EARTH'S FUTURE: TAMING THE CLIMATE
April 22, 2004

Jeffrey D. Sachs, PhD, Columbia University
Welcoming Remarks

Welcome by Jeffrey Sachs

Good morning everybody. I'm Jeff Sachs, the director of the Earth Institute, and it's my enormous pleasure to welcome you to this very important two-day symposium, "Earth's Future: Taming the Climate." This is part of the 250th birthday celebration of Columbia University this year, and we're very honored to be part of that celebration, and particularly honored to be hosting a remarkable array of visiting scholars and leaders on issues of climate change that you're going to be hearing from during these two days.

For those of you who are coming from outside of the field to learn about climate, I think it's fair to say you could not have a better two-day education on this issue. We have speaking in this symposium certainly some of the world's most knowledgeable, most important scientists and most dynamic leaders. The schedule indicated that Governor Pataki would be here this morning. Because of is schedule he has had to rearrange, but will be here tomorrow, so we're really thrilled. We expect to hear an important message from the governor, and President Lee Bollinger would be introducing the governor tomorrow. So there is a slight rearrangement of the program that you'll be hearing about from Mike Purdy, whom I'll introduce in just a moment.

The issue we're going to be discussing in the next two days is of profound significance for all of us, for current society, and especially for the century and generations ahead. It is also a subject not only of profound significance but of truly profound complexity. It's actually hard to think of a public-policy issue that is harder than this one. This is probably the most complicated of the large challenges that we face. As I'll suggest in a moment, maybe not the most intractable, but probably the most complex. It involves issues that are global in scale and science that this enormously multifaceted, and in these two days you're going to be hearing about the complexity and how we might cut through it in a way to face up to the very real challenges that human society faces from this.

Top Ten Challenges of Climate Change

In very brief terms I thought I could give you a bit of the flavor of the complexity, a little bit of a road map of the next couple of days, and why actually as you listen, one shouldn't lose heart either, because despite the complexity you're going to be hearing about some real solutions that can be brought to bear. And so in the spirit of David Letterman I wanted to start with ten reasons why this problem is truly hard, and then a few reasons why it's actually solvable. I'm not going to be the one to exemplify these arguments, you're going to be hearing them in the next couple of days, but perhaps this will help to keep in mind some of the real challenges.

Why is this problem so hard? Why is it fair to say that it's probably the most complicated public-policy challenge we face of this importance in the world?

First, as you'll be hearing shortly, the climate system itself in enormously complex and, as the scientists stress, highly nonlinear. That is, it is subject to enormously change and huge fluctuations, and even large fluctuations from what seem to be relatively small causes perhaps. In other words, high nonlinearity and therefore lots of surprises likely.

Second, human society is extraordinarily complex, and so the social dynamics that we are going to be discussing are themselves subject to abrupt changes, and are also enormously difficult to predict.

Three, climate science is relatively new. The notion of greenhouse gases causing long-term climate change . . . I understand, I may be wrong, but I understand that to be first proposed in detail in 1896. We've had a little over a century of the basic insight, but a lot of the science that you're going to be hearing about is really very, very recent, with huge advances in measurement, observation, and modeling, and huge advances made by the very people that you're going to be listening to in the next two days.

Four, climate-and-society interactions—how the climate affects human society, how humans affect the climate—are still poorly elucidated. We have a two-way interaction. We don't understand very much about it. Part of the problem is the social scientists and the physical scientists have not worked very closely together on these issues up until now, and the Earth Institute is devoted to bringing those two sides of the issue together. But up until now the amount of science that has gone to elucidating climate and society interactions is still much too limited.

Fifth, climate-society interactions are poorly downscaled, meaning that even if we have some global ideas we really don't know what it means for Manhattan, we don't know what it means for the Indonesian archipelago, we don't know what it means for east Africa. And without that local knowledge, the ability to act, to prevent, to motivate, to advocate solutions is limited. We're going to hear about some of the most important early attempts at that kind of downscaling from one of the scientists today, our own Cynthia Rosenzweig.

Sixth, anthropogenic change, that is man-made climate change, is global. It involves multiple actors, about 6.3 billion of them, because everybody is contributing through individual actions to this issue, multiple kinds of actions. We have all played a role in anthropogenic climate change, probably in at least a dozen distinct ways, getting up this morning, coming here through a variety of human actions and especially our interactions with the energy system, and also very complex in terms of market reactions. How the energy markets work—global scale, local scale—is itself a very difficult problem.

Seventh problem is that the costs and benefits of the issues we're going to be discussing are highly differentiated around the globe. Long-term climate change could locally help some places; it could devastate other places. There is a highly differentiated response that we are likely to see, and a highly uncertain one of course at local scale and at global scale.

Eighth problem is that the lead times of the issues we're talking about and the solutions are very long. We're talking about lead times of both effect and interventions that are decadal, if not century-long. We're talking today and tomorrow about remaking an energy system. That is decades long. We're not so good at doing things next week or planning for next month or next year. We're really not so good at planning for the year 2063.

Nine, technological options are still unclear and uncharted. And you are going to hear about some of those options, but there's a huge debate about which kinds of technological approaches could work and which directions we ought to be investing in.

And then tenth on my list is that technological development is itself an enormously complex social enterprise. Technological innovation comes from market forces. It also comes from collective action, from decisions of the Department of Energy to invest, from the National Science Foundation, from the National Oceanographic and Atmospheric Administration, from global enterprises, from World Bank decisions, and so forth. An enormously complex set of actors will play a role in whether we do make the investments in technology and choose well in those investments to find solutions so that fifty years from now we are on a path that is sensible from the point of global society.

Reasons the Problems Are Solvable

Now it's also true that despite these ten factors, one could parse the list in different ways. That makes this issue about as complicated as any that the world faces. There are also reasons why this is solvable, but I could only think of four of them. So it is a really tough issue.

First, and for me it sounds a little ironic, but I think it's true, this issue is promising first because it's essentially a new issue. This is not an issue that human society has wracked its brains on for centuries. This is a new challenge, barely twenty years old in terms of real public awareness, and twenty years old in terms of real commitment to research and development of strategies to mitigate or to obviate or to adjust to this kind of climate change. And that's good because human ingenuity is incredibly important. We haven't put our minds to this one yet. And I think that that is enormously important because there are not only unforeseen problems but unforeseen solutions that are lurking out there.

Second, this is a problem with many promising technologies, and you're going to hear about some of the exciting ones, such as carbon capture and disposal. Engineers for the last two centuries have worried almost not at all about what happens to the carbon that comes out of a power plant because nobody cared and no engineer basically in the world was tasked with solving the problem of limiting the carbon emissions from burning a heap of coal or burning natural gas or oil in a thermal plant. And so we now know there are technological approaches, they just haven't been investigated very far. Individual companies have lacked the incentive, and our government has only, only, only just begun to look at some of these options.

Third, there is growing stakeholder leadership. We see that all over our society and globally. So this is not an issue where we're the only ones thinking of it, thank goodness. Scientists are in the lead. Wally Broecker's Abrupt Climate Change group, which met here last week, has engaged some of the best thinkers in the world. The Intergovernmental Panel on Climate Change, which is a project of the United Nations system—the much maligned and utterly and essentially valuable United Nations system, I might add, that has for over a decade promoted the best global consensus building around these issues. Politicians, like Governor Pataki, who we'll hear tomorrow, are getting seriously engaged. Governor Schwarzenegger yesterday announced the intention to roll out a massive program of hydrogen transport in California during the next decade. Senator McCain [and] Senator Lieberman sponsored legislation that almost won a majority in the Senate. So we have political leadership that we didn't see before.

Companies, major companies, are getting interested in this issue. British Petroleum's logo was "Beyond Petroleum." Swiss Re, the insurance industry, which knows it faces tens of billions of dollars per year of potential claims from this, is very interested, and dozens and dozens of others that we've been in contact with. And finally civil society in many ways. And we're going to hear about one of the most important foundations that's charged to the lead on this, The Pew Foundation, which has already helped to galvanize a kind of consensus in unexpected quarters.

And the fourth reason for optimism is that incentives can make a huge difference once we get our minds around what we want to create the incentives for. But market approaches to this issue could be enormously powerful—arbon taxes, cap-and-trade schemes, subsidies for carbon sequestration. In other words, even though there are billions of actors and tens of billions of decisions that would need to be coordinated for a solution, we have some pretty powerful ways to harness behavior in effective ways once we decide collectively that it's in our interest to do so.

Well this is just a little bit of a tidbit of what lies ahead in the next two days. Now we're going to hear about the substance of those issues. Today really is to define the problem, define what we know about the climate system and possible solutions. Tomorrow is devoted very heavily to how we're going to get from here to there, how we're going to get to viable and sustainable approaches during the twenty-first century.

April 22, 2004

G. Michael Purdy, PhD, Columbia University
Introduction to Day 1

Introduction by Jeffrey Sachs

Jeffrey Sachs: To lead us off I'd like to introduce not only our first speaker but our host and organizer of this whole conference, the director of Lamont-Doherty Earth Observatory and your host for these two days, Dr. Michael Purdy, who is director of LDEO. Lamont-Doherty Earth Observatory is our great bulwark of the overall Earth Institute. It is by far the largest unit and the long-established and great scientific center for the study of Earth processes at Columbia University. Mike Purdy came to Columbia in 2000 as the director, and we're all thrilled with that. He is a graduate, a PhD in marine geophysics from Cambridge University, Cambridge, UK, and after receiving his PhD, he worked and then helped to lead Woods Hole Oceanographic Institution for the next twenty years. He was a scholar there, a researcher in ocean geochemistry, ocean seismology, and then became the director of the Department of Geology and Geophysics at Woods Hole Oceanographic Institution.

In 1995 Mike went from Woods Hole to the government to take up the directorship of the Division of Ocean Sciences at the National Science Foundation, where he was in the lead for the government in deciding on priorities and very effectively mobilizing resources to address critical issues of ocean science, including ocean-atmosphere interactions and the long-term climate. And then Columbia University was absolutely thrilled to be able to lure him from the NSF leadership position to the directorship of Lamont-Doherty in the year 2000. So it's a great pleasure to introduce Mike to you.

The Importance of Climate Change

G. Michael Purdy: Good morning, everyone. It's Earth Day today, very appropriate day to begin the third of the academic symposia that have been organized to celebrate Columbia's 250th. It took fiendishly clever planning to ensure that these two events occurred on the same day, but we were successful.

As Jeff said I'm director of Lamont-Doherty Earth Observatory here, and along with John Mutter I've led a small planning committee that's put together this symposium, and we've been helped substantially in this by colleagues Geoff Heal, Klaus Lackner, Roberto Lenton, who my personal thanks are due to all these good colleagues for the great help that they've given.

Our title is "Earth's Future: Taming the Climate." Intentionally this is a provocative set of words because we intend this symposium to be provocative, not for reasons of empty sensationalism but for sound reasons of social responsibility. The impacts that the ever-changing climate will have on our planet's inhabitants does not receive attention, or more importantly the action on a scale that is commensurate with the magnitude of the impacts. Decision makers in federal and local governments in this nation and others around the world do not place upon this issue the priority it deserves. In order to change that demonstrable fact, we need to understand why that is, what is limiting the use of the vast intellect and capability embodied in the human race from moving forward in a timely way to respond to the inevitability of climate change?

The problem has not been ignored, of course it has not. In our audience today and among the symposium's panelists are many of the world's leading climate scientists, economists, and policy makers who have contributed in major ways to the body of knowledge that exists today. But it is not our intention at this symposium to review the state of that knowledge, it's been done many times before, it's not the intention to plan new research paths. Rather it is to ask, Why is it that we are doing so little about it? The clear goal in tackling this question is to provide insights into how the roadblocks to progress can be surmounted or avoided.

The symposium title, like many great titles, contains a colon that appropriately provides two important themes. *The Earth's future*. There are few factors short of the catastrophic nuclear holocaust or major bolide impact that will more clearly and directly determine the future of our planet than will the changing climate. This is not conjecture or fantasy; you'll hear from our speakers and panelists today the meticulously verified evidence that establishes the magnitude of the shifts in climatic conditions experienced by our Earth. The climate will continue to change. We know this because we know that throughout Earth's history our climate has never been stable. Natural variability of climate over a few years is most commonly exemplified by the El Niño phenomenon. The most dramatic shifts are exemplified by the ice ages, of course, and recent research over the past decade has revealed a history of abrupt changes that can occur in time periods as short as a decade.

But added to this mix is a dangerous new forcing factor, the full impact of which is only very poorly understood, and that is the substantial increase in the carbon-dioxide content of our atmosphere due to the burning of fossil fuels, the fossil fuels that have energized our industrial revolution.

Actions Needed to Tame the Climate Beast

As was noted in my introduction, I have the privilege to be the director of Lamont-Doherty Earth Observatory. Beginning in the 1960s, we have been at the forefront of quantitative basic research on climate. The pioneer who brought us to that position of leadership is the legendary Wally Broecker, who appropriately is identified as the Columbian ahead of his time on the program for this symposium.

Wally has a compelling story that he may tell you later this morning that metaphorically portrays the climate system as an angry beast that is being harassed and annoyed by humankind's mindless addition of greenhouse gases to the atmosphere. This angry beast metaphor is excellent and should be considered seriously. This analogy accurately represents the climate as a profoundly powerful force that can respond destructively in unpredictable ways if inappropriate stimuli are applied. This is the source of the second phrase in our symposium title, *taming the climate*. We need to learn how to tame Wally's angry beast. This will require skill and persistence, and it will require a wide mix of approaches. A simple whip will certainly not do.

But leaving the metaphor behind before I destroy its elegant simplicity, the point here is that learning to protect ourselves from climate change involves a wide range of activities. We need to learn to adapt, changing the way we live, perhaps changing where we live. We must leave to mitigate against the effects of change in a wide range of human endeavors, from the control of the spreading of disease to the impacts of sea-level change. And yes, we will have to face up to the scary word of *control*. The reality is that we are meddling with the climate system today, but we are doing so wearing a blindfold.

We must bring this question of the management of our planet to the forefront. We must engage in a rigorous debate about the types of actions that humankind can take to ensure that its environment remains capable of supporting its population. And this is not science fiction. For example, you will hear over the next two days about mature and practical concepts for the removal of carbon dioxide from the atmosphere, an action that many believe is essential to stop the inevitable buildup of greenhouse gases resulting from the increased fossil-fuel usage that is required for the underdeveloped nations to reach the parity that they deserve.

And a central theme that will dominate most of our deliberations here will be the clear reality that the solutions to these awesome problems do not lie only in the physical sciences, nor only in environmental engineering. Vast economic resources are going to be needed to approach solutions, new policies at both the national and international levels will have to be crafted with a formidable degree of foresight.

Humankind must challenge itself to learn how to make decisions the benefit from which may not be evident for generations. Are we capable of that? We need to talk about this. Climate science and climate engineering are not enough. Practical ideas for progress must be embedded in well-thought-out economic and political-science agendas that recognize the realities of human behavior.

So these are the things, these modest topics that we're going to talk about for the next couple of days. And then towards the end we are going to ask, What is stopping us from taking action? With all this knowledge of the profound impacts why are we not doing more to tame the mighty beast? What are the limiting factors? Is it the science and inadequate understanding of the natural system that disallows action? Is it the engineering? Or does it simply cost too much? Or is it an inability to make the tough decisions to reach the complex international agreements? Undoubtedly of course all these factors play an essential role, but it will be the charge to our concluding panel to use their solemn and like wisdom to probe these questions and try to identify the key roadblocks to progress.

