than specific regulatory requirements.

From the outset of the UNFCCC negotiations, it was generally accepted that any quantitative limitations on GHG emissions would apply, at least initially, only to industrialized countries (listed in Annex I of the UNFCCC and generally referred to as "Annex I parties"[49]). Despite strong efforts by the EU and AOSIS to include a binding emission target, the UNFCCC include only a very nebulous, non-binding "aim" for industrialized countries to return their emissions to 1990 levels, apparently by the year 2000.[50] As it turned out, most OECD countries proved unable to achieve even this modest aim. The principal exceptions were the United Kingdom and

Germany, both of which had lower emissions due to non-climate factors (in the case of the UK, the shift from coal to natural gas as a fuel source and, in Germany, reunification with East Germany).

The principal purpose of the Kyoto Protocol (Table 3) negotiations was to adopt binding emission targets for the post-2000 period. By the terms of the Berlin Mandate, these emission targets were to apply only to industrialized countries, not developing countries. Nevertheless, during the negotiations both before and after Kyoto, the United States continued to press for "meaningful participation" by key developing countries – for example, in the form of "voluntary" commitments to limit GHG emissions. In the

Table 3. Key Provisions of the Kyoto Protocol.

Aim	Reduce Annex I country emissions by 5% from 1990 levels during the 2008–2012 commitment period (Article 3(1))
Commitments	Specific emissions target for each country listed in Kyoto Protocol Annex B for the 2008–2012 commitment period, generally defined relative to 1990 emissions: EU, other West European: –8% US: –7% Japan, Canada: –6% New Zealand, Russia: 0% Norway: +1% Australia: +8% Iceland: +10% Applies to "CO_2-equivalent" emissions of basket of six GHGs (CO_2, methane, nitrous oxide, HFCs, PFCs, and SF_6)
Institutions	Same as FCCC, except decision making by Meeting of the Parties, which meets as part of FCCC Conference of the Parties (COP/MOP) (Article 13)
Flexibility mechanisms	Bubbles (Article 4) – Any group of Annex I parties may, when ratifying, agree to pool their assigned amounts and fulfill their emissions commitments jointly Joint implementation (Article 6) – Annex I parties may earn "emission reduction units" (ERUs) for investments in mitigation projects in other Annex I parties. ERUs are "supplemental" to domestic action Clean Development Mechanism (CDM) (Article 12) – Annex I parties may earn "certified emission reductions" (CERs) for emission reduction projects in non-Annex I parties Emissions Trading (Article 17) – Annex B countries may engage in emissions trading "supplemental" to domestic action
Compliance	COP/MOP to consider the question of compliance. Legally-binding consequences for non-compliance would require amendment of Kyoto Protocol (Article 18)

end, developing countries succeeded in resisting any new mitigation commitments and the Kyoto Protocol sets forth emission targets only for industrialized countries. Rather than establish a single uniform target, the protocol specifies individualized targets for each industrialized country for the 2008–2012 commitment period, ranging from an 8% reduction from 1990 levels for the European Union and a 7% reduction for the United States, to an 8% increase from 1990 levels for Australia and a 10% increase for Iceland.[51] Because, without Kyoto, emissions in most Annex I countries would ordinarily increase due to economic growth, the actual stringency of the Kyoto targets may be significantly greater than the targets themselves would seem to indicate. For example, the United States has argued that, to achieve its target, it would need to reduce its emissions by about one-third from business-as-usual scenarios for the 2008–2012 period. Indeed, even Australia and Iceland, which were given growth targets, claim that their targets will be difficult to meet, given the expected growth in their emissions over the 1990–2012 period.

Kyoto Flexibility Mechanisms

In addition to setting specific short-term emission targets for the 2008–2012 period, the Kyoto Protocol establishes a long-term architecture for climate change mitigation commitments. Although critics of Kyoto usually focus on Kyoto's short-term targets, Kyoto's architecture may prove more important in the long run. Indeed, even if Kyoto ultimately does not survive, elements of its architecture are likely to make their way into any successor regime.

To a considerable degree, Kyoto's architecture reflects the flexible approach promoted by the United States from the beginning of the climate change negotiations. The nebulous emission target in the UNFCCC already incorporated this flexible approach to a limited degree by leaving open the possibility of trade-offs in emission controls both between different greenhouse gases (the "comprehensive approach")[52] and between different countries ("joint implementation," hereinafter JI).[53] However, in the period immediately following the adoption of the UNFCCC, developing countries and environmental groups objected to efforts by the United States to elaborate rules for JI, arguing that JI would be both inequitable and difficult to administer.[54] Instead, COP-1 authorized only a pilot phase of JI, during which industrialized countries would not receive credits towards their UNFCCC target of returning emissions to 1990 levels.

Given this skepticism about JI at COP-1, the incorporation of various flexibility mechanisms into the Kyoto Protocol only 2 years later – and their elaboration in the Marrakesh Accords – represented the triumph of what

might be called (with only a bit of exaggeration), the US approach to climate change mitigation. Significant elements of this approach include the following:

- *What flexibility* – The Kyoto Protocol reflects the so-called comprehensive approach in two ways. First, the Kyoto targets apply to the CO_2-equivalent emissions of a basket of six greenhouse gases (carbon dioxide, methane, nitrous oxide, and three trace gases), rather than to each gas individually, thereby giving parties flexibility in choosing the lowest-cost mix of gases to reduce. Second, parties may receive credit, up to specified limits, for the removal of carbon dioxide from the atmosphere through certain sink activities such as afforestation, reforestation, forest management, and agricultural lands management.
- *When flexibility* – The Kyoto targets apply not on a year-by-basis but to a 5-year commitment period running from 2008 to 2012. In addition, they allow countries to "bank" surplus emission reductions for application in subsequent commitment periods.
- *Where flexibility* – The most important, and most innovative, type of flexibility in the Kyoto Protocol is "where flexibility." During the negotiations both before and after Kyoto, the European Union and developing countries attempted to limit this type of flexibility, arguing that industrialized countries should achieve the bulk of their emission reductions at home, rather than pay for reductions elsewhere. At their insistence, the Kyoto Protocol includes language providing that emissions trading and JI should be "supplemental" to domestic action. But during the negotiations leading to the Marrakesh Accords, efforts by the European Union to define this supplementarity requirement in quantitative terms (by setting a "concrete ceiling" on use of the flexibility mechanisms) proved unsuccessful. The Marrakesh Accords do not impose any quantitative requirement about how much a country must do at home to achieve its target.

The Kyoto Protocol includes three – and by some counts four – mechanisms to enable countries to achieve their targets wherever emission reductions can be made most cheaply.

- *Emissions trading* (Kyoto Protocol, Article 17): First, parties listed in Annex B of the Kyoto Protocol may trade parts of their "assigned amounts" with each other. Emissions trading is a relatively new approach to environmental regulation even at the domestic level. The Kyoto Protocol represents its first significant application internationally. The protocol itself merely authorized the parties to develop rules for emissions trading. These rules were finalized in the 2001 Marrakesh Accords.

- *Joint implementation among Annex I countries* (Kyoto Protocol, Article 6): In addition to emissions trading, developed country parties may receive "emission reduction units" (ERUs) through investments in projects in other developed country parties that result in emission reductions that are "additional" to any that would otherwise occur. These ERUs are added to the emissions target of the acquiring state and subtracted from the target of the transferring state. Like emissions trading, the acquisition of ERUs must be "supplemental to domestic actions," but, as noted above, this condition is not quantitatively defined in the Marrakesh Accords.
- *Clean Development Mechanism* (Kyoto Protocol, Article 12): The Kyoto Protocol establishes the "Clean Development Mechanism" (CDM), which will allow private and public entities to fund projects in developing countries, in order to generate "certified emission reductions" (CERs) that Annex I parties may use to meet their emissions targets. In essence, the CDM allows joint implementation between developed and developing country parties. The CDM is under the control of the meeting of the parties and is supervised by an executive board. Part of the proceeds from CDM projects will be used to cover the CDM's administrative costs, as well as to assist developing country parties that are particularly vulnerable to climate change. As with emissions trading and joint implementation, the modalities and procedures of the CDM are elaborated in detail in the Marrakesh Accords.
- *Bubbles* (Kyoto Protocol, Article 4): Finally, the Kyoto Protocol allows any group of developed country parties, prior to ratifying the protocol, to agree to pool their emissions targets. The European Union used this provision to establish a collective target for the EU as a whole, with a burden sharing agreement that reallocates the Kyoto targets within the EU.

Financial and Technology Transfer

Even if industrialized countries were to succeed in phasing out their GHG emissions, this would not solve the climate change problem, given the growth in emissions in large developing countries such as China and India. A long-term solution to the climate change problem requires addressing these countries' emissions as well.

Rather than imposing requirements on developing countries to limit emissions, the UNFCCC provides a carrot, in the form of commitments by OECD countries (listed in Annex II) to provide financial and technical assistance to developing countries.[55] The UNFCCC explicitly acknowledges that developing country actions to limit emissions will depend on the adequacy of this assistance.[56]

Unlike ordinary development assistance, the financial and technological assistance required by the UNFCCC could be viewed as a form of North–South partnership; its fundamental purpose is to benefit the global environment by averting climate change, not to benefit developing countries themselves. Nonetheless, the UNFCCC's provisions regarding financial assistance are quite weak, and neither require Annex II parties to provide specific amounts of assistance nor provide for mandatory assessments. The UNFCCC requires OECD countries to provide full funding only for the costs of developing country inventories and reports. And, even with respect to these costs, the UNFCCC does not require any particular country to contribute any specified amount. Financial assistance for other mitigation measures depends on approval by the Global Environment Facility (GEF) and covers only a project's "incremental" costs (i.e., the additional costs relating to climate change mitigation). Meanwhile, assistance for adaptation has been limited thus far to capacity building and demonstration projects.

The amount of assistance provided pursuant to these provisions has been quite modest – particularly compared to the expectations (and, in some cases, demands) of developing countries. During the post-Kyoto negotiations leading to the Marrakesh Accords, developing countries renewed their efforts to obtain greater financial assistance. But, although the Marrakesh Accords establish three new climate-related funds, it is unclear whether this will lead to a significant increase in the actual funding provided.

Adequacy of Commitments and Adjustment Procedure

The UNFCCC acknowledges that its limited obligations may be inadequate, and that the regime will need to evolve in response to new scientific information. Accordingly, it establishes a process to reassess its commitments, modeled on that of the ozone regime, which has led to progressively stricter international regulation of ozone-depleting substances (Gehring, 1994). The first such review of commitments took place in 1995 and led to the initiation of the Kyoto Protocol negotiations. By requiring periodic reassessments of the UNFCCC's commitments on the basis of the best available scientific information, the UNFCCC creates channels for scientific developments to influence the policy process.

Institutions

When the climate change issue first emerged as a policy issue, some leaders felt that it required the development of supranational institutions, with

authority to adopt and enforce regulatory standards.[57] At the 1989 Hague Conference, 17 heads of state called for the establishment of "new institutional authority" to address climate change, with non-unanimous decision-making powers. This radical proposal was never pursued in the UNFCCC negotiations, however, and the UNFCCC instead relies on more traditional types of international institutions, which are essentially intergovernmental rather than supranational in nature, and play a primarily coordinating and facilitative role. (Table 4)

Conference of the Parties/Meeting of the Parties

The annual Conference of the Parties (COP) serves as the UNFCCC's "supreme body," with authority to examine the convention's obligations and institutional arrangements, to supervise its implementation, and to develop amendments and protocols.[58] Among its functions, it provides a permanent forum for discussion and negotiation, keeps countries' attention focused on the climate change problem, and helps build a sense of community. Moreover, by permitting environmental and industry groups to attend as observers, it gives them a forum for making inputs and exerting pressure.

Although the COP has no explicit regulatory powers (unlike its analogue in the ozone regime, which can tighten regulatory measures on ozone-depleting substances by a 2/3 vote), its other decision-making authority is broad. COP-1, for example, initiated the new round of negotiations that led to the Kyoto Protocol, established a pilot phase of joint implementation, adopted reporting and review procedures, designated a permanent secretariat, and defined the roles of its subsidiary bodies. Similarly, COP-7 adopted the Marrakesh Accords. The COP's decision-making authority makes its voting rules vital, and countries have not yet been able to reach agreement on this question. Some countries insist that consensus should be required for important decisions such as the adoption of protocols, while others prefer a 2/3 or 3/4 voting rule for all substantive matters so that a small minority of countries cannot block agreement. Until the COP is able to resolve this question, consensus decision making will continue to be the default rule, given the UNFCCC's requirement that the COP's rules of procedure themselves be adopted by consensus.

Because membership in the Kyoto Protocol is quite different than the UNFCCC, Kyoto provides for a Meeting of the Parties (MOP)[59] to decide on Kyoto Protocol issues. Although not authorized to adopt new commitments, the MOP would have quite significant powers, including the authority to revise the rules governing emissions trading, the CDM and credit for carbon sinks.

Table 4. Climate Change Institutions.

Name	Acronym	Description
Intergovernmental Negotiating Committee	INC	Established December 1990 by UN General Assembly. Negotiated the FCCC. Now replaced by the FCCC Conference of the Parties (COP).
Conference of the Parties/ Meeting of the Kyoto Protocol Parties	COP/MOP	Established by FCCC Art. 7. "Supreme body" of FCCC. Meeting of the parties (MOP) of Kyoto Protocol will be held in conjunction with COP (Kyoto Art. 13). Functions: regular review of FCCC implementation; decisions necessary to promote effective implementation; adoption of amendments and protocols. Meets yearly.
Secretariat		Established by FCCC Art. 8. Administrative functions in support of COP and other Convention institutions. Located in Bonn.
Subsidiary Body for Scientific and Technological Advice	SBSTA	Established by FCCC Art. 9. Composed of government experts. Provides assessments of scientific knowledge, reviews scientific/ technical aspects of national reports and effects of implementation measures.
Subsidiary Body for Implementation	SBI	Established by FCCC Art. 10. Composed of government experts. Reviews policy aspects of national reports; assists COP in assessing aggregated effect of implementation measures.
Financial mechanism		"Defined" by FCCC Art. 11. Operation entrusted to GEF on interim basis.
Inter-Governmental Panel on Climate Change	IPCC	Established in 1988 by WMO and UNEP to provide assessments of the science, impacts and policy aspects of climate change. First Assessment Report in 1990; Second Assessment Report in 1995; Third Assessment Report in 2000.
Global Environment Facility	GEF	Established by World Bank, UNDP, and UNEP in 1991. Restructured in 1994.
Clean Development Mechanism	CDM	"Defined" by Kyoto Art. 12. Under the control of the COP, and supervised by an executive board.

Source: Bodansky (2001b).

Secretariat

At COP 1, the parties decided that the interim secretariat initially established for the INC should become the UNFCCC secretariat, providing general administrative and policy support to the COP and its subsidiary bodies. Over the past dozen years, the secretariat has grown substantially in size. During the negotiations, it served a primarily administrative function. But since the UNFCCC's adoption, it has played an increasingly important role in organizing the UNFCCC's review processes and serving as an information clearinghouse.

Financial Mechanism

Apart from targets and timetables, the financial mechanism was perhaps the next most contentious issue in the UNFCCC negotiations. The large donor countries insisted on using the GEF to provide climate assistance – an institution created in 1991 at their instigation and which, through the World Bank, they dominated – while developing countries favored creating a new institution under the control of the COP. Article 11 of the UNFCCC represents a compromise between these positions. Rather than create a new fund, it entrusts the GEF with the operation of its financial mechanism on an interim basis and gives the GEF authority over individual funding decisions.[60] But it gives the COP authority over the financial mechanism's policies, program priorities, and eligibility criteria.

In 1994, in response to demands by developing countries and environmental groups for greater transparency and "democracy," representatives of 73 countries participating in the GEF agreed to restructure it. The restructured GEF is functionally autonomous from the World Bank and is governed by a 32-member council, evenly split between developing and developed country representatives. The decision-making rules require the concurrence of both developing and donor countries for all substantive decisions.

Thus far, GEF financing has focused on assisting developing countries with preparation of their initial national reports under the UNFCCC. Since the GEF's mandate permits it to fund only those "incremental" costs of a project that produce global environmental benefits (and hence are ineligible for ordinary World Bank lending, which focuses on the local benefits of projects), an important question is, which costs should be considered "incremental"? The World Bank has favored limiting GEF assistance to "net incremental costs" – that is, the difference between the total costs of a project and its local benefits. Developing countries and environmental nongovernmental organizations, in contrast, have argued that the GEF should provide assistance for the full costs of projects to implement the UNFCCC;

this would permit funding of "no regrets" strategies, which have a negative net cost. Since determining which costs produce local as opposed to global benefits is nearly impossible, in practice the issue must be worked out flexibly and pragmatically, on a project-by-project basis, through negotiations between the GEF and the country concerned.

Intergovernmental Panel on Climate Change

Until now, the IPCC has served the crucial function of providing collective appraisals of scientific knowledge. Although questions continue to be raised occasionally about the IPCC's role, the IPCC has, in general, walked the tightrope between governmental ownership and professional autonomy, thereby maintaining both political and scientific legitimacy. On the one hand, its intergovernmental character has given governments a sense of ownership and stake in its work, leading them to accept its assessments as authoritative. On the other hand, it has managed to maintain its autonomy as a scientific body and thereby its scientific credibility – a point substantiated by the National Academy of Sciences' endorsement of the IPCC results in a 2001 report on climate change science requested by the Bush Administration.

Implementation Mechanisms

The development of a strong reporting and review procedure for industrialized countries has been one of the principal achievements of the climate change regime. Reporting and review serve several functions. First, they put pressure on countries by holding them up to domestic and international scrutiny. Second, by improving transparency, the review process helps build confidence among parties that others cannot "free ride" without being caught. Third, reporting and review serve an educational function. By sharing information, countries can benefit from each others' experiences. Finally, reporting and review produce useful information for assessing the effectiveness of the UNFCCC and the need for further commitments.

National Reporting

Under the UNFCCC, Annex I parties are required to submit annual GHG inventories and periodic national reports ("communications of information") containing detailed information on their climate change policies together with projections of how those policies will affect emissions. Developing countries must also submit national reports, but have considerably more latitude concerning timing.

The annual GHG inventories are the backbone of the national reporting process. They help improve understanding of the sources and sinks of GHGs and provide a baseline for evaluating the UNFCCC's implementation and effectiveness. In addition, under the Kyoto Protocol, national inventories will provide the basic data used to evaluate the compliance of Annex I parties with their emission targets. In order to be eligible to use the Kyoto flexibility mechanisms, Annex I countries must show that their "national system" to produce emission inventories meets certain minimum conditions of reliability.

International Review

Under the UNFCCC, national reports by industrialized countries are subject to international review by teams of experts nominated by the parties (and certain international organizations) and selected by the UNFCCC Secretariat. The review mechanism is intended to be non-confrontational and facilitative in nature, and has two components:

1. In-depth reviews of each national report to promote individual accountability and enhance comparability. These in-depth reviews are like outside audits; they examine the reliability, consistency, accuracy, and relevancy of national reports by reviewing key data points, verifying methodologies, and comparing assumptions across countries and with international sources. Under the Kyoto Protocol, this review system will be beefed up considerably in order to provide objective assessments of a state's compliance with its Kyoto emissions target.
2. A synthesis report, which compiles and aggregates the data in the various Annex I country reports, to determine their overall progress in implementing the convention.

Dispute Resolution/Compliance System

As a cooperative, forward-looking instrument that attempts to encourage and facilitate rather than coerce national action, the UNFCCC does not include a robust dispute settlement mechanism. It includes a boilerplate dispute settlement provision, calling for the settlement of disputes by negotiation, conciliation, and, if both sides agree, arbitration or the International Court of Justice (UNFCCC Article 14). But this type of procedure, found in virtually every international environmental agreement, is seldom used – in part because global environmental disputes do not have the bilateral character of traditional international disputes.

The Kyoto Protocol would establish a much more robust compliance system, including a standing compliance body with two branches, one focused on facilitation and the other on enforcement.[61] In the event that a country does not comply with its emission target, the Kyoto compliance system provides for the excess tons to be subtracted (at a penalty rate) from the country's emission target in the next commitment period.

CONCLUSION

Although the Kyoto Protocol represents a remarkable achievement, its general regulatory approach – fixed, absolute emission targets – has been embraced by only a limited number of countries thus far. As discussions begin about the next phase in the global climate change regime, it remains unclear whether Kyoto will serve as the model or whether Kyoto-style targets will remain acceptable to only a relatively small group of industrialized countries. One alternative to Kyoto would be an incremental, bottom-up approach, focusing initially on national measures to address climate change and then building outwards (Bodansky, 2001c). In doing so, countries need not return to square one, since the provisions of the UNFCCC providing for regular reporting and review represent a solid base on which to build.[62] Of course, for some, a bottom-up approach might appear too slow. But we should remember that we are dealing with a century-long problem and that the level of emission reductions we achieve in the short-term will have only a modest long-term impact. Delay is not wise, since it merely forecloses options and ultimately raises the cost of responding. But, to be effective, climate change policy need not be built in a day.

NOTES

1. Political scientists use the term "international regime" to refer to a network of rules, institutions, programs, and decision-making procedures governing a given area of international relations (Bodansky, 1995; Krasner, 1983).
2. As of February 17, 2003, 188 states and the European Community had become party to the UNFCCC, making it one of the most widely ratified treaties of any kind.
3. UNFCCC preamble, paragraph 1.
4. World Resources Institute (2003).
5. See generally Barratt-Brown, Hajost, and Sterne (1993), Bodansky (1993), Goldberg (1993), Grubb (1992), and Sands (1992).
6. See generally Breidenich, Magraw, Rowle, and Rubin (1998), Davies (1998), and Oberthur and Ott (1999).

7. DeCanio (1992).
8. Houghton (1997).
9. The reports submitted by industrialized countries under the UNFCCC indicate that fossil fuels account for 97% of their CO_2 emissions and CO_2 for 75% of their overall GHG emissions.
10. World Commission on Environment and Development. (1997). *Our common future*. Oxford: Oxford University Press.
11. See generally Bodansky (1994).
12. Clark (1989, p. 47).
13. For general discussions, see Ausubel (1983), Cain (1983), Kellogg (1987), Revelle (1985), and Weiner (1990).
14. Arrhenius (1896)
15. National Research Council (1979, p. viii).
16. See generally Pomerance (1989).
17. *Proceedings of the world conference on the changing atmosphere: Implications for global security* (1988, June). Toronto, WMO Doc. 710.
18. Although some were sponsored by international organizations such as UNEP and WMO or by sympathetic governments such as Canada.
19. Protection of global climate for present and future generations of mankind. (1988). UN General Assembly Res. 43/53.
20. Declaration adopted at the Hague, March 1989, reprinted in UN Doc. A/44/340-E/1989/120, Annex 5, and *International Legal Materials*, 28, 1308.
21. Netherlands Ministry of Housing, Physical Planning and Environment. (1989). Noordwijk Conference Report.
22. Jäger and Ferguson (1991).
23. The US position on climate change paralleled its position vis à vis Canada regarding transboundary air pollution.
24. ''Developed countries'' include the United States, Western European states, members of the former Soviet bloc, Japan, Canada, Australia, and New Zealand. These countries are listed in Annex I of the UNFCCC. The term ''developing countries'' is a term of art. Developing countries comprise all those countries that are not developed, including the states of Central and South America, the Caribbean, Africa, Asia (except Japan), and the Pacific. ''Developing'' countries are a very heterogeneous group, including both the least developed countries of sub-Saharan Africa as well as quite wealthy countries such as Kuwait, Saudi Arabia, Singapore, and South Korea.
25. Protection of global climate for present and future generations of mankind. (1990). UN General Assembly Res. 45/212, UN Doc. A/45/49.
26. See generally Mintzer and Leonard (1994).
27. There are now well over 150 treaties in the UNEP *Register of International Treaties in the Field of the Environment*.
28. Zaelke and Cameron (1990).
29. Convention on Long-Range Transboundary Air Pollution (LRTAP), adopted November 13, 1979. *International Legal Materials*, 18, 1442.
30. Vienna Convention for the Protection of the Ozone Layer, March 22, 1985. (1987). *International Legal Materials*, 26, 1529; Montreal Protocol on Substances that Deplete the Ozone Layer, adopted September 16, 1987. *International Legal Materials*, 26, 1550.

31. For example, one principle provides that states should "ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction." Declaration of the 1972 UN Conference on the Human Environment (Stockholm Declaration), principle 21.
32. Magraw (1990, p. 8), Developments in the Law – International Environmental Law (1991, pp. 1504–1506). As one leading international scholar has put it, "customary law provides limited means of social engineering." Brownlie (1973, p. 179).
33. Zaelke and Cameron (1990, p. 272–278).
34. Sebenius (1991) and Tolba (1989).
35. Recent international environmental agreements, however, have typically required less time to negotiate than earlier ones (Weiss, 1993, pp. 685–686).
36. Protection of global climate for present and future generations of mankind. (1990). UN General Assembly Res. 45/212, UN Doc. A/45/49.
37. The one exception was the role played by a British environmental law group – the Foundation for International Environmental Law and Development (FIELD) – which helped organize and support the newly-formed Alliance of Small Island States.
38. Lang (1991) and Morrisette (1991).
39. See, e.g., Article 11 (financial mechanism).
40. See, e.g., Article 4(2) (commitments by industrialized countries to limit emissions).
41. See, e.g., Article 13 (directing COP to consider establishing a multilateral non-compliance procedure).
42. Depledge (1999/2000) and Oberthur and Ott (1999)
43. Chayes and Skolnikoff (1992).
44. The so-called Ad Hoc Group on the Berlin Mandate, or AGBM.
45. UNFCCC, Article 2.
46. UNFCCC, Article 3.
47. UNFCCC preamble paragraph 3.
48. UNFCCC, Articles 4(1), 5, and 6.
49. Annex I lists (1) 35 states – including (a) all members of the OECD except Mexico (which had not yet joined the OECD when the UNFCCC was adopted) and (b) countries with "economies in transition" (i.e., the former members of the Soviet bloc) – and (2) the European Community. Newly industrialized countries such as China, South Korea, and Malaysia are not included in Annex I.
50. UNFCCC, Article 4.2.
51. The targets are set forth in Annex B of the protocol, and are defined in terms of an "assigned amount" of emissions for each country listed in Annex B. Even though Australia and Iceland are allowed to increase their emissions above 1990 levels, their targets might still represent a significant decrease in emissions from business-as-usual scenarios for the 2008–2012 commitment period.
52. Stewart and Weiner (1992).
53. Kuik, Peters, and Schrijver (1994).
54. See, e.g., Climate Network Europe (1994).
55. UNFCCC, Articles 4.3 and 4.4.
56. UNFCCC, Article 4.7.
57. Palmer (1992).
58. UNFCCC, Article 7.

59. The MOP will meet in conjunction with the COP and is usually referred to as the COP/MOP.
60. UNFCCC, Article 11.
61. Wiser (2002).
62. Bodansky (2002).

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TACKLING CLIMATE CHANGE: FIVE KEYS TO SUCCESS

Eileen Claussen

Whether we like it or not, global warming is shaping up as one of the most important challenges of the 21st century. It is going to drive far-reaching changes in how we live and work, power our homes, schools, factories, and office buildings, get from one place to another, manufacture and transport goods, and even farm and manage forests. It touches every aspect of our economy and our lives, and to ignore it is to live in a fantasy land where nothing ever has to change – and where we never have to accept what science tells us about what is happening to our world.

My goal is to give you a clear idea of where we stand today in the effort against global climate change. To do that, I would first like to offer you an insider's look at how the world and the United States have responded to this challenge over the last decade.

I would like to suggest to you five keys to success – five things we need to do if we are to successfully meet the challenge of climate change.

Let us travel back in time to 1992, when another George Bush was our President, and when the nations of the world gathered in sunny Rio de Janeiro for the United Nations Conference on Environment and Development, affectionately known as the Earth Summit. This was the event, you may recall, where more than 150 countries signed an agreement called the United Nations Framework Convention on Climate Change (UNFCCC).

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The UNFCCC, as it is known, set an ambitious long-term objective: to stabilize greenhouse gas concentrations in the atmosphere at a level that would "prevent dangerous anthropogenic (or human-caused) interference with the climate system." This is a goal that the United States, and virtually every other nation, has embraced.

As a first step, industrialized countries agreed to a voluntary emissions target: they aimed to reduce their greenhouse gas emissions to 1990 levels by the year 2000. Before long, however, it became clear that the targets would not be met and that voluntary commitments could not deliver genuine action. So the United States and other countries began to negotiate a new agreement, one with binding targets, and they agreed at the outset that these new commitments would extend only to the industrialized countries, which so far have contributed the most to the problem.

The result, negotiated 5 years after the Rio summit in Kyoto, Japan, is the Kyoto Protocol. The Protocol requires countries to reduce or limit their emissions of greenhouse gases in relation to 1990 levels, with different countries agreeing to different targets. The agreement also includes a number of features advocated by the United States to ensure countries a high degree of flexibility as they work to achieve their targets. They can make actual emission reductions at home, trade emission credits with others who have made reductions, and use "sinks" such as farms and forests to remove carbon from the atmosphere.

During the negotiations in Kyoto, Vice President Al Gore flew to the ancient Japanese capital to help hammer out the deal. And what the U.S. negotiators ultimately agreed to was a binding 7% reduction in emissions below 1990 levels by 2012.

The problem was that it was already 1997, and U.S. emissions had already risen over the 1990 levels by more than 8%. In other words, we had pledged to reduce our emissions by nearly 15% and we had neither any kind of program in place to do this nor any will to put such a program into place.

Another problem was that the U.S. Senate, under the Byrd–Hagel resolution, had recently voted unanimously that the United States should not sign any climate treaty that "would result in serious harm to the economy of the United States" or that did not impose some type of commitment on developing countries as well.

Of course Kyoto did not include commitments for developing countries, because the parties, including the United States, agreed at the outset that it would not. And the target agreed to by the United States was portrayed by those who wished to kill the treaty as clearly harmful to our economy, a charge that was not effectively countered by the Administration. So the fact

of the matter is that the Kyoto Protocol negotiated by the Clinton administration was about as welcome in the Senate as the proverbial skunk at a lawn party – and senators had no intention of holding their noses so they could tolerate this thing. They just plain did not want it anywhere near them.

The Clinton administration, for its part, did nothing to try to bring about the ratification of this treaty that its people had made such a big deal of signing. Granted, the President at the time was caught up in a scandal, and Vice President Gore was gearing up for a presidential run of his own and surely wanted to avoid being publicly associated with anything that could be said to pose a threat to the economy. But still, the whole episode of U.S. participation in Kyoto – and, before that, the UNFCCC – was enough to recall the line from Shakespeare: ''full of sound and fury, signifying nothing.'' The bottom line: we clearly were not prepared to deliver at home what we were promising abroad.

But the story does not end there. To fast forward to 2000, American voters elected another President – another Bush – and within months of entering office his administration made a unilateral decision to reject the Kyoto Protocol out of hand, instead of working to change it and make it better. Needless to say, this decision was not received warmly by other nations that had persevered through years of difficult negotiations and that had acceded to U.S. demands early on that the treaty include trading and other business-friendly mechanisms.

As an aside, I think it is interesting to note that in the recent run-up to the war in Iraq, it was hard to find an article about other countries' perceptions of the United States that did not mention the impolitic way in which this administration rejected Kyoto. It was perceived as a real slap in the face – a confirmation of global fears that the United States, which is responsible for almost one fourth of global greenhouse gas emissions, had no intention of acting seriously on this issue.

As if to confirm these fears, the Bush administration in 2002 announced a climate strategy that was big on rhetoric but not so big on results. Here is what this strategy does: it sets a voluntary ''greenhouse gas intensity'' target for the nation. The idea is to reduce the ratio of greenhouse gas emissions to U.S. economic output, or GDP. But the funny thing about the White House target – an 18% reduction in greenhouse gas intensity by 2012 – is that it would allow ''actual'' emissions to ''grow'' by 12% over the same period.

What is more, the Administration's strategy relies entirely on voluntary measures. This, despite the fact that the U.S. climate policy has consisted primarily of voluntary measures for more than a decade. And what have

these voluntary measures achieved? As of 2001, U.S. greenhouse gas emissions were "up" 11.9% over their 1991 levels. And so now we are more than 10 years removed from the Earth Summit, and we still – *still* – have no real plan in place to reduce the U.S. contribution to the problem that we and other countries identified back then as "a common concern of humankind."

The reason I have presented this history lesson is to show that, as the world has set out in the last decade to respond to the problem of climate change, the United States has been both a driver and a drag on the process – a driver in terms of development of a framework for action, a drag because we have made no serious attempt to implement that framework. We are like the boyfriend or girlfriend who says sweet things all the time but will never truly commit. And lately we are not even saying sweet things any more.

The reality is that it is long past the time for playing these sorts of games. We should have committed long ago to serious action on this issue and, having failed, it is all the more urgent that we get serious now. What does that mean? What principles should guide these efforts? I would like to offer five – five keys to success in meeting the challenge of climate change.

Key 1 is that we must forge a global response to the problem of climate change. As I have already said, the United States is responsible for one fourth of global greenhouse gas emissions. The 15 countries of the European Union are responsible for another one fourth. The remainder is divided among other developed nations and rapidly developing countries such as China and India. And, while developed countries clearly are responsible for a majority of these emissions, that will not be the case in the future, as emissions continue to grow more rapidly in developing countries than anywhere else.

It is one of the most contentious issues in the debate over global climate change – that is, the perceived divide between the interests and obligations of developed and developing countries. Equity demands that the industrialized world – the source of most past and current emissions of greenhouse gases – act first to reduce emissions. This principle is embedded in both the UNFCCC and the Kyoto Protocol, which sets binding emission targets for developed countries only. However, with the Protocol now officially entered into force, it is now time to turn our attention to what happens next. And as we do this, we need to think broadly of a framework that will include not only the countries that will be implementing the Kyoto protocol, but also the United States, Australia, and the major emitting countries in the developing world.

I do not claim to know what form this framework should take. But here is what I do know: it must be effective; over the coming decades, it must

significantly reduce global emissions of greenhouse gases. It also must be fair. We must recognize who bears responsibility for climate change, and who will bear the brunt of its impacts; and we must arrive at an equitable sharing of responsibility for addressing it. That probably means different kinds of measures for different countries at different times, but all the major emitting countries must do their part. Finally, this new framework must marry our environmental goals with our economic and development objectives. In the developing world in particular, commitments that are not consistent and compatible with rising standards of living and that do not promote sustainable economic growth have little chance of success. And even in the developed world, all countries will have to be convinced that the environmental goals they agree to, the carbon limits they accept, will not impede their efforts to sustain economic growth. This will mean not only ensuring that countries are given flexibility in how they meet their goals, but also that they can turn over the existing capital stock and acquire more climate-friendly technology at prices they can afford.

This brings us to the second key to success in our efforts to address the climate issue: we need to think in terms of both short- and long-term actions. There is a great deal we can do now to reduce our emissions. At the same time, we need to be looking ahead to longer-term, and potentially more far-reaching, reductions in the years and decades to come.

At the Pew Center, we are developing a plan we call the 10/50 Solution. The idea is to think ahead to where we need to be 50 years from now if we are going to meet the challenge of climate change, and then to figure out decade by decade how to do it.

Why look 50 years out? Because achieving the necessary reductions in our greenhouse gas emissions will ultimately require innovation on a level never before seen. It will require a massive shift away from fossil fuels to climate-friendly sources of energy. And, as I said at the start of my remarks, it will require fundamental changes in how we live and work and grow our economies.

The 10/50 approach does not just look long-term, though. It recognizes that in order to realize that 50-year vision, we have to start right now. We can start with the low-hanging fruit – the countless ways we can reduce greenhouse emissions at little or no cost by simply being more efficient: everything from developing more fuel-efficient cars and trucks (including hybrids) to designing energy-efficient appliances and computers, improving industry efficiency, and enhancing management of animal wastes.

In the medium to long term, the challenge is to begin what we have called a second industrial revolution. The Pew Center is just now completing a

scenario analysis that identifies several technologies as essential to our ability to create a climate-friendly energy future for the United States. These include:

1. *Natural gas*: Substituting natural gas for coal results in approximately half the carbon emissions per unit of energy supplied, but we need policies to encourage the expansion of natural gas supply and infrastructure.
2. *Energy efficiency*: We have the ability to dramatically improve the fuel economy of cars and light trucks "right now" and in the very near future through a combination of advances in the internal combustion engine or through hybrid electric vehicles.
3. *Renewable energy and distributed generation*: The potential here is enormous, but policy support will be essential in promoting investment and breaking barriers to market entry for these technologies.
4. *Nuclear power*: Despite its problems, the fact remains that our carbon emissions would be much higher without nuclear power.
5. *Geological sequestration*: Sequestration holds the potential of allowing for the continued production of energy from fossil fuels, including coal, even in the event of mandatory limits on carbon emissions.
6. *Hydrogen and fuel cells*: The President's recent announcement of a new federal commitment to fuel cell research was a welcome one, but we must have policies that will help pull these vehicles into the market.

Looking down this list, it is hard "not" to see that most, if not all, of these technologies would be important even in a world where we did not have this pressing obligation to reduce the amount of greenhouse gases in the atmosphere. For energy security and economic growth reasons, and a wide range of environmental reasons as well, these are simply smart things to do. The second industrial revolution is not just about responding to the challenge of climate change; it is about creating a common-sense energy future.

And, in order to create that energy future, we are going to have to keep in mind the third key to success: industry must be a partner in shaping and implementing climate solutions. The Pew Center serves as a convenor of leading businesses that are taking practical steps to reduce their contribution to the climate problem. The 38 members of our Business Environmental Leadership Council represent nearly 2.5 million employees and have combined revenues of $855 billion. They include mostly Fortune 500 firms, and they are deeply committed to climate solutions:

- There is DuPont, for example, which made a voluntary pledge to reduce its global emissions of greenhouse gases by 65% by the year 2010. And

guess what? In 2002, they announced they had achieved this target "eight years ahead of schedule."

- Also ahead of schedule in meeting its target is BP, which in 2002 announced it had reduced global greenhouse emissions by 9 million metric tons in just 4 years. This marked a 10% reduction in the company's emissions – and, like DuPont, BP had originally intended to achieve this goal in 2010.

Over the past several years, it has become clear that there are three types of companies when it comes to the issue of climate change: those that do not accept the science; those that accept the science and are working internally to reduce their contribution to the problem; and those that accept the science, are working internally, and are advocating for strong government action to address this issue.

BP, DuPont, and the other companies we are working with at the Pew Center clearly fall into this latter group. And I hope that our government – as well as other governments throughout the world – will take full advantage of their expertise and commitment.

The benefits of active involvement by industry in environmental policy making first became clear to me during negotiations on the Montreal Protocol – the agreement that set out to address the man-made threat to the Earth's protective ozone layer. An important reason for the success of that agreement, I believe, is that the companies that produced and used ozone-depleting chemicals – and that were developing substitutes for them – were very much engaged in the process. As a result, there was a factual basis and an honesty about what we could achieve, how we could achieve it, and when. And there was an acceptance on the part of industry, particularly U.S. companies, that the depletion of the ozone layer was an important problem and that multilateral action was needed.

I am happy to report that we are seeing the same kind of acceptance and determination to act on the climate issue among the companies we work with at the Pew Center. Their involvement should serve as a reminder that it is industry that will develop the technologies and the strategies that will reduce global emissions of greenhouse gases. It is industry that will have to deliver on government requirements and goals. To ignore this as we try to structure a global response to this enormous challenge is to fail.

Speaking of government, let me introduce a fourth key to success in responding to climate change: we have to adopt real, mandatory goals. Voluntary approaches, as I have said, simply have not worked to address this problem. In order to engage the full spectrum of industry and society,

we need to set clear, mandatory goals for emission cuts, and at the same time provide sensible, business-friendly rules that give companies the flexibility they need to help meet those goals as cost-effectively as possible.

This is the approach embodied in recent legislation introduced by the bipartisan duo of Senators John McCain and Joe Lieberman. This landmark measure for the first time brings together several features that would be critical to the success of a national climate change strategy. The bill would establish ambitious and binding targets for reducing U.S. greenhouse gas emissions. Equally important, it would provide companies with the flexibility to reduce emissions as cost-effectively as possible – thanks to the creation of a rigorous nationwide system allowing emissions trading and providing some credit for carbon storage. Last but not least, the bill would recognize those reductions that are being made now by the companies that are taking the lead on this issue and provide additional flexibility for these early actors.

Of course, the McCain–Lieberman measure has little chance of becoming law anytime soon, but it is encouraging nonetheless to see our policy makers in Washington finally coming to grips with exactly what it is going to take to yield real progress toward a climate-friendly future. And what it is going to take is a set of real, enforceable commitments.

This leads us finally, and forgive me if this seems redundant, to the fifth key to success: the United States must be an integral part of the climate solution. Despite having 4% of the world's population, we have contributed nearly a third of worldwide emissions of greenhouse gases in the last century, and we continue to be the largest source of these emissions worldwide. And still, we have decided to sit on the sidelines while the world moves forward with a plan to begin addressing this challenge. Even worse, we have yet to develop anything resembling a domestic program to reduce our own emissions and protect the climate.

This problem, quite simply, will not be solved without us. We owe it to ourselves, we owe it to other nations, and we owe it to future generations, to commit American ingenuity and American leadership to meeting this challenge. I think the job begins at home: we must achieve a national consensus on how best to reduce our greenhouse gas emissions. And from there, we must engage constructively with other nations in the search for a lasting global solution.

So there you have it. Five keys to success: we need to address this issue globally. We need to think and act both short-term and long-term. We need to involve industry. We need mandatory goals. And we need the United States to do its part both at home and abroad.

CITIES PROTECTING THE CLIMATE: THE LOCAL DIMENSION OF GLOBAL ENVIRONMENTAL GOVERNANCE

Michele M. Betsill and Harriet Bulkeley

The threat of global climate change is one of the most significant scientific and political challenges of our time. For more than a decade, members of the international community have debated the need for action to reduce emissions of greenhouse gases, the relative responsibilities of different countries, and the means through which action could, or should, be taken. Given the global nature of the problem, these debates have largely taken place in the context of international treaty negotiations (the 1992 United Nations Framework Convention and its 1997 Kyoto Protocol). However, as is becoming increasingly clear, climate change is also a profoundly local issue. Because greenhouse gas emissions originate from processes that are embedded in specific places, nation-states will be unable to meet their international commitments for addressing climate change without local action. Many local governments have considerable authority over land-use planning and waste management and can play an important role in addressing transportation issues and energy consumption. Moreover, local governments do not just respond to predefined policy goals set within national and international arenas; in many cases they are taking the lead in

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developing innovative policies and programs to control greenhouse gas emissions. In other words, local governments represent an important site for the governance of global environmental issues in their own right.

In this chapter, we analyze the capacity of local governments to enact climate protection policies and control their greenhouse gas emissions. We begin by considering the role of cities in the governance of global environmental issues, such as climate change. We then introduce the "Cities for Climate Protection" (CCP) program, a transnational network of local governments seeking to mitigate the threat of global warming. Drawing on the experience of six local governments engaged in the CCP network, we analyze the opportunities and constraints that have been encountered as climate protection policy has been put into practice in the areas of land-use planning, transport, and energy management in Newcastle, Cambridgeshire, and Leicester in the United Kingdom; Denver and Milwaukee in the United States; and Newcastle, New South Wales (NSW), Australia.[1] We find that the process of translating a rhetorical commitment to climate protection into policies and programs for limiting greenhouse gas emissions in specific sectors is far from straightforward and varies with the particular powers of local government and the conflicts of interest encountered. Based on our case studies, we identify five factors that shape the implementation of climate protection policies: (1) the presence of a committed individual with institutional support for promoting climate protection; (2) the availability of funding for climate protection measures; (3) the extent of local powers over transport, energy, and planning; (4) the way climate protection is framed, particularly in relation to economic objectives; and (5) the political will to act. Finally, we consider the implications of these findings for understanding global environmental governance.

CITIES AND GLOBAL ENVIRONMENTAL GOVERNANCE

Within the field of international relations, global environmental governance is frequently discussed in terms of "international regimes," defined as "social institutions that consist of agreed upon principles, norms, rules and decision-making procedures, and programs that govern the interaction of actors in specific issue areas" (Young, 1997, pp. 5–6). Viewed from the regime theory perspective, nation-states are seen as territorially bounded entities with a monopoly on the use of (economic or military)

force (Agnew, 1999). As a result, they are assumed to have primary authority in matters of global environmental governance. It is nation-states that engage in the negotiation of international treaties (in which the elements of a regime may be formalized), which are then taken home to be either implemented or ignored as the nation-state sees fit. Given that political power is defined by state boundaries within the regime approach, the internal politics of nation-states is considered to be of relatively little import in much of the literature. Aside from some interest in the concept of sovereignty (Litfin, 1998), the notion of transgovernmental coalitions (Risse-Kappen, 1995; Slaughter, 1997), and two-level games (Putnam, 1988), in the main the state remains conceived as a homogenous and unitary actor, a "fixed territorial entity…operating much the same over time and irrespective of its place within the geopolitical order" (Agnew & Corbridge, 1995, p. 78). While a recent focus on knowledge and the role of nonstate actors in international regimes has led to a revision of the nature of interests, politics, and influence, the state remains defined in terms of national government, albeit with potential internal conflicts and the roles of domestic actors noted. Implicitly, regime theory assumes that subnational governments act under the (sole) influence and direction of national government. Critically, the potential role of subnational government is either ignored or subsumed within the nation-state.

Although neglected within international relations accounts of global environmental governance, a burgeoning literature on the importance of cities in the achievement of sustainable development and the governance of global environmental problems has emerged in the past decade (Lafferty & Eckberg, 1998; O'Riordan, 2001; O'Riordan & Voisey, 1998; Satterthwaite, 1997; Selman, 2000; Sharp, 1999). The need to address environmental problems at the local level has been a long-standing tenet of "green" political thought, and has recently been evident in the notion of urban sustainability. The 1987 Brundtland Report prepared by the World Commission on Environment and Development (WCED) included a specific chapter on the environmental issues facing cities, and argued that as the majority of the world's future population will live in urban areas, cities should be central to the pursuit of sustainable development (WCED, 1987). The focus on cities as a means to address environmental issues was subsequently taken up by the European Union through a number of initiatives (Fudge, 1999; Hebbert, 1999; Ward & Williams, 1997). However, it was not until the 1992 United Nations Conference on Environment and Development (UNCED) that cities were recognized internationally as an arena through which sustainability could, and should, be pursued. Chapter 28 of Agenda 21 called for all local authorities to

have established a Local Agenda 21 (LA21) through participation with their communities by 1996, and encouraged the establishment of mechanisms to promote cooperation and coordination between local authorities internationally (Gilbert, Stevenson, Giradet, & Stren, 1996). Since 1992, various initiatives to address sustainable development, frequently involving public participation and partnership between different local organizations, have been promoted under the general heading of LA21 and it is often cited as one of the most successful outcomes of the UNCED process (Hams, 1994; Selman, 2000).

In the aftermath of these developments, ''sustainable cities'' has become a term under which a host of disparate projects, processes, and analyses concerned with social, economic, or environmental issues in urban areas are categorized. While not all such initiatives are novel, it is the profile given to the urban arena as a means of addressing local and global environmental problems that is new. The rationale given for pursuing urban sustainability is twofold (Capello, Nijkamp, & Pepping, 1999; Gilbert et al., 1996; Jenks, Burton, & Williams, 1996; WCED, 1987). First, many environmental problems, both local and global, stem from the activities of individuals, communities, governments, and industries located in urban areas. In effect, this is both an assertion of the need for local action to address environmental problems and a reflection of the increasingly urban nature of consumption and production practices in developed and developing countries. Second, it is argued that cities are places in which efficient solutions can be found, and where achieving a balance between economic, environmental, and social objectives may be possible.

In this context, various commentators have suggested that cities, rather than nation-states, may be the most appropriate arena through which to pursue policies to address specific global environmental problems. On the issue of global climate change, cities are seen to be significant for four related reasons (Collier, 1997; DeAngelo & Harvey, 1998; Lambright, Stanley, Chagnon, & Harvey, 1996; McEvoy, Gibbs, & Longhurst, 1999; Wilbanks & Kates, 1999). First, given the increasingly urban nature of the global population, cities are sites of high consumption of energy and production of waste. The influence of local governments over these processes varies but can include energy supply and management, transport, land-use planning, building regulations, and waste management. Second, local governments have been engaging with issues of sustainable development through LA21 in ways that have implications for the mitigation of climate change. Third, it is suggested that local governments can facilitate action by others in response to climate change by fostering partnerships with relevant stakeholders,

encouraging public participation, and lobbying national governments. Fourth, some local governments have considerable experience in addressing environmental impacts within the fields of energy management, transport, and planning. Further, many such governments have undertaken innovative measures and strategies to reduce their impact on climate change – measures and strategies that can act as demonstration projects or serve as the basis for new experimentation. Through these practices, local governments exercise a degree of influence over emissions of greenhouse gases in ways that directly affect the ability of national governments to reach targets they have agreed to internationally.

Cities for Climate Protection

The CCP program coordinated by the Toronto-based International Council for Local Environmental Initiatives (ICLEI) is one vehicle through which local authorities have developed strategies for controlling greenhouse gas emissions. ICLEI's involvement in the climate change issue began in 1991 with the Urban CO_2 Reduction Project, which was designed "to develop comprehensive local strategies to reduce greenhouse gas emissions and quantification methods to support such strategies" (ICLEI, 1997). This pilot project, which was sponsored by the US Environmental Protection Agency, the City of Toronto, and several private foundations, involved 14 municipalities in Europe and North America. Based on the success of the project, ICLEI launched the CCP program in 1993.

The CCP program seeks to recruit local governments whose collective emissions of greenhouse gases represent 10% of the global total. While the achievements of any single local government are likely to be modest, ICLEI assumes that by working together, local authorities can make a significant contribution to the mitigation of global climate change. Today the CCP network includes more than 600 local authorities in Africa, Asia, Latin America, Europe, and North America (with the majority in Europe and North America), accounting for more than 8% of global greenhouse gas emissions (ICLEI, 2003).

The CCP program is premised on the assumption that the barriers to local action on climate change are primarily due to lack of information, and the network is organized around the production and dissemination of technical information about local contributions to climate change, as well as measures that can be taken locally to address the problem. In joining the CCP network, members commit to passing through five milestones: conducting

an energy and emissions inventory and forecast; establishing an emissions reduction target; developing a local action plan to achieve this goal; implementing policies and measures to this end; and undertaking processes of monitoring and verifying results. ICLEI provides local authorities with technical assistance and training to complete these milestones. For example, in conjunction with Torrie Smith Associates, Inc., a Canadian environmental consulting firm, the CCP program has developed a software package to help local authorities calculate, forecast, and monitor their emissions of greenhouse gases. This software translates data related to energy use across different sectors and other activities into emissions of greenhouse gases, and can be used for evaluating the effectiveness and economic benefits of various options for their reduction. Both the milestone framework and the development of the software package are reflective of the CCP program's emphasis on quantitative performance evaluation. The CCP campaign also promotes networking and provides information on "best practices" through workshops and the publication of case studies. ICLEI routinely highlights the co-benefits of controlling local greenhouse gas emissions. In addition to the climate-related benefits, which may be hard to quantify and link directly to local action, measures to control emissions carry the potential for considerable economic savings, improvements in local air quality, and enhanced "liveability" in CCP communities.

The CCP program has achieved some success in meeting its objectives. Network members are working through the milestones and many local authorities regularly participate in ICLEI-sponsored workshops and exchanges. The US CCP program estimated that its members had reduced their annual greenhouse gas emissions by 7.5 million metric tons in 1999 (an average of 100,000 tons per city) with a savings of $70 million in energy and fuel costs (ICLEI, 2000). In 2000/2001, Australian councils reduced their emissions by 78,182 metric tons, more than doubling their achievements the previous year (CCP-Australia, 2002).

The Impact of the CCP Program

In a detailed analysis of our case studies (Bulkeley & Betsill, 2003), we found that the impact of the CCP program varied considerably, with the greatest effects found in Denver and Newcastle (NSW). In both cities, climate change considerations have been integrated into the institutional structure of local government on the basis of involvement with the program. Denver has designated a staff member to serve as the full-time coordinator for the

city's CCP program; this person monitors and reports on initiatives taking place across departments. Moreover, climate protection has been adopted as a core activity of the environment division. In Newcastle (NSW), in the wake of the establishment of CCP-Australia, the Australian Municipal Energy Improvement Facility was created in order to promote the council's experience to other local authorities in Australia and to coordinate action within the city. In addition, climate change considerations have been formally integrated into policy and financial decisions through a report on energy consumption and emissions of greenhouse gases, which is included in the quarterly budget review process of the city council (NCC NSW (Newcastle City Council New South Wales), 2001).

Officials in Denver and Newcastle (NSW) are actively involved with the continual monitoring and reporting of in-house energy consumption and greenhouse gas emissions, which has in turn established firm links between the local authority and the CCP program headquarters in each nation-state. Participation in the CCP program has also given those parts of the local authority concerned with energy use access to additional funding. In both Denver and Newcastle (NSW), various innovative policies toward the in-house management of energy and the development of alternative forms of energy supply have been developed (though the CCP program has been only one factor in their development), and have formed the basis for the dissemination of experience to other local authorities through the CCP network. Both Denver and Newcastle (NSW) have been net "donators" of best practice information in this network. Politically, the program has raised the profile of those concerned with energy conservation and sustainable development within the authority. However, it is in Newcastle (NSW) that this has been translated into a high-profile commitment to address climate change and a strategy for sustainable economic regeneration of the city. In Denver, external activities have been muted by powerful interest groups and state politics, which reject any explicit attempts to reduce emissions of greenhouse gases.

In Newcastle (UK) and Leicester, the impact of the CCP program has been mixed. In both cases, the program has been one of the transnational networks with which the local authority has been involved, and one among many factors contributing to the establishment of partnerships with other European cities and access to European funding. In Leicester, this has led, for example, to considerable research on the potential for energy conservation and renewable energy measures within the city, the establishment of an energy agency, and the Energy Sense program promoting home energy conservation. In turn, such initiatives have helped shape the policy agenda

for addressing energy issues across the city. The need to lead by example in order to protect the climate has provided a further rationale for existing in-house policies on energy management. Furthermore, involvement in the program gave particular individuals political kudos, at least in its initial stages, and created the opportunity for them to move energy and climate protection up the local agenda. On this basis, it is possible to argue that the CCP program has had an indirect impact on the development of climate protection policies, and urban sustainability more generally, in both cities. However, the exact nature and extent of this influence is impossible to quantify. Moreover, in neither case was the CCP program institutionalized within the administrative, monitoring, or accounting structures of local government. Ongoing processes of assessing local emissions of greenhouse gases were not established, partly for reasons of insufficient access to data, and information on best practice was not seen as necessary or applicable, so that regular contact and involvement with the CCP network was not established. This left the program vulnerable to shifts in personnel and politics, and by the late 1990s it had all but been abandoned in each case, though Leicester retained a passive interest.[2]

Our research indicates that the CCP program has had the least impact in Cambridgeshire and Milwaukee. In neither of these cases did the CCP program lead to significant changes in administrative structures, financial resources, policy development, or the political potency of the issue of climate protection within the local authority. In Cambridgeshire, the program provided individual officers and councilors with an additional rationale for their concerns with energy and climate protection, and the need for in-house energy management. In addition, the milestone approach seems to have influenced the way in which local climate protection policy has been conceived. However, a lack of resources to access the network, and a feeling that the best practice examples offered were not relevant to the UK context, meant that the council remained distant from the program. The lack of any ongoing data-monitoring exercise, hampered by the limited availability of data on the use of energy across the community, or participation in events or exchanges of best practice, meant that the extent of any engagement with the CCP network was minimal. In the midst of personnel and political changes, such connections are easily severed. In Milwaukee, though the officer responsible for the program took part in network events, these events were not connected into the local authority in any meaningful sense, so that the program remained external to every aspect of policy development. Once this individual left the local authority, participation in the CCP program effectively ceased.

INTERPRETING AND IMPLEMENTING CLIMATE PROTECTION LOCALLY

Each of the local authorities discussed above has, to some degree, made a rhetorical commitment to addressing climate change. However, moving from political rhetoric to policy action has not been straightforward. In this section we analyze how climate change considerations have been integrated into policy principles and practice in the areas of planning, transport, and energy management, and assess the opportunities and constraints that local governments have encountered in addressing these issues. While in most cases the need to protect the climate has entered into policy discourse, there is little evidence to suggest that this discourse is being institutionalized within the practices of decision making or changing the nature of urban development.

Planning

The impact of the form and design of urban areas on energy use has attracted sustained attention over the past decade (Banister, Watson, & Wood, 1997; Breheny, 1996; Capello et al., 1999; Carmona, 2001; Jenks et al., 1996; Owens, 1992). The argument is made that land-use planning, with its influence on both the location and density of development, as well as the design of neighborhoods and individual dwellings, plays a significant role in achieving sustainable development, and in particular reducing the energy use of new developments. While it is clearly simplistic to assume that the location, density, and design of development alone can reduce energy use in urban areas, the way in which developments are designed and planned will have a significant impact on future emissions of greenhouse gases.

In three of the case studies, Newcastle (UK), Newcastle (NSW), and Milwaukee, we examined how the land-use planning system had engaged with the issue of climate protection. In each case, the importance of planning as a means for addressing urban sustainability was recognized in policy documents and by policy makers. In Newcastle (UK) and Newcastle (NSW), the impact of planning decisions on local emissions of greenhouse gases was explicitly considered. Moreover, in all three cases, the use of the rhetoric of "urban sustainability," the "urban renaissance," or "new urbanism"[3] in policy making suggests that urban density should be increased, developments should be planned for multiple use, and the need to travel should be reduced. Nonetheless, the links to climate protection remained implicit.

The fact that local land-use planning policy reflects concern about urban sustainability and climate protection is due to a different combination of factors in each case, though none is directly attributable to the CCP program. In Newcastle (UK), planning officials had an interest in the issue of energy use in the urban environment and sought funding from the European Commission to undertake a study on the potential for the city to reduce its emissions of greenhouse gases. Subsequently, policies to improve the energy efficiency of new housing, reduce the need to travel, and promote renewable energy were integrated into strategic planning policy. Bringing national planning policy guidance into line with principles of urban sustainability and the urban renaissance in turn reinforced previous local commitments and prompted a renewed interest in inner-city (re)development within the city. In Milwaukee, the promotion of new urbanism owes much to the interests of Mayor John Norquist and his appointed officials, who viewed planning as a key means of regeneration. In Newcastle (NSW), the commitment of the council to pursue energy conservation has begun to diffuse into the area of land-use planning through the inclusion of new urbanist principles in planning strategies and energy efficiency requirements in development control policies. This process has been facilitated both by state legislation requiring that local authorities take the principles of sustainable development into consideration when designing their strategic plan and making development control decisions and by the NSW Sustainable Energy Development Agency's work to design-development control agreements with local house builders to improve the energy efficiency of individual dwellings. Together, these cases illustrate that the development of climate protection policies within local government is the result of different factors operating at the local, regional, and national scales concurrently.

Despite the explicit or implicit inclusion of policy principles to address emissions of greenhouse gases through land-use planning in each of these case studies, their implementation has been far from straightforward. Where local authorities own land or can exercise significant powers over its use (for example, through reclassifying zoning to require mixed-use development), policies to reduce energy use through the form or design of developments have been implemented. Likewise, if a particular development site is sought after, or if agreements have been entered into with local house builders, it has been easier to persuade developers to adopt more energy conservation measures than they would have adopted otherwise. However, such instances remain few and far between, and in the majority of developments business continues as usual.

While the principles of changing urban form in order to make development more sustainable have been accepted and, to a degree, are being implemented across the case studies, questions remain as to their impact on energy use. For example, it is often argued that reducing the "need" to travel will have the effect of reducing the "amount" of travel. Without accompanying policies to reduce the demand for car travel, land-use planning policies in isolation may not succeed (Owens, 1995; see also discussion below). In the three case studies at issue, the ability of the local authority to implement measures that explicitly target the energy consumption of individual dwellings, such as energy efficiency standards or passive solar design, remains limited. In Newcastle (UK), the local authority has provided guidance on these issues but is unable to enforce high standards through the planning system, in part because these standards are considered matters to be addressed through the national building regulations. In Milwaukee, new urbanist principles fail to include energy efficiency as a design issue. In Newcastle (NSW), success in improving the energy efficiency of new domestic buildings has recently been accomplished through negotiation with the local house builders' federation, though it remains to be seen how this commitment will take shape in practice.

In light of the CCP's focus on information and data, it is notable that, far from resting merely on a lack of information about the relevance of planning to urban energy use, the problems of acting on climate change through the land-use planning system are deep-seated, and reflect the fluid relationship between local governments, state or national governments, and other stakeholders in the development process. Planning does not provide a conduit through which pre-existing concepts are transferred from policy principles into practice, but is, rather, an arena in which the meaning of sustainability is constructed and contested (Owens & Cowell, 2002). While the principles of a new urban development agenda have been embraced in each local authority, what this means for environmental sustainability in general, and climate protection in particular, is not clear. Rather, the struggle to interpret and implement particular versions of these ideas is central to the local politics of sustainable development. In Newcastle (UK), the need to regenerate inner-city areas, promote economic regeneration, and provide additional housing has shaped the debate about urban planning and sustainability, so that any explicitly environmental considerations have been sidelined. Likewise, in Milwaukee, environmental concerns have been peripheral to the main aims of urban regeneration and have largely been framed in terms of local amenity.[4] In Newcastle (NSW), some explicit measures to address energy use in the urban environment have been

implemented, but many officials continue to advocate traditional approaches to development, such as ensuring that there are enough car parking spaces. Far from providing a blueprint for sustainable development, the integration of climate change concerns into land-use planning has brought tensions between economic, social, and environmental objectives to light.