The Event Agenda

But I've said enough here. I hope that I've convinced you that we're not running a piece of scripted theater. Our goal is to stimulate the complex and controversial debate that is essential to progress. We must bring the tough questions into the open and challenge our leaders to respond to the results of wisdom. We're trying something new here, so our deliberations may not be smooth or linear. We will undoubtedly follow a few tangents on our way forward, but I'm confident that our panel chairs will maintain the degree of focus necessary to assure progress.

Let me speedily review the agenda. The symposium's organized around five panels and four keynote speakers. The topics for the five panels are listed in your programs. They will each have an hour and a half during which to deliberate in the form of both presentations from the panel members and discussion, and I request that each panel chair try desperately to reserve five or ten minutes at the end of their sessions to entertain questions from the floor of the symposium. Microphones are provided in the aisles to facilitate this. It's essential that we use the microphones please as the symposium is being broadcast over the Internet, so this also is formal notification to anyone who speaks here that your words will be heard the world over. And also for the same reason I would ask everyone to turn off the ringers on their cell phones, so we're not transmitting cell phone rings over the Internet either. I will facilitate the questioning from the floor and do my best to keep us on time. Tomorrow this role will be taken on by my cochair, John Mutter.

The panels will by reviewing the basics of climate change science and progress through considerations of adaptation and mitigation issues, and in the end tackle the difficult question of what is limiting our ability to act. The panels are anchored by a set of four keynote speakers. Tomorrow we will hear from Eileen Claussen of the Pew Center on Global Climate Change at 9 a.m. As you've heard there's been a change in the schedule. The governor of the State of New York, George Pataki, will speak tomorrow immediately after lunch, at 1 p.m. He'll be introduced by the University president Lee Bollinger. And finally to wrap up the symposium Jeff Sachs will speak at 3:15 and provide a succinct overview of defined key steps for the way forward.

April 22, 2004

Michael McElroy, PhD, Harvard University
Earth's Changing Climate: Past, Present and Future

Introduction by G. Michael Purdy

G. Michael Purdy: Now it's my privilege to introduce our first keynote speaker, Michael McElroy of Harvard University. To anyone familiar with climate science Professor McElroy needs no introduction. He was the founding chair of the Department of Earth and Environmental Sciences at Harvard, as well as its first director of the Interdisciplinary Center for the Environment. He's a world leader in the study of the effects of human activity on the integrity of the global environment. He is uniquely well qualified to open our symposium for us this morning. His keynote presentation is entitled "Earth's Changing Climate: Past, Present and Future." Ladies and gentlemen, Professor Michael McElroy.

Changes in Atmospheric Carbon Dioxide

Michael McElroy: I have to say this is a formidable task. Mike Purdy asked me to speak to this group and to provide in thirty minutes or so a complete summary of what we know about climate, past, present, and future, and not to leave out any of the significant contributions made by many in this audience.

Let me tell you a little bit about what I'm hoping to do in the next thirty minutes or so. I want to first of all talk about what we understand about the changing composition of the atmosphere, so I'll talk about the information we have on changes in carbon dioxide, the most important of the greenhouse gases. I'll show you and talk about the changes that we see in methane, which is the second most important. And I'll show you nitrous oxide, another important change that's taking place. And then I'm going to switch attention and look at the climate record itself, what changes are taking place, what is our understanding of those changes, and I'll make some comments which will be perhaps mildly critical about the interpretation placed on our level of certainty about what is causing the obvious recent climate changes that have taken place. And then finally I'd like to offer some personal comments on where I see the sensitivities of the climate system to really lie, what are the changes that we really have to watch very carefully if we're going to chart a wise course to address this problem.

So if I can figure out how to use this technology let me begin with this slide, which summarizes the changes in carbon dioxide observed over the past thousand years. And the wonderful record that we have from ice cores has played a critical role, it seems to me, in giving us this historical sense of the changes that are taking place, back as far as 450,000 years before present. But over the last thousand years, you see the changes in CO_2 that occurred most recently, beginning in about 1700–1750 A.D., CO_2 begins to rise and it begins to rise extremely rapidly. Now today we're up at 370 parts per million and surely going to go much higher in the near future.

The changes in CO_2 over the past 450,000 years, also very interesting from the Vostok record, and what you see here is that during the colder periods of the planet's history carbon-dioxide levels were down around 190 parts per million, and during the warmer periods they were up about 270, 280, 290 parts per million, so over the past 450,000 years, as best we can tell, we're in new territory. The CO_2 levels are now higher than they've been at any time over this period of almost half a million years.

Now this is an interesting story also. There's a very interesting paper by Bill Ruderman (formerly at Columbia) recently, which suggests that the human influence occurred much earlier than people basically currently think. In other words, the human influence doesn't simply date from the industrial revolution, but it goes back to the beginning of agriculture. And it's not only the impact of deforestation associated with clearance of land for agricultural purposes, but also, I think even more important perhaps, the use of trees as a feed stock for metal smelting in this early period. Now the beginning of modern agriculture dates from about 11,000 years before present, and this chart is showing that the CO_2 level as it comes out of the last ice age begins to rise at about 8,000 years BP. Now coincident with that rise is a drop in the value of del ^{13}C. So the carbon in the atmosphere is becoming lighter at this period, and the simple interpretation of this is that that increase in CO_2 is caused in significant measure by release of biospheric carbon, isotopically light biospheric carbon.

Atmospheric Methane and Nitrous Oxide

Switching attention now to methane, the concentration of methane has also risen extremely rapidly over the past 250 years. You see it's relatively flat from 1,000 years A.D. to about again 1750, at a value of about 600, 700 ppb in this case. Where now up at 1800 ppb, and with an uncertain future in terms of what's going to happen to methane in the next few years. The summary of the changes in methane that have occurred since 1983, this has been much interpreted, as an indication that maybe the rise in methane is over. You can see that the growth rate has slowed down in the '90s, and the growth rate is specifically indicated in the bottom part of this figure.

Now we have a paper in press at the moment, James Huang, a former student is the primary author of this paper, which has interpreted these data and shows that you can actually do a pretty good job of interpreting the trend in methane over this period, the slowdown attributable largely to the fact that the production of methane from cattle in particular is asymptotic. The number of cattle in the world, believe it or not, is sort of slacking off, the growth rate in the number of cattle is slowing down. And so also is production of rice, or at least the land devoted to rice, which is the second significant source of methane. However, the bad news is that this is not likely to continue because the source that is not kicking in is the source associated with the growth in the natural gas industry, and so I don't think that one can take for granted that methane has reached an asymptote and is going to stay flat. More likely it's going to resume its upward trend, with the possibility that that may be even more rapid for reasons that I'll come back to in a little while.

I might also comment that in the analysis that we've been doing on methane, there is beginning to be a case to argue that the concentrations of OH, the primary sink from methane, may be overestimated in current models. In other words, the lifetime of methane may be a little longer than the literature currently suggests. What's the implication of that? Well the implication of that is that if the lifetime of methane is longer than the greenhouse gas, forcing potential of methane will go up, so methane may become a more important radiate of forcing of the climate system than we currently believe.

The variations in methane over the past ice age are also very intriguing over the past 110,000 years. And what's particularly intriguing here, the methane date is indicated in the lower of these various panels. The upper panel is an indication of the temperature as recorded by Delo and team. You'll notice over this generally cold period from 110,000 years to roughly 10,000 years is that the methane concentrations don't stay constant. It doesn't simply go down to a low value and stay there; it flickers, and the climate system itself flickers. And these numbers, these interstadial numbers, indicate some of those very significant flickers. And you can also see that some of the increases in methane, which are generally coincident with the onset of a warming event, are extremely rapid in time. In fact, if you look at the one at about 85,000 years BP, that increase in methane is on a rate basis comparable to the increase that we've seen over the past 250 years; it's a very rapid rate of increase. And the flickering of the climate system I'll come back to in a little while. In particular I want to offer some comments on perhaps some new thoughts on how the climate system in these longer timescales is really controlled.

Carbon dioxide is produced by fossil-fuel burning, by deforestation. Methane is produced by cattle, by rice-paddy fields in terms of anthropogenic effects, natural wetlands also making a contribution. Nitrous oxide is the third important greenhouse gas, and this is a really intriguing problem because the rise in nitrous oxide is also pretty dramatic in recent years, and nitrous oxide is not produced significantly by burning fossil fuel.

The primary source of nitrous oxide is microbial oxidation or reduction of nitrogen compounds. And so the putative contributions here come from agriculture, from chemical fertilizer applied in agricultural systems, and most importantly, in my opinion, from the disposal of human and animal waste. So that increase is basically tied to the fact that our world population is increasing and that we also have an increasing population of ruminants. Nitrous oxide is not only important as a greenhouse gas, it also plays a very critical role in controlling stratospheric ozone.

Fossil Fuels and Atmospheric CO_2

Now a few words about our understanding of CO_2. One of the really critical recent developments in this field of trying to understand what is responsible for the trends that you observe in CO_2 comes from Ralph Keeling, the son of Dave Keeling. And where Dave Keeling spent his life making very precise measurements of CO_2, giving us this incredibly valuable record that goes back to 1958, his son Ralph picked up the same challenge and he said, "Well, if my father can measure CO_2, I'll measure oxygen. And with the combination of oxygen and CO_2, you actually have a very important additional lever on understanding what's going on."

This chart is intended to illustrate how that works. If you imagine starting at some time at point A, and then you release over some period, the analysis that I did here was for a three-year period in the early 1990s, you release a certain amount of CO_2 by burning fossil fuel. Well, you can immediate calculate that that amount of fossil fuel will provide a source of CO_2 that is estimable, and it will also consume some oxygen. So you can estimate that CO_2 level will go up by a predictable amount, and the oxygen will go down. Now the ocean plays an important role in taking up CO_2, but since oxygen is not particularly soluble, ocean uptake doesn't have any significant effect on O_2. So the role of the ocean is to move you back in a sort of horizontal direction. And suppose the actual observation point three years later from point A is point D, you have to get to point D, and the only way you can get there is by following the appropriate ratio of oxygen to CO_2 associated with the biosphere. So this is a really neat technique, and Ralph Keeling's incredible achievement was to make oxygen measurements which were so precise that you could actually apply this methodology.

Now this is a summary of oxygen and CO_2 measurements for the period of the 1990s, and what you see over this decade of the '90s is that, okay, CO_2 levels went up, oxygen levels went down. And if you follow this simple analysis that I'm suggesting, you have to invoke not only an uptake of CO_2 by the ocean, but also a net sink of CO_2 by the biosphere. So the global biosphere is currently, at least over the period of the '90s, represents a net sink for atmospheric CO_2.

This is a paper by David Keeling and associates, which is a very interesting paper analyzing all of the CO_2 measurements back to 1958. And what he did in this upper chart was to say okay, how can I fit the . . . his assumption was that primary contribution to the increase in CO_2 was fossil-fuel use. Then he said, "Let's now estimate what fraction of the CO_2 that you add to the atmosphere stays in the atmosphere, the rest presumably going into the ocean." So the airborne fraction, as it's called, is 56 percent in this particular calculation that gives you the fit to his data that you see in the upper chart, which is pretty remarkable. So the upper chart is fitting the observations with an assumption that 56 percent of all fossil-fuel use CO_2 release remains in the atmosphere. And David also goes on to essentially try to analyze anomalies over the period of the '80s which I won't particularly talk about.

Now here's a summary of what this means. And what I'm going to do here, and I think Wally may particularly appreciate this, what I'm going to do is to define the airborne fraction here as the net input to the atmosphere excluding the ocean. So if there's a biospheric sink I'm going to subtract it from the fossil-fuel source. When you do that for the period 1991 to 1994, which I did in my book, I got an airborne fraction of 58 percent, compared again with Keeling's value of 56 percent. I said, "Wow, this is really pretty incredible." If you then interpret this a little bit further, you realize that this biospheric uptake is a complicated problem. It's not simply that the biosphere is taking up CO_2, it's that deforestation in the tropics is releasing CO_2 which is being offset to some extent by the uptake of CO_2 at midlatitudes of the northern hemisphere. How do we know that? We know that by analyzing the interhemispheric gradient of CO_2. And the uptake at midlatitudes is not small; it's about one and a half gigatons per year out of a total fossil-fuel source currently of about six gigatons per year. So what actually was happening in the early 1990s, there's no question about this in my mind, is that the relatively large biospheric uptake at midlatitudes stayed more or less where it was, but the tropical deforestation turned off, whereas over the whole Keeling period my interpretation would be that biospheric uptake which was still significant was more or less offset by a comparable source in the tropics. And over the entire period of the 1990s, this is consistent with the result that you get from this analysis that I've just outlined.

Circulation and Climate Change

Now let me switch attention and talk about the climate change issue, and I'm going to make a few points which I hope you'll find persuasive. This is the IPCC summary of the measurements for the northern hemisphere, the southern hemisphere, and for the globe, surface-temperature changes. And as you can see the characteristics of the observations that you saw on the previous chart is that the global average temperature from 1850 to 1910 didn't do very much. From 1910 to about 1940 it increased. From 1940 to about 1970 it decreased a little bit. And from 1970 or '75 to present it's been on a rapid upward climb.

Now if you analyze where this temperature change is taking place, as summarized in this particular chart, one of the things that's interesting is that that cooling that occurred over the 1940s to 1975 period you see as largely reflected in the North Atlantic. It's generally a cooling that's most pronounced in the North Atlantic, and you see the very rapid warming over the downwind side of the North Atlantic over the period 1976 to 2000. The North Atlantic oscillation is a fascinating phenomenon, which I think is intimately involved with the changes that we are currently seeing, and perhaps also will be involved with many of the paleo changes that took place.

North Atlantic oscillation, as I'll summarize in the next chart, in very simple terms, at least my simple terms, it reflects the pressure gradient between Greenland and Bermuda; it reflects the pressure difference between the Bermuda high and the Greenland low, which essentially is controlling the speed of the winds that are blowing from the southwest to the northwest across the Atlantic and bringing warm water up into the Arctic and bringing warm air into western Europe. The positive side of this North Atlantic oscillation corresponds to a high-pressure gradient and strong winds. That's been characteristic of the recent past, and you can see. And over this period from about 1970 to present, I think you can make a case that a significant part of that temperature rise is associated with this phenomenon, an intensification of this circulation anomaly controlled by the Greenland and Bermuda pressure gradient. This is from Ahren's book simply showing you for winter conditions the low pressure system over Greenland and the high pressure somewhat to the west of Bermuda, which I think is ultimately controlling this North Atlantic oscillation.

I want to also say the north Atlantic oscillation is not disconnected from the other parts of the polar region, and it's associated not only with strong westerly flow in the Atlantic segment but also with a general intensification of the trade winds. And in particular there's a very recent paper by Ruth Curry and associates that records an increase in the salinity of the tropical and subtropical Atlantic Ocean over the past thirty, forty, fifty years, particularly over the past decade, with a compensating decrease in salinity of the higher latitude Atlantic Ocean. Well I think that may be related to exactly the same phenomenon, that basically the intensification of the trades is in fact providing a larger transfer of vapor from the tropical Atlantic into the Pacific, as well as increased precipitation at high latitudes with the stronger westerlies bringing vapor and freshening up the higher latitude ocean regime.

This is a very interesting chart here because it shows that over the recent period, this is showing you the increase in the heat content of the world ocean and the northern hemispheric ocean and southern hemispheric ocean. So what you see is that the world ocean over the past decade—this period of the past couple of decades, this period of rapid warming—is storing a very significant additional amount of heat. And so you see the indications of this storage in this very interesting paper by Levitas et al.

Issues of concern again related to the recent warming, this is the thinning of the Arctic sea ice. So you see that the extent of the sea ice has been decreasing over this extended period, as has apparently the thickness of the sea ice as well, the presence of multiyear ice has sort of slowed down, the buildup of multiyear ice has slowed down.