Transport

In each of the three countries from which the case studies are drawn, the transport sector is an important and growing source of greenhouse gas emissions. Technical fixes in the form of improvements to the energy efficiency of motor vehicles or the development of less carbon-intensive fuels have long been heralded as a means through which to reduce emissions from this sector. In Denver, this approach has taken shape in the Green Fleets program, a scheme to reduce energy costs associated with operating the municipal fleet[5] by reducing the size of the fleet, the size of vehicles within the fleet, and the vehicle miles traveled. The program has been widely replicated by other cities in the CCP network. However, it is increasingly recognized that such measures, by themselves, will be inadequate and that reductions in emissions of greenhouse gases from this sector will depend on an absolute reduction, or at least containment, of the number and length of car journeys (Potter, Enoch, & Fergusson, 2001; RCEP (Royal Commission on Environmental Pollution), 2000) – in short, the introduction of demand management measures.

In three of our case studies – Cambridgeshire, Denver, and Newcastle (NSW) – we examined the development of climate protection policies in the transport sector. In each case, to at least some degree, the principle of transport demand management as a necessary means for addressing urban sustainable development has entered into the policy arena. In Denver, this debate is largely confined to the city's own employees, for whom a bus pass program has been introduced, though the city also lobbies for increased provision of public transport in the metropolitan area. In Newcastle (NSW), emphasis is also placed on the need to create a modal shift away from the car to alternative forms of transport, through providing public transport and information about it to the community. In Cambridgeshire, debates about demand management have been the most extensive, and have focused on "soft" or "persuasive" measures (Marvin & Guy, 1999a), such as providing information about alternatives to the car, creating more public transport infrastructure, and integrating land-use and transport planning. In

addition, elements of "hard" demand management, such as restraining access by cars to the city center, increasing parking charges, and experimenting with road-user charging, have also been included in the Council's transport policy.

The rationale for addressing the demand for car transport differs in each case. In Denver, initially it was concerns about local air quality that prompted the city to invest in alternative transport for its employees, though the greenhouse gas emissions reductions benefits have been acknowledged by calculating and including them in the city's CCP program reports. Across the metropolitan area, congestion levels are also rising, prompting investment in transport infrastructure. In Newcastle (NSW), concerns about air quality have been accompanied by realization on the part of those working on climate protection in the city that the transport sector needs to be addressed, though to date action has been limited. The introduction of state legislation, which demands that local authorities address sustainable development, and new urbanist planning principles (discussed above) may provide some impetus for action in this area in the future. In Cambridgeshire, it is argued that the economic, social, and environmental impacts of continued traffic growth need to be managed. This debate reflects increased awareness of local trends in traffic growth and congestion, as well as national concern about the impacts of car transport on economic efficiency, communities, health, and the environment. Here, climate change has explicitly been recognized locally and nationally as an issue that transport policy should address. From these case studies, we can see that arguments for demand management stem from policy development at different, interacting, scales of governance. In Newcastle (NSW), state policies promoting the integration of land-use and transport planning have been significant, and in Cambridgeshire, the influence of national policy development is also evident.

In practice, the impact of demand management measures on emissions of greenhouse gases in each of these case studies has been minimal. In Denver and Newcastle (NSW), this is partly a function of the limited extent to which such measures have been put in place, but also, as in Cambridgeshire, reflects issues concerning the influence, resources, and powers of local authorities in this sector; conflicts over how demand management should be interpreted; and a continuing belief in the necessary connection between economic development and traffic growth. In each of the cities, emphasis has been placed on the need to improve alternative forms of transport provision, particularly public transport.

In each case, the extent to which the local authority can affect the provision of public transport is limited. In Denver and Newcastle (NSW)

regional authorities and in Cambridgeshire private companies supply public transport. In this context, the role of the local authority becomes one of lobbying for better provision, creating transport infrastructure, such as bus lanes, for the supply of more public transport, and informing the public about, and persuading them to use, these services. Although other forms of soft and persuasive demand management have been experimented with in each of these local authorities, such as developing commuter transport plans and "safer routes to school," the focus remains on the provision of infrastructure for, and information about, alternative modes of transport. In Cambridgeshire, this focus is a reflection of traditional approaches to transport provision (Marvin & Guy, 1999b), a policy climate in which the benefits of particular schemes have to be accounted for in concrete terms, and financing arrangements that favor capital projects over support for non-capital schemes. Whether or not such measures can, by themselves, bring about a reduction or containment of car traffic growth is a moot point. For example, in Cambridgeshire, the development of Park and Ride has increased the number of people coming into the city center by bus, but has not led to a reduction in car traffic across the city center, and despite provision of public transport facilities in Denver and Newcastle (NSW), fewer than 5% of journeys in either city are made by public transport.

Despite the possible limitations of soft and persuasive demand management in isolation, hard demand management measures have not been vigorously pursued. In Denver and Newcastle (NSW), proposals to restrict car access to the city, or to increase the costs of driving in order to provide an incentive for using alternatives, have not been made. In Cambridgeshire, various forms of hard demand management have been applied to the city of Cambridge, including a scheme that restricts access to the city center and increasing parking charges, primarily as a revenue raising exercise to fund the alternatives discussed above. More radical versions, in which workplace parking levies or road-user charges are implemented by local authorities, have been sanctioned by central government. However, the political and pragmatic difficulties associated with such schemes have meant that they remain on the backburner.

In each of the case studies, engagement with demand management has not led to the abandonment of plans to increase road capacity. Rather than being seen as an alternative to increasing provision for traffic growth, demand management measures are seen as an additional strategy for increasing the capacity for travel within urban areas (Bulkeley & Rayner, 2003). This suggests that, far from questioning the legitimacy of continued traffic growth in the face of its economic, social, and environmental impacts, the

assumption is still made that traffic growth is a necessary part of economic growth, and that to reduce the former is to challenge the latter. If, as we argued above, reducing local emissions of greenhouse gases from the transport sector demands reductions, or at least containment, of the number and length of car journeys, these findings raise serious doubts about the extent to which climate protection is being advanced through local transport policy, and therefore the possibilities of reaching national objectives and international targets in the long term.

Energy Management

Outside the land-use planning and transport sectors, local authorities have a significant role to play in managing energy in the built environment, both in the housing sector and within their own buildings and operations. While land-use planning and regulation can affect the energy efficiency of new developments and buildings, additional measures, which local governments can influence or introduce, are required to improve the existing housing stock. Furthermore, some local authorities own large quantities of housing stock and/or office space in which they can take measures to improve energy efficiency. In this section, we compare the experiences of Leicester, Denver, and Newcastle (NSW) in addressing these issues, turning first to measures to manage energy use in the housing sector.

In Leicester, initiatives for energy management within the housing sector date back to the 1970s, and have been manifest in various experiments with energy supply, such as combined heat and power and solar energy projects, as well as in programs to improve the energy efficiency of housing and to encourage individuals to take energy conservation measures within the home. Concern among council members and officers about fuel poverty[6] and the environmental impacts of energy use, the establishment of an energy advice center and an energy agency within the local authority, access to additional funding, and the introduction by central government of the "Home Energy Conservation Act" have all been important factors in developing energy policy and measures within the housing sector. Likewise in Newcastle (NSW), the formation of an energy management agency within local government (the Australian Municipal Energy Improvement Facility) and access to additional funding through the CCP-Australia program have been central to the recent development of community initiatives. Such initiatives included an energy town meeting during which 900 participants developed strategies for the council, community energy workshops to provide information about actions the public could take to reduce energy

and water use, and the Greenhouse Action Partnership undertaken with local businesses.

The dependence of these initiatives on additional funding creates its own problems. First, such funding tends to be focused on innovation, which means that there is little money available for the continued support of (successful) projects. Second, the competitive nature of such funding means that as some local authorities gain, others will miss out (Guy & Shove, 2000; Jones & Leach, 2000). In Leicester, the focus of energy efficiency policy in the housing sector has been on improving the structure of existing buildings on the basis of additional funds, and on providing individuals with information about measures they could implement to conserve energy. Such an approach clearly reflects the limited capacities for local authorities in the UK to directly influence domestic energy use.[7] It is not clear whether such initiatives, which focus on technical fixes and individual action, will be effective in delivering substantial reductions in greenhouse gas emissions. This is implicitly acknowledged in Leicester's Energy Sense program, which tries to address the social and institutional contexts of energy use by offering householders a comprehensive approach to planning and installing energy efficiency measures, with some success. In Newcastle (NSW), community initiatives for energy management are at an embryonic stage, and it remains to be seen how they will take shape. In Denver, explicit action on energy management in the community has not been undertaken for fear of opposition from the state government, which has explicitly banned the use of state funds for implementation of climate protection policies and programs, and from the coal industry.

In contrast, in each of the local authorities, significant progress has been made in reducing the use of energy within the council's own operations and buildings. In Leicester, Denver, and Newcastle (NSW), similar initiatives have been undertaken, including improving the energy efficiency of buildings and office equipment, educating staff about the use of energy and other resources, purchasing renewable energy, and cosponsoring renewable energy demonstration projects. In each case, the initial rationale for action was based on the potential monetary savings, and the interests of particular individuals within the local authority. The implementation of energy efficiency measures has been facilitated in each case by innovative financial mechanisms allowing a proportion of the monetary savings accrued to be reinvested in further initiatives. In this endeavor, each of the local authorities has benefited from rigorous means of accounting for energy savings and reductions in emissions of greenhouse gases, though it has only been in Denver that the CCP software has been used for this purpose.

However, there are also factors specific to each case that have promoted the in-house conservation of energy. In Denver, the local government has benefited from the mandatory financial contribution made by the local utility company to energy conservation measures, and from energy efficiency programs organized by the US Environment Protection Agency. In Newcastle (NSW), energy utilities have played a significant role by promoting the development of renewable energy projects after changes to energy legislation in NSW that require such companies to reduce their emissions of greenhouse gases. Newcastle's leading role in CCP-Australia, and its demonstrated success in delivering reductions in energy use and financial savings, have also lent the energy agenda and those supporting it political credibility within the local authority. In Leicester, an energy management department, energy advice center, and energy agency have been created through funding from external bodies, including the Energy Savings Trust and the European Commission. Energy management has also been encouraged by recent shifts in local government in the UK, as it fits with the ethos of modernizing local government and with approaches to sustainability that stress the need to articulate indicators and measure progress against them.

Each of the local authorities has found its ability to act in reducing emissions of greenhouse gases from within its own operations and buildings constrained. This is perhaps most acute in Leicester, where changes to local government financing and structure in the UK have meant that the managers of individual services, such as schools and hospitals, run their own budgets. At this scale, the financial gains of implementing energy efficiency measures are significantly reduced, and the costs of coordination and implementation increased. At the same time, the cost of energy has fallen substantially, and monetary savings can more easily be gained by shopping around between suppliers than by reducing energy use. This points to a flaw in the strategic approach adopted in each of these cases, and advocated by the CCP program; the message is that in-house energy reductions will have financial gains. While this is intuitively sensible and desirable, problems arise if the return periods for gains are defined in the short term, or if energy prices fall, so that measures that will have significant benefits in terms of climate protection but have high up-front costs are not considered. There is the danger that, once the "easy fruit" has been picked, in-house energy management will be abandoned if its other goals are not made explicit and supported. Furthermore, whatever their size, local authorities face the challenge that their own use of energy is relatively minimal and that in order to be effective in terms of climate protection, they need to influence energy use across the community, where the approaches that have so far been taken

– focusing on modeling and accounting for energy – may not be as easy to pursue or as successful. Local governments may need to search for alternative approaches to energy conservation and urban sustainability in order to reduce local emissions of greenhouse gases across the community.

THE LOCAL POLITICS OF CLIMATE CHANGE

From the analysis above, five key factors emerge that have shaped the opportunities and constraints encountered in addressing climate change. The first relates to the presence of committed individuals, both officers and politicians, for whom the environmental, social, and economic impacts of energy use are considered important. However, individuals alone cannot make local action on climate change a reality. Rather, they have to be positioned within the administrative and political structures of local government so as to be effective. In some cases, like Denver and Leicester, this means gathering support from across different departments. In others, like Newcastle (NSW), one department has managed to have a significant impact on the policy direction of the council because it has spoken to a wide agenda with which the whole council is concerned – the finances of the local authority and the regeneration of the local economy.

The second critical factor shaping the extent and form of local climate protection initiatives is the availability of funding, either through internal financial arrangements or through access to external funding sources. What seems clear from these case studies is that climate protection measures are not being undertaken with the support of mainstream local government finances, though of course the day-to-day activities of local governments that are funded in this way may have positive impacts on reducing emissions of greenhouse gases indirectly.

The third factor relates to the powers of local government in the critical areas of land-use planning, transport, and energy management. Although in each country from which the case studies are drawn the powers awarded to local government differ, in each case local government has at least some influence over these sectors. However, the use of direct influence has been limited by conflicting policy objectives (locally, regionally, and nationally) and by a lack of guidance or consensus as to the weight that should be given to climate change considerations in local policy decisions. DeAngelo and Harvey (1998, p. 134) argue that "there is considerable scope for effective action by municipal governments to reduce local greenhouse gas emissions by informal approaches which do not require formal jurisdictional

authority.'' In the cases presented here, many initiatives to address climate change locally have been based on voluntary or additional initiatives, rather than being part of the mainstream council business. While such schemes, which often take the form of the provision of information and encouragement to local businesses and communities, may be effective in getting ''quick wins,'' our findings suggest that it is unlikely that they can address institutionalized patterns of energy use over the long term. Furthermore, the very nature of such schemes means that they can easily be sidelined or neglected within the local authority when changes of personnel or politics occur.

Our case studies also illustrate that the power to act on climate protection is no guarantee that such action will take place. A fourth critical factor in the local politics of climate change is how the issue is defined and understood. One of the advantages of local action on climate change, as argued by the CCP program and other initiatives, is that it will have other dividends, such as reducing local air pollution, improving the local economy, enhancing the liveability of urban spaces, and addressing social and economic inequities. While there are undoubtedly synergies between reducing emissions of greenhouse gases and other environmental, social, and economic goals, there are also conflicts. At one level, conflicts emerge between different parts of the energy agenda. For example, reducing greenhouse gases produced from vehicles through promoting ''greener'' fuels will not necessarily reduce congestion, and hence enhance the liveability of urban places. At another level, these case studies show that in protecting the climate conflicts with other social and economic goals, such as economic regeneration or the interests of particular local industries, political will for the former weakens or disappears.

This finding is critical for, as our evaluation suggests, the final factor that emerges from these case studies as shaping the opportunities and constraints for local action on climate change is the extent to which the political will to address such conflicts exists. While local initiatives to address climate change continue to stress the win–win potential of such initiatives, the danger is that only those measures that constitute the lowest common denominator will be implemented (Gibbs, Longhurst, & Braithwaite, 1998, p. 1363), leaving the majority of local emissions of greenhouse gases untouched. Such conflicts not only reveal the particular politics of certain places, but point to fundamental dislocations between the different goals of sustainable development (Owens & Cowell, 2002).

These findings suggest that approaches to local climate protection that rest on assumptions about the need for more knowledge of local emissions

of greenhouse gases, the transferability of best practice, and the compatibility of different elements of sustainable development under the banner of climate protection do not suffice once the agenda moves from in-house energy use to wider issues about energy consumption and production. Rather than being a technical issue, requiring more information or better practice, or an issue of changing behavior within existing institutional structures, the interpretation and implementation of climate protection locally is a political issue, where different actors and groups seek to have their understanding of the problem, and its solutions, acted upon (Hajer, 1995). As Flyvbjerg (1998, p. 27) argues, "power does not 'seek' knowledge…[r]ather power 'defines' what counts as knowledge." Information about the nature of local greenhouse gas emissions, potential solutions, and best practices from other cities does not act in a neutral way to enlighten and change policy making, but, rather, forms part of new discourses that urge change in the remit and responsibilities of local planning, transport, and energy policies (Betsill & Bulkeley, 2004).

CONCLUSION: THE LOCAL DIMENSION OF GLOBAL ENVIRONMENTAL GOVERNANCE

The politics of climate change is not merely a matter of international negotiation and national policy development, but is also taking place on the local scale through different policy sectors, as struggles emerge over what it should mean to act to protect the climate (Guy & Marvin, 1999). At the same time, the local politics of climate change is not confined within a discrete sphere of local governance, but occurs through vertical relations of power and governance between the subnational and national state, and through transnational networks of local government. Thus, to understand global environmental governance as either negotiated at the international level and then trickled down to other institutional arenas as responsibilities are assigned and implemented or to see local initiatives as the result of isolated actions by more ecologically rational institutions is too simplistic.

Clearly, processes at the global level are important in the governance of environmental issues, particularly in establishing common sets of norms and rules of behavior. However, by viewing the world in terms of hierarchical, territorially discrete, scales, regime theory approaches miss emerging forms of multilevel governance involving transnational networks that are simultaneously global and local, while minimizing the role of local actors in addressing global problems (Bulkeley & Betsill, 2005; Betsill & Bulkeley, in

press). Local authorities, which are largely absent from explicit consideration within the regime theory framework, are assumed to act in response to directives from the central state as part of the national implementation of these international agreements.

The case studies confirm that indeed, local authorities exercise a degree of influence (with significant variation) over greenhouse gas emissions through their activities in the areas of energy, transport, and land-use planning and will thus be important actors in the implementation of national and international climate protection policies. At the same time, the cases demonstrate that the significance of cities in the governance of global climate change goes beyond their role in implementing policies established at other levels. Cities represent an important site for the governance of global issues in their own right. In the area of climate change, cities have been innovators in terms of climate protection policy and practice, often in the absence of any international or national policy requiring them to do so (here, the cases in the US and Australia are particularly illuminating). Moreover, even where attempts to address climate change are not leading to emissions reductions or an increased appreciation of the importance of the issue, this does not signal a lack of governance but rather its failure. The development of local climate change policy has not been the direct result of a linear process of international policy formulation, national policy adoption, and local implementation. Rather, the process is more chaotic, fragmented, and opportunistic, and is shaped by institutions and actors operating across different policy sectors at and between different levels of governance.

While it is clear that cities are important actors in the governance of climate change, the case studies also indicate that it would be naive to assume that climate change can be addressed entirely at the local level. Many analyses of urban sustainability, with their inward focus and optimistic assertions of the influence of local government, also miss the shifts taking place toward multilevel governance and create little opportunity for recognizing the role of international and transnational actors, let alone transnational networks of local governments, in environmental governance. Moreover, such approaches ignore the particular social, political, and economic context in which local climate protection efforts take place, which, as demonstrated above, has significant implications for the capacity of local authorities to develop and implement climate change policies. Our analysis suggests that in order to better understand global environmental governance, we will need to move beyond perspectives that focus on either ''thinking globally'' or ''thinking locally,'' and instead seek an approach that can traverse the different scales and spaces of environmental governance.

NOTES

1. These case studies were developed during 1998–2001 through three different research projects: "Global Sustainability in an Urban Form: The Impacts and Implications of ICLEI's Cities for Climate Protection Programme," conducted by Bulkeley in the UK and Australia 1999–2001 with support from the Nuffield Foundation and the Smuts Memorial Fund; "Localizing Global Climate Change," conducted by Betsill in the US during 1999–2000 as part of the Global Environmental Assessment Project, Belfer Centre for Science and International Affairs, Harvard University with support from the National Science Foundation (Award No. BCS-9521910); and "Valuing the Global Environment," doctoral research conducted in Australia by Bulkeley in 1995–1998, with support from the University of Cambridge, the Smuts Memorial Fund, and the Sir Robert Menzies Centre for Australian Studies, London. This support is gratefully acknowledged, though the views represented in this chapter are those of the authors alone. While the methods used in each project varied to some extent, they all involved conducting semi-structured interviews with key actors at local, national, and international levels, as well as the analysis of policy documents and grey literature.

2. The recent launch of the UK "Councils for Climate Protection" program has galvanized interest within Leicester City Council once again, leading to renewed efforts to model energy use across the city and community. By helping local governments address issues of data gathering and emissions modeling, and through creating examples of best practice that are more relevant to the UK context, this program may provide some support for further local initiatives on climate change in the UK.

3. The term "urban renaissance" was coined by the UK's Urban Task Force in the late 1990s to refer to the need for urban regeneration to take into account social, economic, and environmental factors concurrently, and mirrors the development of the same sentiments in North America under the heading "new urbanism." For more on the urban renaissance see Urban Task Force 1999, and on new urbanism, consult the Congress for the New Urbanism's website http://www.cnu.org/

4. Where local amenity refers to the useful or desirable features of a place.

5. Vehicles owned and operated by the local authority for the delivery and provision of local services. This varies from place to place but can include a public transportation system (e.g., buses, metro, trams), waste collection vehicles, snowplows, etc.

6. "Fuel poverty" refers to the inability to afford adequate warmth because of the energy inefficiency of the home (Boardman, 1991).

7. While the 1995 "Home Energy Conservation Act" gave local authorities the duty of reporting on home energy consumption, no mandate for intervention was introduced. Local authorities can only provide guidance on the energy efficiency of new buildings, have no official remit to intervene to retrofit buildings to reduce energy consumption, and have no influence over the energy performance standards of white goods and other electrical items which consume energy within the home. Rather, actions to address household energy consumption by local authorities are based on attaining specific grants and on the interest of one or more individuals within the local authority.

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PART 4:
PHILOSOPHICAL PERSPECTIVES

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ADAPTATION, MITIGATION, AND JUSTICE

Dale Jamieson

INTRODUCTION

In this chapter I claim that climate change poses important questions of global justice, both about mitigating the change that is now under way and about adapting to its consequences.[1] I argue for a mixed policy of mitigation and adaptation, and defend one particular approach to mitigation. I also claim that those of us who are rich by global standards and benefit from excess emissions have strenuous duties in our roles as citizens, consumers, producers, and so on to reduce our emissions and to finance adaptation.

THE UNAVOIDABILITY OF ADAPTATION

When I began my research on global climate change in the mid-1980s, it was commonly said that there were three possible responses: prevention, mitigation, and adaptation. Even then we were committed to a substantial climate change, although this was not widely known. This realization began to dawn on many people on June 23, 1988, a sweltering day in Washington, DC, in the middle of a severe national drought, when climate modeler James Hansen testified before a US Senate Committee that it was 99% probable that global warming had begun. Hansen's testimony was front-page news in the

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New York Times, and was extensively covered in other media as well. Whether or not Hanson was right, his testimony made clear that we were entering a new world, what Schneider (1989) called "the greenhouse century."

Once it became clear that prevention was no longer possible, mitigation quickly moved to center stage. One week after Hansen's testimony, an international conference in Toronto, convened by the World Meteorological Organization (WMO), called for a 20% reduction in greenhouse gas (GHG) emissions by 2005. In November, the World Congress on Climate and Development, meeting in Hamburg, called for a 30% reduction by 2000. Later that same year, acting on a proposal by the United States, the WMO and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in order to assess the relevant scientific information and to formulate response strategies.[2] In December 1989, the United Nations General Assembly adopted a resolution, proposed by Malta, that essentially authorized the negotiation of a climate change convention. The following year the IPCC published its first report and the International Negotiating Committee (INC) was established. In 1992 the Framework Convention on Climate Change (FCCC) was officially opened for signature at the Rio Earth Summit. It came into force on March 21, 1994, and by May 24, 2004, had been ratified by 189 countries.

The main objective of the FCCC is to stabilize "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." This goal is consistent with accepting some degree of climate change so long as it is not "dangerous." In the negotiations leading up to the adoption of the FCCC, all the developed countries except the United States and the Soviet Union favored binding targets and timetables for emissions reductions as a way of reaching this goal. However, in the end the FCCC embodied voluntary commitments on the part of developed countries to return to 1990 levels of GHG emissions by 2000.

It soon became clear that while some European countries might succeed in keeping this commitment, the United States, Australia, New Zealand, Japan, Canada, and Norway would not. In 1995, at the first Conference of the Parties (COP 1), the "Berlin Mandate" was adopted. The parties pledged that by the end of 1997 an agreement would be reached establishing binding, "quantified, emission limitation reduction objectives" for the industrialized countries, and that no new obligations would be imposed on other countries during the compliance period. In December 1997, the parties agreed to the Kyoto Protocol, which in its broad outlines satisfied the Berlin Mandate. However, many of the most important details regarding the rules of implementation were left for future meetings.

Almost immediately the Kyoto Protocol came under fire from several different directions. It was simultaneously attacked as too weak, too strong, unworkable, and, at least in the United States, politically unacceptable. Meeting in The Hague in November 2000, a lame-duck American administration and its allies, Japan, Russia, Canada, Australia, and New Zealand (collectively known as "JUSCAN"), argued that countries should be able to satisfy up to 80% of their reductions by emissions trading and by establishing carbon sinks.[3] The Europeans rejected this, and the meeting seemed headed for disaster. However, rather than admitting defeat, the conference was suspended until July 2001. In the interim, in March 2001, the new Bush administration caught the world by surprise by renouncing the Protocol. Ironically, this improved the negotiating position of America's JUSCAN partners. In order to come into force the Protocol had to be ratified by at least 55 countries, including Annex 1 countries responsible for 55% of Annex 1 country emissions in 1990.[4] Since the U.S. share of such emissions is about 36%, it became imperative to keep the rest of JUSCAN in the Protocol. In addition, some hoped that by offering concessions, the United States could be persuaded to climb down from its extreme position and rejoin the negotiation. The result was that in July 2001, in Bonn, the European Union (EU) acceded to most of the demands that the Americans had made earlier in The Hague. The Protocol was further weakened in Marrakech in November 2001, when negotiators gave in to Russia's demand that its transferable credits for sinks be doubled. After two more years of study and negotiation, Russia finally ratified the Kyoto Protocol on November 18, 2004. On February 16, 2005, the Kyoto Protocol came into force, binding virtually every country in the world except the United States and Australia.

It is not completely clear what will be the effect of the Kyoto Protocol. While once it was envisioned that it would reduce developed country emissions by about 14% between 2000 and 2010, it now appears that in the wake of the Bonn and Marrakech agreements it could countenance as much as a 9% increase in emissions from these countries.[5] Were that to occur, there would be little difference between the Kyoto path and a "business as usual" scenario, at least with respect to GHG emissions over the next decade.

Essentially what has occurred is that the vague loopholes that were embedded in the text of the Kyoto Protocol, rather than being eliminated, have been quantified and transformed into central features of an emissions control regime. In order to convey the flavor of these loopholes I will mention only the example of Russian "hot air." As a result of the post-communist economic collapse, Russian GHG emissions have sharply declined since

1990. What has happened, in effect, is that Russia is being allowed to sell the rights to emissions that would not have occurred, to countries that will in fact use them. Thus, more GHGs will be emitted than would have been the case under a regime that simply established mandatory emissions limits without such flexible mechanisms as emissions trading and credits for carbon sinks. Russia benefits economically, countries with high levels of GHG emissions are allowed to carry on business more or less as usual, and politicians can take credit for having addressed the problem. Meanwhile, global climate change continues largely unabated.

At the eighth Conference of the Parties (COP 8) meeting in Delhi in October 2002, the United States, once the foremost advocate of bringing developing countries into an emissions control regime, joined with the Organization of Petroleum Exporting Countries (OPEC), India, and China in blocking the attempts of the EU to establish a more inclusive regime after the Kyoto commitments expire in 2012.[6] At COP 10, meeting in Buenos Aires in December 2004, the United States did everything it could to block even informal discussion of a post-2012 emissions regime. In retrospect, COP 8 may be seen as our entrance into an era in which the world has given up on significantly mitigating climate change, instead embracing a *de facto* policy of "adaptation only." Indeed, the most public pronouncement of COP 8, the Delhi Ministerial Declaration on Climate Change and Sustainable Development, emphasized adaptation almost to the exclusion of mitigation.

As should be clear already, the climate change discussion has its own vocabulary, and it is important to understand exactly what is meant by such terms as "adaptation." One influential characterization is this: "…adaptation refers to adjustments in ecological–social–economic systems in response to actual or expected climate stimuli, their effects or impacts.[7] Various typologies of adaptation have been developed,[8] but for the present purposes it is sufficient to mark distinctions on two dimensions.

Some adaptations are conscious responses to climate change while others are not. For example, plans that are currently under way to evacuate low-lying Pacific islands are conscious adaptations, while adaptations by plants, animals and ecosystems, and also those by farmers who incrementally respond to what they see as climate variability and changes in growing season, are nonconscious adaptations. Intuitively, this distinction is between climate change policy adaptations and those responses that are autonomous or automatic. On another dimension, some adaptations are anticipatory while others are reactive. An example of an anticipatory adaptation is constructing seawalls in order to minimize the impact of an expected sea level rise. An

example of a reactive adaptation is the efforts of a coastal community, damaged by a hurricane, to rebuild to a more secure standard. This dimension marks the intuitive distinction between adaptations based on foresight and those that are responses to immediate events. Taking these dimensions together, we can say that climate change adaptations can be driven by policy or by autonomous responses, and they can be based on predictions or stimulated by events.

There are, of course, other dimensions on which one might distinguish adaptations, and the categories that I have characterized admit of degrees of membership. These complications need not concern us for the present purposes, however.[9]

From the beginning of the climate change controversy, some in the research community have been concerned about the place of adaptation on the policy agenda.[10] There were several sources of this concern.

First, the community that studies climate and weather impacts is greatly influenced by the natural hazards community, which has long been committed to the idea that human societies are to a great extent maladapted to their environments. Researchers point to ongoing failures to adapt to such predictable features of a stable climate regime as droughts, storms, and hurricanes. For people who suffer from these events it matters little if they are part of normal variability, associated with various long-term natural cycles, or consequences of anthropogenic climate change. What people experience is weather, not the statistical abstractions constructed by climatologists. An increasing focus on adaptation would help vulnerable people whether or not climate change is occurring.

A second source of concern, often expressed by anthropologists and those influenced by the social movements of the 1960s, is rooted in opposition to scientistic, top-down, managerial approaches to human problems. Here the concern is that focusing primarily on mitigation (i.e., reducing GHG emissions) transforms problems of human survival and livelihood into technical problems of "carbon management," best approached by scientists with their formal methods of prediction and their economistic approaches to evaluating policy options. With this view, subsistence farmers in the developing world would do better by adjusting and adapting to changing environmental conditions based on their indigenous knowledge than waiting for the right sort of policy to emerge in New York, Geneva, or Washington and then filtering down through a panoply of national institutions, subject to who knows what kinds of distortions and revisions.

In the discussion surrounding the Kyoto Protocol some researchers seemed to suggest that adaptation was a neglected option as a response to

climate change.[11] Yet concern for adaptation is both implicit and explicit in the FCCC.[12] The sentence that follows the statement of the objective quoted earlier states that "such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to assure that food production is not threatened, and to enable economic development to proceed in a sustainable manner. Article 4, which specifies the commitments undertaken by the parties to the Convention, mentions adaptation on several occasions. The parties agree to implement national or regional adaptation measures, to cooperate in preparing for adaptation to the impacts of climate change, and to take adapting to climate change into account in their relevant social, economic, and environmental policies and actions. In 1994, the IPCC published technical guidelines to assist nations in performing "vulnerability and adaptation assessments," and in 1995 at COP 1 in Berlin, explicit guidance was provided on adaptation planning and measures. The second IPCC report published in 1996 observed that many societies are poorly adapted to climate, and emphasized the importance of adopting "no-regrets" policies to better adapt to both the prevailing climate regime and what may come next.

More recently, in July 2003, the strategic plan of the United States Government's Climate Change Science Program listed, as one of its goals, understanding "the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes."[13] No comparable goal regarding mitigation figured in the plan.

Once it became clear that prevention was not possible, adaptation had to be part of the portfolio of responses. The logic of the U.S. government's *Climate Action Report* 2002 is unassailable: "because of the momentum in the climate system and natural climate variability, adapting to a changing climate is inevitable."[14] The adaptations may be clumsy, inefficient, inequitable, or inadequate, but it has been clear for some time that human beings and the rest of the biosphere will have to adapt to climate change or they will perish. What is in question is not whether a strategy of adaptation should and will be followed, but whether in addition there will be any serious attempt to mitigate climate change.[15]

THE IMPORTANCE OF MITIGATION

My claim is that a policy of adaptation without mitigation, the one we may be slouching toward, runs serious practical and moral risks. The practical risk, which itself has moral dimensions, is that a GHG forcing may quite

suddenly drive the climate system into some unanticipated, radically different state to which it is virtually impossible to adapt. Such a catastrophic climate surprise could occur through climate change setting off a series of positive feedbacks, for example warmer temperatures leading to lower albedo (surface reflectancy), leading to warmer temperatures, leading to lower albedo, and so on – or through the flipping of a climate "switch." The current climate regime depends on regular circulation systems in the oceans and atmosphere that at various times have turned on, shut down, or been radically different. At the end of the Younger Dryas, about 11,500 years ago, global temperatures rose up to 8°C in a decade and precipitation doubled in about three years.[16] The GHG forcing that is now occurring increases the probability of such an abrupt change. As a recent report from the National Academy of Sciences (2002, p. 107) states,

> In a chaotic system, such as the earth's climate, an abrupt change could always occur. However, existence of a forcing greatly increases the number of possible mechanisms. Furthermore, the more rapid the forcing, the more likely it is that the resulting change will be abrupt on the time scale of human economies or global ecosystems.

Indeed, there is some evidence that abrupt changes may already be occurring. The Arctic circulation appears to be slowing,[17] and since the 1980s the Arctic Oscillation has been stuck in its positive phase, causing lower pressures to persist over the Arctic. This has led to warmer summers and stormier springs, resulting in the greatest contraction of Arctic sea ice since modern measurements began, and perhaps much longer if anecdotal and anthropological reports are to be believed.[18] The recent Arctic Climate Impact Assessment sponsored by the Arctic Council, a high-level intergovernmental forum that includes the United States, found that the warming in the Arctic is much more extreme than that in the mid-latitudes, with some Arctic regions having warmed 10 times as much as the mid-latitude average.[19] Perhaps most telling, in the summer of 2000 a Canadian ship succeeded in transiting the legendary, once impassable Northwest Passage, the elusive goal of mariners since the 16th century.

Even without abrupt climate change, an "adaptation only" policy runs serious moral risks. For such a policy is likely to be an application of the "polluted pay" principle, rather than the "polluter pays" principle. Some of the victims of climate change will be driven to extinction (e.g., some small island states and endangered species), and others will bear the costs of their own victimization (e.g., those who suffer from more frequent and extreme climate-related disasters).

Consider what happens when a climate-related disaster strikes a developing country. Often large amounts of aid are pledged and commitments are made to provide both humanitarian assistance and support for transforming the society in order to reduce its vulnerability to future disasters, but little meaningful change actually occurs. Consider an example.[20]

In 1998 Hurricane Mitch struck Honduras, killing at least 6,500 people and causing $2–4 billion in damage, an amount equivalent to 15%–30% of Gross Domestic Product (GDP). At the height of the emergency, donors pledged $72 million to the World Food Program for immediate humanitarian assistance. More than a year later, less than one-third of the promised funds had been delivered. At a donors' conference convened in Stockholm in 1999, $9 billion was pledged for the reconstruction and transformation of Central America. The conference report stated that "the tragedy of Hurricane Mitch provided a unique opportunity to rebuild not the same, but a better Central America."[21] Many of the resources that were provided were reprogrammed funds or "in kind" contributions. Much of the promised aid was not delivered in any form. Still, a significant amount of aid did find its way into the country, especially compared to pre-Mitch levels of assistance.

The 3-year reconstruction period is now over, and we can ask what has been accomplished. There are success stories trumpeted by various governments and non-governmental organizations (NGOs), and it would be incorrect to say that no improvements have been made. Still, Honduras remains extremely poor and vulnerable to climate-related disasters. One observer writes that even

> …after Mitch, we see many environmentally bad habits on replay. People are moving back into high-risk zones, farming practices degrade upper watersheds, illegal logging damages forests, trash dumping and sediment stop up storm drains (50 percent are out of order…), new buildings weaken river channels; lack of educational campaigns, poor emergency readiness, forest burning.[22]

Tragically, we have lived through this story before. In 1974, Hurricane Fifi swept through Honduras, killing about 8,000 people and causing about $1 billion in damages. Shortly after this event, studies showed that the destruction was exacerbated by various social, economic, and political conditions. These included deforestation, as well as the displacement of campesinos into isolated valleys and on to steep hillsides by foreign-owned banana plantations and large-scale beef ranches. After Hurricane Mitch, studies again implicated these same factors. The report of the 1999 donors' conference states that the tragedy "was magnified by man-made decisions

due to poverty that led to chaotic urbanization and soil degradation.''[23] This cycle of vulnerability is made vivid by the following description:

> On the North Coast, the Aguan River flooded big after Fifi. It is a closed basin and dumps huge amounts of water straight into the ocean. Not only did the same flooding occur with Mitch, but it carried the village of Santa Rosa de Aguan out to sea, drowning dozens. There was no effort in the headwaters to do something to avoid this repeat catastrophe.[24]

What I am suggesting is that the moral risk of a policy of ''adaptation only'' is that it will hit the poor the hardest, yet it is they who have done the least to bring about climate change. They will suffer the worst impacts and they have the least resources for adaptation.

Some people would deny that the poor are most vulnerable, pointing to the long history of mutual accommodation between indigenous peoples and their environments. However, underdevelopment is not the same as lack of development. In some regions of the world people are less able to feed themselves and to manage their environments than they were in the distant past.[25] In some cases contact with the Northern-dominated global economy has brought the risks of capitalism without the benefits. Traditional ways of coping have been lost or driven out, while modern approaches are not available. From this perspective underdevelopment should be thought of as something that has been produced by the global economy rather than as some point of origination from which development proceeds. This, however, is not to endorse any ''myth of merry Africa'' in which all was paradisiacal before European contact. No doubt, in many regions ''capitalist scarcity [has simply] replaced precapitalist famine.''[26]

Whatever is true about the details of these speculations, it is clear that poor countries will suffer most from climate change just as poor countries suffer most today from climate variability and extreme events. Honduras suffers more from hurricanes than Costa Rica, Ethiopia suffers more from drought than the United States, and probably no country is more affected by floods than Bangladesh. In 1998, 68% of Bangladesh's land mass was flooded, affecting about 30 million people, and this was only one of seven major floods that occurred over a 25-year period. Generally, 96% of disaster-related deaths in recent years have occurred in developing countries.[27]

The vulnerability of poor countries to climate change has been widely recognized in international reports and declarations, including the most recent IPCC report.[28] The Johannesburg Declaration, issued on the 10th anniversary of the 1992 Rio Earth Summit, declared that ''the adverse effects of climate change are already evident, natural disasters are more

frequent and more devastating and developing countries more vulnerable.''[29] The Delhi Declaration, cited earlier, expressed concern at the vulnerability of developing countries, especially the Least Developed Countries (LDCs) and Small Island Developing States (SIDS), and identified Africa as the region suffering most from the synergistic effects of climate change and poverty.

One response to the fact that it is the poor countries which will suffer most from climate change would be to internationalize the costs of adaptation. This is favored by many of those in the research community who have championed adaptation and was also envisioned in Article 4.4 of the FCCC, which commits developed countries to ''assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects.''

Discussions about providing such assistance did not begin until COP 1 in Berlin in 1995, and only recently have begun to move to the center stage. The 2001 Marrakech Accords established three new funds to assist developing countries with adaptation. The Least Developed Countries Fund supports the development of adaptation action plans. The Special Climate Change Fund assists all developing countries (not only the LDCs) with adaptation projects and technology transfer. The Kyoto Protocol Adaptation Fund finances concrete adaptation projects and programs. The latter fund is resourced by an adaptation levy placed on transactions under the Clean Development Mechanism, the program under which greenhouse gas reductions are traded between companies in the developed and developing world. The other two funds are supported by voluntary contributions. Canada and Ireland have committed $10 million to the Less Developed Country Fund, and various nations have pledged to contribute a total of $450 million per year to the Special Climate Change Fund. These funds were supposed to begin operation in 2005, but they were stalled at the COP 10 meeting in December 2004, in part due to demands by Saudi Arabia that it receive compensation if the world turns away from the use of fossil fuels.

While I am in favor of establishing these funds, many practical problems must be overcome before significant resources are invested, and even on the most optimistic scenarios there are clear limitations on what these funds can accomplish.[30] Parry, et al. (2001) have shown that on ''business as usual'' emissions scenarios, hundreds of millions of additional people will be at risk from hunger, malaria, flooding, and water shortages. Economists standardly estimate the damages of climate change on such scenarios at 1.5–2% of GDP.[31] This implies damages of between $705 and $940 billion per year in current dollars once the full impacts of climate change are felt. The damages

from sea level rise alone have been estimated at $2 trillion over the next 50 years.[32] Although more than half of global GDP is in the developed countries, the damages of climate change are likely to be significantly higher than 2% of GDP in the LDCs.

These numbers have an air of unreality about them, and the cost of adaptation would presumably be less than the damages that climate change would entail. Still, even if the Marrakech mechanisms were fully funded, it seems quite unlikely that they would begin to approach the level of resources required to fully finance adaptation to climate change in the poor countries. Moreover, even if these mechanisms would significantly defray the costs of adaptation for the poor, another injustice would be entailed. The United States is the largest emitter of GHGs; yet it is outside the Kyoto framework, thus not a contributor to the funds established by that agreement. It is difficult to see any system as just in which the world's largest emitter of GHGs does nothing to pay for the damages it causes.

Even more troubling than the fact that poor countries suffer more from climate-related impacts than rich countries is the fact that poor people suffer more from such impacts than rich people, wherever they live. The disproportionate impact on the poor was specifically cited in the donors' report on Hurricane Mitch, but this pattern of the poor suffering most from extreme climatic events has been documented as far back as the "little ice age" that occurred in Europe from 1300 to 1850.[33]

A recent example is the Chicago heat wave of July 14–20, 1995. In a fascinating book, Klineberg (2002) documents in detail the victims of this event; they were disproportionately low-income, elderly, African-American males living in violence-prone parts of the city. A total of 739 people died in the heat wave, more than four times as many as in the Oklahoma City bombing that occurred three months earlier although it received much less media attention. This pattern of the poor suffering disproportionately from climate-related impacts, even in rich countries, occurred once again in the wake of Hurricane Katrina, which struck the Gulf Coast of the United States in September 2005. As I write these words the damages have not yet been assessed, but it is clear that they are quite catastrophic.

Poor people suffer more than do rich people from climate-related impacts, wherever they live, but poor people in poor countries suffer most of all. A recent report from a consortium of international organizations concluded that

> climate change will compound existing poverty. Its adverse impacts will be most striking in the developing nations because of their geographical and climatic conditions, their high dependence on natural resources, and their limited capacity to adapt to a changing

> climate. Within these countries, the poorest, who have the least resources and the least capacity to adapt, are the most vulnerable.[34]

This conclusion should not be surprising since the poor suffer more from "normal" conditions, and often only need a good shove to plunge into catastrophe.

Climate change and variability have enormous and increasing impacts on developing countries, yet very little has been done to integrate these considerations with overall development objectives. At the United Nations Millennium Summit in September 2000, the worlds' governments committed themselves to eight Millennium Development Goals (MDGs), the achievement of which is supposed to result in a 50% reduction in global poverty by 2015. Despite the fact that one of these goals is "ensuring environmental sustainability," the MDGs make no mention of climate change or climate-related disasters as threats to environmental sustainability or to the overall goal of poverty reduction. Yet the report from the African Development Bank et al. (2003) quoted earlier states that "climate change is a serious threat to poverty reduction and threatens to undo decades of development effort." A similar conclusion was reached in a recent review of the United Nations International Decade for Natural Disaster Reduction, which stated that "millennium development targets cannot be reached unless the heavy human and economic toll of disasters is reduced."[35] It is clear that climate change and variability should be thought of not only as environmental problems, but also as major influences on the development process itself.[36]

These claims are borne out by a brief look at some examples. Climate change is expected to increase the incidence of malaria in some regions. While malaria is a human health problem, it is also an obstacle to development. Gallup and Sachs (2000) found that between 1965 and 1990, a high incidence of malaria was associated with low economic growth rates and that a 10% reduction in malaria was associated with a 0.3% increase in economic growth. Freeman, Martin, Mechler, Warner, and Hausmann (2002) showed that in Central America over the next decade, exposure to natural disasters could shrink a growth rate of 5–6% per year to one that is virtually flat. This would have the effect of consigning millions to poverty which they might otherwise escape.

It is the poor who suffer most from climate-related disasters, and in the end they are largely on their own. International assistance is typically inadequate, and many of the changes required to reduce vulnerability can be made only by affected communities themselves in conjunction with their governments. In turn local, regional, and national decision-makers are often

constrained by the economic and political realities of the global order. There is little reason to expect this pattern to shift as a changing climate increasingly makes itself felt in climate-related disasters.

Grand proposals have been made for addressing these problems. For example, Senator Al Gore (1992) proposed a "Global Marshall Plan" aimed at "heal[ing] the global environment." Even if there were popular support for such proposals, there would not be much reason to be optimistic. Rich countries, perhaps especially the United States, have the political equivalent of attention deficit disorder. A "Global Marshall Plan," or even a conscientious effort to finance adaptation to climate change on a global scale, would require a level of sustained commitment that most Western societies seem incapable of maintaining, especially now when the war on terrorism presents similar challenges and is perceived as much more urgent. Indeed, if we had the moral and political resources to internationalize adaptation and distribute the costs fairly, it seems likely that the attempt to control emissions would succeed and we could effectively mitigate the effects of climate change. A just approach to adaptation is not really an alternative to a just approach to mitigation, since it would mobilize the same resources of respect and reciprocity. Just as we must acknowledge the necessity of adaptation, so a just approach to climate change cannot escape the challenge of mitigation.[37]

Mitigating climate change by reducing GHG emissions is important for a number of reasons. First, slowing down the rate of change allows humans and the rest of the biosphere time to adapt, and reduces the threat of catastrophic surprises.[38] Second, mitigation, if carried out properly, holds those who have done the most to produce climate change responsible, at least to some extent, for their actions. It is a form of moral education. As President Bush has said in other contexts, it is important for actions to have consequences. As I have said, mitigation as envisioned by the FCCC embodies aspects of the "polluter pays" principle. By bearing some costs to reduce GHG emissions, those who have been most instrumental in causing climate change bear some of the burdens. An exclusive focus on adaptation is an instance of the "polluted pays" principle. Those who suffer from climate change bear the costs of coping with it.[39]

MITIGATION: A MODEST PROPOSAL

There are various mitigation schemes that could plausibly be seen as both just and economically efficient, including what I have elsewhere called a

"modest proposal."[40] The proposal is modest in that it conjoins two ideas that are very much alive in the policy world, each of which has influential supporters. However, the conjunction of these ideas has not been forcefully advocated because those who support one conjunct typically oppose the other. Still, the elements of the proposal have been discussed by a number of authors in varying degrees of detail.[41]

The United States government, especially during the Clinton administration, made a very strong case for the idea that a GHG mitigation regime should be efficient, and that emissions trading is a powerful instrument for realizing efficiency.[42] Developing countries, led by India, have convincingly argued that a GHG mitigation regime must be fair, and that fairness recognizes that the citizens of the world have equal rights to the atmosphere.[43] In my view both the United States and the developing countries have a point. The emphasis on efficiency promoted by the United States is potentially good for the world as a whole. The emphasis on equality promoted by the developing countries seems to me to be morally unassailable. The challenge is to construct a fair system of emissions trading.[44]

The main problem with emissions trading as it is developing is that not enough thought is being given to what might be called the end game and the start game: the total global emissions that we should permit and how permissions to emit should be allocated. I propose that we give the Americans what they want: an unrestricted market in permits to emit GHGs, but that we distribute these permits according to some plausible principle of justice.

What would be such a principle? I can think of the following general possibilities.

1. Distribute permissions on a per capita basis.
2. Distribute permissions on the basis of productivity.
3. Distribute permissions on the basis of existing emissions.
4. Distribute permissions on the basis of some other principle.
5. Distribute permissions on the basis of some combination of these principles.

Principles 4 and 5 are principles of last resort,[45] and Principle 3 is implausible. The existing pattern of emissions primarily reflects temporal priority in the development process, rather than any moral entitlement. In general, it is hard to see why temporal priority in exploiting a commons should generate any presumptive claim to continue the exploitation. Suppose that I started grazing a large herd of cows on some land that we own together before you were able to afford any cows of your own. Now that you have a few cows you want to graze them on our land. But if you do,

some of my cows will have to be taken off the land and as a result I will be slightly less rich. Therefore, I demand compensation. Surely you would be right in saying that since we own the land in common you have a right to your fair share. The fact that you haven't been able to exercise that right does not mean that you forfeited it.

Principle 2 has a point. Surely we would not want to allocate emissions permissions toward unproductive uses. If the world can only stand so many GHG emissions, then we have an interest in seeing that they are allocated toward efficient uses.[46] But what this point bears on is how emissions should be allocated, not on how emissions permissions should initially be distributed. Markets will allocate permissions towards beneficial uses. But it is hard to see why those who are in a position to make the most productive use of GHGs should therefore have the right to emit them for free. This is certainly not a principle that we would accept in any domestic economy. Perhaps, if you owned my land, you would use it more productively than I do. For this reason you have an incentive to buy my land, but this does not warrant your getting it for free.

In my opinion the most plausible distributive principle is one that simply asserts that every person has a right to the same level of GHG emissions as every other person. It is hard to see why being American or Australian gives someone a right to more emissions, or why being Brazilian or Chinese gives someone less of a right. The problem with this proposal is that it provides an incentive for pro-natalist policies. A nation can generate more permissions to emit simply by generating more people. But this problem is easily addressed. For other purposes the FCCC has recognized the importance of establishing baseline years. There is no magic in 1990 as the reference year for emission reductions. But if 1990 is a good year for that purpose, let us just say that every nation should be granted equal per capita emissions permissions, indexed to its 1990 population. If you do not like 1990, however, then index to another year. It is important to my proposal that per capita emissions be indexed to some year, but exactly which year is open to negotiation.[47]

Three problems (at least) remain. First, in indexing emissions to 1990 populations I am in effect giving the developed countries their historical emissions for free. But don't the same considerations that suggest that everyone who was alive in 1990 should have equal permissions, apply to everyone who has ever lived? There is some force to this objection. But knowledge of the consequences of GHG emissions does to some extent seem morally relevant. Suppose that when my mother grazed her cows on our common property, the world was very different. Neither of us thought of

what we were doing as eroding common property. Indeed, neither of us thought of the area on which the cows were grazing as property at all. I benefited from the activities of my mother, but neither your mother nor mine was aware of any harm being produced. If my mother had been cleverer perhaps she would have asked your mother for the exclusive right to graze cows on this piece of land. Perhaps your mother would have acceded because she had no cows and didn't think of land – much less this land – as property (much less as her property). Suppose that I say that since we now have different understandings, I'm going to set matters right, and that from this point on you have an equal right to graze cows on our land. I acknowledge that if I am to graze more cows than you I will have to buy the right.

I think many people would say that I have done enough by changing my behavior in the light of present knowledge. Perhaps others would say that there is still some sort of unacknowledged debt that I owe you because of the benefits I reaped from my mother's behavior.[48] But what I think is not plausible to say is that what my mother did in her ignorance is morally equivalent to my denying your right to use our land to the same extent that I do. For this reason I don't think that historical emissions should be treated in the same way as present and future emissions. The results of historical emissions are also so much a part of the fabric of the world that we now presuppose that it is difficult to turn the clock back. At a practical level, countries such as Canada, Australia, and the United States have had a difficult time determining what compensation they owe their indigenous peoples. Determining the effects of unequal appropriation of the atmosphere through history would be even more difficult.

The second problem is that some would insist that it matters where GHG emissions occur, not because of their impact on climate, but because of their effects on quality of life. A high quality of life, it is argued, is associated with high levels of GHG emissions. What this objection brings out is that a bad market in emissions permissions would be worse than no market at all. In a properly functioning market, nations would only sell their emissions permissions if the value of the offer was worth more to them than the permission to emit. But while no international market in emissions permissions could be expected to run perfectly, there is no reason to think that such a market cannot run well enough to improve the welfare of both buyers and sellers.

This leads to the problems of monitoring, enforcement, and compliance. These are difficult problems for any climate regime. Perhaps they are more difficult for the regime that I suggest than for others, but I think that it is

clear that any meaningful emissions control will require a vast improvement in these areas.[49]

The scheme that I suggest has many advantages. It would stabilize emissions in a way that would be both efficient and fair. It would also entail a net transfer of resources from developed to developing countries, thus reducing global inequality.

AGENTS AND BENEFICIARIES

Thus far I have argued that it is important to mitigate climate change both in order to reduce the risks of a climate surprise and because a policy that involves mitigation is more likely to distribute the costs fairly than a policy of "adaptation only." I have also briefly sketched and defended one approach to mitigation that is both fair and efficient. However, it is one thing to say how the world ought to be and it is another to give an account of whose responsibility it is to bring that world about. When it comes to the specification of moral agents and beneficiaries at the global scale, there are three important models in play.[50]

The first model is the familiar one of state sovereignty that goes back at least to the Treaty of Westphalia in 1648. This model sees states as morally decisive over their own people, and the international order as constructed from agreements or conquests among these sovereigns. In this view states are both the agents and beneficiaries of any duties that might exist to address climate change. While this view continues to have strong advocates, in a world in which people and states are tied together by a single environment, a globalized economy, and common threats, this model seems less plausible than it once did.[51] Indeed, it is rejected both by those who seek to establish a global order based on human rights and environmental protection, and by those who want to establish the hegemony of a single power based on its unique commitment to some set of preferred values.[52]

A second model, the sovereignty of peoples, has been developed by Rawls (1999), arguably the leading political theorist of the 20th century. Rawls characterizes a people as having the following three features: a reasonably just government that serves its interests in various ways, including protecting its territory; a common culture, usually in virtue of speaking the same language and sharing historical memories; and finally, having a moral conception of right and justice that is not unreasonable. A society of peoples is established when decent peoples agree to adopt the law of peoples, codified in eight principles that express a commitment to keep agreements and to

honor human rights, and to go to war only in self-defense and then to abide by the laws of war.

While Rawls is a liberal and his account of the law of peoples is sometimes called "a theory of liberal sovereignty," he specifically rejects the idea that a theory of distributive justice applies globally. The main reason for this is that the purpose of the negotiation that leads to the establishing of the law of peoples is to arrive at "fair terms of political cooperation with other peoples."[53] Representatives of peoples would accept duties to contribute to the welfare of other peoples, but they would only be instrumental to the larger purpose of assisting other peoples to play their proper role in the society of peoples. Either as peoples or individuals we do not, according to Rawls, have direct duties to the individuals who constitute other peoples.

Rawls's distinction between peoples and states is central to his view; yet it is difficult to maintain. "Peoples," insofar as this concept is well defined, seem suspiciously state-like. One way that peoples are supposed to be importantly different from states is that, unlike states as traditionally conceived, peoples can only wage defensive wars and must honor human rights. However, these features do not clearly distinguish states from peoples, since they can be seen as moral restrictions on the sovereignty of states rather than as indicating a change of subject from states to peoples. If peoples are not states, then it is unclear what they are or whether they behave coherently enough to star in a theory of international justice.

Rawls speaks as if peoples are well-defined, self-contained, and as if they map on to territories and the Law of the Excluded Middle applies to membership in them. None of this is true. We need only to contemplate the claims of Palestinians, Kurds, or Orthodox Jews, or consider various national laws that attempt to legislate a people's identity in order to see that the very attempt to define a people is a problematical and highly political act. The fact that peoples are not self-contained and do not map on to specific territories is evidenced by several recent wars, notably in the Balkans. That the Law of the Excluded Middle does not apply to membership in a people can be seen by Mexican-Americans, Irish-Americans, or any number of other claimed, hyphenated identities. Indeed, individuals may shift their identities, depending on their purposes.[54] These considerations suggest that either Rawls's law of peoples is at heart a "morality of states," which he denies, or it is founded on a vague and unstable concept.

One particularly objectionable feature of Rawls's views is that because he thinks of peoples as normally occupying territories, he invests national boundaries with a moral significance that they do not have.[55] It is unjust, if anything is, that a person's life prospects should turn on which side of a

river she is born, or where exactly an imaginary line was drawn decades ago by a colonial power. But for Rawls, there is nothing morally objectionable about the arbitrariness of borders or the differential life-prospects that they may engender. When a pregnant woman in Baja California (Mexico) illegally crosses the border to San Diego, California (United States) so that her child will be born an American citizen with all the advantages that brings, there is for Rawls nothing troubling about the circumstances that motivate her action. Peoples have the right to control the borders of their own territories, but how can we fault a woman for doing what she thinks is best for her child?[56]

Problems such as these lead people to embrace a third view, "cosmopolitanism," which holds that it is individual people who are the primary agents and beneficiaries of duties.[57] In this view duties, including duties of distributive justice, project across national boundaries, connecting individuals with each other, regardless of citizenship and residency.

While there are real differences between Rawls and his cosmopolitan critics, I believe that they can be brought closer together than one might think. Perhaps we can begin to see this when we realize that Rawls and his critics are to some extent motivated by different concerns. Cosmopolitans are concerned with what we might call moral or social "ontology." They insist that it is individual people who are the fundamental grounds of moral concern, not collectives or abstractions such as peoples or nations. Rawls is concerned with the question of how peoples with different views of the good can cooperate fairly with each other, and move together toward a peaceful future in which human rights prevail.[58] From the perspective of a person in a developing country who is being provided with a micro-loan (for example), it makes little difference whether she is being aided because she is the direct beneficiary of a moral obligation, or because the people of which she is a part is being aided so that it can become part of the society of peoples.[59]

Rather than adjudicating between these views, I want to offer another perspective. We do not have to choose between being individuals who have duties to other individuals, or being members of a people which owes duties to other peoples. Both are true, and more besides. We are parents, students, members of NGOs, Irish-Americans, Muslims, citizens of towns and states, stockholders, consumers, patrons of the arts, sports fans, home-owners, commuters, and so on. We occupy multiple roles that have different responsibilities and causal powers attached to them. It is from these roles and powers that duties flow.

For example, I may have duties to reduce my consumption of energy, encourage my acquaintances to do the same, join organizations and support

candidates that support climate stabilization policies, disinvest in Exxon, support NGOs and projects in developing countries that assist people in adapting to climate change, and contribute to organizations that protect nonhuman nature. Exactly what duties I have depends on many factors including my ability to make a difference, how these duties compete with other moral demands, and so on. In the picture that I am urging, our duties form a dense web that crosses both institutional and political boundaries. We do not have to choose between accounts that privilege particular levels of analysis.[60]

A full account would have to explain exactly how the clear, urgent duties relating to adaptation and mitigation that I have described map on to us as individuals in the various roles that we occupy. Indeed, it is here where much of the slippage occurs between the abstract recognition of what ought to be done and what I am motivated to do. In fact, a kind of "shadow" collective action problem can break out within each of us. I may agree that as a consumer I am responsible for intolerable amounts of GHGs, yet it may be very difficult to disaggregate this responsibility to me in my various roles as father, teacher, little league baseball coach, and so on. Many questions remain, but my central claim is clear: We have strenuous duties to address the problem of climate change, and they attach to us in our various roles and relationships.

OBJECTIONS

The simplest objection to what I have said would involve denying that there are any such things as duties that transcend national boundaries.[61] Whatever plausibility such a claim might have would rest on supposing that it is neutral in applying to all countries and their citizens equally. For example, this claim would imply both that Americans have no duties to Sierra Leoneans and that Sierra Leoneans have no duties to Americans. However, while this claim may be formally neutral it certainly is not substantively neutral.[62] Americans, acting both as individuals and through their institutions, can greatly influence the welfare of the citizens of Sierra Leone, but Sierra Leoneans are virtually powerless to influence the welfare of Americans. Thus, the apparently reciprocal nature of the duties involved can easily be seen as a mere charade.[63]

However, it is easy to see why in the past some may have thought that duties do not transcend national boundaries. Famines and other disasters have occurred throughout history, but in many cases it was not known

outside the affected regions that people were dying. Even when it was known and people were willing to provide assistance, little could be done to help those in need. When people are not culpably ignorant and they are not in a position to be efficacious, there is little point in ascribing duties to them. But today things are very different with respect to information and causal efficacy. We live in an age in which national boundaries are porous with respect to almost everything of importance: people, power, money, and information, to mention a few. These help to make obligations possible. If people, power, money, and information are so transnational in their movements, it is hard to believe that duties and obligations are confined by borders.[64] The view that duties do not transcend national boundaries (unlike lawyers, guns, and money – not to mention drugs and immigrants) is really equivalent to denying people in the developing world a place at the table. It is the global equivalent of the domestic denial of rights to women and minority populations.

While most philosophers and theorists these days would not challenge the very existence of transnational duties, some would hold that there are very few such duties and that they are comparatively weak. Such a view is sometimes expressed by granting the existence of transnational duties but denying that they are duties of justice. There are two distinct grounds for such a view.

The first ground, which is broadly based in the tradition of the 17th century philosopher Thomas Hobbes, is based on denying that there is any such thing as "natural justice." On this view justice is entirely a matter of convention: Justice consists in conforming to enforceable agreements; injustice consists in violating them. Since there is little by way of enforceable, international agreements, there are few transnational duties.

The second ground for such a view is based on a Communitarian account of justice. While this view may grant that enforceable agreements across communities can generate duties of justice, it holds that such duties typically arise within, rather than among, communities, and do not require explicit agreements. Since the world is characterized by a plurality of communities rather than by a single global community, the necessary condition for a dense network of transnational duties of justice is not satisfied. Thus, Communitarians come to the same conclusion as Hobbesians: there is little ground for supposing that there is a panoply of transnational duties of justice.[65]

I will not mount a systematic refutation of these views here but instead restrict myself to a single observation about the view that while transnational duties may exist, they are not duties of justice. As I have indicated,

there are different grounds for such a denial. Such a denial may rest on the view that some transnational duties are distinct from duties of justice because they do not originate in agreement, are not owed to specific beneficiaries, or are less urgent than duties of justice. What I want to insist on is that that there are urgent duties to respond to climate change, that those of us who are part of the global middle class contribute significantly to causing the problem, and that we can identify generally those who will suffer from our actions.[66] If this much is granted, then I am not sure that anything of significance turns on either asserting or denying that the duties in question are duties of justice.[67]

The second objection has been raised most consistently and forcefully by Schelling (1992, 1997, 2000), who argues in the following way. Suppose that it is true that we have duties to improve the welfare of those who are worse (or worst) off. There are other, more efficient and efficacious, ways of doing this than by reducing our GHG emissions. For example, we could invest in clean water systems, vaccinations, literacy programs, and so on. Or we could simply give money to those who are worse off. Schelling concludes that

> it would be hard to make the case that the countries we now perceive as vulnerable would be better off 50 or 75 years from now if 10 or 20 trillions of dollars had been invested in carbon abatement rather than economic development.[68]

While this objection has some force, plausible responses can be given.