So what I want to do here is to emphasize areas of potential sensitivity in the climate system. So this area of the North Atlantic, in particular the influence of the North Atlantic oscillation, basically the influence of the Greenland-Bermuda pressure gradient, which is presumably associated also with the polar distribution of highs and lows around the polar regime in the north, the interesting question is the extent to which that North Atlantic oscillation is currently being influenced by human activity, and that's a question, I don't have an answer. But it is clear to me that you can rapidly change the climate if you adjust that oscillation—the record shows it. I think you can make a very strong case that if you do change the North Atlantic oscillation, you can potentially change the salinity budget of the subtropical Pacific Ocean by changing the amount of vapor that you're sending over with the trade winds. And if you do that, I would presume relatively easily you can change the characteristics of the circulation in the thermocline region in the tropical Pacific, which in turn means that you have the potential to globalize the impact that you invoke in the North Atlantic.

Learning from the El Niño Phenomenon

The El Niño phenomenon, then, becomes one of considerable interest. And Mark Cane, who's in the audience, and Steve Zebiak and others have made very, very important contributions to our understanding of this particular phenomenon.

It is clear that if you can change the distribution of warm water across the surface of the tropical Pacific by this interesting interaction between the trade winds and the ocean circulation that you get a global impact associated with that, you change the global climate. It's not particularly surprising because what you really have done by distributing the warm water and capping off the cold is you really have changed the average temperature of the tropics quite significantly during an El Niño as compared to the opposite phase the La Niña. And particularly in the winter hemisphere you see dramatic associated impacts on climate, hot, dry, wet, and so on.

This is a set of papers that I find very, very intriguing, and Mark was involved with this as well, but this is an attempt to reconstruct the characteristics of the going back to 1880. I haven't seen a detailed statistical analysis here, but my sense is that—and this is consistent with some of Dan Schreib's work—my sense is that it's been warm more recently than it's been cold, that the El Niño has been a more common phenomenon over the recent, since about 1975, than it was earlier, and Kevin Trenberth has drawn a similar conclusion from a statistical analysis of data such as this. And of course the two biggest El Niños are in the last twenty years.

Just to make this point about the salinity distribution in the current world's ocean, you see in the subtropical Atlantic, that big red patch is the high salinity region, the salinity has increased in that region over the past thirty, forty years according to Ruth Curry's very interesting paper, and it has decreased in the high latitudes. Now look at that sort of patch of blue that goes off the coast of the Panama Isthmus. That's low-salinity water and that wedge goes out and I think the conventional interpretation is that's associated with precipitation originating in the Atlantic, and is an important part of the circulation that maintains the salinity gradient between the Atlantic and Pacific, and that ultimately controls the conveyor belt that Wally has so creatively discussed in many of his papers.

Good and Bad News

Good news, bad news. The bad news is that there's certainly indications that the recent climate, the last twenty years or so and particularly the last ten years, has been pretty unusual. It's been getting warmer and, you know, people can make the connections between what fraction of the nine warmest years in the record occurred in the '90s, statements like that. But the good news is that there's no particular trend in some of the weather phenomena that really has a big impact on our lives, at least in this part of the world. The upper chart is a summary of all U.S. hurricanes going back to 1900, and the black lines indicate the major hurricanes. And the bottom one is a summary of all hurricanes, all major storms. And I don't see any particular indication that we're heading for a disaster associated with the warming that's taken place. Now that doesn't mean that the disaster is not around the corner. Hurricanes, I think as most people know, there are several factors that influence the probability of getting hurricanes in the Atlantic. One is temperature, so it's getting warm, you've got a better chance of triggering the conditions for a hurricane. But the other is the strength of the trade winds, and if you have strong trade winds, you tend to carry the top off the hurricane, it doesn't really get going, the vector system doesn't really grow. So it's quite possible that we've had the warmer conditions to generate hurricanes in the '90s but the stronger-than-usual trade winds associated with North Atlantic oscillation maybe has moderated that, and is that likely to continue in the future? Who knows, but it's certainly something that one to be concerned about.

Same comment about tornadoes. Again devastating weather phenomena in the middle part of the United States, but no significant indication that they're increasing in frequency or intensity.

Radiative Forcing and Climate Change

Now I want to talk a little bit about radiative forcing, what's ultimately driving the climate system. And here I'm going to be, I'm afraid, a little critical of some of the conclusions reached by IPCC. This is the IPCC summary of what we know about radiative forcing. What does radiative forcing mean? For those of you who don't live with this thing every day, this is basically the fact that . . . let's take CO_2. As you increase the CO_2 content of the atmosphere the atmosphere will begin to radiate infrared radiation to space from a higher level, so it will radiate energy to space less than it did before. But if it's absorbing the same amount of sunlight. That means that the Earth's system is gaining energy. And this is a measure of the amount of energy that's it's gaining, and radiative forcing is a measure of the net absorption of heat from the Earth's sun system. And so you see on the left-hand side the greenhouse gases: CO_2, methane, nitrous oxide, halocarbons. A little bit more than half of the greenhouse gas forcing is coming from CO_2. Given the caveat I mentioned earlier, maybe that methane contribution is going to go up.

Tropic area ozone, when the IPCC One did its analysis, what they did was to try to compare the model calculations of temperature trend over the past 150 years with what was actually observed, so they're basically testing if our understanding of greenhouse forcing is consistent with the observations. What did they find? They found that they were overestimating the observed change in temperature, and they expressed some concern. In other words, models were predicting a larger temperature change than was actually observed. Now after that IPCC One analysis people started thinking well what else could be going on? And they came up with the idea that sulfate aerosols, sulfur released by burning coal, could provide offsetting cooling, and so the new generation of models were exercised including sulfate cooling. And as you'll see they get very good agreement with the global average temperature by tuning the amount of sulfate cooling that takes place. What that do not show you, however, is that had they done that analysis separately for the two hemispheres, in my opinion, they would've found that they would not have gotten any good agreement for the southern hemisphere because sulfate will not be important in that hemisphere. The lifetime of sulfur in the atmosphere is just days to weeks, and they probably would not have gotten as good a result for the northern hemisphere either. So one must be very cautious about drawing conclusions about understanding, unless you are really critical about the underlying assumptions.

Now here's the most recent IPCC analysis with all forcing, and if you look at the bottom chart—but notice this is only global average temperature—if you look at the bottom chart, it looks extremely convincing. I mean it looks like they're picking up a lot of the wiggles and so on from a combination of greenhouse-gas forcing, warming, added to which is sulfate cooling, and some black carbon, and some solar variability, many of those factors extremely uncertain, particularly with the aerosol contribution. And voila, at the bottom it looks good. But my strong suggestion is that if you look at this comparison for the northern hemisphere and southern hemisphere separately you might find that things didn't look that good.

Now how do you do these analyses? Well, it's a very tough problem, I don't want to belittle the incredibly important contributions of many people to this climate modeling exercise. If you are going to describe the climate system, you need to be able to describe the circulation of the atmosphere; you need to be able to describe how it interacts with the ocean and vice versa; you need to be able to describe how sea ice is changing; you need to be able to describe release of energy even associated with cracks in the ice, which can be very significant in winter; you need to be able to describe the changes in the biosphere. It's an incredibly complicated problem. And so the general circulation groups who tried to tackle this problem, they tried to start off in 1850, and then the question is, Can I validate my model by showing that it gives a good record of the changes in temperature observed from

1850? And if it does, then I have some confidence in its ability to predict forward into the future.

Now there's a number of problems with that in my opinion. And the model can be shown to give good agreement with what's been observed as we just saw on that previous chart. The problem with it is that you start off assuming that the climate system is in some steady state. In other words, you ignore the natural variability of the climate system on scales like centuries, like the Little Ice Age in the medieval optimum. And even this chart from IPCC shows that things have not been constant up to 1850. So if you are not capturing in the model the natural centennial scaled variability, and you're now trying to do a test over a 150-year period, beware. I mean that's not necessarily going to give you convincing and conclusive results. And again, scientific honesty in my opinion dictates the appropriate level of caveat on the conclusions drawn from that, which are missing to some extent from the IPCC.

The Last 10,000 Years of Climate Change

Changes in climate over the past 10,000 years. This is a paper that I used extensively in my book a few years ago, which I find extremely interesting. This is a record of changes in a snowfield in Norway, bottom coming out of the Younger Dryas period you see warming coming out of the Younger Dryas, then you see this event of cooling, which Richard Donnelly talks about very nicely in his beautiful book. This is an indication of a final degorging of ice, perhaps through the Hudson Bay route. I think this may be the indication of that cooling event. The timing is probably wrong, but I would guess the timing here has to do with uncertainties in dating of the various events here. Then the snowfield disappeared completely, and then beginning about 5,000 years ago it begins to grow back, and you see these ripples.

The data are represented by the continuous line here. This is the author's interpretation of what the temperature was doing over this long period. You see the warming coming out of the Younger Dryas period, followed by the cooling of this most recent ice degorging event, 8,000 years or so ago, then the warming up the thermal 5,000–6,000 years ago, and then a slow cooling. And what I did on this chart is just for the heck of it I thought I would fit this using the solar insulation at that latitude for the summer sort of a classic Milankovitch kind of story. And so that dotted line is exactly that. Now I don't pretend that the temperature in Norway is controlled by summer insulation necessarily, but at least gives your eye a very good guide to understand that these ripples that are on that line represent climatic variations that are not insignificant. I mean they may not be as big as the flickers that you see during the Ice Age or associated with the Younger Dryas, but they are in human terms significant. The medieval optimum period, Little Ice Age, these are ripples that we need to understand, and if we don't understand them and we don't model them I would raise questions about the absolute validity of the tests that we apply to our understanding of what's happened in the past 150 years.

Changes in climate over the recent past, the Quelccaya ice core and the beautiful work by Lonnie Thompson and his colleagues is very intriguing because the accumulation of snow in that ice field is strongly correlated with the El Niño phenomenon, with the tropical ocean. And what you see here going back over a 1,500-year period or so is that there are extended periods of higher-than-normal precipitation and lower-than-normal precipitation. And I would say that the indications here are that you do have significant centennial-scale variability in the tropical climate system, and I think also presumably in the global system associated with that. You might also say that one of the very intriguing results here is that, as many of you know, this core was drilled in 1974–5 or so. These guys went back to Quelccaya to get the last twenty years record and they found out they couldn't get it because between 1972 and 1990 it had rained and the surface ice had melted and percolated through the core and the core was gone essentially as a useful scientific tool. So there's no doubt that tropical climate in the high Andes in the subtropics, at least at Quelccaya, was anomalous over a 1,500-year period for the last decade.

I wanted to use this mostly to raise a speculative—I don't think it's that speculative—suggestion. My sense is that if you look at the recovery of the Earth from the last ice age, and if you look at the lowest chart here . . . what I find intriguing here is the indication that the recovery from the last ice age first shows up in Antarctica and then on a delayed basis, maybe 3, 4, 5,000 years later you begin to see the effect in Greenland. And this is a fairly characteristic thing it seems to me of many of the climatic fluctuations that are recorded in the ice cores and in the deep-sea records. So what can be going on here? The rapid warming that precedes the Younger Dryas is indicated in the GRIP's core, and there's a cooling that precedes the warming, cooling in Antarctica that seems to precede the warming seen in Greenland.

Wally's sort of view of the general circulation difference between glacial and interglacial time is illustrated schematically here, the idea being that today we have deep water forming largely in the North Atlantic and a small intrusion of very cold, relatively fresh water from Antarctica, but in glacial times maybe the system reversed, and you had the Antarctic source playing a much larger role than the source in the high-latitude northern region. So the question is, What might be changing the role of the southern part of this conveyer belt? How can you modulate the supply of cold water, deep water in the southern region?

I think that focusing attention on sea ice in the southern hemisphere is a very important thing to do. You'll notice here that Antarctic sea ice is very extensive in the local winter season, and it could be extremely variable. And my suggestion is that a very important control on the climate system, particularly in the longer timescales, may be exercised by the changes in insulation, I suggest, in September at a latitude of about 40 degrees south. Why do I pick that? I pick that because it gives a very good fit to the total climate record, as a matter of fact, but on a physical basis the idea is that that's the region where the export of heat from the atmosphere has the potential to beat back the spring advance of the sea ice. And once you do that you've liberated an enormous heat source. The ocean is warm compared to the atmosphere in winter, so you have this big heat source, and I think that's a plausible explanation for what you see in Greenland. And the associated changes in circulation are going to have a major impact, I think, on how the recovery from the glacial condition might occur. That's not to say that the conventional Milankovitch operation mechanism in the northern hemisphere is not also operating.

Here's a comparison of . . . conventional forcing of the climate system is to use June insulation at 60 degrees north, and actually it doesn't give a very good fit to the Greenland data because it would suggest that the warming in Greenland should've occurred at about 25 K BP. However, the September insulation at 40 degrees south gives a very good fit to what you observe in Greenland, and I think that the climate change coming out of the Ice Age and throughout the Ice Age is in fact a combination of the two.

Now I need to wrap up very soon, but you may have noticed that the climate system was extremely variable between 30 and 60 thousand years BP. That's when you had all those interstadials and methane flickers. Notice that over that 30 to 60 K period, there's more variability in insulation at 40 degrees south than there is in the north. This is the competition between the processional effect and the up and down nodding of the rotation axis, playing a differential role at different latitudes.

This actually was just to illustrate. The shaded area to the right is showing this 8.2-kiloyear event that I mentioned earlier, this flicker that may be associated with the last degorging of ice from North America.

Modeling the Future Climate

Now a few words about the future. Given all of the uncertainty, it's a pretty daring thing to predict the future. But I don't think that the criticism that I've tried to advance here of the certainty with which we can do a direct attribution of changes in twenty years to a particular cause takes away from the concern about what may happen in the future. And our best effort to understand what might happen in the future is going to come from those same models that I'm actually being a little bit critical of. Now this is a chart that I took from the Hadley Center, I don't know that it was ever never actually published, but with their permission I included it in my book. What it shows, in their case . . . this is using one of the IPCC profiles for future growth in CO_2, a relatively moderate one, they're talking about quite significant changes in global average temperature and differences as you would expect between ocean temperature and land temperature. The next chart is the temperature map that they produced for 2040–2050, so if you think about Columbia being founded 250 years, it's sort of like the next 250 years. But it's actually less than 250 years because this particular chart is actually for 2040–

2050, so it's of real practical interest to people alive today. Now what does it show? Well it shows, as most models do, that you have very significant warming, particularly at high latitudes in winter. And there are good reasons why that should be the case. That's where the trapping of heat in winter is going to have the biggest impact. There's no sunlight, you trap the heat, it's going to keep summer warming in place for a longer period of time, and so you've got a warmer high-latitude regime.

But the more interesting thing for me, and the reason I included this chart, was that it shows a very significant warming, like 6 degrees, in the Brazilian rainforest region. In fact this model predicts that the rainforest in Brazil will disappear in twenty, thirty years. And why is that? Well, the next chart gives you the clue.