First, for any actual transfer from the rich to the poor, there is likely to be another possible transfer that is more beneficial. However, this does not imply that every such transfer we make is wrong, irrational, or ill-advised. This is because the alternative policies we choose between are not all those that are logically or physically possible, but those that have some reasonable chance of actually being implemented. Some of our duties with respect to climate change have a reasonable chance of being implemented because they involve controlling our own behavior or taking action in a democratic society. Even if the results of our discharging these duties were not optimal relative to the set of logically or physically possible actions that we might perform, their consequences would be very good indeed and this is sufficient for making it at least morally permissible to carry them out.[69]

Furthermore, the duty to mitigate climate change does not depend on some general duty to benefit the worse (or worst) off. Such a principle might generate this duty, but so would more modest principles that require us to refrain from imposing serious risks on others. Indeed, the modesty of the principles required to ground such duties is part of what makes action on

climate change both possible and urgent, despite the obstacles hindering such action.[70]

Finally, transferring resources to the worse (worst) off rather than mitigating our carbon emissions would do nothing to reduce the risk of catastrophic climate change. Nor would it provide comfort to those morally considerable aspects of nature that are vulnerable to climate change. There is no guarantee that transforming the poor into the rich would in itself protect environmental values, such as respect for what is wild and natural, that are at the heart of many people's concern about climate change.

For these reasons, despite the power of Schelling's objection, the idea that we have a duty to mitigate climate change is not defeated.

THE PROBLEM OF MOTIVATION

Even if what I have said is correct, a problem may linger. Morality is fundamentally directed toward action. Many would say that it seems clear that we are not motivated to address this problem. What is the point of seeing climate change as posing moral questions if we are not motivated to act? To this I have four related responses.

First, outside the United States, especially in Europe and the developing world, the problem of climate change is widely seen as a moral issue. Much of the anger at the American withdrawal from the Kyoto Protocol can only be understood by appreciating this fact. Seeing climate change as posing moral questions is part of appreciating others' points of view. Of course, having appreciated how climate change can be viewed in this way, we are free to reject this perspective. However, I believe that once we appreciate climate change as a moral problem, this view is virtually irresistible.[71]

Moreover, rejecting the moral framing of the climate change problem and instead approaching it from the perspective of self-interest does not lead to solutions. Although I think we could get further on this ground than we have gotten thus far, ultimately acting on the basis of narrow self-interest locks us into collective action problems that lead to worse outcomes overall. This is borne out by the current state of climate change negotiations and also helps explain why we as individuals often feel so powerless in the face of this problem.[72]

Third, a moral response to climate change is difficult to escape. For the challenge of climate change is not only global and abstract, but also local and intimate. Once obligations are seen in the way described in the previous section – as forming a dense web of connections that link us in our myriad

roles and identities to people all over the world – then it becomes clear that virtually everything we do is morally valenced. When we bike instead of drive or donate money to Oxfam, we issue moral responses to the problem of climate change. Denying responsibility, dissembling, and ignoring the problem are themselves moral responses.

Finally, I think that it is a plain fact that climate change poses moral questions. While I do not want to argue in detail here about the concept of morality or defend the idea that there is a simple and direct relation between grasping the way the world is and being motivated to act, surely there is some connection between seeing an act as morally right and performing it. That something is the morally right thing to do is a powerful consideration in its favor. It may not always carry the day, but it cannot easily be ignored.

Taken together, these considerations go some way toward demonstrating the utility of viewing climate change as a moral problem.

CONCLUDING REMARKS

There are some reasons to be hopeful that the global community is beginning to wake up to the problem of climate change. The Kyoto Protocol came into effect in 2005, and the European Union is eager to take more aggressive action after 2012, when the first Kyoto commitment period expires. American corporations that do business outside the United States will be governed by the Kyoto system, and many are increasingly receptive to the idea of a single global system for managing GHG emissions. Even the northeastern states and California, largely ruled by Republican governors, are moving toward adopting their own GHG emissions policies. Meanwhile, the Inuit peoples are preparing a case to present to the Inter-American Commission on Human Rights, charging that the United States is threatening their existence through its contributions to global warming.

Despite these signs of hope, climate change is a scientifically complex issue that is difficult to address effectively and, in the United States at least, politicians can safely ignore this issue without fear of punishment. It is in part another victim of the war on terrorism. While climate change may be far from the public mind, GHGs continue to build up in the atmosphere, and the risks of climate change continue to magnify. When it comes to responding to fundamental changes in the systems that control life on Earth, denial, distortion, and spin are not viable long-term strategies.[73] Eventually, concern about climate change will emerge as an important public issue, and a movement toward creating a law of the atmosphere will gain momentum.

In the meantime it is important to recognize that those who suffer from extreme climatic events are often the victims of greed, indifference, and mendacity. It is human beings and their societies that are largely responsible for the climate change now under way, not nature or fortune. People and nations who willfully evade taking responsibility for the consequences of their actions may one day be called to account.

NOTES

1. In discussions of climate change "mitigation" refers to policies or actions directed toward reducing greenhouse gas emissions; "adaptation" refers to how plants, animals, and humans respond to climate change (excluding, of course, their mitigation responses). The meaning of these terms is further elaborated later.

2. For an account of the formation of the IPCC, see Agrawala (1998).

3. Emissions trading is a scheme in which an entity (such as a nation) whose emissions of some substance are limited by a binding agreement can purchase the right to emit more of the substance in question from an entity that will limit its emissions by the same amount in exchange for the payment (emissions trading is discussed in detail below). Carbon sinks are biological or geological reservoirs (such as forests) in which carbon is sequestered; the idea being that nations can "offset" their emissions by sequestering carbon that would otherwise be in the atmosphere.

4. Annex 1 countries are the industrialized countries of North America and Europe, Japan, Australia, and New Zealand (a full list can be found on the web at http://unfccc.int/resource/docs/convkp/conveng.pdf); together they were responsible for more than two-thirds of global GHG emissions in 1990.

5. Babiker, Jacoby, Reilly, and Reiner (2002).

6. For a list of OPEC member states see www.opec.org.

7. Smit, Burton, Klein, and Wandel (2000, p. 225). It should be noted that the term "adaptation" is typically used positively in opposition to the negative term, "maladaptation."

8. See, for example, Abramovitz et al. (2002), Smithers and Smit (1997), Kates (2001), Kelly and Adger (2000), Reilly and Schimmelpfennig (2000), and Smit, Burton, Klein, and Wandel (2000).

9. Still, it is worth observing that adaptations can stand in feedback relations to the climate change to which they are a response. For example, one possible adaptation to a warmer world is more extensive use of air conditioning, which itself contributes to greater warming. Thus, we must be careful that in trying to live with climate change, we do not make it worse. I owe this point to Steve Gardiner.

10. For example, see Jamieson (1990, 1991).

11. For example, Rayner and Malone (1997), Pielke, Jr. (1998), Parry, Arnell, Hulme, Nicholls, and Livermore (1998), and Pielke, Jr. and Sarewitz (2000).

12. Because he has a definition of the term different from the one employed in the FCCC, Pielke, Jr. (2005) claims that adaptation is a neglected option, despite the occurrence of the word in the treaty and in many subsequent official documents. This way of putting the point seems to transform an important substantive critique into

what appears to be a linguistic dispute. The core of Pielke's, Jr. challenge is that focusing on adaptation to climate variability and extreme events, whatever their causes, would be much more effective than focusing on climate change, with the emphasis on scientific knowledge and mitigation strategies that this approach brings along, and the attendant policy gridlock that follows. While I am sympathetic to this view, it raises important questions about how to determine relevant alternatives when faced with policy questions. Why not, for example, abandon questions of weather and climate altogether and focus instead on global poverty? I have more to say about this in my response to Schelling below.

13. http://www.climatescience.gov/Library/stratplan2003/vision/default.htm (accessed August 8th, 2003).

14. http://www.epa.gov/oppeoee1/globalwarming/publications/car/ch6.pdf (accessed June 22nd, 2002).

15. The idea that climate change poses a dichotomous choice between adaptation and mitigation may stem from Matthews (1987), who drew a sharp distinction between those she called "adaptationists" and "preventionists;" but already by 1991 Crosson and Rosenberg (1991) were treating this as a mistaken dichotomy that had been bypassed by the policy discussion.

16. National Academy of Sciences (2002, p. 27).

17. Häkkinen and Rhines (2004).

18. Thompson and Wallace (2001).

19. Available at http://amap.no/workdocs/index.cfm?dirsub=%2FACIA%2Foverview (accessed December 17, 2004).

20. The following discussion is based on Glantz and Jamieson (2000).

21. Summary report of proceedings: Inter-American Development Bank Consultative Group meeting for the reconstruction and transformation of Central America (May 1999), Stockholm, Sweden (http://www.iadb.org/regions/re2/consultative_group/summary.htm, accessed November 7, 2000).

22. *Honduras This Week* (May 29, 2000) (http://www.marrder.com/htw/special/environment/70.htm, accessed April 23, 2003).

23. Summary report of proceedings: Inter-American Development Bank Consultative Group meeting for the reconstruction and transformation of Central America (May 1999), Stockholm, Sweden (http://www.iadb.org/regions/re2/consultative_group/summary.htm, accessed November 7, 2000).

24. *Honduras This Week* (May 29, 2000) (http://www.marrder.com/htw/special/environment/70.htm, accessed April 23, 2003).

25. Davis (2001).

26. Iliffe (1987, p. 3).

27. See African Development Bank et al. (2003) and the sources cited therein for documentation of the claims made in this paragraph.

28. IPCC (2001).

29. Available on the web at http://www.johannesburgsummit.org/html/documents/summit_docs/1009wssd_pol_declaration.doc (accessed August 12, 2003).

30. One problem is that these funds are intended to finance adaptation to climate change, not adaptation to natural climate variability. This requires a successful applicant to identify the incremental risk posed by climate change and show that the benefit that the proposed project would provide would address only this increment.

This burden is not only almost impossible to discharge in many cases, but it is an absurd requirement for reasons explained below.

31. IPCC (2001).
32. Ayres and Walters (1991), as cited in Spash (2002, p. 164).
33. Fagan (2001).
34. African Development Bank et al. (2003, p. 1).
35. http://www.id21.org/society/S10aisdr1g1.html (accessed August 12, 2003).
36. See also Jamieson (2005a).
37. For reasons discussed in the next section and suggested in note 30, it is also easier to specify and quantify duties related to mitigation than those related to adaptation. Carbon dioxide emissions are directly measurable; success in adapting to climate change is not.
38. However, we should bear in mind that, though they are importantly related, reducing emissions is not exactly the same as slowing down the rate of climate change (Pielke, Jr., Klein, & Sarewitz, 2000).
39. For more on justice in adaptation see Adger, Huq, Mace, and Paavola (2005).
40. Jamieson (2001).
41. For example, Athanasiou and Baer (2002), Brown (2002), Cazorla and Toman (2001), Clausen and McNeilly (1998), Grubb (1995), Meyer (2000), Sachs et al. (2002), Shue (1995), Singer (2002), and the papers collected in Toth (1999). Of course, these ideas also have their detractors. For a critique of emissions trading see various papers by Larry Lohmann at www.thecornerhouse.org.uk. For an excellent survey of the issues see Gardiner (2004).
42. For a thorough defense of emissions trading in a GHG control regime see Stewart and Wiener (2003); for a contrary view, see Schelling (2002).
43. For a defense of this view see Agarwal and Narain (1991).
44. The following nine paragraphs are revised from Jamieson (2001).
45. Principle 4 is a principle of last resort because my list includes all the principles that I can think of that are attractive, and Principle 5 because it does not have the theoretical economy of the other principles on the list.
46. While this principle is one that is often associated with the American position and there are different ways of understanding the data, it is clear that the United States is an inefficient producer of GDP relative to most European countries and Japan. Thus, this principle might imply that some American emission permissions should be transferred to France (for example).
47. For a defense of 2050 as the index year, see Singer (2002); generally, for a discussion, see Gardiner (2004).
48. For example, Gardiner (2004) and Shue (1992).
49. See Stewart and Wiener (2003) for further discussion of these issues.
50. Cf. Held (2002).
51. For an argument that some transnational corporations are more powerful than many states, and hence *de facto* more sovereign, see Korten (1995) and Hutton (2002).
52. For the first view see Singer (2002); for the second see Boot (2002).
53. Rawls (1999, p. 69).
54. For more on these points see O'Neill (1994).
55. Pogge (1994) vigorously argues this point; I have learned much from his critical discussion of Rawls.

56. For further objections along these lines see Beitz (2000), Buchanan (2000), and Kuper (2000).

57. There are more expansive ways of characterizing cosmopolitanism (e.g., Jones, 1999, p. 15), and less expansive ways (e.g., dropping the requirement that individual people are the primary agents); this will do for the present purposes.

58. Here I have benefited from discussions with Leif Wenar, and from reading Wenar (2002).

59. For further discussion, see Crisp and Jamieson (2000).

60. Related views have been put forward by Kuper (2000) and Sen (2002). In Jamieson (2005b) I have discussed this view in some detail from a utilitarian perspective.

61. Dobson (1998) chides me for largely ignoring this view in Jamieson (1994). I have been helped by his discussion.

62. Cf. Anatole France who derided the claim that laws against sleeping under bridges apply equally to the rich and poor.

63. I have selected Sierra Leone for my example since it ranks dead last in the United Nations Development Programme's Human Development Index (UNDP, 2000).

64. While philosophers often draw technical distinctions between duties and obligations, for the present purposes I use these terms interchangeably.

65. Of course a Hobbesian or Communitarian could consistently hold that there are extensive and rigorous transnational duties but that they are not duties of justice. This sort of Hobbesian or Communitarian could agree with much that I say.

66. See Sachs (1993, p. 5) on the idea of the global middle class.

67. A clarification (at the behest of Walter Sinnott-Armstrong): my claim is that (everything else being equal) X's contributing significantly to causing a problem that harms a generally identifiable moral patient is a sufficient (not a necessary) condition for supposing that X has a duty with respect to the contribution.

68. Schelling (1992, p. 7).

69. Indeed, it may be obligatory to carry some of them out. There are a number of ways of defending such a claim in detail; one such way is by recourse to a moral theory that I call "progressive consequentialism" in unpublished work.

70. Because climate change involves actions in which some identifiable people and corporations are involved in inflicting harms on other people, there is beginning to be interest in viewing these actions as candidates for legal remedies. There has been discussion of such litigation in the pages of *The New York Times*, *The Economist*, and the *Financial Times*, as well as in the offices of various reinsurance companies and multinational corporations (or so it is said). However, the most severe consequences of climate change will be suffered by those in the further future, and there are serious philosophical problems about how duties to such beneficiaries should be understood. See Parfit (1984) and Howarth's essay in this volume.

71. Indeed, I believe that there is generally a movement toward environmental justice becoming the key organizing concept of environmentalism (see Jamieson, 2005c).

72. See Jamieson (2005b) and Gardiner (2003).

73. Cf. the following remark from Melissa Carey of Environmental Defense: "The Earth is round, Elvis is dead, and yes, climate change is happening."

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IDEAL DECISION MAKING AND GREEN VIRTUES

Julia Driver

This chapter is not concerned with the empirical issue of whether or not global warming is a genuine phenomenon. It is not concerned with the normative issue of whether or not this warming is a bad thing. The evidence that it is occurring is quite compelling, and it also seems fairly clear that on balance the long-term effects will be bad. Thus, this essay will be taking these points for granted. Instead, it will focus on how a particular ethical theory – Utilitarianism – could be used to argue that the U.S. has an obligation to help solve the problem even if other countries are not doing their "fair share." This issue came up in the recent past when the U.S. failed to sign onto the Kyoto Accord. I am not endorsing the Kyoto Accord itself, and in fact believe that various shortcomings of the accord have been pointed out by Professor Bodansky, for example, in this volume. However, I do think that one line of argument used to justify the noncompliance of the U.S. is completely wrong. The policy upon which the decision was based made an appeal to fairness – the U.S. would not sign on unless developing nations did as well. However, I will argue that not only does the U.S. have an obligation to reduce emissions even if the developing countries do not agree to be bound by emissions reduction standards, but the U.S. has an even "greater" obligation under these circumstances than if the developing nations had agreed to sign on.[1]

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1. UTILITARIANISM: DIRECT AND INDIRECT

One feature of Utilitarianism that provides its link to rational decision making is that the basic principle of utility demands that one maximize the good. One can disagree about what exactly the good is – perhaps it is pleasure, autonomy, beauty, or some set of items on a list mixing a variety of intrinsic goods. However, whatever the good turns out to be, we ought – morally – to maximize it. A failure to maximize the good is seen as not only a moral failure but also a rational one. So, for example, suppose that a friend of yours offers you a choice between $100 and $10. Most would hold that the rational thing to do is maximize the good and take the $100, all other things being equal. The person who took the $10 option would be considered irrational and imprudent. Maximizing or optimizing one's finances, all other things being equal, would be prudent, but the general point about maximizing carries over to the moral area. What one ought to do, morally, is maximize the good. In the moral area, this means maximizing human well-being, impartially considered. The above illustration is an artificial one, and real life introduces all sorts of complexities such as how to weigh disparate goods and how to deal with risk and uncertainty. However, the basic point that one ought to maximize the good, or do the best one can, stands.

Even though it seems intuitively very plausible, at least in the abstract, Utilitarianism has come under fire in environmental ethics debates since some writers believe that the theory remains indifferent to issues of distributive justice. Donald Brown (2002, p. 53), in *American Heat*, writes: "Utilitarian theory cannot determine how benefits or costs of subgroups should be distributed among potential winners and losers.... Utilitarian theory is indifferent in respect to distributions of utility as long as total utility is maximized." This criticism has a long history in the theoretical debate over Utilitarianism. Rawls (1971), for example, held that Utilitarianism was inadequate in giving an account of just, fair distributions of benefits and burdens within society. For Rawls, the unfairness had to do with the fact that Utilitarianism seemed committed to inequitable distributions, as long as total utility was maximized. Thus, a utilitarian might well end up endorsing a system in which some members of society live in misery while others flourish at their expense, as long as that society has the best overall utility rating. However, my claim will be that this approach ignores the subtlety of a utilitarian account of obligations regarding the environment. Indeed, this account, I believe, can best account for the fact that the U.S. has failed to live up to obligations with respect to curtailing greenhouse gases.

Utilitarianism in practice can appeal to diminishing marginal utility to support egalitarian intuitions on distribution of resources. This feature helps to deal with some of the criticisms that have been levied against it, like the one made by Brown, detailed above. The basic idea is pretty simple. Suppose I have $100 to distribute. I could give it to (1) a poor, struggling single parent or (2) Bill Gates, one of the richest persons on the planet. Utilitarianism holds that I should give it to (1) because the $100 in that case would make a large positive impact on that person's happiness level; it would mean more to that person and make a larger contribution to that person's well-being. The value to a person of the $100 diminishes as the person's other resources increase (all other things being equal). Since it is also the case that for the utilitarian no one person's utility in principle matters more than any other person's, there is built into Utilitarianism a kind of egalitarianism with respect to distribution. This maneuver will not completely resolve the issue for writers like Brown, but it goes a long way toward making the theory more compatible with our intuitions about just distribution.[2] The implication with respect to emissions, then, is that if anyone "should" cut them it would be the top emitters. The bottom emitters would then have more of what is necessary to improve their standard of living.

Dale Jamieson has also explored this issue of how utilitarian theorizing can be put to use to help address this problem. Jamieson adopts a utilitarian approach to dealing with global environmental change. He argues that we should be trying to minimize our negative impact on the environment, but that we should do so without worrying about how other people are behaving. We instead need to cultivate "green virtues" – habits of behavior that, being habits, do not call for the complicated calculation involved in regulating our behavior relative to the behavior of others. Jamieson has argued, specifically with respect to the problem of global environmental change, that "…one feature of a successful response would be Non-Contingency. Non-Contingency requires agents to act in ways that minimize their contributions to Global Environmental Change, and specifies that acting in this way should generally not be contingent on an agent's beliefs about the behavior of others (Jamieson, 2005)." Given the context of this discussion, I believe he means that agents should not worry about whether or not others will do the same kind of thing when it comes to harming or helping the environment. This non-contingency, he argues, is necessary because contingency requires "sophisticated calculation." My approach differs from his, however, in that I will be rejecting his commitment to non-contingency. His idea seems to be that in order to consider the behavior of others one would need to gather a good deal of evidence about that behavior and then calculate

optimal outcomes, before embarking on a plan of improvement. His alternative is to suggest we cultivate virtues that promote our ends – those of minimizing environmental damage.

But as stated, this cannot be right. Here is one reason. Minimizing one's contribution to global environmental change is not without costs – otherwise, we would not have this problem in the first place. Buying a more expensive hybrid car means I have less money to spend on other goods; walking to work instead of driving means I have less time to spend on projects I deem very important. Whether or not the cost is worth bearing will depend on the behavior of others; thus, my belief about the behavior of others should be a factor (though certainly not the only factor) in my decision about how or if to modify my behavior. For example, suppose I would like to contribute some money toward a gift for a colleague's baby shower. It makes perfect sense to gage my level of giving by how much others are contributing. My calculation in this case need neither be sophisticated nor be in the global warming case (though perhaps it ought to be). This point is also relevant to the issue of when to internalize costs. Garret Hardin points out that when you are the only person in the middle of the wilderness, dropping a tissue or taking an extravagant shower is not environmentally harmful. But large numbers of people doing that will be harmful. Thus, my behavior does need to take into account others – where they are and what they are doing or not doing.

However, Jamieson does seem to recognize later in his essay that a commitment to non-contingency with its rejection of calculation has its dangers. If people do develop stable habits that lead to positive environmental change – habits intended, for example, to minimize environmental damage – then these habits will have a kind of inertia that makes the agent slow to respond to changing circumstances. Thus, habits of conserving water and living a frugal, low-energy-consumption life may be good for the environment now in ways that pay off for future generations. However, this might not always be the case; indeed, if the environmental prospectus improves dramatically it may be better for future generations if agents engage in more development that could improve their standard of living – but the habits would act as a brake on changing strategies. Or, to use a more dramatic example, and one that Jamieson focuses on, habits may get in the way of being able to deal effectively with emergencies. That is, it may be the case that conservation strategies (and, therefore, the habits based on them) would result in disasters in particular cases – where, for example, one needs to drain a marshland to prevent malaria from wiping out large numbers of people. Thus, Jamieson also discusses the problem of complacency, and

allows for escape clauses for 'extreme cases.' For example, one may reject non-contingency if an entire population's existence hangs in the balance. In that case, one may go back to the calculative model rather than rely on the "green virtues."[3] However, on his view, aside from these sorts of extreme cases the emphasis should be on the 'green virtues.' We should be relying on them, cultivating them, as a means of achieving the very worthy end of emissions reduction. I certainly would not want to argue against this as part of a strategy – developing good habits of conservation is great. But the justification for these habits is defeasible, and defeasible precisely in response to evidence of the behavior of others.

In effect, what Jamieson is offering us is a kind of indirect consequentialism. Rule consequentialism is the most familiar variant of this approach. The Rule consequentialist holds that the right action is that action performed in accordance with a rule (or set of rules) that maximizes utility. This is generally contrasted with the Act consequentialist or utilitarian approach that Jamieson's criticisms focus on, which holds that the right action is that action which maximizes (expected) utility. But Jamieson's indirect variety seems to be a form of virtue consequentialism – the right act, what one ought to do, is the act performed in accordance with a virtue, one that expresses a virtue. What counts as a virtue is to be determined by consequentialist considerations (e.g., it is a character trait that systematically produces the good).[4] But the analogy with Rule consequentialism is instructive, since in my view Jamieson's commitment to non-contingency will mean that his account is at risk for a problem similar to the one faced by Rule consequentialism – the "absolutist" objection. This is the criticism made when the rules are simple and straightforward, but then seem to lead us in the wrong direction. For example, "Don't lie" is simple and straightforward, but surely it is okay to lie in some circumstances – for example, to save an innocent person from death at the hands of an evil dictator. Yet, if exceptions are allowed, the theory runs the risk of turning into Act consequentialism, at least in practical terms.[5] For Jamieson's account, the problem, as he notes, will be complacency. As with the Rule consequentialist, he will have difficulty distinguishing his virtue consequentialism in a way that makes it plausible as well as practically distinct from Act consequentialism.

Further, Jamieson's account needs some clarification as to how we judge the consequentialist account – as a decision procedure or as a criterion for rightness.[6] If the Act consequentialist view is interpreted simply as a criterion of rightness, then Jamieson's criticism misses the mark. On this interpretation of consequentialism, we evaluate actions by looking at

whether or not the good has been maximized. A calculation at the time of a particular choice is not even required.[7]

However, I do not think the consequentialist needs to reject a consequentialist decision procedure. That is far too radical. And Jamieson's portrayal of the Act utilitarian as one who recommends a constant use of such a decision procedure is inaccurate. One should not give up on calculation even if it is true that one should not use it constantly, since that would be counterproductive. So Jamieson seems to be presenting a false dichotomy.

However, the concern that prompts Jamieson here is a serious one for an Act consequentialist, and the general point that Jamieson makes may be correct in that Act consequentialism – though not as deficient as Jamieson maintains – will still have a problem when it comes to getting the agent to do something that only produces a greater good collectively.

But the Act consequentialist has responses. Consider the example of policies geared toward minimizing casualties in World War II during the blitz. No one was allowed outside the bomb shelters during a bombing raid. Note that the probability of any particular single individual being harmed by a bomb was astronomically small. Thus, Alice, as an individual, should not be too worried that she will be hit by a bomb. It might well be rational for her (in the absence of laws preventing it) to go out and about during a bombing raid. However, the probability that some people will be killed and/or harmed if people are allowed to be outside the bomb shelters is quite high, indeed, a virtual certainty. Thus, from the point of view of the policy maker it does maximize the good to prohibit people from being outside the shelters during bombing raids. And governments are in the position of the policy makers. They make and enforce laws and policies. This difference between ordinary individual rational decision making and the appropriate decision procedures for policy makers helps explain a recent disagreement between the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) regarding travel to Toronto in the wake of the severe acute respiratory syndrome (SARS) epidemic. The CDC (as of April 26, 2003) has not issued a travel advisory for Toronto; the WHO has. My view is that the CDC is thinking in terms of risk to the individual, whereas the WHO is thinking in terms of risk to individuals, understood collectively. The risk to a particular individual of contracting SARS while in Toronto may be quite small, but the risk that someone will contract it while visiting if people are not discouraged from traveling there may be quite high indeed, and this could lead to additional outbreaks of the disease throughout the world.

This example explains why Jamieson also seems to be relying on an approach that is geared toward individuals, and prompting them to take the

initiative in acting on environmental change. While this vision is important, effective change will require government action, realistically. Broome (1992, p. 17) writes: "…national governments must take some action…. It must be *governments* that take action, because the greenhouse gases are public bads *par excellence*."

The point that Broome is making is that one cannot rely simply on individuals since individuals, acting on rational self-interest, will not be able to coordinate behavior efficiently so as to avoid a "tragedy of the commons" scenario for the atmosphere. No one would deny that individuals acting collectively could create enormous positive environmental change. Of course, however, coordination is crucial, and this is where the role of government is so important. Government regulation is necessary to enforce compliance with a norm. One cannot rely on conscience, particularly in a competitive environment. Those without a conscience would exploit the competitive disadvantages of others.[8] If some individuals internalize the costs of reducing emissions while others do not, and then flourish by comparison, then the conscientious are in effect penalized. Other writers disagree because they believe that government regulation is coercive and that the best strategy involves an appeal to our better nature. However, I think that this approach involves the trap of thinking along idealized lines. One cannot rely on voluntary compliance at the individual level, particularly in communities where informed agreements do not seem to have much binding influence. This is not to reject the workings of conscience, either. It is just to note that government regulation is also needed, and that for many problems this regulation must be very aggressive. Of course, this problem at the international level has led some to expand the government model and hold out the hope that bodies such as the United Nations can enforce norms at the international level.[9]

Jamieson could always argue that governments could, in some derivative sense, cultivate the 'green' virtues. We often speak of "honest" governments, so why not "frugal" ones as well? Governments engage in aid campaigns and public education programs intended to address social problems. And this supplement to calculation is fine, but calculative decision making on the part of governments is still necessary.

But the problem Jamieson points to is certainly a real and serious one. Even people who want to help sometimes feel completely helpless. He points out that they feel this way because they view their own individual contribution as insignificant. Note that one way to solve the collective action problem is, well, collectively – measures such as the Kyoto Protocol help to do this.

2. THE ISSUE OF NON-COMPLIANCE

Up to this point I have tried to defend the Act consequentialist against some of Jamieson's concerns and to sketch how the Act consequentialist could approach a solution to the problems he raises. But another problem that should be addressed is that to many people not only is the problem itself seemingly overwhelming, but the demands morality seems to be placing on them to solve the problem are also overwhelming. This can lead to a sort of emotional backlash – the kind Anscombe pointed out with respect to pacifism – which leads people to reject it altogether because they feel that falling short is just completely inevitable.

However, we need to use this theory under various realistic constraints. Philosophers have suggested a number of such constraints. But the one I would like to explore here, and that I feel is helpful specifically to understanding what went wrong with respect to the U.S. position on the Kyoto Accord, is the "nonideal" constraint. So, I may believe that under certain ideal circumstances the best career choice for me would be "tap dancer." However, in real life, not the ideal world, I have both inadequate talent and inadequate training – so no tap-dancing career.

One non-ideal circumstance is the reality of partial compliance to norms. This helps to stifle both benevolent and obligatory activity. In a world where all persons complied with the duty to, for example, help others in need, the cost of such aid to each person is greatly reduced. Many have made this point with respect to other problems, such as famine relief. Though it may well be the case that famine could be obliterated, or at the very least, greatly ameliorated if everyone made a fairly modest contribution to famine relief efforts, most people do not contribute at all. In the real world, of course, we have only partial compliance. This can sometimes leave those who do comply feeling a bit like "suckers" and certainly feeling they need not pick up the slack for others. The thought is something like "I'll just do my fair share" – so, if everyone gave, let us say, $10 a month to famine relief hunger would be alleviated, well, then, I will give my $10 a month, though of course I know that others – indeed, many others – will fail to give anything at all.

Philosophers, economists, and political scientists have long recognized that practical decision making under non-ideal circumstances has serious pitfalls. One problem is that persons will at least sometimes make decisions on the basis of idealized circumstances, and fail to consider practical impediments and factor them into their calculations. Thus, Penny might choose to go to London on holiday as opposed to Cancun after seeing a flier

of Big Ben under sunny skies. Actually, she may experience a few sunny days in London, whereas the chances for sun in Cancun are much greater.