This is the diagnostics in the model of precipitation. And what it implies to me is you'll notice that Brazil becomes extremely dry, and so it becomes very dry, and that means it gets very hot because you don't have evaporative cooling taking place, and you don't have that nice forest system maintaining a reasonably benign temperature. And what I think this says, and there's no discussion that I can see in the Hadley Center Web page of what they think it means, so this is just my off-the-cuff interpretation of what it is. It looks to me as though their model is actually predicting a significant change in the characteristics of the tropical Pacific Ocean, and is predicting what you might describe as a sort of a permanent El Niño kind of condition, the thermocline perhaps going deeper, because you've got a larger warm water pool in that region. And so as a consequence you get the predicted El Niño effect, you get droughts in Indonesia, and you shift the precipitation pattern closer to the central Pacific, and you get droughts in northeast Brazil, which are problems of today for places like Fortaleza or Ceara. And if this were the case, there were a real indication of what could happen in the future, this is a big deal. I mean it's a big deal for a lot of poor people who will have great trouble in adjusting to this particular problem. So I'm a skeptic about our level of confidence, but the analogy I would use is that I'd buy fire insurance for my house, and I don't buy fire insurance with the hope that the house will burn down, I buy fire insurance with the hope that it will not burn down. And same thing with this climate system: the weight of the evidence is that this is a big deal problem, and we have to take it very seriously. But at the same time I think we in the scientific community have an absolute obligation to be scrupulously honest in how we state our confidence and our understanding. And in this high-visibility world where a word here becomes a newspaper headline, there's a great danger that we're not sensitive enough to how these things can go. But certainly official or semiofficial reviews such as IPCC has to be super cautious, and I think on the whole IPCC does a very, very good job, so my criticisms are really not that serious perhaps in the larger sense.

Preparing for the Future

Let me wrap up with a few summary charts.

Is human activity largely responsible for the recent rise in greenhouse gases? Not a question, there's no question about it. So you cannot play around with crazy interpretations of what's responsible for the rise in CO_2 or methane or nitrous oxide of CFCs. We know what they are, and they're all associated with different forms of human activity, fossil fuels, animals, people, those are the primary forcing functions.

Now can you conclude based on the global average-temperature trends over the last thirty years or so that anthropogenic forcing is necessary the primary cause? No, I don't think you can absolutely draw that conclusion for all the reasons I said, natural variability we don't understand, we've got to work harder to understand. But I think it's still likely that human activity is a big deal for the reasons that I've tried to state.

Uncertainty is a two-edged sword, so whenever we talk about potentially modest changes in the future, if you a person that wants not to take it seriously, just remember that uncertainty goes the other way, too. And there's surely a tendency, a bias, in models to give you a slow secular change whereas the complicated physics that gives you the rapid change is probably not going to be easily resolved by the model unless it has some clue as to the underlying cause. I mean the models are not going to get the El Niño phenomenon unless they explicitly work to get it. So I think that the problem could be worse rather than better.

Now number four here. I think in terms of really getting ready for the future and keeping an eye on things we should be particularly sensitive [to], not just to the global average-temperature trend but specifically to where we think there are opportunities for rapid change. And I'm sure there are more, but I've sort of highlighted three here, one of which I haven't actually talked about it. One is this NAO; the other is the behavior of the tropical Pacific—is there any change in the average position of the tropical thermocline? If it's going down, that's a warning sign; if it's going up, that might be good news for those who wish to argue that the climate system is going to warm up more slowly. The stratosphere I want to mention is a very interesting one because some of the biggest changes that have occurred in the climate in the past, periods where the polar regions didn't cool off, are probably in my opinion the result of intense releases of methane converted to water vapor in the stratosphere, the water vapor in the cold polar regions forming relatively dense polar stratospheric clouds, providing the world's greatest greenhouse. And today a significant fraction of the water vapor that is produced, that you see in the stratosphere, actually comes from oxidation of methane, and it is further controlled by the climate system underneath. The water vapor that gets into the stratosphere is drawn in by waves breaking in the stratosphere. We need to keep an eye on that because upper-level water vapor is the critical part of the water greenhouse effect, not the lower-level water vapor. So there's the potential for rapid change there that we need to be watching. And finally, feedback we haven't really worried about too much, we need to be careful about. For example, there's no doubt that the record suggests that we're seeing significant warming in the polar region. Well, if you have warming in the Arctic region what is that going to do to CO_2? I suspect Steve Wofsy may say a little bit about that, but the indication is that you're beginning to see where carbon is going into the biosphere at midlatitudes, at higher latitudes with winter warming CO_2 is being released from the tundra, but in particular here's an incredible place where you might get a heck of a lot of methane, not just from methane captured but just simply from bacterial activity associated with the water logging and the oxygen deprivation in those very, very rich organic soils. There's as much carbon in the tundra region as there is in the entire tropical rainforest environment, so that's a source that we need to keep an eye on. And so you can imagine other feedbacks here, with warming you get more methane release, you get more CO_2 release and then the problem is fairly clear.

Final comment and I'm going to wrap up. I want to come back to repeat what I tried to say about our understanding of the CO_2 cycle. I believe that there are three factors that are critically important in determining the current and future fate of CO_2. One is the amount of fossil fuel we release. The second is the continuing capacity of the northern midlatitude biosphere to suck up carbon. And the third is what we're doing with deforestation in the tropics, in Indonesia and in Brazil. The deforestation averaged in the tropics is accounting for something like 20 or 25 percent of the . . . it's a contribution equivalent to 25 percent, maybe as much as 25 percent, of the fossil-fuel source globally. The biospheric uptake is about the same magnitude, but varying year to year, which is what you see reflected in these oxygen-CO_2 trends. The easiest thing we could do to slow down the rate of change of CO_2 would be to provide incentives to discourage deforestation of the tropics. You can pick up one and a half or two gigatons a year, and I think you can do that in a fashion that would be of great benefit to biodiversity, and of great benefit to maintaining the integrity of the tropical ecosystem, and in principle a great benefit to the poorer people who live in that region, if not to the small privileged number that may be profiting from burning the forest.

Thank you very much. I'd be happy to take your questions.

Question 1: Criticizing Climate Modeling

G. Michael Purdy: Thank you very much Professor McElroy. We've got just a few minutes for a couple of questions. If you'd step up to the microphone, sir. Thank you. If you could identify yourself, please.

Man: Gavin Schmidt. I'm actually a climate modeler, and I was a little bit disturbed that you kind of accused climate modelers as being a little scientifically dishonest, which I think is a quite strong statement. I mean we work very hard on trying to incorporate natural variability, we work very hard on trying to identify the amount of forcings from the different aerosols and greenhouse gases, and we're very aware that, you know, 1850 was not a magic starting date. We're very aware that many of the important forcings are extremely spatially heterogeneous and difficult to assess, even going back before 1979. So we try quite hard to look at the metrics that allow us to distinguish the amount of forced versus intrinsic variability. Now the global mean temperature seems to be a good metric to look at for distinguishing that, because the amount of intrinsic variability in that is quite small. And so it's not dishonest to show that the global mean temperature responds to the global mean forcings.

Michael McElroy: First of all, if I gave the sense that I was accusing my colleagues of being dishonest, let me make it clear that that was not what I was trying to say. I didn't say it very well. What I was trying to say is that how you present and interpret results, particularly when you get this thing pulled into an executive summary at the front and then it gets into the newspapers and the policymakers and so on, there's a real problem there. And I sympathize with those who have to sort of run herd over that particular translation process. But let me repeat my specific criticism, which I don't think is contradicted by what you said. If the people who did that latest IPCC report focused up-front on this global average-temperature trend, and surely you will agree that the uncertainty in sulfate effect is so large that I can . . . that's a knob I can twiddle, big time. If you twiddle that knob to get a good agreement with the global average temperature, which is very interesting, had you also presented the northern hemisphere and southern hemisphere separately, which was presented in the later IPCC report, it would not have looked as good.

Man: If you look at the source publications for the summaries all of these things are discussed, you know, there's maps and maps and maps and maps. You know, they have to summarize, and so you know, they just show one.

Question 2: Aerosols and Solar Radiation

G. Michael Purdy: Go ahead, Wally. We'll repeat your question.

Michael McElroy: The comment from Wally Broecker was that there's significant indication of something that is inhibiting the transfer of solar radiation to the surface, both northern hemisphere and southern hemisphere, presumably related to fine aerosols. And my comment was that I think that the aerosol issue is the big atmospheric chemistry challenge right now, to understand it. It's a very complicated problem. There's an interesting paper by Jim Hanson and his colleagues, I don't know if Jim is here, which attempted to take the existing database around the world on transmission of solar radiation and with some spectral resolution, admittedly a limited database, to try to resolve the relative importance of absorptive aerosols and scattering aerosols, black carbon sulfate, to make it simple. And the conclusion, if I remember correctly from that paper, was that they're more or less offsetting today, positive forcing and negative forcing about the same, but both are significantly large, and I think there's a real need to understand the whole aerosol problem, including the raised fine dust that clearly plays a role in the northern hemisphere with dust transfer from the Asian region all the way across to the western U.S., so presumably in the southern hemisphere you have comparable sources that can not be ignored.

G. Michael Purdy: Okay one just very quick question, because we're 15 minutes over right now.

Question 3: Prioritizing Efforts to Manage CO_2

Man: I'm Lewis Gilbert. You showed that it's unquestionable that the human impact upon the CO_2 increase—everybody agrees on that. You also demonstrated that there is debate about the relative role between human and natural functions and temperature. I'm curious from the perspective of making policy and from managing the carbon cycle why the question of the human versus natural impact on temperature is an important problem versus a problem of managing the larger carbon system?

Michael McElroy: I'm not sure I really understand.

Man: From the perspective of managing the carbon cycle, wouldn't our placing effort on managing the large human signal be the place to prioritize our effort as opposed to separating and natural signals in temperature?

Michael McElroy: I agree, I think that's true. I think that focusing initial attention on how to reduce the demonstrable radiative forcing is the right way to go. And I think—I mean I know Jim Hanson may disagree with this—I think it's tough to do things that are really going to significantly affect methane. What do you want to do? Order that all Indians kill a cow every day? I mean I don't think it's easy, or that Chinese people stop eating rice? But CO_2, deforestation, conservation, some of the creative ideas that Klaus and Wally and people here have been talking about in terms of the carbon sequestration are all very, very interesting strategies to use.

April 22, 2004

Session 1: Climate Change Defined

G. Michael Purdy: Introduction

Our first panel discussion is going to lay the foundation for many of the deliberations that are going to go on through this symposium. It's entitled "Climate Change Defined." This will be a one-and-a-half hour session of presentations from panelists and discussion among the panelists, ending with an opportunity for questions from the floor. The chair of this panel is professor Richard Alley, one of the world's leaders in the research that has provided the insight and the knowledge that allows us to speak with such confidence about the recent history of climate change. Professor Alley earned his PhD from the University of Wisconsin-Madison, and has led a most illustrious career at Pennsylvania State University where he is the Evan Pugh Professor of Geosciences. He has authored or coauthored more than 130 refereed publications and has received honors too numerous to list here. But his book on abrupt climate change, published in 2001, entitled *The Two-Mile Time Machine* is a classic in the field. So without further adieu, I introduce professor Richard Alley.

Richard Alley: An Authoritative View of Climate Change

Richard Alley: It is indeed a pleasure to be here. I am going to start with three slides and only three slides, and then we will go to our distinguished panelists. So if we could go ahead and hit the first slide here, please. We have been asked to provide you an authoritative view of climate change and variability, and these are three slides from the United Nations-sponsored "View of the World," the past and the future. A thousand years ago is on your left, and this is carbon dioxide concentration in the atmosphere, and if you went from a thousand years ago to 800 years ago to 600 years ago to 400 years ago, not much was happening. And then we sort of got into burning fossil fuels and we started ramping it up, and we are right *there* now, so we humans have changed the atmosphere about that much. If we do not change the way we are behaving we will be disappearing off the top of this plot, which goes out to the year 2100. So the change we're looking at so far is small; the change that is coming if we do not change our behavior is likely to be fairly large.

If we look at this one, which professor McElroy showed earlier, if you go to the upper-left panel, starting in the year 1850 on your left and coming to today on the right the red curve is the history of temperature. You see lots of wiggles and a general warming. Can we explain this history of temperature over the last 150 years by natural forcing? So far no one can do so. If we take a model and we tell the model what the sun has done as best as we can estimate it, and what volcanoes have erupted to block the sun and so on, you get this gray band coming through here, including uncertainties. You'll notice that some of the wiggles in temperature have natural causes, and you'll notice that recently it's been getting warmer and we can't explain that by natural causes. On the other hand, if you tell the model the best estimate of what nature did and what humans did, then you get the panel down here at the bottom, and in fact the simulated changes look like what really happened. And so with reasonably good confidence can we explain what happened as having a large human component? Yes we can. Can we explain what happened based on nature alone? No we cannot.

This is a third picture, which takes that temperature history. Starting over the left here in year 1800, and you can see the temperature changes that we've been trying to explain so far, and the temperature changes that are expected if we don't change our behavior. And so there's a very skinny synopsis. Are humans changing the atmosphere? Yes, with very high confidence. Is this changing the climate? Yes, that is likely. Is this likely to keep changing the climate? Yes, it is.

Wallace Broecker: An Insurance Policy Against a Damaging Global Warming

Richard Alley: And so now we have a very distinguished panel, who is going to give you an authoritative view of climate change and variability, starting with Professor Wallace Broecker. Wally has been at Columbia for more than 20 percent of that Columbia 250. He is the author of more than 400 journal articles, eight texts; he is the recipient of the National Medal of Science; he is a member of the National Academy of Sciences; he is the recipient of the Blue Planet Prize; the list of honors and awards goes on almost forever. The easiest thing that one can say, though, is that if you're at an environmental-science meeting anywhere in the world and you make the statement, "Wally says . . . . " everybody will stop to listen because they know who Wally is, and they want to know what he says. And so Wally is going to talk about abrupt climate changes. Please.

Wallace Broecker: I was actually a graduate student when Columbia had its 200th anniversary, and we had a symposium. So as of June 15, it'll be 52 years of continuous service.

I mea culpa, in the sense that by discovering this conveyer circulation relationship to climate, I introduced an issue which makes the whole thing much more complicated. Those of you who've seen television documentaries, read the Pentagon report about climate, and you'll all certainly see the movie, *The Day . . .* what? *The Day After*? *The Day After Tomorrow*, which comes out May 28, which shows us here in New York taking a real shellacking in one day from an abrupt climate change. All this stuff goes back to an idea that I had, and what I'm going to try to do in this 15 minutes is put that idea in context, because since I got the idea in 1985, lots of things have happened, and we're learning more, and we're getting closer to saying how we might look at this as far as the future.

Well my ideas came from this record of temperature basically in the Greenland ice cores, and it came during a lecture that Hans Oeschger gave in Berne, Switzerland—I was attending a conference on ice—and he said that these jumps during glacial period, which Jeff Severinghaus has now shown back and forth, they're about 10 degrees centigrade, that he suggested they represented two states of the climate system. And I went home, came back to New York, and I puzzled over what these two states might be, and since I'd spent a fair amount of my career measuring radiocarbon in water samples from the Atlantic Ocean, I was aware of the basic circulation pattern in the Atlantic, and I suggested that these changes might relate to a turning on and off of this great conveyer. And the conveyer . . . I call it a conveyer because it delivers heat from the tropics to the high latitudes of the north Atlantic—that heat is extracted during the winter and helps keep Europe warm.

Now a surprise came when it was found that not only is this record preserved in North Atlantic sediments and Greenland ice, but as shown in the next slide, they're repeat records that look very much like the one I just showed, first from the Santa Barbara basin, then from all parts of the world, including more recently Hulu Cave in China, where a stalagmite beautifully shows these things and relates them to changes in the strength of the monsoons. So the big puzzle that came up is how in the heck can these changes in the ocean, why do they make such a big change in the atmospheric climate, and how is that message sent around the world? And we think in decades. We can't maybe prove that, but the evidence pretty strong that these are abrupt changes and they occur probably at the same time in all these places.