This is kind of a trivial example, but my claim is that at least some government policy is flawed due to the fact that agreements will fail to be made because the current administration seems to be holding out for ideal circumstances. This is holding out for full compliance on the part of the less developed countries. The administration does not settle for what is more realistic. The less developed countries argue with justification that the "fairness" issue is misplaced since it is the industrialized countries, and particularly the U.S., that have engaged in wasteful practices leading up to the current problem, and thus it is these countries that have a moral obligation to rectify the situation. However, we need not endorse this approach, which looks at what has happened in the past – even simply focusing on what can be accomplished in the future, we have a compelling argument, I think, for why the U.S. should take the lead in limiting emissions. And the blow to development can be ameliorated by strategies suggested, for example, by Singer (2002, p. 44), who endorses forward-looking strategies in general. Emissions trading might allow for the industrialized nations to continue producing emissions, but also compensate less developed areas for the development that they would be forgoing.

The U.S. failure to endorse the Kyoto Accord is but one example of this, I believe, and one that will have an impact on our policies with respect to global warming. I would like to take a look at what some current philosophers have said about decision making under non-ideal conditions, and then critically evaluate those discussions and apply them to the global warming controversy, focusing on the U.S. failure to endorse the Kyoto Protocol.

Decision making that insists on conformity to ideal standards is "practically" untenable. While ideals can often help us sharpen our goals, and I certainly do not mean to reject them, practical decision making is just that – "practical" – and must take into consideration that our decisions are made, in reality, under non-ideal circumstances. Thus, the U.S. administration's mistake was to fail to comply at all because they did not have assurance that others would comply so as to also be doing their 'fair share' to reduce emissions.[10] So, for example, the Byrd–Hagel Resolution, while calling on the president to refrain from any action that would harm the U.S. economy, also enjoins the following:

> the U.S. should not be a signatory to any protocol to, or other agreement regarding, the United Nations Framework Convention on Climate Change of 1992, at negotiations in Kyoto in December 1997, or thereafter, which would – (A) mandate new commitments to limit or reduce greenhouse gas emissions for the Annex I Parties, unless the protocol

> or other agreement also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country Parties within the same compliance period….

George W. Bush, in campaigning for president, was asked at one point what he would do about global warming and responded: "I'll tell you one thing I'm not going to do is I'm not going to let the U.S. carry the burden for cleaning up the world's air, like the Kyoto treaty would have done."[11] Thus, the administration has been fairly consistent in expressing the view that the U.S. has no obligation to live up to the accord or even to sign onto it, and at least one reason given for this is that such a scheme is not 'fair' to the U.S. My claim is that maybe it is fair, maybe it is not. But this issue is beside the point in determining the U.S.'s level of obligation in meeting emissions standards set out in agreements such as the Kyoto Accord.

In focusing on this particular issue, I do not by any means intend to ignore the other factors that led to the U.S. failure to sign onto the accord. Instead, I simply want to focus on the one issue of fairness that has been raised vis-à-vis emissions. The U.S.'s insistence that the developing world first make a commitment to reductions does not acknowledge that the U.S. still has an obligation to limit reductions no matter the behavior of other countries (with one caveat). Indeed, we may even be able to make a stronger claim: the U.S.'s obligation to comply may be "even greater" if other countries fail. If we are to make use of 'fairness' considerations at all, then the developing world has a greater case for insisting on initial U.S. compliance with emissions standards. This translates into an obligation on the part of individuals to do what they can as well to lower emissions.

Philosopher and legal scholar Murphy (2000, p. 117) has recently articulated a principle he believes best captures obligations under non-ideal circumstances. He calls the principle "The Collective Principle of Beneficence":

> Everyone is required to perform one of the actions that, of those available to her, is optimal in respect of expected aggregate weighted well-being, except in situations of partial compliance with this principle. In situations of partial compliance, a person's maximum level of required sacrifice is that which will reduce her level of expected well-being to the level it would be, all other aspects of her situation remaining the same, if there were to be full compliance from that point on. Under partial compliance a person is required to perform either an action, of those requiring no more than the maximum level of required sacrifice, that is optimal in respect of expected weighted aggregate well-being, or any other action which is at least as good in respect of expected weighted aggregate well-being.

What he is suggesting, basically, is a permission to fail to optimize under the non-ideal circumstance of partial compliance. Thus, the moral agent may act responsibly in not optimizing under conditions of partial compliance.

The moral agent still ought to help others, but her obligation ends when she has done her 'fair share'; that share is determined by looking at what her optimal option would be under conditions of full compliance.[12] Note that Murphy's strategy is possibly in opposition to Jamieson's, since Murphy clearly intends that we factor in how many others there are in determining our level of obligation.[13] Our level of obligation cannot exceed what would be sufficient for the maximal outcome under full compliance.

However, Murphy's principle best applies to cases like famine relief, where agents with an obligation to give 'their fair share' are not the cause of the calamity. Development in the U.S. is a major cause of the problematic emissions that are responsible for global climate change. Thus, one could argue that it is only fair that the U.S. bear the primary responsibility for lowering emissions. One could argue that Murphy's standard is not applicable, since he is talking about obligatory sacrifices to prevent harms from occurring – harms that are either caused by others or not the result of agency at all. However, if the U.S. has an obligation it is to avoid causing harm, and surely that obligation would be much stronger than the obligation to prevent a harm from occurring.

However, it is worth pointing out that there are competing standards of fairness. One standard would claim that the country that caused the problem, even if initially not aware that its actions were harmful, is the country with the primary responsibility for dealing with the problem. Yet people also think that it is not fair to let someone develop a resource, and then take away what they have developed or grown to depend on. This is why some will argue that it is only fair to "grandfather" consumption levels so as to minimize the impact on those who have grown to depend on them. For example, a town may decide to restrict the building of three-car garages, and yet not insist that those who already have three-car garages replace them with smaller ones. Typically, the larger ones would be grandfathered since it is not considered fair to coerce someone into wasting the investment they have already made. The same argument might well be made for grandfathering certain emissions standards that are due to previous investments in factories, automobile design, and so forth.

Back to the Kyoto protocol. The U.S. position, either exemplified by the Senate or through the executive branch – Clinton and Bush – has been that the U.S. does not commit unless other nations and, specifically, developing nations, commit (they hold developing world commitment to be crucial). The optimal course of events would have been to have full compliance on emissions standards. But this is not realistic, and to refuse to act in the face of partial compliance shows an inappropriate disregard of the good to be

achieved by one's compliance. Leaving aside the issue of causation and its impact for obligations under conditions of noncompliance, Murphy's point applied to this case is that the U.S. would still be under an obligation to comply with emissions standards even if others did not comply. Further, even on his somewhat relaxed standard the U.S. would still have an obligation to do "a lot," because the problem is such an enormous one. However, the compliance standard set for the U.S. should be determined by the effective rate of compliance for everyone – for example, one might take the number of persons living and determine effective emissions standards for those persons, and then multiply by the number of persons living in the U.S. to help determine some compliance standard for the U.S.. I am not actually suggesting this as a standard – just trying to give an idea of one way it might work. Murphy's point is simply that, however we determine 'fair share,' the U.S. should do its fair share even if others are not – just as an individual may have an obligation to donate to famine relief, even when others are not giving.[14]

There is at least one caveat to this claim: if the U.S. thought or had good evidence to think that its emissions reductions would actually encourage or cause other countries to increase their own emissions, then there would be a legitimate complaint against those controls. But I see no evidence for this. It may be true that if the U.S. *dramatically* cuts oil consumption the price would fall and thus encourage a lot more consumption elsewhere, though this is simply an argument for a more graduated process of reduction. Thus, a mere correlative increase in emissions does not establish a causal connection between U.S. reduction and an increase in other areas. Another argument would have to be given, and, off-hand, a causal argument seems quite unlikely. Those who are doing things that, as a side effect, produce emissions, are not waiting around to see what the U.S. is going to do before they act. Indeed, the causal connection is more likely to be in the other direction – countries will feel that the U.S. is finally behaving in a responsible manner and feel encouraged to respond in kind.

One possible problem for the Murphy suggestion is epistemic. Tim Mulgan has pointed out that a principle such as Murphy suggests can have some problematic implications. Consider the following, which has been adapted from a case presented by Mulgan:

> GW does not know how many people will be harmed through toxic emissions and their side effects; he only knows that one of the following is true:
>
> 1. few people – relatively speaking – will be harmed (less than 1 million)
> 2. a moderate number of people will be harmed (5 million)
> 3. a very large number of people will be harmed (10 million or more).[15]

His obligation, on Murphy's principle, is limited to the total good divided by the number of agents there are who can do something about it – in this case, emitters who are in a position to stop and/or curtail their emissions. Let us suppose for the sake of argument that a 10% reduction in emissions would do the trick, and that this would require of GW that he simply buy a hybrid car and make modest adjustments to his standard of living. But one implication of Murphy's principle is that GW is not obligated to do more if others fail in their obligations – indeed, that is the point of Murphy's principle, to get people off the moral hook in these cases. But writers like Mulgan believe that this approach leads to the view that a person's level of obligation, even in the face of disaster, is determined by how many others there are to share it with, and this seems counterintuitive. Suppose that Mary and Susan see two people drowning in a lake. Suppose also that Mary jumps in, swims out and saves one of the people, though she could have saved both. Using Murphy's principle, she decides that her level of obligation is determined by how many others there are to share the burden, and in saving one person she has done her fair share, even if Susan fails to act to save the second person. This seems like the wrong judgment to make in this case. The force of this case suggests that what matters is not simply how many others are there to share the burden, but what they are actually doing, or could be expected to do.

Here is a case that helps illustrate the point in another way. Suppose that Alice is sitting in a crowded subway. At the next stop the subway doors open and a little old lady gets on. No one gets up to give her their seat; even the young and healthy people sitting in the seats that are reserved for the elderly do not budge. Alice, who is seated far from the subway doors, must make a choice. Under ideal circumstances, it is true, the person in the reserved seat closest to the door would get up and give his seat to the little old lady. But he is not moving. Given that, what should Alice do? She should offer her seat to the little old lady. It is not the optimal outcome under ideal conditions, but it is the optimal outcome under real-world conditions.[16]

Similarly, it would be best if the Kyoto Accord could be formulated so as to get full compliance from all emitters right away. But given that it cannot, the U.S., like Alice, still has a responsibility to help solve the problem. Underlying my claim in this chapter is the utilitarian commitment to some form of negative responsibility. Roughly, the idea is that moral agents are responsible for what they fail to do as well as for what they do. If an agent could act in such a way as to prevent something bad from happening, but fails to do so, then the agent is at least partly responsible for the bad effect. This is true even when the bad effect is also the result of another's agency.

The U.S. consumptive practices both produce the greeenhouse emissions and the failure to cut emissions. There is a consumer inertia, or even acceleration, that resists cutting and reducing consumptive practices. If the U.S. administration fails to act in such a way as to reduce them then it still shares some responsibility for the outcome. How we go about apportioning praise, blame, reward, and punishment will all be justified on consequentialist grounds, just like any other action. And it is worth noting that in this view everyone in a position to help has some responsibility to do so – but the wealthier nations can do so with less detrimental effect to themselves.

The U.S. administration cannot argue that global warming is not its problem when its actions can help alleviate the problem, and, further, when the activity of its citizens is a major cause of the problem in the first place. In this particular case, the fact that other nations may not comply is not relevant, given the view that compliance on the part of the U.S. would have a major impact on alleviating the problem. The U.S. can, and does, appeal to reasons of prudence – but these alone are not moral reasons. People who live outside the U.S. matter morally, too.

Again, of course, there is still the caveat mentioned earlier. If U.S. compliance were taken to license unbridled emission growth in noncompliant countries then the U.S. should refrain from complying. In that scenario, U.S. compliance with emissions standards would be counterproductive. However, there is no evidence that this would be the case. While there may be emissions growth in developing countries, there is no evidence of a causal connection between this growth and the potential for the U.S. to curb its own emissions.

3. CONCLUSION

With respect to the U.S. policy, given that we will have increased emissions at least in some quarters and all other things being equal, those increased emissions should be allowed more in countries with currently low emissions. That is assuming that there is a correlation between increased emissions and a higher standard of living. That increase will mean more to those living in the developing nations than to those living in the U.S. Again, this is an application of diminishing marginal utility, discussed at the outset of the chapter.

Of course, in the end, the U.S. may just be like the agent who hoards some good, unwilling to give it up. But appeals to 'fairness' will not work here.

What the U.S. has tried to do, in my opinion, is moralize a position that is really based on pure short-term self-interest. Utilitarian moral theory has the resources to suggest a morally appropriate course in this matter. Since the U.S. is in a position to create positive change it ought to do so. While I believe that individuals cultivating green virtues is a good idea I do not believe it offers a sufficient solution. The government must act to regulate behavior to avoid everything from free-riding, bad conscience, to problems arising from lack of proper coordination.

That being said, it is a separate issue as to what realistic measures can be taken to encourage U.S. policy to change in a more favorable direction. I favor, myself, the pragmatic approach: one that would allow the U.S. to use emissions trading schemes as a way to maintain its emissions output, in balance with the rest of the world. Singer (2002, p. 46) has noted that some view this approach as unfair, since it "…allows the U.S. to avoid its burdens too easily…." However, he adds, "…the point is not to punish nations with high emissions, but to produce the best outcome for the atmosphere." Another strategy would be to allow the creation of carbon sinks to count against emissions produced. Yet another would be to figure out a mechanism by which the U.S. could trade on its technological strengths to get credit for making technological advances that would reduce the effect of emissions. Of course, not being a specialist on the technical aspects I leave this issue to other writers. My aim has simply been to address one moral concern raised by those in the U.S. administration against the Kyoto Protocol, or any other protocol, for that matter, that fails to demand full compliance.

NOTES

1. For the sake of focus I will not consider more complicated possibilities: for example, the utility of the U.S. refusing to agree, yet complying with the standards in any case.
2. It will not, for example, be able to handle "utility monster" cases.
3. This raises the interesting issue of whether or not calculation is necessary to determine when to calculate. But maybe there are virtues of assessment as well.
4. Thus, to respond to Jamieson's query in his paper, my account in *Uneasy Virtue* is compatible with his, since I am just offering an account of what the virtues are.
5. For more on this criticism of Rule utilitarianism, see Smart's discussion of Utilitarianism in Smart and Williams (1977). Recently, Brad Hooker (2001) has tried to defend Rule consequentialism against this sort of criticism.
6. See Bales (1971).
7. Of course, this can lead to a separate set of problems. See, for example, Kagan (1998) and also Lenman (2000, Fall).

8. Garret Hardin (1977) explores this issue. I certainly do not mean to endorse Hardin's pessimism. However, the issue of what mechanisms to put in place to deal with persons who would exploit the conscientiousness of others is an important one. It seems to me that government regulation is one way to do this on a large scale and more efficiently than other mechanisms.

9. See, for example, Singer (2002, pp. 49–50).

10. In this essay I will be leaving aside issues of what emissions standards would be "fair." I think it quite likely that other countries can make a case that the U.S. is already way over the top in terms of polluting the air, and using more than its "fair share."

11. Second televised debate, as quoted in Singer (2002, p. 26).

12. Note that in the real world this may not be very demanding – but, of course, it "could" be demanding if the level of need were so great that under even full compliance the agent's contribution would have to be quite a bit to bring about the optimal outcome.

13. This will depend on how one interprets Jamieson on non-contingency.

14. I do not mean to suggest that the famine relief cases and the global warming cases are completely analogous. Fairly modest sacrifices of money can have a measurable impact on a starving person's standard of living; modest efforts on emissions reduction will not have much impact on the overall problem. However, many people do see the famine relief problem overall as overwhelming, and not one that the ordinary individual can solve.

15. See Mulgan (2001, p. 107).

16. I discuss this case as an example of a morally charged situation in Driver (1992).

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RESPONSIBILITY TO FUTURE GENERATIONS AND THE TECHNOLOGICAL TRANSITION

Henry Shue

The nature and extent of moral responsibility toward climate change depend on the nature and extent of climate change. One cannot specify degrees of responsibility for dealing with a problem without first specifying, or implicitly assuming, the salient features of the problem itself. The likely causes and consequences of climate change are not for normative debate but, rather, for scientific investigation. Nonetheless, much discussion of ethical issues concerning climate change assumes that climate change takes one, not another, of the many forms it might be imagined to take. We normative theorists must do our best not to engage in the equivalent of assuming that the primary moral dilemma facing the passengers on the *Titanic* was the selection of the principles for the allocation of the deck-chairs.

Much of what has been written about the ethics of climate change, including several of my own articles, has assumed that a central issue is the allocation of emissions of greenhouse gases (GHGs). However, it is increasingly evident that there is no allocation of GHG emissions specifically in the form of carbon dioxide that is both morally tolerable and, at present, politically feasible as long as most economies are dependent for energy upon carbon-based fuels, that is, fossil fuels.[1] In order to be morally tolerable, total GHG emissions need to be reduced to a level that will not cause

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climate change so rapid that societies and species cannot adjust; wherever exactly that level is, it is significantly below current levels, which are meanwhile rising.[2] To reduce GHG emissions significantly below present levels would involve sharply reducing the source of those emissions, the combustion of fossil fuel. Climate policy is energy policy. But as long as the combustion of fossil fuel is the predominant source of energy, sharply reducing the combustion of fossil fuel means sharply reducing the total use of energy. Most rich and powerful states, with the U.S. at the far extreme, are completely unwilling today to reduce their energy consumption to anywhere remotely near the level at which the GHGs emitted from carbon-based sources of energy would no longer cause rapid climate change.

Questions about the political and sociological bases for this reluctance – for example, the extent to which the reluctance reflects middle-class American consumers' infatuation with sport utility vehicles (SUVs) and romance with the car generally, and the extent to which it is the corrupt political influence of oil- and coal-company executives – are vital, but we will not explore them here.[3] Even so, we can work unrelentingly both to change popular attitudes and to fight elite corruption. Concurrently, it appears at least as economically and politically viable also to move away from the fossil-fuel energy regime that is overwhelmingly the primary source of GHGs, to some non-carbon-based regime.

The thesis of this chapter is that, besides practical political reasons, we have, perhaps surprisingly, strong moral reasons, involving responsibilities to future generations, for an aggressive search for alternative sources of energy – sources other than coal, oil, and gas. Choices among alternative allocations of GHG emissions in the short-term may turn out to matter principally because of the incentives they do or do not create for moving decisively beyond fossil fuels, the consumption of which injects such monumental, and consistently growing, emissions of GHGs into our planet's atmosphere.[4]

DATES AND THRESHOLDS

I have applied the phrase "the date of the technological transition" to the year in human history in which the accumulated atmospheric total of all GHGs ceases to grow.[5] Carbon dioxide from the combustion of fossil fuel is only one GHG, of course, but increases in carbon dioxide have made by far the greatest contribution to the swelling of the total. Perhaps quantities of some other GHGs would even need to continue to grow, perhaps not – this

is a murkier realm. But if emissions of carbon dioxide were reduced sufficiently, quantities of other GHGs could, if necessary, increase while total annual emissions of all GHGs declined because carbon dioxide is such a large part of current annual emissions of all GHGs and of annual increases in emissions of all GHGs. Reductions in emissions of carbon dioxide could "make room" for any necessary increases in other GHG emissions.

This stabilization in the quantity of atmospheric GHGs could only begin after a cessation in the now-annual increases in total global emissions.[6] The mere elimination of net increases in annual emissions would by no means produce a stabilization in the atmospheric accumulation, any more than the mere elimination of increases in annual national deficits can produce an end to growth in the national debt. As long as any annual deficit occurs (even a deficit smaller than previous deficits), the amount of that deficit will constitute an addition to the accumulated national debt. In order to stop the debt from growing, annual deficits must be eliminated entirely, not merely made smaller. Similarly, the atmospheric concentration of GHGs will stop mushrooming only when annual emissions are reduced to an amount that can be recycled in the short-term so that no net additions to the accumulated total are made.[7] The rate of annual emissions must become, to use the fashionable term, "sustainable," if the atmospheric accumulation is not to continue to expand indefinitely. The current annual rate is far above any sustainable rate, so the rate must not only stop growing but must decrease to a sustainable level, a level that makes no addition to the accumulated atmospheric total. On this much, everyone agrees.

It is also evident, although somewhat less commented on, that the stabilization of the size of the atmospheric accumulation of GHGs has a critical similarity to the more familiar case of the stabilization of the size of a national population. Suppose the populations of countries A and B are the same size and have been growing at the same rate. Country A then reduces, over a period of 25 years, its overall fertility rate to a replacement rate, at which the population can remain stable indefinitely; that is, it takes 25 years for the fertility rate to fall from the current rate to the replacement rate. Although beginning at the same place, country B moves more slowly and spends 75 years reaching a zero-growth fertility rate. Obviously, because country B's population expanded for 50 years longer than country A's population did, the population at which B stabilizes will be considerably larger than the population at which A stabilizes, in spite of their having begun with populations of equal size. It could easily happen, depending on the curve of the decline in fertility rates in each case, that while the population in country A doubled once during its 25-year transition to stability,

the population in country B doubled at least twice during its 75-year transition. From the date of stabilization, the population of B will no longer grow, but its population will always be much larger than the population of country A if they both remain stable thereafter, and specifically larger by its net growth over the additional 50 years during which its population continued to expand.

Similarly, the absolute size of the atmospheric accumulation of GHGs at which stabilization occurs, if it ever does, will be dramatically different depending on how soon it occurs, depending, that is, on "the date of the technological transition." Many years of compound growth at even relatively small rates can yield far higher ultimate totals. This is plain arithmetic, not rocket science or even atmospheric science: the longer a total grows, the larger it ends up being. Consistent growth compounds totals. At any very significant rate of growth, a total can double several times within one century, just as a savings account doubles fairly often at any significant interest rate (doubling every 12 years at 6%, for example).

The fundamental principle of the science of climate change as far as humans are concerned, since we live on the surface, is that increases in the atmospheric concentration of GHGs around a planet tend to produce increases in the surface temperature of that planet – global warming – other things being equal. Needless to say, the ratio between the two increases (in atmospheric concentration and in surface temperature) cannot be specified precisely, and there are many other factors to be, or not to be, equal. Generally speaking, however, we have solid reason to fear that the larger the atmospheric concentration of GHGs, the more severe the changes at the planet's surface to which living things will have to adapt if they are not to die. Therefore, probably – not certainly, but considerably more likely than not – the later the date of the technological transition is, the more threatening to forms of life the conditions at the surface of the planet will become. The longer the atmospheric concentration expands, the more severe the stresses upon living things will be.

Abrupt reversals in temperature trends, like the Younger Dryas (rapid warming succeeded within a few years by rapid cooling), have occurred several times.[8] The authoritative 2002 report from the National Academy of Sciences, which the Bush Administration has completely ignored after having requested it, begins: "Large, abrupt climate changes have repeatedly affected much or all of the earth, locally reaching as much as 10 degrees C change in 10 years. Available evidence suggests that abrupt climate changes are not only possible but likely in the future, potentially with large impacts on ecosystems and societies."[9] A rapid change in climate is never

good for living things because they need time to adapt; and the only thing worse than simple rapid change is rapid change in one direction abruptly followed by rapid change back in the other direction. Zig-zag adaptation by animals or plants to abrupt reversals is especially unlikely to occur because natural selection is on a much slower timescale.[10]

Disturbing evidence is accumulating that another abrupt reversal may in fact be under way already.[11] For the date of the technological transition, then, sooner is definitely better. Just how much better, we do not know, but if there are critical thresholds within total accumulation, such as a threshold for a Younger-Dryas-like abrupt reversal, sooner might be far, far better. A delay in the technological transition makes abrupt reversal more likely, other things being equal, because it means a greater accumulation of GHGs, thus likely a warmer surface temperature, more melting of Artic ice into fresh water, and thus a greater dilution of the salinity of the North Atlantic, tending to undermine the driver of the deep ocean circulation, which is relatively heavier salty water sinking toward the bottom of the North Atlantic.[12]

In general, we do not know – and, as far as I can tell, may never know until it is too late to do anything about it – how often smooth, gradual increases in total atmospheric accumulation of GHGs will lead to smooth, gradual increases in the difficulties for forms of life on the surface, and how often various types of life will instead reach a limit that individuals cannot tolerate and to which species cannot adapt. Any plant or animal can handle gradual increases or decreases across a certain range at up to a certain rate in critical parameters like temperature, moisture, nutrition, sunlight, top wind speed, length of growing season, and so on. But at some point for each parameter for each species, a limit is reached. And of course many species are interdependent: If a plant becomes extinct, an animal for which it was food may become extinct, and a predator for which that animal was prey may, as well. The extent of adaptation is astounding; and the resilience of individuals and species can be remarkable. Nevertheless, adaptation has severe – in fact, fatal – limits for each species on the rate at which adjustments can occur. I would suggest, therefore, that a fundamental moral responsibility regarding climate change is to take all necessary actions to make the date of the technological transition, at a minimum, soon enough to avoid the crossing of thresholds critical for very many species, including of course the human species. In the words of the *Framework Convention on Climate Change*, this must be soon enough to "prevent dangerous anthropogenic interference with the climate system."

The date of technological transition will certainly come, one way or another, but it may well come too late for individuals, for communities, or for

species. At the extreme, the date of technological transition will come when fossil fuels have become sufficiently scarce for their prices to rise, purely from market forces, above the prices of alternative sources of energy. Unfortunately, the foreseeable supplies of fossil fuels that will be economically profitable for their owners and marketers to exploit are gigantic. For gas, oil, and especially coal to become sufficiently scarce for their relative prices to rise to a point at which they are no longer competitive, vast further quantities would have to be consumed. Put differently, vast amounts of carbon that have been safely sequestered out of circulation underground for millennia in coal, oil, and gas will have to be injected into the atmosphere as carbon dioxide through the combustion of these fossil fuels in order to reduce the supply enough to cause a significant purely market-induced price rise. If large percentages of the remaining stocks of fossil fuel are indeed burned at current or higher rates of consumption, the atmospheric concentration of carbon dioxide will have soared by the date of the technological transition. "Consuming what remains of fossil fuels could well lead to a four- to eight-fold increase in CO_2."[13]

We have identified, then, one ultimate extreme policy regarding climate change: do nothing – simply wait for combustion of fossil fuels to reduce the supply to the point at which price increases reduce consumption to the level at which GHG emissions are sustainable. The consequences of this policy of political passivity and myopia are clear: the date of technological transition drifts far into the future, and the total accumulation at which GHGs are stabilized becomes very high, making the consequences for climate change severe. For all we know, these consequences could be catastrophically beyond one or more thresholds critical for humans, certainly beyond extinction thresholds for more slowly adapting species and beyond survival thresholds for some human communities (for example, South Pacific societies whose island homes will be submerged by the rising sea level).[14]

DANGERS AND RESPONSIBILITIES

I have already suggested a moral responsibility to advance the date of the technological transition nearer in time in order to avoid the risk that later increases in atmospheric concentrations of GHGs will cause critical limits in aspects of the climate on the planet's surface to be exceeded. In order to be acceptable, this suggested responsibility needs fuller explanation: to whom would such responsibility be owed and what kind of responsibility would it be? The clearest case is future generations, that is, individual persons who

will live in the future. A great deal of interesting philosophical analysis has been carried out in recent decades regarding issues arising from the fact that which policies are followed in the present on many matters will determine not only the size of future generations of human beings but the identities of the specific individuals who will constitute these generations.[15] While these analyses are important, they do not much affect the general shape and character of our responsibilities to whichever human beings turn out in fact to live in the future. If one has any responsibilities to human beings whose interests one can significantly affect, then one has these responsibilities to any such human beings who happen to live in future times, whatever their numbers and identities. The key question is, what kinds of such widespread responsibilities might be relevant?

Discussions of the ethics of climate change have tended to assume that the primary, if not the only, responsibilities are responsibilities of distributive justice: what we owe to members of future generations are such duties as doing our fair share to solve any common problems and not consuming more than our fair share of common resources like the capacity of the atmosphere to absorb GHGs without untoward effects. I next want to explore these suggested responsibilities a bit in light of what we have seen to be the nature of the date of the technological transition.

One way of trying to conceive the issue of responsibility is the following. All human beings potentially share some responsibility generally for dealing with climate change and, specifically, for preventing unjustifiable delays in the date of the technological transition, that is, for avoiding the creation of unnecessary dangers for people in the future. Plainly, these specific responsibilities need to be assigned in accord with some allocative principles, like ability to contribute to the solution or past contribution to the problem. Thus, it will emerge that some people who are unable to contribute to the solution and made no contribution to the problem bear no actual responsibility, while other people bear heavy responsibility on one or both of these (or other) grounds, and so on.[16] In practice, not everyone can reasonably be assigned any responsibility, but in theory everyone is a candidate for bearing responsibility, depending on how the principled assignment of specific responsibilities works out. This conception can lead to the following general picture of the responsibilities.

All the people who are alive now or will live prior to whatever turns out in the end to be the date of the technological transition constitute the general pool of persons eligible to bear some degree of responsibility for when the date will in fact be; clearly, one might also include people in the past, who may or may not already have failed in their responsibilities, as part of the

pool of responsibility, but matters are complicated enough without them. The fundamental issue then becomes whether one is carrying out one's fair share of responsibility, if any, given everyone in the general pool, given the total responsibility, and given the allocative principles for the assignment of responsibility. If one fails to carry out one's responsibility, one acts unfairly toward the others in the pool of shared responsibility, who consequently may to some degree – this is a difficult, contested issue – be required to add to their own share of responsibility some portion of the unfulfilled responsibilities of others like oneself who are slackers.[17] Thus, if those of us in this generation fail to carry out our responsibility of preventing avoidable delays in the date of the technological transition, we are guilty of unfairness toward at least some members of future generations.

What I want to suggest, however, is that while this picture of failures of responsibility as unfairness is not strictly inaccurate as a portrayal of a piece of the moral problem, it wildly understates the seriousness of failures on the part of our generation and immediately succeeding ones. I will point out two major reasons why the seriousness of a failure to act now is misleadingly minimized on the usual picture focusing on fairness, sketched above. What is wrong with this standard picture?

First, the usual picture of responsibility is distortingly static. Implicitly, the suggestion is that a fixed amount of effort is necessary to bring about a relatively early date of technological transition and that if we now are not doing our part, others will unfairly need to do more or yet others who otherwise would not have needed to do anything – for example, distant generations who would have inherited a safe environment if we had carried out our responsibilities – will have to take up burdens then in order to make up for our failure now. The strong implication is that all that changes if we fail is that someone else needs to pick up after us: we shirk our responsibilities and so others have to carry them instead of us.

But the identity of those carrying responsibilities is not all that changes, nor is it the most important change. For, as we have seen, the date at which atmospheric accumulations of GHGs cease to expand determines the maximum absolute severity of the resulting weather and other surface problems: the later the date of technological transition, the worse the climate change (more likely than not, although not for sure). The initial picture that understates the problem suggests, in effect, that if the date of technological transition will occur after six generations if the present generation fulfilled its responsibilities, then it will occur after seven generations if we fail to act. An extra generation, the seventh, is unnecessarily and unfairly burdened if we drop the ball now. The unfair burden, however, might be the least of it

for the seventh generation. For another effect is that the problem of climate change that would, let us say, have reached a level of severity #6 in the sixth generation would reach a level of severity #7 in the seventh generation.