Recently two things have come to light that sort of push us along in the understanding. First of all Richard Alley here and Georgia Denton went with Lands' End Gary Comer up to Greenland last summer, and they made a very interesting observation that indicated that the great differences in the cold times were probably more centered in winter climate than summer climate; the winter coolings were maybe five times bigger than the summer coolings. And this focused the attention of everybody on sea ice, that area up in there that Richard's pointing to is now open water all the way up, all that region, and we now think that during these cold winters it froze over. So that was the start of understanding. Now the question is why sea ice would make such a big difference to climate at lower latitudes. And a young man named John Chiang, who's assistant professor at Berkeley, came up with a very interesting idea that showed in models that if you create sea ice in the North Atlantic, that pushes the inner tropical convergence zone to the south and changes rainfall all through the tropics. So he's come up with what may be the missing link as far as how do you transmit these things rapidly.

So the thing that these TV broadcasts and the movie are pushing is that if the conveyer were to shut down it would return us to cold conditions. So what do we know about that? Well, we think that a number of the switches that occurred during glacial time were triggered by immense releases of fresh water in the form of either ice coming out as armadas from the Hudson Bay region or melt water stored in proglacial lakes where the ice dam was released and let a lot of water in. We don't see any scenario where that will happen in the near future, so the models say the way if the conveyer were to shut down, and some of them do shut it down, it'll be because there's more rain falling at higher latitudes, but in order to get enough extra rain up there you have to warm the planet by 4 to 6 degrees. And this probably won't happen, you know, as you've seen, for a hundred years. So the models would say if it happens it's going to be way down the road.

Recently scientists at Woods Hole have presented very good evidence that the conveyer is weakening. I don't think there's any doubt that that's the case. The question then is, Is this weakening just a natural cycle related to the NAO that Mike McElroy is talking about, or what is it? Well, we don't really know. But their director at Woods Hole has pushed with a warning that there may be an imminent shutdown. So if you take that evidence of weakening to suggest we're on our way to shutdown, then that could be something that could happen in the next couple of decades instead of the next century.

Now then the question comes up if it were to shut down, either on the short-term green or in the long-term red, would the great sea-ice amplifier kick back in? The models sort of say no because the same models that predict if they put in a 4- to 6-degree warming, the Arctic gets incredibly much warmer and the likelihood that there's any sea ice, at least in the summers, in the Arctic becomes very small, so to say that turning this off would reintroduce sea ice to the North Atlantic and hence trigger all these large climate changes, you have to say that's unlikely. On the other hand, if the Woods Hole prediction is correct that this might happen much sooner, well we do know—Richard has written papers about this—that there was a little event at 8,200 years ago which we think was triggered by a release of melt water stored in front of the glacier, and that, as shown by Jeff Severinghaus, caused Greenland to cool 5 degrees, and of course the implication is that it allowed sea ice to form. Now that was a warmer time of the Holocene, and so you could say if it could happen then it could happen now.

So we're moving toward understanding this, but we've got a ways to go, and in the meantime we're really got to keep track of what the circulation, especially in the North Atlantic, is doing. So I have on the cover of a book that I wrote for a new science course here at Columbia my favorite picture of what we're doing is that by adding CO_2 to the atmosphere, if we continue that for a hundred years, business as usual, we're really giving the beast a jolt. The beast has shown that he can or she can respond violently. To take a chance and say that these changes won't occur in the future I think is pure madness. I mean maybe they won't but what percent does a risk have to be before we not do it? So I'm a strong advocate of doing something about CO_2 starting right away, and I think there's only one sure solution and that's capturing CO_2 and putting it away. It's not the only solution, but I think it's the ultimate solution, and we have to work that out and figure out how to do it, how to pay for it, how to get people to agree around the world to do it. And you'll hear more about that from a number of the speakers yet to come.

So thank you.

Mark Cane: **Climate Variation and Climate Change**

Richard Alley: What we're doing to you, if you had not figured it out, is you will hear from the three distinguished panelists here, then we in the panel will talk for a while, and then we will open it up for questions from the audience and hope to get you into the discussion as well. And Wally has obviously gotten us off to a very wonderful start here.

Our next speaker is Mark Cane. Mark is also from Columbia where he is the G. Unger Vetlesen Professor. He's a graduate of Harvard and MIT. He is the man who first enabled the forecasting of the El Niño phenomenon and the understanding of the physical basis of the El Niño phenomenon in the Zebiak-Cane model that has been used in a great variety of ways, including forecasting impacts on humans, what will happen to production of grains in disadvantaged countries, for example, and so there are people who are saving lives and doing good things with the work that Mark has pioneered. He has been recognized for this work with a great variety of awards and honors—the Sverdrup Medal and the Cody Award—and he's a fellow of a whole list of various important organizations, and he will be speaking to you on climate variation and climate change. Mark Cane.

Mark Cane: Thank you. It's always a pleasure to follow Wally and from his talk I learned who the Dennis Quaid character in the upcoming movie is based on, it's clearly Wally.

We were supposed to talk about climate change defined, that was the title of the panel, so I went to the dictionary and looked up *change*, and it said "alteration, variation, etc." We who work on climate tend to use *variation* and *change* differently, often reserving *change* for the changes we expect in the future due to greenhouse warming, and extending that perhaps to cover some of the major changes that Wally was just talking about, things that happened abruptly and had very large amplitudes. *Climate*, I didn't take the definition out of the dictionary, I took it out of an aphorism, and in particular I chose this anthropocentric definition of climate because I want to emphasize the point, as I will in this talk, that some of what we mean by climate change now is in fact, in our minds at least, defined relative to human beings, to what is going to impact us.

Mike McElroy showed this picture earlier, and it is a particular kind of climate variation, the one associated with the El Niño phenomenon, this occurs roughly speaking every four years. It follows a particular pattern, we know it follows a particular pattern because we've analyzed data for the last 120 years, and you see certain things that repeat themselves. You see, for example, when you have an El

Niño year, there tends to be a below-average rainfall in India, below average rainfall in Brazil. Also you see a tremendous area of drought centered on Indonesia and New Guinea, as well as droughts in southern Africa and a tendency toward wet periods, toward flooding, in the horn of Africa.

Now this takes—this by climate-change standards—rather modest variation and looks at the impacts of the 1997–1998 El Niño event, and there's a whole sequence of droughts and floods around the world. Some of these . . . maybe somebody was generous in attributing to El Niño, but most of them follow the pattern that was shown on the previous slide, and so the attribution, if you will, is based on this historical record. In particular again I would call attention to the forest fires in Indonesia that burned down a significant part of Kalimantan. There were also forest fires like that after the '82–'83 event, and they had significant health implications. These estimates are hard to make, and maybe are useful only as orders of magnitude ideas, but it's estimated that the '97–'98 event costs something like 34 billion dollars U.S. in losses, 24,000 deaths, and 6 billion displaced people. It's not insignificant. It pales before the impacts of the 1877–1878 event, in which it's estimated that literally tens of millions of people died in famines in India and China, in Ethiopia, in Brazil. In some ways this is maybe the strongest El Niño in the record. It certainly was the largest deficit in rainfall in India that we've experienced. These deaths are due to famine, and they're due to disease, and it's more complicated, of course, than saying that everything is due to a climatic cause. There were the policies of the British Raj, there were all sorts of reasons why this happened that had to do with the way social systems are organized, but climate nonetheless contributes to what some people contributed, in this case to what some people would refer to as an example of complex emergencies, these sometimes massive emergency catastrophic events that have multiple causes. And when they all pile on, you're in real trouble.

This is back to '97–'98. Some of you may remember that this forest fire spread smoke over Southeast Asia, they had to close airports in Singapore, there was a plane that was lost when it slammed into a mountainside. The health effects were appalling, the levels of particulate matter and so on in the air were in some cases almost in order of magnitude greater than what are recommended amounts. And this is, again, in the context of this historical record not such a big change. And you can ask, What if just such a small change were to persist, how would we cope with that?

This is a record of the past 15,000 or 18,000 years, and you can see in the earlier part of the record. This is again from the Greenland ice core, and you can see these huge swings. This one is associated with this period called the Younger Dryas. This change, by the way, took about a decade. That's roughly two-thirds of the way or more of the change between the depth of the glacial epoch and the Holocene era, where we live now. But what I want to talk about are not these big changes but these little puny variations that show up in the Holocene, in the period in which basically most of human civilization has happened. Agriculture begins somewhere around there. You can see a couple of events you're probably all familiar with, the Little Ice Age, because we all have seen these Bruegel pictures. There's another one called the medieval warm period, which was a cultural flourishing. These on this scale of things look like very small events, and yet many of them had profound consequences for human societies. These are three examples, one based on archeological evidence from a lake in Kenya, one from the Yucatan that fits together with a record of the Mayan civilization, and one from the Gulf of Oman that fits together with what we know from archeological digs about the collapse of an Acadian civilization. And in each one of these cases you see either something like a collapse, had periods when the climate was unusually dry, and there's a tendency too to have relatively, let's say, flourishing periods at times when the climates were unusually wet. And again these are in the sweep of 100,000 years or 500,000 years or even 20,000 years small climate changes.

Here's another example a little closer to us in time and space. This is work of Dave Stahle and colleagues, so-called megadrought in the sixteenth century centered in Mexico. It's coincident in time with an epidemic which it's estimated was responsible for something on the order of 15 million deaths. This apparently is a disease that was not brought by the Spanish, or at least it was not recognized by the man who had been the court physician to King Philip in Spain, and perhaps it's associated with this very severe and long-term drought. In any case, the combination of the two would certainly be more devastating.

Coming to the U.S., this is a picture from Ed Cook, who is at Lamont, based on tree-ring records, a kind of index of how much of the area of the West was in drought conditions going from 800 to the present. And essentially this whole period, much of which corresponds to the medieval warm period, was a period of drought in the western United States. There are other epochs later on in the sixteenth century and seventeenth century in particular, where we have extended periods of drought. These are droughts that lasted for decades, far longer than the dust bowl drought of the '30s, which for most of us is a kind of historical reference point. Let me point out something. It's fairly well established that drought in the western United States is often coincident with La Niña like conditions, the opposite of El Niño, and I'll come back to that point toward the end. And just again to mention that a lot of this drought coincides with the medieval warm period.

This is again getting us still closer to the present. This is perhaps to some of you a familiar picture from the dust-bowl era in the United States. There's been some work very recently that's been published within the last few months, within the last year, in which people have put in temperature patterns in the ocean from the 1930s and been able to simulate the droughts that occurred over the United States at that time, and you can rather loosely characterize the temperature pattern that seems to matter as being somewhat similar to the La Niña pattern that we're familiar with as a cause of drought on much shorter time scales.

Will this happen again? I don't know. I do say that at least within the Holocene epoch, I think it's a fair statement to say that the biggest social impacts are caused by these long-term drought episodes.

Now let's try to get a bit toward the future before I sum up. This is a picture that's either the same as or similar to one that was shown earlier, basically emphasizing how the temperature is going to rise very abruptly over the next few years unless the unlikely happens and we do something about it quickly.

The thing I want to point out is that with these temperature changes there will be great changes in the distribution of rainfall. Now the first cut would be to say, "Look, it gets warmer, the hydrological cycle is enhanced and therefore they'll be more rain." And that's going to be true in some places, and there's going to be more flooding as a consequence to that, as I'll discuss in one particular instance in a moment, but it's also true that the distribution of rainfall will change, and so you can have more intense rain and absence of rain and still have it all add up to more rain globally, and indeed a good part of the globe is predicted in this manner to experience drought, including a substantial part of North America.

Here's one particular example that has to do with flooding. Bangladesh, much of it is a very low lying area, and so the first thing to worry about in a climate-change scenario is the fact that sea level will rise and so much of the delta that is where people live in Bangladesh is likely to be inundated or at least more subject to storm surges. At the same time it's predicted that the precipitation in this area is going to increase, so it's a kind of double whammy for these people, not a society that can sustain it easily.

Let me sum up some of what I've tried to say.

These abrupt changes that Wally and others started to talk about, they're real, they happened. They can be large, they seem to be global as far as we can tell, rapid certainly, on timescales that societies might have a hard time adjusting to, even now should one occur. We like to think we've made great progress and probably can somehow use our technology to get out of the kind of things that happened to all of those other ancient civilizations I showed, like the U.S. in the '30s, but it may not be true. They're not that unusual if you take a long view of history, and things can happen even in the warm era, not just in the cold era. They may not be as impressive in terms of temperature signal or even hydrological signals, but they seem to be impressive enough if you're the person who's living under them.

We don't know why they happen, we don't know how they work. One idea which is interesting is that some of these changes in the Holocene may have been triggered by changes in solar radiance and volcanic aerosol. In particular, I've done some work recently that suggests that at times of increased solar heating, like the medieval warm period seems to have been, you would have more of a tendency for the Pacific to go into a La Niña–like state, which would mean more of a tendency to have drought over the U.S. Will the global warming due to greenhouse gas increases work the same way? I don't know, it's not clear, and the models are not very good at doing the changes in the tropical Pacific. That's a little bit scary. The models don't do these abrupt changes and they don't do a lot of the very delicate kind of ocean-atmosphere interactions that are part of what lets the climate system switch so quickly from one state to another. The models seem to be less sensitive than nature. Is that going to bite us when we go ahead and rely on these models for forecast? Finally I would point out that societies have not always survived these kind of things, and presumably we will survive but it may do us some damage.

One more slide. I didn't want to leave everything on a completely negative note, so I leave you with this article from the *New York Times*. In general there will be winners and losers from global warming; it's not going to be all bad for everyone, and one of the groups of winners will be people in certain wine-growing areas in Europe, which is something I suppose we can all look forward to.

Thank you.

Steven Wofsy: Global Forests and Climate

Richard Alley: Outstanding. I have an ecologist acquaintance who is fond of saying that nobody actually cares about the climate, we're only interested in what it means to us, and what it means to other living things on the planet. And so there may be a little truth in that; we are a little self-centered somehow. Fortunately we are now going to hear a little bit about interactions that go beyond various things. Professor Steven Wofsy is the Abbott Lawrence Rotch Professor of Atmospheric and Environmental Chemistry at Harvard, educated at Chicago and then PhD Harvard from 1971. He has worked his way through atmospheric chemistry, troposphere and stratosphere, into climate change, into interactions with ecosystems, into carbon fluxes, a variety of feedbacks between the living environment and the physical environment. He holds a host of awards including the Macelwane Award from the American Geophysical Union and the Distinguished Public Service Medal from NASA. And he is going to tell us something about how the climate might evolve in the future interacting with living things. And so Professor Wofsy.

Steven Wofsy: Okay, so I'm going to talk about vegetation and climate, we care about both. And I'd like to start with a premise. I'm going to focus actually mostly on forests in terms of vegetation. The forests over the world have changed dramatically over the last 300 years, that same time period that people have been talking about. They've changed under human influence. And actually people think about deforestation as a major change in the forest cover of the Earth, deforestation continuing to today, but actually there's also been enormous amounts of reforestation, and I'd like to talk about both the reforestation and the deforestation and how that interacts with climate.

To start off, I'm going to be able to go over these things only briefly, but we'll talk about two basic aspects: the effects of forests on climate and the effects of climate on forests. Now up until now we've mostly heard about the effects of ocean on climate, and you say, "Well how can forests affect climate?" And we'll see that they can affect climate by affecting the albedo of the Earth, which is the amount of radiation that's received and stored in the atmosphere-ocean system; they can affect climate by affecting the CO_2 in the atmosphere; and they can affect climate by affecting the fluxes of water vapor and energy between the surface of the Earth and the atmosphere.

And then I'll also talk about the effects of climate on forests, and we'll see that land-use change has been a major factor in changing the forest cover of the Earth over the last 300 years in ways that maybe are surprising to us. And that climate change can promote forest growth in some places. It can also devastate forests, and it can change how much CO_2 is in the atmosphere by interacting with the forests.

Okay, this is just a slide that I borrowed from Scott Denny in Colorado State, which shows on this axis here time from 1960 to 2000, and here is a measure in ten to the ninth metric tons of carbon per year, the amount released to the atmosphere by combustion of fossil fuel, you can see increasing from 2 in 1960 to about almost 7 in 2000. And this bottom part here shows the amount of CO_2 accumulating in the atmosphere, and you might see there's a mystery here, a miracle actually, which is that the amount that's accumulated in the atmosphere has been basically constant since the mid-1970s until 2000, even though the amount we're adding goes up. So this green part, which is the difference, has disappeared. So this is a miracle, and were it to continue maybe we wouldn't need the Kyoto Protocol. Just for purposes of comparison this in the late 1990s was taking about 55 percent of the CO_2 that was being released from combustion, was going into something, ocean plus atmosphere, as we'll see more and more actually into the land versus the ocean. And that 55 percent can be compared to the 7-percent reduction in CO_2 that was mandated in the Kyoto Protocol, so all we have to do is figure out how to make this work better, and we don't need to worry about Kyoto.

This is just another picture that illustrates the same thing. This shows the record of CO_2 in the atmosphere over time, and I just drew a line on here which is 1.5 parts per million per year or about 3.1 petagrams of carbon per year, and you see that it kind of lines up very nicely through this whole period from the mid-'70s to the current time, although for those of you who are in the day-trading business, you might notice a bit of a trend happening here toward the end. Maybe the miracle is losing some of its punch.

Okay, now what I'd like to do is to examine scenarios that have been run as part of the IPCC exercise, looking at climate change where we add CO_2 to the atmosphere and allow the oceans and the land surface to respond. And there's two of them here. This red one is the Cox et al, the Hadley Center one, that people have talked about, and the blue one is by Friedlingstein et al, which basically the main difference was a difference in the way they treated the land hydrology and the way the ecosystems respond to climate change. So during this time period that they're simulating to 2100 the flux of CO_2 into the ocean is slightly different in the two, but the big difference is that somewhere around 2050, there's a huge change in the amount of CO_2 flux between the land and the atmosphere in these simulations. So the Friedlingstein one shows the forests continue to take up something like what they're taking up in 2000, maybe a little bit more, and the Cox et al shows it turning around and releasing CO_2 to the atmosphere, a huge amount of CO_2. And this is actually largely due to changes in Amazonian and other tropical forests.

So what's actually going on here? Well the effect of this is pretty clear. The CO_2 rise in the Cox et all is much higher than the CO_2 rise in the Friedlingstein, and the temperature rise is almost 70 percent greater. So we understand that the interaction between the climate and the forest is a big deal.

Now can we say anything about which of these is right? I mean what's happened is that since these are very complicated models, the way that the forest is represented has to be very simple. And so they respond to the mean conditions, so at some point the Amazon gets a little too dry for the forests in the Cox et al, and the forests all disappear in short order. The Friedlingstein one, the forests don't happen to reach that threshold. And I think we're going to see that actually there's an issue here altogether about how these simulations are done.

What I'm going to do is I'm going to show you a little bit about how we might actually look at what we currently know about forests, and address this question. Well what's realistic there? And we'll actually see that neither is really realistic, and we'll see why that is in a minute. So I'm going to just focus on a couple of places in Amazonia, Manaus, and Santarem. Rio Blanco we can ignore for the moment. In Manaus you have a dry season of about one to two months; the rest of the time it rains. And you can see here in this particular year there are only two months with less than 5 millimeters per day average precipitation, whereas in Santarem you have as long as five months, but sometimes even more, which is dry.

What does that actually mean? Well, if you look at the species of trees growing here, these both have evergreen tropical forests, the species of trees are largely the same. But the forests are different, and let's see how they differ. One thing that we should mention in passing here which is relevant to this, which is relevant to the issue that we're going to actually hone in on, is that when you have an El Niño event, it has significant effects on rainfall in Amazonia, but mostly in eastern Amazonia. So Santarem which is over here, and these are rainfall anomalies in different El Niño years, you get very significant anomalies at the drier site to the east, but you have almost no anomalies in the center of Amazonia. So that's telling us something about what the forcing actually is, the climate forcing that's affecting these forests.

I won't have time to go over the data. Let me just tell you how these forests differ from one another. So what you see is that the species are the same, but the trees are distributed in a somewhat different way. The variance of the rainfall is higher at the site that has a drier climate. Now that actually means that on average the growing conditions are better at the drier place, but the variance gives you the possibility of having catastrophic disturbance, because if you're in a rainforest it's very nice to have nice, sunny days for a few months. It's not nice to have them for maybe eight months, where you could get the forest dry enough to burn and catastrophically disappear. So the variance is very important, the mean conditions are better, the variance is not better as you move into a drier climate, more like an El Niño climate may be a model for how climate warming will go. So disturbance increases as you move to drier conditions; biodiversity decreases because you have these catastrophic disturbances or near catastrophic disturbances from time to time that push out some of the less resilient species. The number of big trees actually increases as you make it drier because the average growing conditions are getting better and the amount of dead wood that's growing there. So what does this actually mean is that from the standpoint of simulating what will happen to the forests, we need to think very hard about the variance of the climate, as well as how the mean climate changes, and the variance is in some sense more important.

Another thing which is very nasty about this is the following. Suppose we move to a warmer climate with higher variance? Of course those extreme events still occur only infrequently, so what that means is we could buy ourselves into a situation where the Amazon forests are in fact unstable, the way Cox said, but not actually know it. Everything will go along fine, and then we have an extreme event, and bingo the system goes into a really major decline. This is something comparable to what Wally was talking about with extreme climate change, and it illustrates—in both the ocean example that Wally talked about and this example—a fundamental characteristic of the climate system when you think about including the vegetation and the ocean circulation and all that in climate. It's a very nonlinear type of system, and we don't understand it very well. And not only don't we understand it very well, one of the few predictions I can make with assurance is that we will not understand it very well, because in order to get such understanding we have to see the system respond, we have to make the observations that validate whatever theory we have, and we don't have the opportunity to do that when you have these abrupt changes that can take place. So this is now I think another example of this really critical matter that Wally brought to our attention some years ago.

Other ways that forests affect climate is by changing the distribution of latent and sensible heat. What does that mean? If you have a forest, you know, it's nice and cool underneath the forest. If you climb up to the top it's kind of hot up there at the canopy. If you have a pasture or a cornfield instead, it's very hot down there. What's happening is that the forests are mining water out of the soil and taking sunlight in and turning sensible heat into latent heat. What that does is—and this is a really nice simulation that was done by Roy and Avissar, they just took a plot of Amazonia a hundred kilometers on a side that was about half pasture, or 40 percent pasture and 60 percent forest, and they actually kept the total heat flux the same, but they allowed this partitioning to take place. And what you see is that the climate at the surface gets cooler when you have forest there, even if the total energy balance is the same, and the humidity goes up, and there's a corresponding change in the opposite direction higher in the atmosphere. That tells you that you can have a situation where the climate as defined by climate modelers gets warmer, because when I add forest where pastures were, the albedo of the system goes down so more heat is absorbed, but it can actually get cooler where I am, and maybe that's what I care about rather than the average temperature of the atmosphere. It depends. Now we have to decide what we care about. The other thing is, of course, that this is putting moisture and momentum into the atmosphere in a different way, and that can affect global climate.

These same people took this same example, and they then extended deforestation over the whole Amazon, so you imagine a hundred years from now most of it's pasture or soybeans I guess is what's likely to happen, and they showed that in Amazonia, this is just a precipitation anomaly. You get a very significant decrease in precipitation, which is what you expect because the croplands are less efficient at bringing water out of the soil than putting it into the atmosphere. And that effect extends to Central America, North Dakota, into the Gulf of Mexico. It's because you're basically changing the whole circulation of the atmosphere by inducing this anomaly in the Amazon Basin.

Now I'd like to think about a different type of forest. We've been focusing on the tropics, let's move into the midlatitudes. This is a picture of Harvard Forest in Petersham, Mass[achusetts]. Everybody knows this is a New England forest. That's what the forests have always looked like, except it isn't actually. This landscape and all those mixed hardwood forests that you see around New England and New York State are in fact artifacts of prior land use. There's very, very few places where you can find land that was not significantly disturbed over the last 300 years, so in fact this vegetation is very different from what was there before. This picture just shows over the last 300 years the forest cover in two states in New England. I don't know how many people are surprised by this, but let's say in the late nineteenth century, Massachusetts was 30 percent forest and 70 percent croplands, and today it's the reverse. New Hampshire even more so. It's over 90 percent forest. So now what effect does that have?

Well, we just talked about the fact that forests have a lower albedo than croplands, so a recent paper that attracted a lot of attention by Richard Betts said, "Hey, you know what? Maybe a lot of the climate warming that we've observed is due to the fact that hundreds of millions of hectares have undergone this same reforestation at midlatitudes." And maybe he's right. But you do have to take into account something that isn't discussed in this short nature paper, which is what we just talked about before, which is yes, the total energy budget of the atmosphere will be changed in a way that adds more heat to the atmosphere when we put forests where there were croplands. But that heat actually winds up being deposited at much higher altitude due to the fact that the forests are converting the sensible heat to latent heat. So this is another factor that makes it extremely difficult to model this. Most climate models, as I'm sure Mark will admit, do a terrible job on the boundary layer, the atmospheric boundary layer. It's all kind of hoked up because it's very hard to represent, the scales are very small. And yet that can have a significant effect on the way climate is experienced at the surface, and maybe on the circulation of the atmosphere as well.

So to just sum up this part of the talk: I've talked about albedo, fluxes of latent and sensible heat, and I pointed out that forests may warm the climate when they come back in where there was cropland, but that maybe they will be cooling the surface, and that kind of says, "Okay, now which climate do we care about?" And of course the forests themselves are valuable on their own. The presence or absence of a forest in a major region like Amazonia can affect climatic trends worldwide. This is a very big deal, and very, very hard to model because again we're talking about phenomena that originate at the mesoscale, the scale of storms and such, which are really hard to represent in models. And another thing to think about is that the very large trends in forest cover can then confound our analysis of climate trends based, for example, on surface measurements. So this actually is a big deal not just for what it does to climate but for what it does to our understanding of climate. It's the old adage that it's not what you don't know that will kill you, it's what you think you know that just ain't so. And this can certainly be a factor here when you have many climate stations in areas that have been reforested over the last century or so.

The next part of this I'm going to talk very briefly about land use change and climate change, and then wrap it up. At this same place at Harvard Forest we can measure the total amount of CO_2 that's going between the atmosphere and the surface, and we do that with this little tower here. And this typical vegetation assemblage that we recognize as being a New England forest has, in fact, over the last 15 years or so, been taking up two tons of carbon per hectare per year, which is a lot. And there are hundreds of millions of hectares like this in North America and the northern part of Europe. Why is it doing that? Well, it's doing that because there's reforestation going on. These forests are seventy years old, and Steve Pacala and his colleagues did a very nice job of kind of doing a little budget for North America, and they estimated that roughly half of the CO_2 fossil fuel that we release is being taken back up by our forests, leading to some very interesting machinations at Kyoto. And about half of that half is due to the fact that these forests are growing, and a little bit of that due to the fact that they're used in wood products that last for a while. This other half we'll talk about in a minute.

Other reasons why forests may be taking CO_2 out of the atmosphere is fertilization. You add CO_2 to the atmosphere, forests become more efficient in some respects, by deposition of nutrients, etcetera, and by perhaps longer growing season at midlatitudes. Well this bottom part represents things that are actually not good and that won't continue, so for example this part here, this red one, talks about woody encroachment, which you've heard about. In the West we have a lot of brush land in little old trees, where there used to be grassland, because of fire suppression, or shrub land because of fire suppression. This stuff is fuel, and it's a hazard.

Additional issues that can happen as climate warms. We can take the northern peat lands, which underlie the forests up there, which contain huge amounts of carbon and warm them up and dry them out and turn them into CO_2. And that's the part of the talk that I'm going to have to skip in order to get through this without running too long.

Just to give you an example of how this is actually working, this is a record at Harvard Forest showing uptake of CO_2, about 2 tons per hectare per year. Compare that to arboreal forest with peat that underlies it, and what you see is that forest is actually losing CO_2 to the atmosphere. Although the trees are growing bigger, the growing seasons are longer, what's happening is that the meter or 2 meters of peat that accumulated over the last 7,000 years is starting to decay away as the climate warms up there.

So to wrap up then, we're talked already about the effects of forests on climate, now let's think about effects of climate on forests. Land use change has led to reforestation at midlatitudes, and in the latter part of the twentieth century, this appears to have created a very powerful terrestrial sink for fossil fuel CO_2. But before we get too excited about that, we have to recognize that some of it was not real, and I didn't actually have a chance to talk about this, but some of it is basically representing fertilization of croplands, if you will, using fossil fuel to do that, so it may be not real. And some of it won't continue, and some of it's actually bad, like the brush lands in the West.

On the other hand I think we could argue that if we manage forests wisely, we could actually preserve a significant fraction of this sink for a good while, so it's worth thinking about. From the standpoint of the Kyoto Protocol, it's a very troubling issue to deal with, because you say, "Well you're going to give the U.S. credit for having cut down its forests in the nineteenth century and now letting them grow back, or what are you actually going to do there?" And that's an issue.

The other thing that we've talked about here is that climate change can promote forest growth; for example, you get longer growing seasons —you can see that's a factor in some places like Harvard Forest—but it can also devastate forests of boreal peat. And the thing that I find most troubling about this is that the bad effects can (a) come on very quickly and (b) come on rather in a delayed fashion so you don't see them until you've already bought them. And I think that that's an issue that we need to think about when we formulate policy.

So just to make a summary statement: climate is very complex. What we define as climate is not even actually really clear, that was a discussion there between Professor McElroy and a questioner about what was the correct definition of *climate*. And the question said, "Well, what we got was something that's more robust in the models," which I think is fair enough. On the other hand, maybe it's not what we really care about, and I think that's a big issue. We know a lot about climate, we know a lot about climate change, and one of the things that we know is that we will never have enough information to really predict climate. What we can do if we really learn a lot is to assess the risks. And I think for those of you who might be in finance you might say, "Well that's what we do all the time," right? We don't buy stocks or companies with some perfect knowledge of what's going to happen in the future. But we're not going to buy a climate that way, either. We will never be able to predict climate, but we can make those assessments.

And finally I think to end of a positive note, with this type of knowledge, we can perhaps develop wise courses of action to reduce risks and maximize benefits to human beings and other living things.

Thank you very much.

April 22, 2004

Session 2: Responding to Climate Change: Living in a Greenhouse

G. Michael Purdy: Introduction

G. Michael Purdy: We have a tight schedule this afternoon, so really would like to get started on time. Going to have two consecutive panel sessions without a break in order to get through the complex material that we've got to deliberate about this afternoon.

I'd like to start by introducing our second panel, entitled "Responding to Climate Change: Living in a Greenhouse." This panel will begin the process that . . . clearly based on all the questions we got this morning, you want to see us start moving towards discussion of actions that need to be taken to respond to our changing climate.

This panel is chaired by Professor Upmanu Lall. Professor Lall got his PhD at University of Texas in Austin and is currently a professor and chair of the Department of Earth and Environmental Sciences, not really the Department of Earth and Environmental Engineering, sorry Upmanu, here at Columbia. He works on the statistical and numerical modeling to hydrologic and climatic systems, and has over the past 25 years made a number of seminal contributions to the management of water resources and the development of modeling methods for groundwater flow and contaminant transport. I won't take any more time with introductions, but hand over to Professor Lall.