What will be the difference between severity level #6 and severity level #7? I wish I knew. Conceivably, not a lot – perhaps level #7 is just a bit worse than #6 but not significantly different. On the other hand, level #7 could be dramatically worse if some threshold is passed during the transition between these two levels that would not ever have been passed if the planetary deterioration had stopped at level #6. Perhaps at level #7 species extinctions begin to cascade, perhaps the global human pandemic comes, perhaps the Younger-Dryas-like reversal from rapid warming to rapid cooling is triggered, and so on. Obviously these "levels" are merely an illustrative abstraction, and I do not know exactly what they might mean. Yet the point is clear: to delay is to play with fire (and ice). At some point things will probably become truly nasty. Maybe the nasty one is level #13, and the difference between levels #6 and #7 is unremarkable. Maybe the nasty one is level #3, and the passage beyond #6 to #7 will by then be immaterial. We do not know, and we are very unlikely ever to know very far in advance.

Nevertheless, a good policy is readily evident. We do not need more information in order to know a wise way to act, which means that, contrary to the assertions of defenders of current U.S. obstructionism, uncertainty is no excuse for inaction. Suppose you know that you are walking through a fog toward a cliff, but you do not know how many steps lie between you and the cliff – can you think of a good policy? Yes: stop as soon as you can. Now, I realize that energy policy, which is the key to climate change, is not that simple, especially since in the real world "stopping" would have large costs too. And I am not advocating "stopping," whatever that could actually mean: we need to move forward but in a direction that does not lead toward a cliff. Knowing which other direction that is, is not a simple matter. This is why vigorous well-financed research on alternatives to fossil fuel is urgent. What carries over from the analogy with heading for the cliff in the fog is that those like George W. Bush who say "nothing needs to change yet" are being at least as simplistic as someone who says "just stop," and they are flagrantly tempting fate. A "few" years in the date of technological transition could make a spectacular difference if in those years some point of no return was passed that would otherwise never have been passed. We are not simply strolling in the fog – we are playing poker as we stroll in the fog; and we do not even know what stakes we are playing for, although the stakes could be very, very high, and if our gamble loses, our great-great-grandchildren will pay.

Under this much uncertainty it is perfectly reasonable to pay attention to the costs as well as the benefits of advancing the date of technological transition. It would not be reasonable to try to make the date as soon as possible no matter what the cost. The "fog" of uncertainty prevents us from knowing whether the potential train-crash is just around the corner or much farther down the line, either of which would make what we do largely irrelevant, or somewhere between immediate and distant, which could make what we do utterly crucial. Assuming the worst case would be extremely – and, I would think, excessively – expensive in light of all the other urgent matters also requiring attention.[18] Thus, for example, it would obviously not be reasonable to divert all the funds that might otherwise go toward curing cancer and AIDS into slowing climate change because these diseases are scourges too, and their harms are quite clear, even if the value of any particular line of research in those cases is far from obvious, as it is in the instance of nonfossil energy sources. But, in symmetry, it is also not reasonable to devote only relatively trivial amounts to research on arbitrarily chosen alternatives to fossil fuel, as the U.S. is now doing. The assumption of the best case, which would be the only way to try to make non-corrupt sense of the lackadaisical passivity of the Bush Administration, would be at least as extreme and unwarranted as assuming the worst case.[19] U.S. policy could be far less dismissive without even coming close to overreacting.

Whatever is exactly the right approach to such a case in which there is strict uncertainty (that is, no calculable probabilities of alternative outcomes but some disastrous outcomes definitely possible on the basis of fairly well-understood planetary mechanisms), the point remains that if the present generation continues to fiddle around the edges of the problem rather than take a grip on its responsibilities, the moral failure will not consist only or primarily of unfairness to those to whom our burdens are then shifted. Much more important, we will be responsible for allowing the consequences of climate change to become worse – to reach a more extreme point—than they would have been had we acted with some seriousness. Far worse or only a little worse? George W. Bush and Richard Cheney do not know any more than you and I do, and they find it much more difficult to be open-minded about whether to challenge entrenched fossil-fuel interests.

The second reason why the usual picture is misleading insofar as it suggests that a moral failure by our generation would be only unfairness – not that unfairness is not already a serious and fundamental moral failure – is that in a historical process like rapid climate change it is impossible to do later all of what it is possible to do now. Suppose that in fact, although we do not yet know this fact, the species on the surface of the planet, including humans, can

on the whole handle the effects of one further doubling of the atmospheric concentration of carbon dioxide reasonably well, but that a further redoubling will produce cascades of extinctions including the extinction of food plants of great value to humans. Burning all remaining fossil fuel will take us well beyond a further redoubling of atmospheric carbon.[20] Determined action now can prevent that further redoubling, but action after a certain point in time (specifically, after a certain additional proportion of the carbon in the remaining fossil fuel has been injected by combustion into the atmospheres) will simply come too late to make a significant difference. The atmospheric commitment will at that time have already been made.

This is because carbon dioxide has a long atmospheric residence time, averaging around a century. Once a certain amount of carbon dioxide is in the atmosphere, we know of no way of removing it. And any given level of GHGs in the atmosphere creates a commitment to consequent climate changes on the surface. Suppose the people in generation #4 – we are #1 – discover the fact that a further redoubling of atmospheric carbon is going to immiserate some societies and generally impose great strains upon humanity. They are nevertheless doomed to suffer this fate if either of two things has happened. First, obviously, if enough additional fossil fuel has already been burned by us and the intermediate generations to produce the atmospheric commitment to the surface changes, it is physically impossible for them to stave off the changes (without some miraculous stratosphere-cleansing technology not remotely in prospect). More agonizing, even if the fatal amount of fossil fuel has not yet been burned, but generation #4 has been left with a world economy dependent upon fossil fuel because no good alternative energy sources have yet been developed, it is politically impossible for them at that date to stave off disaster. They cannot simply "stop" the world economy by "turning off" energy consumption – then practically everyone would die of deprivation. So, they themselves may produce the fatal emissions because they still have no more alternative than we now have because we were content to leave them with no alternative to fossil-fuel energy sources and our successors followed our bad example. In a way, they would hang themselves, but of course only because we had not prepared the way for them to have any alternative to fossil-fuel use other than starving. By the time of their generation it is too late to be doing the research and development that we could have done at earlier times (that is, now). Many choices in history are irreversible. Either a technology is ready when it is needed or it is not; if it is not, it cannot be used because it is not there. We could perhaps see to it that the safer technology is available by then, but currently the U.S. government is not even trying.

VULNERABILITY AND BETRAYAL

If I were a desperate member of that later generation, I think I would be furious at our generation and the short-sighted and self-centered do-nothing-ism of the U.S., Australian, Canadian, and other laggard governments of the early 21st century, not to mention the belligerent obstructionism of the Saudis and some of the other governments sitting contentedly on oil that they are absolutely determined to sell. It would be a good thing that one cannot harm one's ancestors, other than by trashing their reputations. They might well view us with the contempt we have for forebearers who were slave-owners or pirates. This is not how I was hoping to be remembered: as a good-for-nothing great-great-grandfather who wallowed in comfort and convenience to such an extent that no viable options remained.

Suppose that either out of greed and corruption, or simply out of indifference and self-centeredness, we cannot be bothered to move aggressively to replace fossil fuels with alternative sources of energy before scarcity and price rises force later generations to do it – we fail to spend even as much on research and development of alternative energy as, say, we spend on a peripheral boondoggle like ballistic missile defenses, which would be irrelevant to almost all the worst threats the U.S. faces even if the technology could someday pass realistic tests.[21] Our moral offense, it seems to me, goes well beyond unfairness. It constitutes the infliction of harm, a violation of what is arguably the most fundamental moral principle of all: Do no harm.

Why is there no concerted research and development initiative on alternative energy? The morally most acceptable explanation would be forgivable ignorance. Climate change is difficult to grasp: much of the evidence comes from sophisticated models inaccessible even to well-educated and intelligent people who are not specialists, and there are few telegenic disasters from climate change evident yet.[22] If it cannot be seen on TV, it is not happening – this is the American ontology. Climate change is too pervasive to point to, and many perfectly decent people do not understand what the fuss is all about.

The morally most outrageous explanation is greed and cover-up. Those whose wealth depends on pumping all the oil and digging all the coal have a lot to lose if the political decision is ever made to leave the stuff in the ground; many of them intend to see that this political decision is never made and indeed that no one who would make it ever gains significant political power (by winning a U.S. presidential election, for example). For some of these people, the advocates of alternative energy are simply the enemy, and this is a war. It would be naive to expect such selfish people to be moved by concern for the welfare of other people, not to mention other generations. They

cannot be persuaded or moved to empathize – they can only be outsmarted and outmaneuvered. At present, they are winning the struggle and dominate what passes for energy policy in the U.S.: pump more oil and dig more coal.

In between these extremes is what I hope is the vast majority of people who actually care about the environment in general but are not quite sure where ozone depletion ends and climate change begins and for now do not feel safe invading an Interstate in anything other than a tank-like SUV (or even an absurd Hummer). We in this group are less wise and less compassionate, especially toward those distant in space and time, than we might ideally be, but we do not really want to hurt anyone who is not threatening us. For us, I hope, it might matter if our failure to do much about climate change would do genuine and serious harm to people who are utterly at our mercy.

And assuming again that we are generation #1, this seems to be the situation of the people in generation #7, who are utterly and asymmetrically vulnerable to us. Their very existence is in our hands and the hands of the intermediate generations; if we unleashed a massive nuclear winter (less likely for now than it once was) or failed to control some virulently contagious and fatal epidemic, the people of generation #7 might never live. And the quality of the lives of whoever are born in that generation is under our control to a profound degree, in completely familiar ways. Whether they can enjoy beautiful forests and great universities depends upon whether we leave them any – a single generation cannot grow a magnificent forest (although they can plant one) or suddenly throw together a great university. These things take time: If one generation is to have them, earlier generations must see to it. There is no express route.

In some of these cases, perhaps, if we do nothing, we fail to provide a benefit we might have provided to future generations, but we thereby do them no wrong. Suppose there were no decent university in our state, and we did nothing to create one. Future generations might be unhappy with us because we did not provide this benefit, but I cannot see that we would actually have done them any harm. And they could always start one if they thought it was important, although it would take more than their own lifetime for it to flourish as an outstanding and enduring institution. It could be their gift to the generations that succeeded them.

A failure to take action to put a floor under how bad climate change can become seems to me to be a much worse failure than a failure to give a gift that one might well have given but was under no obligation to give. Suppose that every generation after ours will do whatever it ought to do about climate change in the circumstances that it then faces (perhaps because the damage will have become more obvious as time passes). Then how bad

climate change becomes at its worst turns on how much we do now. There may be harms that will occur only if we do nothing because only if we do nothing will climate change become severe enough to cause those harms.

What if an intermediate generation, inspired perhaps by contempt for our generation, did twice what it could reasonably be expected to do and tried to make up for our failure? Generation #1 (us) does nothing, but generation #4 does twice what it could be expected to do in order to make up for our failing – might generation #7 turn out then to be just as well off as if generation #1 had done its share? We are here engaging in abstract speculation of a possibly not very reliable kind, but here is what I can make of it. It is of course conceivable that one share of effort each by generations #2 and #3, plus two shares by #4, would add up to the same thing as one share by each of the four generations. If the task were to build a stone wall by adding individual stones, four shares of effort supplied by three generations ought to produce the same result as four shares by four generations. Let us say that each share of effort contributes 2 feet of height to the whole wall; either way an 8-foot wall results. Suppose the need were for a wall too tall to be jumped by mounted marauders, the requisite height for security was 6 feet, and the marauders were going to attack early in the fourth generation. The fact that generation #1 had done no work would mean that at the beginning of generation #4 the wall would only be 4 feet tall, when it would have been 6 feet tall if generation #1 had done its job. So the marauders would conquer generation #4 before they could get very far with their double-effort of wall-building, which would have taken the wall to 8 feet at a later point in time. Thus, even with something as simple and cumulative as adding stones to a wall, earlier omissions can have irreversible effects. The attack of the marauders constitutes a critical threshold, and on that day the wall either will or will not be tall enough to stop them. Safety depends on how much has already been done by the crucial date.

And, almost needless to say, irretrievable effects are far more likely in the case of climate change. Return to the example mentioned earlier: perhaps the effects of a doubling of the atmospheric concentration of carbon dioxide are manageable, but the quadrupling (and more) that would result from the combustion of all the fossil fuel exploitable at a profit to those who control it will have much more severe effects. Then it is critical whether the date of technological transition, the date when the atmospheric accumulation ceases to expand, occurs before or after the concentration has quadrupled. Suppose that if this generation launched a serious initiative on alternative energy, it would be very likely that the research and development could be completed in time for widespread adoption of alternative sources well before enough of

the vast remaining supplies of cheap fossil fuel had been burned to cause the atmospheric concentration of carbon dioxide to quadruple. But suppose that if serious research and development did not begin until the generation after us, the concentration would quadruple before the eventually emerging alternative forms of energy have replaced enough of the fossil fuels.

How should this generation's failure to act be evaluated? "They could have helped, but they didn't"? "They unfairly left their share of the effort to be done by some succeeding generation"? Unfortunately, it seems incomparably worse than those assessments: They made the choice that determined how bad climate change became at its worst, and their choice resulted in its becoming worse than it would have if they had chosen differently. They were not for the most part evil people (although they complacently tolerated corrupt political leaders), but they were simply preoccupied with their own comfort and convenience, not very imaginative about human history over the long run, and not particularly sensitive to the plight of strangers distant in time. They did not mean to do any harm, but in fact they inflicted severe damage on their own descendants. A sad chapter in human history – so much opportunity lost while a tiny clique with financial interests in fossil fuels amassed short-term profit. Will this be our legacy?

Now, the "two" reasons I have given why a failure to act is worse than an unfair shirking of responsibility – that delay is likely to magnify severity (to make the worst worse) and that historical choices can be irreversible – are essentially the same point: The irretrievability of lost historical opportunities matters in this case because the opportunity that is now being lost is to prevent climate change from becoming as extreme as it will otherwise probably become. I have simply highlighted two facets of one very hard rock.

I have also highlighted the responsibility of the present generation, noting that even if all other generations were to do their part after we had failed to do ours, our failure might well set the bottom limit on how bad things finally become. Naturally if we did our part and one or more succeeding generations failed to do theirs, the depths of the disaster might be at least as bad or worse than if we had not evaded our responsibility. So, why pick on us? For one thing, we are the only ones available to be picked on, although I hope to leave behind a book provoking future generations as well! More seriously, one is only responsible for what one can in fact affect. We cannot control what future generations do, but the broader public might be able to wrest control of what our generation does from those narrow interests who now dominate it. *Climate policy is energy policy*, and changes in energy policy affect the value of the holdings of some of the wealthiest firms and individuals in the world – they will not surrender their grip on the political

power that protects their wealth without a prolonged and dirty fight. But ordinary decent people do outnumber them, so if democracy could be made to work, there would be a little hope.[23] Secondly, as already noted, there is the bittersweet possibility that, as the problems become worse, they will become more visible. Succeeding generations may sadly need less imagination than we do to understand the seriousness of the situation, so they may be a little more likely to act because they are more frightened. In sum, there is no guarantee that if we act, all will be well, but there is a high probability that if we do not act, the best that will be possible will be worse than it relatively easily could have been.

Finally, I have said nothing about how to encourage the alternative energy sources needed to supplant fossil fuel. Technological change is not well understood, although many understand it better than I. That simply throwing public money at a problem does not solve it is amply demonstrated by the tens of billions poured into the Strategic Defense Initiative (SDI), now born-again as Ballistic Missile Defenses, which can only succeed in rigged or farcically easy tests. Perhaps a "Manhattan Project" for alternative energy would be as bad an idea as the SDI/BMD. One of the reasons for profound doubt about the *Kyoto Protocol* is the extent to which its various "flexibility mechanisms," like the Clean Development Mechanism, create financial incentives to disperse throughout the Third World the same fossil-fuel-based technology that brought us climate change in the first place, and contain no strong incentives to use alternative energy. This reflects the extent to which "Kyoto" was designed to please dominant interests in the U.S., although the current U.S. administration dismissed it contemptuously anyway.[24] Yet local governments, state governments, universities, and the private sector need not wait for the federal government to stop favoring fossil fuel; they could provide the initiative and vision absent in Washington.

I defer to others who are wiser in practical matters on exactly how to proceed. But now is the time for thoughtful but determined action to prevent the sale and burning of all the vast remaining cheap fossil fuel, an economic choice that bids fair to become the most short-sighted "bargain" in human history.

NOTES

1. I first stumbled my way reluctantly into this conclusion in Shue (1995). My fundamental analysis of the issues of distributive justice is Shue (1993). A later summary overview, with some modifications, is Shue (2002).

2. See Houghton et al. (2001). For a lucid brief account, see the chapter by Mahlman in this volume.

3. See Paterson (2000), Rutledge (2005), and Ness (2005).

4. Fairer processes for the allocation of emissions, like the one proposed in this volume by Dale Jamieson, would increase the incentive for the worst emitters to pursue alternative sources of energy. The importance of the incentive structure created by emissions allocations was clearly set out in the classic article by Grubb (1995). A moral philosopher who has recently made a serious attempt to incorporate considerations of incentives is Traxler (2002). A critique of Traxler's proposal appears in Gardiner (2004). Gardiner provides an excellent comprehensive interdisciplinary overview of the ethics, economics, and science.

5. See Shue (2004). My formulation is inspired by Michael Grubb's distinction between dynamic efficiency and static efficiency – see Grubb (1998, p. 2) and Grubb, Chapuis, and Duong (1995).

6. It is net increases that matter, naturally. A theoretical alternative would be to increase sinks for carbon dioxide faster than emissions of carbon dioxide increase, but this is in practice impossible. Many places would now benefit from reforestation, for example, but the limits on land to serve as carbon sinks will be reached long before the limits of the human demand for additional energy. Various exotic engineering solutions are imaginable, but none is yet feasible.

7. How much can be recycled in the short term changes somewhat with changes in the total accumulation – see the chapter by Mahlman in this volume. The change is in the direction helpful to humans but is far too small to save us.

8. See, for a remarkably accessible and engaging account, Alley (2000). Also see Weart (2005).

9. See United States, National Academy of Sciences, National Research Council, Committee on Abrupt Climate Change (2002, p. v.) On the Younger Dryas, specifically, see pp. 24–36. Also see Vellinga and Wood (2002).

10. See, for example, McCarthy (2004a, b).

11. See Gagosian (2003). Especially alarming are data indicating a decades-long decline in the salinity crucial to driving the ocean circulation that allows the Gulf Stream to warm New England and Western Europe – see Dickson et al. (2002).

12. Two popular explanations of the underlying mechanisms are Broecker and Denton (1990) and Alley (2004).

13. See Kasting (1998, p. 18).

14. Yes, they could try to preserve their cultures in some now-deserted part of Australia if the xenophobic Australian immigration policy were changed to permit them to enter.

15. I refer to the work done, and stimulated, by Derek Parfit.

16. For the argument that all the plausible allocative principles converge on the same agents in the case of climate change, see Shue (1999). Two splendid recent discussions of the assignment of responsibility are Miller (2001) and Green (2002).

17. On this issue, see Kutz (2000) and Murphy (2000).

18. For the Pentagon's usual worst-case thinking, see Townsend and Harris (2004). Also see Schwartz and Randall (2003).

19. I would myself bet on the corruption explanation, that is, that this administration is under the control of the oil interests out of which Bush and Cheney come (and to which they will likely return). The Bush Administration continues to cover up scientific data on climate change; see Revkin and Seelye (2003).

20. See Kasting (1998).

21. The double standard involved in ignoring promising energy technology while throwing billions at unpromising military technology is astounding! And profoundly irrational.

22. Yet warnings accessible to the general public abound. See, for example, Regalado (2003).

23. See Eckersley (2004).

24. I am not endorsing the Kyoto Protocol, precisely because it needlessly pits today's poor against tomorrow's poor in order to avoid inconveniencing the rich at any time – see Shue (2004). But the current Bush administration not only high-handedly rejected the protocol but sneered at the process of trying to move beyond it, preferring what has become its customary unilateralism. For a general overview of the situation regarding the Kyoto Protocol, see Grubb et al. (2003). For recent empirical findings on effects on the U.S., see Parmesan and Galbraith (2004).

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IT'S NOT *MY* FAULT: GLOBAL WARMING AND INDIVIDUAL MORAL OBLIGATIONS

Walter Sinnott-Armstrong

Previous chapters in this volume have focused on scientific research, economic projections, and government policies. However, even if scientists establish that global warming is occurring, even if economists confirm that its costs will be staggering, and even if political theorists agree that governments must do something about it, it is still not clear what moral obligations regarding global warming devolve upon individuals like you and me. That is the question to be addressed in this essay.

1. ASSUMPTIONS

To make the issue stark, let us begin with a few assumptions. I believe that these assumptions are probably roughly accurate, but none is certain, and I will not try to justify them here. Instead, I will simply take them for granted for the sake of argument.[1]

First, global warming has begun and is likely to increase over the next century. We cannot be sure exactly how much or how fast, but hot times are coming.[2]

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Second, a significant amount of global warming is due to human activities. The main culprit is fossil fuels.

Third, global warming will create serious problems for many people over the long term by causing climate changes, including violent storms, floods from sea level rises, droughts, heat waves, and so on. Millions of people will probably be displaced or die.

Fourth, the poor will be hurt most of all. The rich countries are causing most of the global warming, but they will be able to adapt to climate changes more easily.[3] Poor countries that are close to sea level might be devastated.

Fifth, governments, especially the biggest and richest ones, are able to mitigate global warming.[4] They can impose limits on emissions. They can require or give incentives for increased energy efficiency. They can stop deforestation and fund reforestation. They can develop ways to sequester carbon dioxide in oceans or underground. These steps will help, but the only long-run solution lies in alternatives to fossil fuels. These alternatives can be found soon if governments start massive research projects now.[5]

Sixth, it is too late to stop global warming. Because there is so much carbon dioxide in the atmosphere already, because carbon dioxide remains in the atmosphere for so long, and because we will remain dependent on fossil fuels in the near future, governments can slow down global warming or reduce its severity, but they cannot prevent it. Hence, governments need to adapt. They need to build seawalls. They need to reinforce houses that cannot withstand storms. They need to move populations from low-lying areas.[6]

Seventh, these steps will be costly. Increased energy efficiency can reduce expenses, adaptation will create some jobs, and money will be made in the research and production of alternatives to fossil fuels. Still, any steps that mitigate or adapt to global warming will slow down our economies, at least in the short run.[7] That will hurt many people, especially many poor people.

Eighth, despite these costs, the major governments throughout the world still morally ought to take some of these steps. The clearest moral obligation falls on the United States. The United States caused and continues to cause more of the problem than any other country. The United States can spend more resources on a solution without sacrificing basic necessities. This country has the scientific expertise to solve technical problems. Other countries follow its lead (sometimes!). So the United States has a special moral obligation to help mitigate and adapt to global warming.[8]

2. THE PROBLEM

Even assuming all of this, it is still not clear what I as an individual morally ought to do about global warming. That issue is not as simple as many people assume. I want to bring out some of its complications.

It should be clear from the start that individual moral obligations do not always follow directly from collective moral obligations. The fact that your government morally ought to do something does not prove that you ought to do it, even if your government fails. Suppose that a bridge is dangerous because so much traffic has gone over it and continues to go over it. The government has a moral obligation to make the bridge safe. If the government fails to do its duty, it does not follow that I personally have a moral obligation to fix the bridge. It does not even follow that I have a moral obligation to fill in one crack in the bridge, even if the bridge would be fixed if everyone filled in one crack, even if I drove over the bridge many times, and even if I still drive over it every day. Fixing the bridge is the government's job, not mine. While I ought to encourage the government to fulfill its obligations,[9] I do not have to take on those obligations myself.

All that this shows is that government obligations do not always imply parallel individual obligations. Still, maybe sometimes they do. My government has a moral obligation to teach arithmetic to the children in my town, including my own children. If the government fails in this obligation, then I do take on a moral obligation to teach arithmetic to my children.[10] Thus, when the government fails in its obligations, sometimes I have to fill in, and sometimes I do not.

What about global warming? If the government fails to do anything about global warming, what am I supposed to do about it? There are lots of ways for me as an individual to fight global warming. I can protest against bad government policies and vote for candidates who will make the government fulfill its moral obligations. I can support private organizations that fight global warming, such as the Pew Foundation,[11] or boycott companies that contribute too much to global warming, such as most oil companies. Each of these cases is interesting, but they all differ. To simplify our discussion, we need to pick one act as our focus.

My example will be wasteful driving. Some people drive to their jobs or to the store because they have no other reasonable way to work and eat. I want to avoid issues about whether these goals justify driving, so I will focus on a case where nothing so important is gained. I will consider driving for fun on a beautiful Sunday afternoon. My drive is not necessary to cure depression

or calm aggressive impulses. All that is gained is pleasure: Ah, the feel of wind in your hair! The views! How spectacular! Of course, you could drive a fuel-efficient hybrid car. But fuel-efficient cars have less "get up and go." So let us consider a gas-guzzling sport utility vehicle. Ah, the feeling of power! The excitement! Maybe you do not like to go for drives in sport utility vehicles on sunny Sunday afternoons, but many people do.

Do we have a moral obligation not to drive in such circumstances? This question concerns driving, not buying cars. To make this clear, let us assume that I borrow the gas-guzzler from a friend. This question is also not about legal obligations. So let us assume that it is perfectly legal to go for such drives. Perhaps it ought to be illegal, but it is not. Note also that my question is not about what would be best. Maybe it would be better, even morally better, for me not to drive a gas-guzzler just for fun. But that is not the issue I want to address here. My question is whether I have a moral obligation not to drive a gas-guzzler just for fun on this particular sunny Sunday afternoon.

One final complication must be removed. I am interested in global warming, but there might be other moral reasons not to drive unnecessarily. I risk causing an accident, since I am not a perfect driver. I also will likely spew exhaust into the breathing space of pedestrians, bicyclists, or animals on the side of the road as I drive by. Perhaps these harms and risks give me a moral obligation not to go for my joyride. That is not clear. After all, these reasons also apply if I drive the most efficient car available, and even if I am driving to work with no other way to keep my job. Indeed, I might scare or injure bystanders even if my car gave off no greenhouse gases or pollution. In any case, I want to focus on global warming. So my real question is whether the facts about global warming give me any moral obligation not to drive a gas-guzzler just for fun on this sunny Sunday afternoon.

I admit that I am inclined to answer, "Yes." To me, global warming does seem to make such wasteful driving morally wrong.

Still, I do not feel confident in this judgment. I know that other people disagree (even though they are also concerned about the environment). I would probably have different moral intuitions about this case if I had been raised differently or if I now lived in a different culture. My moral intuition might be distorted by overgeneralization from the other cases where I think that other entities (large governments) do have moral obligations to fight global warming. I also worry that my moral intuition might be distorted by my desire to avoid conflicts with my environmentalist friends.[12] The issue of global warming generates strong emotions because of its political implications and because of how scary its effects are. It is also a peculiarly modern

case, especially because it operates on a much grander scale than my moral intuitions evolved to handle long ago when acts did not have such long-term effects on future generations (or at least people were not aware of such effects). In such circumstances, I doubt that we are justified in trusting our moral intuitions alone. We need some kind of confirmation.[13]

One way to confirm the truth of my moral intuitions would be to derive them from a general moral principle. A principle could tell us why wasteful driving is morally wrong, so we would not have to depend on bare assertion. And a principle might be supported by more trustworthy moral beliefs. The problem is: which principle?

3. ACTUAL ACT PRINCIPLES

One plausible principle refers to causing harm. If one person had to inhale all of the exhaust from my car, this would harm him and give me a moral obligation not to drive my car just for fun. Such cases suggest:

The harm principle: We have a moral obligation not to perform an act that causes harm to others.

This principle implies that I have a moral obligation not to drive my gas-guzzler just for fun *if* such driving causes harm.

The problem is that such driving does not cause harm in normal cases. If one person were in a position to inhale all of my exhaust, then he would get sick if I did drive, and he would not get sick if I did not drive (under normal circumstances). In contrast, global warming will still occur even if I do not drive just for fun. Moreover, even if I do drive a gas-guzzler just for fun for a long time, global warming will not occur unless lots of other people also expel greenhouse gases. So my individual act is neither necessary nor sufficient for global warming.

There are, admittedly, special circumstances in which an act causes harm without being either necessary or sufficient for that harm. Imagine that it takes three people to push a car off a cliff with a passenger locked inside, and five people are already pushing. If I join and help them push, then my act of pushing is neither necessary nor sufficient to make the car go off the cliff. Nonetheless, my act of pushing is a cause (or part of the cause) of the harm to the passenger. Why? Because I intend to cause harm to the passenger, and because my act is unusual. When I intend a harm to occur, my intention provides a reason to pick my act out of all the other background circumstances and identify it as a cause. Similarly, when my act is unusual in

the sense that most people would not act that way, that also provides a reason to pick out my act and call it a cause.

Why does it matter what is usual? Compare matches. For a match to light up, we need to strike it so as to create friction. There also has to be oxygen. We do not call the oxygen the cause of the fire, since oxygen is usually present. Instead, we say that the friction causes the match to light, since it is unusual for that friction to occur. It happens only once in the life of each match. Thus, what is usual affects ascriptions of causation even in purely physical cases.

In moral cases, there are additional reasons not to call something a cause when it is usual. Labeling an act a cause of harm and, on this basis, holding its agent responsible for that harm by blaming the agent or condemning his act is normally counterproductive when that agent is acting no worse than most other people. If people who are doing no worse than average are condemned, then people who are doing much worse than average will suspect that they will still be subject to condemnation even if they start doing better, and even if they improve enough to bring themselves up to the average. We should distribute blame (and praise) so as to give incentives for the worst offenders to get better. The most efficient and effective way to do this is to reserve our condemnation for those who are well below average. This means that we should not hold people responsible for harms by calling their acts causes of harms when their acts are not at all unusual, assuming that they did not intend the harm.

The application to global warming should be clear. It is not unusual to go for joyrides. Such drivers do not intend any harm. Hence, we should not see my act of driving on a sunny Sunday afternoon as a cause of global warming or its harms.

Another argument leads to the same conclusion: the harms of global warming result from the massive quantities of greenhouse gases in the atmosphere. Greenhouse gases (such as carbon dioxide and water vapor) are perfectly fine in small quantities. They help plants grow. The problem emerges only when there is too much of them. But my joyride by itself does not cause the massive quantities that are harmful.

Contrast someone who pours cyanide poison into a river. Later someone drinking from the river downstream ingests some molecules of the poison. Those molecules cause the person to get ill and die. This is very different from the causal chain in global warming, because no particular molecules from my car cause global warming in the direct way that particular molecules of the poison do cause the drinker's death. Global warming is more like a river that is going to flood downstream because of torrential rains. I pour a quart of water into the river upstream (maybe just because I do not want to carry it).

My act of pouring the quart into the river is not a cause of the flood. Analogously, my act of driving for fun is not a cause of global warming.