Upmanu Lall: Introduction

Upmanu Lall: Thank you very much, Mike. It's my pleasure to welcome all of you to this panel on living in a greenhouse, something we've been doing for quite a while but might have a new flavor added to it. The format we've established for this particular panel is that the speakers will each give talks, as you might expect. We'll do a minimum of introductions for the speakers because they're all eminent and distinguished and well known, and in the package that you have we have biographies available, so we'll try to save some time there. And then we'll have a little bit of a panel discussion and two or three of the panelists have ideas that they wish to communicate back to you in response to things they have heard already, so we'll get those out. And then we'll take questions from the audience.

By way of introduction to this particular panel, I would like to say a few things, and they come down in a nutshell to my personal point of view, which is one of being a skeptic as to climate-change science. And so if you've already decided that I'm an outcast from that particular statement I'll elaborate. I accept the history of warming, I accept the human role in the history of warming. What I don't accept necessarily are what are projections for the future, particularly at the scales where people are interested in impacts. Given the state of the science as I individually understand it, my reaction is that we might be looking at two possible futures, one which is different from what we have today but not perhaps cataclysmic, and another which is perhaps cataclysmic beyond the bounds of any of the forecasts put forth by the climate models. This may not be a popular view, but this particular notion goes beyond the notion of the typical uncertainty in predictions that other people talk about. I suggest that we may not necessarily know the sign of what's forthcoming, but if we accept that it's going to be cataclysmic, this is analogous to the situation which led to Noah's ark, or at least the story of Noah's ark. So in the sense of what we should be doing may be the way I'm posing this question to the panel and to the rest of you is, Do we need a Noah's ark? What does that mean, and how will be go about it if we do indeed decide that that's what we need to do? Because attempts that we may put forward to control climate change are not likely to materialize in time.

With that I'll go ahead and introduce the panel and get things started. Our first speaker is Sir Partha Dasgupta, and following that is Dr. Jonathan Patz, following that is Dr. Atiq Rahman, and finally Dr. Cynthia Rosenzweig from right here. So Sir Partha.

Sir Partha Dasgupta: Discounting Future Gains and Losses

Sir Partha Dasgupta: Thank you very much. The chair asked me whether he should make the remarks that he made, and I said, "So long as you're willing to have eggshells thrown at you, do," and he did. I will want to respond to one or two of the conclusions that you came to later during the panel. I'm an economist by profession so what I want to do today is to pose a puzzle which is well stated there, but is not in the form of a puzzle, it's a quotation for a 1999 publication of the newspaper magazine *The Economist*, which is never in doubt, as you know, about anything. So this isn't a puzzle, it's a statement of fact, and I'll be coming to that. But the puzzle is the following. Colleagues in ecology, climatology, take global warming very seriously, and we had expression of that view earlier today. And yet the climate models that have been used by economists, or the climate models that have been constructed by economists and then run to study public policy, or the desirability of public policy, for the main part, have been very lukewarm to doing anything. The policy implications seem to be, well, nothing to get very excited about because the costs of doing things are very high, and they come up now. The benefits are in the future, and of course in the context of global warming we're looking at the distant future. And the power of compound interest, or in this case compound discounting, makes those distant benefits from doing things now look very small. And a typical well-known set of exercises would say not to do very much in terms of curbing—these models were on the whole about curbing emissions as opposed to sequestration—but the argument goes through. It's a metric one basically, that the costs are sufficiently high not to do anything, or not much anyway for the next thirty, forty, fifty years, and then perhaps, because the costs then would look small now, given the power of discount. And that's a puzzle, because I keep rather wide open my acquaintanceships and friendships, I have lots of ecologist friends and they ask me how I can bear to be an economist with such barbarians in my neighborhood, and my economist friends ask me how I could bear to be with ecologists who obviously don't understand the power of discounting. "Haven't they taken any high-school mathematics?" they ask.

Well what I want to do is a reconciliation, I want to show you that the way discounting has been used by economists in this particular problem area has been wrong. The problem is not with economics but the way it is done. And this is not a controversial view, it's just slight schizophrenia we economists have; we understand the theory but when we apply it we use it perhaps annoyingly or unconsciously in a wrong way.

These global models that have been studied, the public policy models, have used discount rates of the order of 4 to 6 percent. In the late 1970s, the first set of models that were published used even a 10-percent discount rate. There would be one or two people who have used lower discount rates. Bill Klein for example of Washington, D.C., used a 2-percent discount rate, and he was immediately told that he didn't quite know economics because the cost of capital is higher than 2 percent. And you can see the power of what could happen with a 6-percent discount rate. The quotation from *The Economist* that I have given over here, the arithmetic is absolutely correct, but the implication is quite horrendous, and you can see why we economists get a bad name, that we're not willing to put more than 10 billion dollars now to prevent a zero output at year 2200, if you use a 7-percent discount rate. The arithmetic is correct. Should we believe the interpretation? Is the question, the problem well posed?

Now the weakness of this is that the presumption here is that a discount rate you can pluck from air. When we do social-cost benefit analysis, that is to say, we ask ourselves is it worth doing something, a policy change or an investment project, what we are doing is perturbing the future of the economy, future of the world. Undertake some investment, things come out of it, and so forth. So it's a perturbation. And we want to ask whether the perturbation is worth doing, given that we are interested in human well-being. Now the unit of count in any of these exercises is roughly speaking something like consumption. And I want to think of consumption here in a very, very liberal way. It's not just goods and services but also the equivalent of values we put to biodiversity, all that stuff out there, the beings out there, which we care about, or we wish to care about. So when I write down something like consumption, think generously. Okay? If you don't wish to be generous, don't, but this doesn't preclude you from being generous in your interpretation.

So the question I want to raise is in a sense answering Professor Sachs' . . . I think the eighth or ninth that he made in the morning, namely how do we think about the future and why is it that we are reluctant to undertake actions preventing disasters in the future? And this explains why, or is putative explanation.

That looks like math, and it is, but I'm going to be very fast about it. When we are discounting future consumption, so our unit is consumption or income or some generalized notion like that, the rate at which a society ought to discount, and I'm thinking now by the way in a very generous way, I'm thinking we want to see the world coming together and thinking about the future, or maybe a big nation thinking about its future. I'm not talking about the private citizen. We use the words *social discount rate* to indicate that we are thinking ethically. Then it can be shown, and it is shown in pretty much every textbook in economics, that that discount rate—I'm now glossing over details here—is proportional to the percentage rate of change in consumption. And the constant proportionality I have written here as eta; it's a symbol which we use. So the subscript *t* here is the social rate of discount to be used at date *t*, or moment *T*, and it's proportional to the forecasted percentage rate of change in consumption. All right? And we are perturbing that forecast through, wondering whether or not to undertake the project, and we want to use that discount rate to see whether the project is worth undertaking. Notice first that if the percentage rate of change changes or expected to change, then the social discount rate at that date will change also. So it's not a constant discount rate by any means, unless you happen to be on a steady state.

So let me give you an illustration. I'm giving you three illustrations and you will see exactly where I head, and that will be the last slide. Suppose just for the sake of argument I'm going to take the constant proportionality to . . . I haven't plucked it quite out of air, but it's not far removed from empirical evidence of how people think about it. Suppose consumption were to expected to increase at 2 percent per year. Then your social rate of discount according to that formula will be 4 percent per year. Suppose on the other hand, in this next scenario, suppose long-run economic forecasts indicate that growth in aggregate consumption is not sustainable, but rather that growth is expected to decline at a constant rate of 1 percent per year from the current figure of 2 percent per year to zero. It's the growth which will be declining, so it's a little more pessimistic scenario than the first, but it's still a buoyant economy. Then again if I take eta equal to 2, my social rate of discount rho *t* will decline over time at 1 percent per year from a current high 4 percent per year to zero.

Notice what it's doing. If you're slightly pessimistic that if you think that you can't keep up the pace of consumption growth, then your discount rate will be declining over time. And you will know that in advance and when you discount future benefits those discounts will be not that high. Okay?

Now look at the third one, that's the pessimistic one. Imagine again rho equal to 2, our constant proportionality, and imagine that you expect consumption to decline at

1 percent per year in the indefinite future. Then your social rate of discount rho *t* should be minus 2 percent per year. Now notice what a negative discount rate means. It means that future damages which you wish to prevent will not be attenuated, as we usually think of when we use positive discounting, but will be amplified. Now this is correct theory, and the point about it is this, that when the economists, the first slide I showed you, had that scenario in which the year 2200 world GNP will be zero, and said that you are not willing to do anything beyond spending 10 billion dollars now at 7 percent per year discounting, the flaw in the argument is that if that's the scenario you have no business to choose 7-percent discount rate. The discount rate cannot come out of the air, it has to reflect the future scenario that you are tracking around which you're choosing your project. In other words, if you have a forecast in which you are thinking that in year 2200 the income is going to be zero, then there must be a long period when income has been falling, and that's being picked up in the third scenario before you, in which case, of course, that disaster or that horror is going to be amplified today, and the implication of social cost-benefit analysis will be do a lot. Ten billion is nothing to prevent catastrophe two hundred years from now. Okay?

That's in other words the analytical framework is tight. Next time economists tell you that they are using such-and-such discount rate I think you should ask, "On what basis have you chosen the discount rate for the purpose at hand?" It depends very much on the forecast that you have.

I want to conclude by pointing out of course that I haven't introduced uncertainty here. At this point I don't wish to do that because in the panel discussion no doubt people will be wishing to discuss it. But at this point what I want to say is that global warming to the extent that there are possibilities of disaster or abrupt change leading to difficulties in sufficiently large chunks of the world, this aggregate consumption that I had here, of course, is aggregating over people throughout the world, and that aggregation, if you really care about equity, then that aggregation will pick up the needs of the poor at a higher rate than the needs of those who are already very well off. So the inequalities that exist and the possible exaggerated impact of these changes on the world's poorest will be picked up in my index, by the way, so it's not as though those things can't be put together. But the main thing is that to the extent that there is a downside possibility, to that extent your discount rate to be used should be lowered, if there is an indication or suggestion that there will be huge fluctuations a hundred years down the road, ninety years down the road, to that extent damages in those dates will be amplified today because you'll be wishing to use a negative discount rate.

Thank you very much.

Jonathan Patz: Climate Variability, Climate Change, and Disease

Upmanu Lall: Thank you very much, Sir Partha. That was a very lucid talk making a very nice point. Our next speaker is Dr. Jonathan Patz from Johns Hopkins.

Jonathan Patz: Thank you very much. There's a little bit of reverberation up here, does it sound clear out there? Yeah, okay, good, okay. I would like to just say it's an honor to be here at this 250th-anniversary presentation. If you see the movie trailer for the Twentieth Century Fox movie *The Day After Tomorrow* that comes out on May 28, it's based on Professor Broecker's work, actually. I wonder if this could be the last year of Columbia, because you see what happens to New York in that movie, but hopefully there will be another 250 years of Columbia.

Today I'm going to talk a little bit about the human-health implications of climate change. Right now the climatologists are talking about what we may expect for climate and the physical science, and then my job is to say what does that mean as far as human-health impact? And if we think about the physical attributes of climate change— temperature rise, sea level rise, and extremes of the hydrologic cycle—it could be impact in quite a direct way. When you think about some of the health effects that certainly cut across these issues, like we know that people die in heat waves, and Dr. Rosenzweig will be talking about that related to New York at the end, certainly air pollution, ozone air pollution, is very sensitive to temperature. And some of the other speakers this morning talked about other air pollution issues, when you think about extreme climate, like droughts, the El Niño droughts, where Indonesia was on fire and had many health impacts. By the way, the potential good news and the cooling effect of sulfate aerosols I don't think it's going to be there because if I have my way as a public-health person, we will quickly do away with sulfate aerosols, which are very hazardous to our health. So the climatologists forget about the sulfate aerosols, we're going to get rid of those because of pollution.

Then there are issues of more ecologically mediated factors—vector-borne diseases, diseases carried by insects or rodents are very sensitive to subtle climate changes, as are water-borne diseases if we're talking about extremes of the hydrologic cycle, more flooding, for example. And certainly public health depends on food and water supply, and I think this issue . . . environmental refugees where we have the least amount of information, and yet when you think about refugee health, people that don't have shelter, that are on the move, that either bring diseases to where they go or are susceptible to diseases in places they move to, my personal opinion is that this issue which we have the least certainty about could be the iceberg under the tip of the iceberg.

It doesn't take a rocket scientist to know that heat is hazardous. Last summer it's estimated that nearly 15,000 deaths occurred in that one summer heat wave in France, so we know that heat is a problem, and there are certainly vulnerable populations, and there's debate about how many of these people may have died soon after the heat wave anyway, but estimates are about 60 to 80 percent of people that die in heat waves should not be dying in heat waves.

And when we think about climate impacts, the hazardous exposure of climate extremes on health, we need to be thinking about climate change in the context of other environmental changes. For example, urban sprawl is a problem when you think about heat-retaining surfaces, and Cynthia will talk about this a little bit more, but the bottom line is that the urban core can be a lot hotter than the suburbs.

Now this is a picture of Baltimore, where I come from, in the year 2025. It's New York beltway, formerly New Jersey. I mean if we have land-use issues like this and sprawling out and building more black asphalt surfaces that retain heat, we have a problem. There are also issues regarding impervious surfaces where you have more rainfall and heavier runoff and contamination, and I'll talk about that towards the end.

Certainly with air pollution, the ozone . . . this is not the good stratospheric ozone that protects us from UV, this is ground-level smog, photochemical smog on the ground. And nitrous oxides plus volatile organic compounds at temperature with ultraviolet radiation form the secondary pollution, ozone. And you can see that for New York, this relationship that in fact as temperature increases, ozone increases; it's almost a threshold effect. Above a certain temperature ozone goes up. And any of you know that we get our red-ozone alert days, you know, very hot summer days, when it's clear skies.

And actually Columbia University has an EPA project, and we've actually piggybacked on and so there's this collaboration. Based on Cynthia Rosenzweig's greenhouse-gas modeling future scenarios for climate, we've actually done some collaboration and we're looking at ozone, based on Columbia's work—how that may affect human health around the region. And Cynthia will talk about the New York area, and we've actually tried to expand it, working with Columbia, to look at the eastern United States, and on average ozone will increase. We know that ozone is a lung irritant, and we've known that ozone exacerbates asthma, and there are some recent studies, one coming out of Yale and one that was done in California, that possibly show that ozone may actually cause asthma. Now this is not the only cause of asthma, and I wouldn't want to be quoted as saying ozone is the bad actor for asthma, but some of the new studies are beginning to implicate ozone as a worse health agent than we thought.

Okay, you've probably heard a lot about climate change and infectious diseases. This is from the David Suzuki Foundation, stating that global warming's greatest threat may also be its smallest. And the message here is that cold-blooded insects are far more susceptible to slight changes in the environment than we are. And many diseases are carried by mosquitoes, ticks, and other insects that are cold-blooded. So this is where when people say, "Okay, we're going to have global warming, how much warming will we have?" And a lot of folks will say< "Well, it's one degree, two degrees, no big deal." Well to a mosquito it's a big deal, and I'll show you some information.

Malaria's probably the vector-borne disease that we have the most experience with. This is a graph showing malaria, two parasites of malaria, *Plasmodium falciparum*, the more dangerous form, *Plasmodium vivax*. And what you're seeing here is the development time inside the mosquito. In other words, that parasite needs to . . . once a mosquito bites someone that's infected and draws up the parasite in the blood, it takes time for that parasite to cross the mosquito's stomach lining and develop into an infectious sporozoite in the salivary glands, so the next person that mosquito bites becomes infected. Well guess what? That time is very temperature sensitive. And you can see that, for example, if in this room someone's infected, let's say I'm infected and a mosquito bites me and the mosquito is in this room and it's 20 degrees centigrade, when you come back in this room two weeks later will you get *Plasmodium vivax*? Not really, because it takes about 17 days for that mosquito to be infectious. But if it's a few degrees warmer, that mosquito now becomes infectious at day 12 or 13. So you can see that just a slight change in temperature can have a dramatic effect on malaria transmission. Also note these are asymptotic lines. In other words, below a certain temperature malaria cannot develop inside the mosquito, which is why malaria is a tropical disease, you need temperature.