Contrast also another large-scale moral problem: famine relief. Some people say that I have no moral obligation to contribute to famine relief because the famine will continue and people will die whether or not I donate my money to a relief agency. However, I could help a certain individual if I gave my donation directly to that individual. In contrast, if I refrain from driving for fun on this one Sunday, there is no individual who will be helped in the least.[14] I cannot help anyone by depriving myself of this joyride.

The point becomes clearer if we distinguish global warming from climate change. You might think that my driving on Sunday raises the temperature of the globe by an infinitesimal amount. I doubt that, but, even if it does, my exhaust on that Sunday does not cause any climate change at all. No storms or floods or droughts or heat waves can be traced to my individual act of driving. It is these climate changes that cause harms to people. Global warming by itself causes no harm without climate change. Hence, since my individual act of driving on that one Sunday does not cause any climate change, it causes no harm to anyone.

The point is not that harms do not occur from global warming. I have already admitted that they do. The point is also not that my exhaust is overkill, like poisoning someone who is already dying from poison. My exhaust is not sufficient for the harms of global warming, and I do not intend those harms. Nor is it the point that the harms from global warming occur much later in time. If I place a time bomb in a building, I can cause harm many years later. And the point is not that the harm I cause is imperceptible. I admit that some harms can be imperceptible because they are too small or for other reasons.[15] Instead, the point is simply that my individual joyride does not cause global warming, climate change, or any of their resulting harms, at least directly.

Admittedly, my acts can lead to other acts by me or by other people. Maybe one case of wasteful driving creates a bad habit that will lead me to do it again and again. Or maybe a lot of other people look up to me and would follow my example of wasteful driving. Or maybe my wasteful driving will undermine my commitment to environmentalism and lead me to stop supporting important green causes or to harm the environment in more serious ways. If so, we could apply:

The indirect harm principle: We have a moral obligation not to perform an act that causes harm to others indirectly by causing someone to carry out acts that cause harm to others.

This principle would explain why it is morally wrong to drive a gas-guzzler just for fun if this act led to other harmful acts.

One problem here is that my acts are not that influential. People like to see themselves as more influential than they really are. On a realistic view, however, it is unlikely that anyone would drive wastefully if I did and would not if I did not. Moreover, wasteful driving is not that habit forming. My act of driving this Sunday does not make me drive next Sunday. I do not get addicted. Driving the next Sunday is a separate decision.[16] And my wasteful driving will not undermine my devotion to environmentalism. If my argument in this chapter is correct, then my belief that the government has a moral obligation to fight global warming is perfectly compatible with a belief that I as an individual have no moral obligation not to drive a gas-guzzler for fun. If I keep this compatibility in mind, then my driving my gas-guzzler for fun will not undermine my devotion to the cause of getting the government to do something about global warming.

Besides, the indirect harm principle is misleading. To see why, consider David. David is no environmentalist. He already has a habit of driving his gas-guzzler for fun on Sundays. Nobody likes him, so nobody follows his example. But David still has a moral obligation not to drive his gas-guzzler just for fun this Sunday, and his obligation has the same basis as mine, if I have one. So my moral obligation cannot depend on the factors cited by the indirect harm principle.

The most important problem for supposed indirect harms is the same as for direct harms: even if I create a bad habit and undermine my personal environmentalism and set a bad example that others follow, all of this would still not be enough to cause climate change if other people stopped expelling greenhouse gases. So, as long as I neither intend harm nor do anything unusual, my act cannot cause climate change even if I do create bad habits and followers. The scale of climate change is just too big for me to cause it, even "with a little help from my friends."

Of course, even if I do not cause climate change, I still might seem to contribute to climate change in the sense that I make it worse. If so, another principle applies:

The contribution principle: We have a moral obligation not to make problems worse.

This principle applies if climate change will be worse if I drive than it will be if I do not drive.

The problem with this argument is that my act of driving does not even make climate change worse. Climate change would be just as bad if I did not

drive. The reason is that climate change becomes worse only if more people (and animals) are hurt or if they are hurt worse. There is nothing bad about global warming or climate change in itself if no people (or animals) are harmed. But there is no individual person or animal who will be worse off if I drive than if I do not drive my gas-guzzler just for fun. Global warming and climate change occur on such a massive scale that my individual driving makes no difference to the welfare of anyone.

Some might complain that this is not what they mean by "contribute." All it takes for me to contribute to global warming in their view is for me to expel greenhouse gases into the atmosphere. I do that when I drive, so we can apply:

The gas principle: We have a moral obligation not to expel greenhouse gases into the atmosphere.

If this principle were true, it would explain why I have a moral obligation not to drive my gas-guzzler just for fun.

Unfortunately, it is hard to see any reason to accept this principle. There is nothing immoral about greenhouse gases in themselves when they cause no harm. Greenhouse gases include carbon dioxide and water vapor, which occur naturally and help plants grow. The problem of global warming occurs because of the high quantities of greenhouse gases, not because of anything bad about smaller quantities of the same gases. So it is hard to see why I would have a moral obligation not to expel harmless quantities of greenhouse gases. And that is all I do by myself.

Furthermore, if the gas principle were true, it would be unbelievably restrictive. It implies that I have a moral obligation not to boil water (since water vapor is a greenhouse gas) or to exercise (since I expel carbon dioxide when I breathe heavily). When you think it through, an amazing array of seemingly morally acceptable activities would be ruled out by the gas principle. These implications suggest that we had better look elsewhere for a reason why I have a moral obligation not to drive a gas-guzzler just for fun.

Maybe the reason is risk. It is sometimes morally wrong to create a risk of a harm even if that harm does not occur. I grant that drunk driving is immoral, because it risks harm to others, even if the drunk driver gets home safely without hurting anyone. Thus, we get another principle:

The risk principle: We have a moral obligation not to increase the risk of harms to other people.[17]

The problem here is that global warming is not like drunk driving. When drunk driving causes harm, it is easy to identify the victim of this particular

drunk driver. There is no way to identify any particular victim of my wasteful driving in normal circumstances.

In addition, my earlier point applies here again. If the risk principle were true, it would be unbelievably restrictive. Exercising and boiling water also expel greenhouse gases, so they also increase the risk of global warming if my driving does. This principle implies that almost everything we do violates a moral obligation.

Defenders of such principles sometimes respond by distinguishing significant from insignificant risks or increases in risks. That distinction is problematic, at least here. A risk is called significant when it is too much. But then we need to ask what makes this risk too much when other risks are not too much. The reasons for counting a risk as significant are then the real reasons for thinking that there is a moral obligation not to drive wastefully. So we need to specify those reasons directly instead of hiding them under a waffle-term like "significant."

4. INTERNAL PRINCIPLES

None of the principles discussed so far is both defensible and strong enough to yield a moral obligation not to drive a gas-guzzler just for fun. Maybe we can do better by looking inward.

Kantians claim that the moral status of acts depends on their agents' maxims or "subjective principles of volition"[18] – roughly what we would call motives or intentions or plans. This internal focus is evident in Kant's first formulation of the categorical imperative:

The universalizability principle: We have a moral obligation not to act on any maxim that we cannot will to be a universal law.

The idea is not that universally acting on that maxim would have bad consequences. (We will consider that kind of principle below.) Instead, the claim is that some maxims "cannot even be thought as a universal law of nature without contradiction."[19] However, my maxim when I drive a gas-guzzler just for fun on this sunny Sunday afternoon is simply to have harmless fun. There is no way to derive a contradiction from a universal law that people do or may have harmless fun. Kantians might respond that my maxim is, instead, to expel greenhouse gases. I still see no way to derive a literal contradiction from a universal law that people do or may expel greenhouse gases. There would be bad consequences, but that is not a contradiction, as Kant requires. In any case, my maxim (or intention or motive)

is not to expel greenhouse gases. My goals would be reached completely if I went for my drive and had my fun without expelling any greenhouse gases. This leaves no ground for claiming that my driving violates Kant's first formula of the categorical imperative.

Kant does supply a second formulation, which is really a different principle:

The means principle: We have a moral obligation not to treat any other person as a means only.[20]

It is not clear exactly how to understand this formulation, but the most natural interpretation is that for me to treat someone as a means implies my using harm to that person as part of my plan to achieve my goals. Driving for fun does not do that. I would have just as much fun if nobody were ever harmed by global warming. Harm to others is no part of my plans. So Kant's principle cannot explain why I have a moral obligation not to drive just for fun on this sunny Sunday afternoon.

A similar point applies to a traditional principle that focuses on intention:

The doctrine of double effect: We have a moral obligation not to harm anyone intentionally (either as an end or as a means).

This principle fails to apply to my Sunday driving both because my driving does not cause harm to anyone and because I do not intend harm to anyone. I would succeed in doing everything I intended to do if I enjoyed my drive but magically my car gave off no greenhouse gases and no global warming occurred.

Another inner-directed theory is virtue ethics. This approach focuses on general character traits rather than particular acts or intentions. It is not clear how to derive a principle regarding obligations from virtue ethics, but here is a common attempt:

The virtue principle: We have a moral obligation not to perform an act that expresses a vice or is contrary to virtue.

This principle solves our problem if driving a gas-guzzler expresses a vice, or if no virtuous person would drive a gas-guzzler just for fun.

How can we tell whether this principle applies? How can we tell whether driving a gas-guzzler for fun "expresses a vice"? On the face of it, it expresses a desire for fun. There is nothing vicious about having fun. Having fun becomes vicious only if it is harmful or risky. But I have already responded to the principles of harm and risk. Moreover, driving a gas-guzzler for fun does not always express a vice. If other people did not

produce so much greenhouse gas, I could drive my gas-guzzler just for fun without anyone being harmed by global warming. Then I could do it without being vicious. This situation is not realistic, but it does show that wasteful driving is not essentially vicious or contrary to virtue.

Some will disagree. Maybe your notions of virtue and vice make it essentially vicious to drive wastefully. But why? To apply this principle, we need some antecedent test of when an act expresses a vice. You cannot just say, "I know vice when I see it," because other people look at the same act and do not see vice, just fun. It begs the question to appeal to what you see when others do not see it, and you have no reason to believe that your vision is any clearer than theirs. But that means that this virtue principle cannot be applied without begging the question. We need to find some reason why such driving is vicious. Once we have this reason, we can appeal to it directly as a reason why I have a moral obligation not to drive wastefully. The side step through virtue does not help and only obscures the issue.

Some virtue theorists might respond that life would be better if more people were to focus on general character traits, including green virtues, such as moderation and love of nature.[21] One reason is that it is so hard to determine obligations in particular cases. Another reason is that focusing on particular obligations leaves no way to escape problems like global warming. This might be correct. Maybe we should spend more time thinking about whether we have green virtues rather than about whether we have specific obligations. But that does not show that we do have a moral obligation not to drive gas-guzzlers just for fun. Changing our focus will not bring any moral obligation into existence. There are other important moral issues besides moral obligation, but this does not show that moral obligations are not important as well.

5. COLLECTIVE PRINCIPLES

Maybe our mistake is to focus on individual persons. We could, instead, focus on institutions. One institution is the legal system, so we might adopt.

The ideal law principle: We have a moral obligation not to perform an action if it ought to be illegal.

I already said that the government ought to fight global warming. One way to do so is to make it illegal to drive wastefully or to buy (or sell) inefficient gas-guzzlers. If the government ought to pass such laws, then, even before

such laws are passed, I have a moral obligation not to drive a gas-guzzler just for fun, according to the ideal law principle.

The first weakness in this argument lies in its assumption that wasteful driving or gas-guzzlers ought to be illegal. That is dubious. The enforcement costs of a law against joyrides would be enormous. A law against gas-guzzlers would be easier to enforce, but inducements to efficiency (such as higher taxes on gas and gas-guzzlers, or tax breaks for buying fuel-efficient cars) might accomplish the same goals with less loss of individual freedom. Governments ought to accomplish their goals with less loss of freedom, if they can. Note the "if." I do not claim that these other laws would work as well as an outright prohibition of gas-guzzlers. I do not know. Still, the point is that such alternative laws would not make it illegal (only expensive) to drive a gas-guzzler for fun. If those alternative laws are better than outright prohibitions (because they allow more freedom), then the ideal law principle cannot yield a moral obligation not to drive a gas-guzzler now.

Moreover, the connection between law and morality cannot be so simple. Suppose that the government morally ought to raise taxes on fossil fuels in order to reduce usage and to help pay for adaptation to global warming. It still seems morally permissible for me and for you not to pay that tax now. We do not have any moral obligation to send a check to the government for the amount that we would have to pay if taxes were raised to the ideal level. One reason is that our checks would not help to solve the problem, since others would continue to conduct business as usual. What would help to solve the problem is for the taxes to be increased. Maybe we all have moral obligations to try to get the taxes increased. Still, until they are increased, we as individuals have no moral obligations to abide by the ideal tax law instead of the actual tax law.

Analogously, it is actually legal to buy and drive gas-guzzlers. Maybe these vehicles should be illegal. I am not sure. If gas-guzzlers morally ought to be illegal, then maybe we morally ought to work to get them outlawed. But that still would not show that now, while they are legal, we have a moral obligation not to drive them just for fun on a sunny Sunday afternoon.

Which laws are best depends on side effects of formal institutions, such as enforcement costs and loss of freedom (resulting from the coercion of laws). Maybe we can do better by looking at informal groups.

Different groups involve different relations between members. Orchestras and political parties, for example, plan to do what they do and adjust their actions to other members of the group in order to achieve a common goal. Such groups can be held responsible for their joint acts, even when no

individual alone performs those acts. However, gas-guzzler drivers do not form this kind of group. Gas-guzzler drivers do not share goals, do not make plans together, and do not adjust their acts to each other (at least usually).

There is an abstract set of gas-guzzler drivers, but membership in a set is too arbitrary to create moral responsibility. I am also in a set of all terrorists plus me, but my membership in that abstract set does not make me responsible for the harms that terrorists cause.

The only feature that holds together the group of people who drive gas-guzzlers is simply that they all perform the same kind of act. The fact that so many people carry out acts of that kind does create or worsen global warming. That collective bad effect is supposed to make it morally wrong to perform any act of that kind, according to the following:

The group principle: We have a moral obligation not to perform an action if this action makes us a member of a group whose actions together cause harm.

Why? It begs the question here merely to assume that, if it is bad for everyone in a group to perform acts of a kind, then it is morally wrong for an individual to perform an act of that kind. Besides, this principle is implausible or at least questionable in many cases. Suppose that everyone in an airport is talking loudly. If only a few people were talking, there would be no problem. But the collective effect of so many people talking makes it hard to hear announcements, so some people miss their flights. Suppose, in these circumstances, I say loudly (but not too loudly), "I wish everyone would be quiet." My speech does not seem immoral, since it alone does not harm anyone. Maybe there should be a rule (or law) against such loud speech in this setting (as in a library), but if there is not (as I am assuming), then it does not seem immoral to do what others do, as long as they are going to do it anyway, so the harm is going to occur anyway.[22]

Again, suppose that the president sends everyone (or at least most taxpayers) a check for $600. If all recipients cash their checks, the government deficit will grow, government programs will have to be slashed, and severe economic and social problems will result. You know that enough other people will cash their checks to make these results to a great degree inevitable. You also know that it is perfectly legal to cash your check, although you think it should be illegal, because the checks should not have been issued in the first place. In these circumstances, is it morally wrong for you to cash your check? I doubt it. Your act of cashing your check causes no harm by itself, and you have no intention to cause harm. Your act of

cashing your check does make you a member of a group that collectively causes harm, but that still does not seem to give you a moral obligation not to join the group by cashing your check, since you cannot change what the group does. It might be morally good or ideal to protest by tearing up your check, but it does not seem morally obligatory.

Thus, the group principle fails. Perhaps it might be saved by adding some kind of qualification, but I do not see how.[23]

6. COUNTERFACTUAL PRINCIPLES

Maybe our mistake is to focus on actual circumstances. So let us try some counterfactuals about what would happen in possible worlds that are not actual. Different counterfactuals are used by different versions of rule-consequentialism.[24]

One counterfactual is built into the common question, "What would happen if everybody did that?" This question suggests a principle:

The general action principle: I have a moral obligation not to perform an act when it would be worse for everyone to perform an act of the same kind.[25]

It does seem likely that, if everyone in the world drove a gas-guzzler often enough, global warming would increase intolerably. We would also quickly run out of fossil fuels. The general action principle is, thus, supposed to explain why it is morally wrong to drive a gas-guzzler.

Unfortunately, that popular principle is indefensible. It would be disastrous if every human had no children. But that does not make it morally wrong for a particular individual to choose to have no children. There is no moral obligation to have at least one child.

The reason is that so few people want to remain childless. Most people would not go without children even if they were allowed to. This suggests a different principle:

The general permission principle: I have a moral obligation not to perform an act whenever it would be worse for everyone to be permitted to perform an act of that kind.

This principle seems better because it would not be disastrous for everyone to be permitted to remain childless. This principle is supposed to be able to explain why it is morally wrong to steal (or lie, cheat, rape, or murder), because it would be disastrous for everyone to be permitted to steal (or lie, cheat, rape, or murder) whenever (if ever) they wanted to.

Not quite. An agent is permitted or allowed in the relevant sense when she will not be liable to punishment, condemnation (by others), or feelings of guilt for carrying out the act. It is possible for someone to be permitted in this sense without knowing that she is permitted and, indeed, without anyone knowing that she is permitted. But it would not be disastrous for everyone to be permitted to steal if nobody knew that they were permitted to steal, since then they would still be deterred by fear of punishment, condemnation, or guilt. Similarly for lying, rape, and so on. So the general permission principle cannot quite explain why such acts are morally wrong.

Still, it would be disastrous if everyone knew that they were permitted to steal (or lie, rape, etc.). So we simply need to add one qualification:

The public permission principle: I have a moral obligation not to perform an act whenever it would be worse for everyone to know that everyone is permitted to perform an act of that kind.[26]

Now this principle seems to explain the moral wrongness of many of the acts we take to be morally wrong, since it would be disastrous if everyone knew that everyone was permitted to steal, lie, cheat, and so on.

Unfortunately, this revised principle runs into trouble in other cases. Imagine that 1000 people want to take Flight 38 to Amsterdam on October 13, 2003, but the plane is not large enough to carry that many people. If all 1,000 took that particular flight, then it would crash. But these people are all stupid and stubborn enough that, if they knew that they were all allowed to take the flight, they all would pack themselves in, despite warnings, and the flight would crash. Luckily, this counterfactual does not reflect what actually happens. In the actual world, the airline is not stupid. Since the plane can safely carry only 300 people, the airline sells only 300 tickets and does not allow anyone on the flight without a ticket. If I have a ticket for that flight, then there is nothing morally wrong with me taking the flight along with the other 299 who have tickets. This shows that an act is not always morally wrong when it would (counterfactually) be disastrous for everyone to know that everyone is allowed to do it.[27]

The lesson of this example applies directly to my case of driving a gas-guzzler. Disaster occurs in the airplane case when too many people do what is harmless by itself. Similarly, disaster occurs when too many people burn too much fossil fuel. But that does not make it wrong in either case for one individual to perform an individual act that is harmless by itself. It only creates an obligation on the part of the government (or airline) to pass regulations to keep too many people from acting that way.

Another example brings out another weakness in the public permission principle. Consider open marriage. Max and Minnie get married because each loves the other and values the other person's love. Still, they think of sexual intercourse as a fun activity that they separate from love. After careful discussion before they got married, each happily agreed that each may have sex after marriage with whomever he or she wants. They value honesty, so they did add one condition: every sexual encounter must be reported to the other spouse. As long as they keep no secrets from each other and still love each other, they see no problem with their having sex with other people. They do not broadcast this feature of their marriage, but they do know (after years of experience) that it works for them.

Nonetheless, the society in which Max and Minnie live might be filled with people who are very different from them. If everyone knew that everyone is permitted to have sex during marriage with other people as long as the other spouse is informed and agreed to the arrangement, then various problems would arise. Merely asking a spouse whether he or she would be willing to enter into such an agreement would be enough to create suspicions and doubts in the other spouse's mind that would undermine many marriages or keep many couples from getting married, when they would have gotten or remained happily married if they had not been offered such an agreement. As a result, the society will have less love, fewer stable marriages, and more unhappy children of unnecessary divorce. Things would be much better if everyone believed that such agreements were not permitted in the first place, so they condemned them and felt guilty for even considering them. I think that this result is not unrealistic, but here I am merely postulating these facts in my example.

The point is that, even if other people are like this, so that it would be worse for everyone to know that everyone is permitted to have sex outside of marriage with spousal knowledge and consent, Max and Minnie are not like this, and they know that they are not like this, so it is hard to believe that they as individuals have a moral obligation to abide by a restriction that is justified by other people's dispositions. If Max and Minnie have a joint agreement that works for them, but they keep it secret from others, then there is nothing immoral about them having sex outside of their marriage (whether or not this counts as adultery). If this is correct, then the general permission principle fails again.

As before, the lesson of this example applies directly to my case of driving a gas-guzzler. The reason why Max and Minnie are not immoral is that they have a right to their own private relationship as long as they do not harm others (such as by spreading disease or discord). But I have already argued

that my driving a gas-guzzler on this Sunday afternoon does not cause harm. I seem to have a right to have fun in the way I want as long as I do not hurt anybody else, just like Max and Minnie. So the public permission principle cannot explain why it is morally wrong to drive a gas-guzzler for fun on this sunny Sunday afternoon.[28]

One final counterfactual approach is contractualism, whose most forceful recent proponent is Tim Scanlon.[29] Scanlon proposes:

The contractualist principle: I have a moral obligation not to perform an act whenever it violates a general rule that nobody could reasonably reject as a public rule for governing action in society.

Let us try to apply this principle to the case of Max and Minnie. Consider a general rule against adultery, that is, against voluntary sex between a married person and someone other than his or her spouse, even if the spouse knows and consents. It might seem that Max and Minnie could not reasonably reject this rule as a public social rule, because they want to avoid problems for their own society. If so, Scanlon's principle leads to the same questionable results as the public permission principle. If Scanlon replies that Max and Minnie *can* reasonably reject the anti-adultery rule, then why? The most plausible answer is that it is their own business how they have fun as long as they do not hurt anybody. But this answer is available also to people who drive gas-guzzlers just for fun. So this principle cannot explain why that act is morally wrong.

More generally, the test of what can be *reasonably* rejected depends on moral intuitions. Environmentalists might think it unreasonable to reject a principle that prohibits me from driving my gas-guzzler just for fun, but others will think it reasonable to reject such a principle, because it restricts my freedom to perform an act that harms nobody. The appeal to reasonable rejection itself begs the question in the absence of an account of why such rejection is unreasonable. Environmentalists might be able to specify reasons why it is unreasonable, but then it is those reasons that explain why this act is morally wrong. The framework of reasonable rejection becomes a distracting and unnecessary side step.[30]

7. WHAT IS LEFT?

We are left with no defensible principle to support the claim that I have a moral obligation not to drive a gas-guzzler just for fun. Does this result show that this claim is false? Not necessarily.

Some audiences[31] have suggested that my journey through various principles teaches us that we should not look for general moral principles to back up our moral intuitions. They see my arguments as a "reductio ad absurdum" of principlism, which is the view that moral obligations (or our beliefs in them) depend on principles. Principles are unavailable, so we should focus instead on particular cases, according to the opposing view called particularism.[32]

However, the fact that we cannot find any principle does not show that we do not need one. I already gave my reasons why we need a moral principle to back up our intuitions in this case. This case is controversial, emotional, peculiarly modern, and likely to be distorted by overgeneralization and partiality. These factors suggest that we need confirmation for our moral intuitions at least in this case, even if we do not need any confirmation in other cases.

For such reasons, we seem to need a moral principle, but we have none. This fact still does not show that such wasteful driving is not morally wrong. It only shows that we do not *know* whether it is morally wrong. Our ignorance might be temporary. If someone comes up with a defensible principle that does rule out wasteful driving, then I will be happy to listen and happy if it works. However, until some such principle is found, we cannot claim to know that it is morally wrong to drive a gas-guzzler just for fun.

The demand for a principle in this case does not lead to general moral skepticism. We still might know that acts and omissions that cause harm are morally wrong because of the harm principle. Still, since that principle and others do not apply to my wasteful driving, and since moral intuitions are unreliable in cases like this, we cannot know that my wasteful driving is morally wrong.

This conclusion will still upset many environmentalists. They think that they know that wasteful driving is immoral. They want to be able to condemn those who drive gas-guzzlers just for fun on sunny Sunday afternoons.

My conclusion should not be so disappointing. Even if individuals have no such moral obligations, it is still morally better or morally ideal for individuals not to waste gas. We can and should praise those who save fuel. We can express our personal dislike for wasting gas and for people who do it. We might even be justified in publicly condemning wasteful driving and drivers who waste a lot, in circumstances where such public rebuke is appropriate. Perhaps people who drive wastefully should feel guilty for their acts and ashamed of themselves, at least if they perform such acts regularly; and we should bring up our children so that they will feel these emotions. All of these reactions are available even if we cannot truthfully say that such driving violates a moral *obligation*. And these approaches might be more constructive in the long run than accusing someone of violating a moral obligation.

Moreover, even if individuals have no moral obligations not to waste gas by taking unnecessary Sunday drives just for fun, governments still have moral obligations to fight global warming, because they can make a difference. My fundamental point has been that global warming is such a large problem that it is not individuals who cause it or who need to fix it. Instead, governments need to fix it, and quickly. Finding and implementing a real solution is the task of governments. Environmentalists should focus their efforts on those who are not doing their job rather than on those who take Sunday afternoon drives just for fun.

This focus will also avoid a common mistake. Some environmentalists keep their hands clean by withdrawing into a simple life where they use very little fossil fuels. That is great. I encourage it. But some of these escapees then think that they have done their duty, so they rarely come down out of the hills to work for political candidates who could and would change government policies. This attitude helps nobody. We should not think that we can do enough simply by buying fuel-efficient cars, insulating our houses, and setting up a windmill to make our own electricity. That is all wonderful, but it does little or nothing to stop global warming and also does not fulfill our real moral obligations, which are to get governments to do their job to prevent the disaster of excessive global warming. It is better to enjoy your Sunday driving while working to change the law so as to make it illegal for you to enjoy your Sunday driving.

NOTES

1. For skeptics, see Lomborg (1998, chapter 24) and Singer (1997). A more reliable partial skeptic is Richard S. Lindzen, but his papers are quite technical. If you do not share my bleak view of global warming, treat the rest of this essay as conditional. The issue of how individual moral obligations are related to collective moral obligations is interesting and important in its own right, even if my assumptions about global warming turn out to be inaccurate.
2. See the chapters by Mahlman, Schlesinger, and Weatherly in this volume.
3. See the chapter by Shukla in this volume.
4. See the chapter by Bodansky in this volume.
5. See the chapter by Shue in this volume.
6. See the chapter by Jamieson in this volume.
7. See the chapter by Toman in this volume.
8. See the chapter by Driver in this volume.
9. If I have an obligation to encourage the government to fulfill its obligation, then the government's obligation does impose some obligation on me. Still, I do not have an obligation to do what the government has an obligation to do. In short, I have no parallel moral obligation. That is what is at issue here.

10. I do not seem to have the same moral obligation to teach my neighbors' children when our government fails to teach them. Why not? The natural answer is that I have a special relation to my children that I do not have to their children. I also do not have such a special relation to future people who will be harmed by global warming.
11. See the chapter by Claussen in this volume.
12. Indeed, I am worried about how my environmentalist friends will react to this essay, but I cannot let fear stop me from following where arguments lead.
13. For more on why moral intuitions need confirmation, see Sinnott-Armstrong (2005).
14. Another difference between these cases is that my failure to donate to famine relief is an inaction, whereas my driving is an action. As Bob Fogelin put it in conversation, one is a sin of omission, but the other is a sin of emission. But I assume that omissions can be causes. The real question is whether my measly emissions of greenhouse gases can be causes of global warming.
15. Cf. Parfit (1984, pp. 75–82).
16. If my act this Sunday does not cause me to drive next Sunday, then effects of my driving next Sunday are not consequences of my driving this Sunday. Some still might say that I can affect global warming by driving wastefully many times over the course of years. I doubt this, but I do not need to deny it. The fact that it is morally wrong for me to do all of a hundred acts together does not imply that it is morally wrong for me to do one of those hundred acts. Even if it would be morally wrong for me to pick all of the flowers in a park, it need not be morally wrong for me to pick one flower in that park.
17. The importance of risks in environmental ethics is a recurrent theme in the writings of Kristin Shrader-Frechette.
18. Kant (1785/1959, p. 400, n. 1).
19. *ibid*, 424. According to Kant, a weaker kind of contradiction in the will signals an imperfect duty. However, imperfect duties permit "exception in the interest of inclination" (421), so an imperfect obligation not to drive a gas-guzzler would permit me to drive it this Sunday when I am so inclined. Thus, I assume that a moral obligation not to drive a gas-guzzler for fun on a particular occasion would have to be a perfect obligation in Kant's view.
20. *ibid*, 429. I omit Kant's clause regarding treating others as ends because that clause captures imperfect duties, which are not my concern here (for reasons given in the preceding note).
21. Jamieson (2005)
22. Compare also standing up to see the athletes in a sporting event, when others do so. Such examples obviously involve much less harm than global warming. I use trivial examples to diminish emotional interference. The point is only that such examples share a structure that defenders of the group principle would claim to be sufficient for a moral obligation.
23. Parfit (1984, pp. 67–86) is famous for arguing that an individual act is immoral if it falls in a group of acts that collectively cause harm. To support his claim Parfit uses examples like the Harmless Torturers (p. 80). But torturers intend to cause harm. That's what makes them torturers. Hence, Parfit's cases cannot show anything wrong with wasteful driving, where there is no intention to cause any harm. For criticisms of Parfit's claims, see Jackson (1997).

24. Cf. Sinnott-Armstrong (2003) and Hooker (2003).
25. Cf. Singer (1971).
26. Cf. Gert (2005). Gert does add details that I will not discuss here. For a more complete response, see Sinnott-Armstrong (2002).
27. The point, of course, depends on how you describe the act. It would not be disastrous to allow everyone "with a ticket" to take the flight (as long as there are not too many tickets). What is disastrous is to allow everyone (without qualification) to take the flight. Still, that case shows that it is not always morally wrong to do X when it would be disastrous to allow everyone to do X. To solve these problems, we need to put some limits on the kinds of descriptions that can replace the variable X. But any limit needs to be justified, and it is not at all clear how to justify such limits without begging the question.
28. The examples in the text show why violating a justified public rule is not sufficient for private immorality. It is also not necessary, since it might not be disastrous if all parents were permitted to kill their children, if no parent ever wanted to kill his or her children. The failure of this approach to give a necessary condition is another reason to doubt that it captures the essence of morality.
29. Scanlon (1998).
30. Scanlon's framework still might be useful as a heuristic, for overcoming partiality, as a pedagogical tool, or as a vivid way to display coherence among moral intuitions at different levels. My point is that it cannot be used to justify moral judgments or to show what makes acts morally wrong. For more, see Sinnott-Armstrong (2006, chap. 8).
31. Such as Bill Pollard in Edinburgh.
32. Developed by Dancy (1993, 2004). For criticisms, see Sinnott-Armstrong (1999).

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