Now we all know that altitude is a very good surrogate for temperature. For every thousand meters that you go up in elevation it's 6 degrees centigrade colder. Well Zimbabwe has a marked topography. This is the high plateau. It's very elevated here, and as you go down the Zambezi River, you fall off in elevation, and you also drop in elevation in this direction. So what we see geographically is in the African Highlands, in highland Zimbabwe, there's very little incidence and prevalence of malaria. But as you go in either direction down in elevation, you get more malaria.

And colleagues Kris Ebi and her group did some modeling where they said, "Look, we know a lot about the ecology of malaria, we know the climate factors involved with mosquito development, with the development time of the parasite that I just showed you, we know climate suitability for malaria and we can model that." So here's a model of current climate suitability in Zimbabwe, which I just showed you, that map, those cold colors are the high plateau, low risk. This is where you have higher risk. Now let's run into the future. Climate-change scenario. . . this area warms up a little bit, 25 years later, the risk looks like that, and by 2050 those highlands now are climatologically suitable for malaria. So that population that has absolutely immunity or partial immunity to malaria is very susceptible. So this is one concern, is diseases moving geographically as well as changing in their transmission dynamics.

Now here's a disease that's a little closer to home, West Nile Virus. This is a zoonotic disease that cycles between mosquitoes and birds, that's its normal cycle. But it infects horses and people. Now West Nile Virus, I'll tell you right now, is we really don't know necessarily the relationship between climate, and certainly not climate change and disease, but it's interesting that last summer the focal point was right here. Look at this: Colorado, 1,500 cases, and you get a bunch of cases around here. I was in Colorado at NCAR for a mini-sabbatical last summer, and I'll tell you it was the wrong summer to escape Baltimore and go to Colorado, because in July last year they had record temperatures, 109 degrees in Pueblo, Grand Junction, a record number of days over 100 degrees. It was very hot in July in Colorado. Now also in other places where West Nile Virus . . . there have been large outbreaks, like in eastern Europe, Israel, and in New York City in 1999, each of these times there was a pretty dramatic drought and heat wave. In fact in New York City in 1999—and the climatologists please correct me if I'm wrong, Cynthia you're right there—July of 1999 was the warmest July on record for New York. So we know that ecologically this is a disease that is marching across the country, primarily from bird migratory pathways, so I can't tell you this is a climate story, but the issue of climate extremes possibly contributing is a big question mark. And some research done in Florida looking at St. Louis encephalitis shows some relationship with drought, and this disease is almost identical to St. Louis encephalitis. It may be an issue. So climate variability may be one issue with West Nile, but the jury is still out and the work's got to be done.

Now I'm a physician and epidemiologist, but I know that climatologists beat this over our head: do not call it global warming because climate change is not just about warming. And so the issue of extremes to the hydrologic cycle . . . there are health issues here, not only direct flooding and droughts and famine, but the issue of infectious diseases. And we did a study under EPA funding to look at the relationship between water-borne diseases in the United States related to heavy rainfall. We looked at all outbreaks from 1948 to 1994, and you can ignore this map, but these are all the outbreaks, and there's a lot of reporting bias. So we did not compare one place versus the other because it either gets reported or it doesn't. But what we compared is for a given single outbreak; for example, we asked the question in a fifty-year weather record, fifty years of weather data, in the watershed around the outbreak, was there abnormal precipitation? And then we ran a Monte Carlo analysis for control to test for statistics, and what we found was in fact that for—this is all water-borne disease outbreaks—first excluding recreational outbreaks, recreational water-related outbreaks, and also eliminated outbreaks that were known to be from engineering failures. So we're trying to get just to what we think are climatologically related.

Two-thirds of water-borne disease outbreaks in this country were preceded by heavy precipitation months in the upper 20th percentile. And 51 percent were preceded by rainfall events in the upper 10th percentile in the fifty-year record. So we think that there's a strong relationship between heavy rainfall and water-borne disease. And if climatologists are saying you're going to be experiencing more heavy-rainfall events, as has been the case in the United States and around the world, that there has been a trend upward, this is a public-health issue. And in fact Milwaukee—I'm sure you know the 1993 cryptosporidiosis outbreak in Milwaukee, 400,000 cases, fatalities. In our analysis that outbreak, that epidemic really, was preceded by the heaviest rainfall month in the fifty-year record. So we think that rainfall has a lot to do with this issue.

And in the United States, even though we are a rich country and we have pretty good water supplies, we still have many cities, because of the cost of changing the water-treatment systems, that have combined sewer systems, and these combined sewer overflows, the CSO events, happen all the time. I'm sorry for this graphic picture, but over a trillion gallons of sewage and storm water every year are discharged during these combined sewage overflows, which would keep Niagara Falls running for 18 days. So this is a problem today, already. And if we're talking about extreme precipitation this is going to be compounding this issue.

So in conclusion, many health outcomes are sensitive to climate conditions. Climate change will cause diseases to shift either geographically in their distribution, or in their intensity of transmission. There are newly emergent diseases that are likely to arise from altered climate or changes in ecology, and in fact earlier Professor Cane talked about the El Niño fires, or no, maybe Steve Wofsy, talked about the El Niño fires. Not only did that cause health impacts directly, but it's believed that the fires drove fruit bats out of Indonesia up into Malaysia, which led to a brand-new emergent disease, Nipah virus. Actually Peter Daszak and others here at Columbia are studying [it].

And finally the bottom for this conference I think is that environmental and climate policy in fact equals public-health policy. And my last slide is just to say, How do we think about this in the framework of public health? And for example, when we're talking about disease prevention, when people ask us, they say, "Well look, show me a case of illness caused by global warming," that's an unfair question. Now the World Health Organization actually has begun that assessment, and they think that the current warming of the last century has contributed to, or it's caused, 150,000 deaths. I think that's a gross underestimation, but it's very difficult to put those numbers on. And what we need to think about is you can't ask the question show me a death caused by global warming; you need to say the hazardous exposure of climate change cuts across so many aspects of health, and there are so many exposure pathways, indirect pathways, that this is a very difficult question.

The other issue that our chair posed with us about Noah's ark: do we build Noah's ark or do we try to prevent the flood? And this deals with the issue of adaptation versus mitigation of greenhouse-gas emissions. It's similar to the issue of secondary prevention in public-health terms, or primary prevention, reducing or eliminating the exposure, the main exposure. And earlier today the father-son discoveries by the Keelings was brought up, about looking at CO_2 and oxygen measurements, and I can tell you that between my father and myself, my father—it's an oxygen-CO_2 story, except in reverse. My father studied oxygen and blindness of prematurity, and that was his discovery about too much oxygen, and so the idea is that you don't want to be treating blind infants, you want to reduce the exposure, reduce oxygen in the incubator. And so I picked a topic related to another gas, CO_2, global warming and public health.

And then the other issue, the moving target is that we don't know what we're talking about for future scenarios. Lastly that there are some "no regrets" policies that in fact fossil-fuel burning not only leads to global warming but it also leads to local and regional air pollution. So it's a good idea anyway. And I'll just leave this up here to say that there is a new journal out called *Ecohealth* that sort of combines some of these issues of ecology, global change, and health.

Thank you very much.

Atiq Rahman: Responding to Climate Change: Living in a Greenhouse (A View from the South)

Upmanu Lall: Thank you, Dr. Patz, for calling attention to an important impact of changes. Our next speaker is Dr. Atiq Rahman from the Bangladesh Institute for Advanced Studies.

Atiq Rahman: Good afternoon, ladies and gentlemen. Great pleasure to be here.

The way the sessions have been laid out is how Intergovernmental Panel of Climate Change has laid it out as well. The first bit was the science, all about molecules. Then there was a bit about dollars and money, which was also addressed. And then in IPCC 3, they tried to bring some human beings into it, which probably is a superficial inhabitant, and molecules might take care of that. But the way I would like to address the issue is from the view of the human species, and particularly in poor countries, and that's the take I'll take.

So it was a view from the south but could as well be a view from the bottom up where most of the world's population live, and those are the populations who didn't cause the problem. It's a funny thing, those who didn't cause the problem will suffer the greatest consequence of this particular problem of climate change.

So why should they be bothered about it? In the emerging concerns of climate change, it says that there is an increasing awareness and involvement of that, and all the development processes assumed that climate was constant. That's how agriculture was designed, that's how infrastructure was designed. But over the next thirty, fifty years, the life of a dam, life of a big building, did not take climate change into account because that was the presumption in all project documents, whether they're [inaudible] project document or the poor people's community agriculture says that we will plan for the future and leave something for our future generations, which was the essence of sustainable development, and which people now are threatened and they have to change that whole system. So in ecosystems where there is precipitation, that's what goes about.

And I want to look at the discussion in terms of the five people's lives, individuals. Now collective is very easy, you know, one-third of the population lives on one dollar a day, two-thirds of the population lives under two dollars a day, easy as said. One dollar is less than the price of that bottle, that's the whole day's expense for the whole human being, including the rental of the house, to the food, to going somewhere, to attending health, all that. So it's the individual that we have to take care of. I will look at it from the individual point of view. And I'll tell you some story that each of those human beings, I have touched them, I know them, I have worked with them.

And the first one what I call is "Miss Cabinet", the systems integrator. This is the village woman in any village in Asia or Africa or even Latin America. She is the finance minister in the house, she manages the finance, she is the water minister, she is the health minister, she is the food minister, she manages the energy, walks around everywhere, gets the wood for the fuel, so she is the ultimate integrator, and she holds the whole cabinet embodied. And now we are saying scientists must find integrated research. Well that lady is the ultimate integration in her own life, she's integrated everything, she hasn't got a choice. So she's the integrator, and that is more than one-third of the world population. And she lives on less than one dollar a day, or maximum two dollars a day.

The lady, this is the life of the woman what I call the "Renewable Future" living in six centuries. We have run a project on solar energy in an island which was not going to get electricity for a long time, and this is the woman, 75 years old, who has never left that island. It's a tiny island, has never left it. But because the solar energy, solar power, which I came into the village, she has started watching television, and the day I visited her she was watching CNN, and she was seeing the impeachment of President Clinton, of that whole saga that was going on. And I asked her, "What is going on?" and she told me exactly what was going on. She doesn't understand a single word of English, but the message is pretty clear. So she gets that. And she lives in three centuries because she is living in a century where she never left that house, never left that village, in the eighteenth-century lifestyle. She hardly gets anything imported in her life. And she is living in this century looking towards the future century of renewable energy, [inaudible] will reach many societies which otherwise would not be reached.

"Planting the Seedling" is the sustainable mover is the woman that I know, and I've worked with. She is 65, and she plants trees on the roadsides. The land doesn't belong to her, and in her lifetime she will not get the fruit of the trees she is planting. And through such a process in Bangladesh, we have planted a billion trees over the last five years, a billion trees. No project, no funding, no [inaudible], no exchange, no [inaudible]. People have done it. So there are things happening which people do. And she is the sustainable development because she is not trying to get the fruit out of that tree in her own lifetime, but doing it.

The fourth is the mobile cellular woman, who is a communicator. Many of you might know that Grameen Bank has established a cellular telephone technology by which the woman, poor woman, 6,000 of them take the mobile phone, go house by house, and become the mobile connector of telephones. If we have time and anybody wants to know, I can tell more about it. But basically so she is the communicator, she is connecting communication and doing it in a situation which is less than one dollar a day.

And the fifth one is very tragic and where climate change in a big way. I have been involved . . . in 1991 there was a big cyclone in Bangladesh, many of you know. One hundred and thirty-four thousand people died, one shot. A hundred and thirty-four plus or minus 10,000 people died in that one event. And I went to visit one of the . . . just after the cyclone went to visit [inaudible], and there was a gentleman who had almost, you know, gone frozen and total blind vision, and wanted to understand what was going on. And basically what happened was the cyclone was coming—it's a wave front, it's a huge wave of water coming towards them. They tried to move to different places, couldn't, and he had enough strength—he's the father and he had a son and a daughter. He was holding both of them. Unfortunately his strength was such he could hold only one. Now who would he let go, son or the daughter? He can't hold both. This is the greatest challenge of judgment at that point. This man has been trained on gender training. But who would he let go? And when I asked these questions of school children in villages people come to the same conclusion that the girl had to go.

So this is what a cyclone will do to families, the individuals of the tribe. And this is expected to grow more intense, more severe, and extreme events are expected to be more dangerous as we go along.

The last story is about a man when in [inaudible]first negotiation—and Mr. Estrada is here—I had the privilege and I felt honored to be elected to represent the Global Civil Society to the United Nations first meeting on climate change. And I told the story of this man who lives in a remote village. When he was in that village, and this is in the UN literature now, he was the only man in that village with a pair of slippers, others didn't have it. Now there lots of people with slippers in that village, 14 years later. And he asked me the question, "Why should my island go underwater because somebody has to use energy, ride a little more or eat a little more. What have I done to deserve this?" And that was the challenging question that remains in front on the issue, and that question we are still trying to address.

So in the cyclone of 1991 Bangladesh, as I said, 134,000 plus minus 10,000 people died. The whole ecosystem was devastated. A similar cyclone happened in Florida, hurricane happened in Florida, Andrew Hurricane as you remember, similar sort of time, similar sort of magnitude. Twenty-nine people died, but what collapsed was the insurance industry. So somebody had to pay. Here the economy was strong, the economy paid. Their vulnerability of lifestyle, life was the only thing that was there, so lives had to pay. Now there is the difference of payment. And that difference must be appreciated when you look at the climate change issue across the board.

Now let me come to the other issue. As you know, Maldives is an island. If there is one-meter sea-level rise, one and a half meter, that island will be underwater. Given the onset preparatory process in the summit before Rio 1992, there was a group that was trying to design the whole process, and some of us happened to be in that group. And the question was, What is this answer going to be about? And the question in the, you know, the wise people ask, What is the core business of United Nations? The core business, the conclusion came out after three days of discussion that the core business of United Nations is to protect the sovereignty of its member states. That is the central business. Everything else, you know, development, health, all that, is for that purpose. That's what they do. Now if that is the purpose, then this island country when it goes underwater, or one-meter sea-level rise, we have not done any legal mechanism in the United Nations or otherwise or having water-based states. To have a state you must have one square meter of land, have a pole and little flag, and one man to hang on there, that can be a state. But in the water there can not be a state. When this country goes, with it goes sovereignty. If sovereignty can not be protected by United Nations, the United Nations' justification goes. It's a very complex story that deeper issues are involved in the climate-change equations.

Now coming to the impact, when there is a severe event, extreme event, whether a flood, drought, cyclone, you name it, the impact of the event is a function of the intensity of the event, obviously. Bigger event, more people die, more things get affected. It's a function of the baseline condition. And when the cyclone happened the chief of Bank said, "The cyclone is not the main disaster. Poverty is my disaster." Because that is the baseline condition of the communities there, that's what . . . because the Florida people were not that poor, not so many people died. Baseline condition.

There comes another condition which you can call adaptive capacity. Now this is where adaptation comes in, and just to make the point of this very clear, mitigation, adaptation must not be [in] lieu of mitigation. Stopping climate change as far as possible, as quickly as possible, is urgent, has to be done, and adaptation comes after that. So mitigation must, adaptation must follow, but the way the scientists tell us certain amount of footprint has already been implemented which obliges certain adaptive measures to be taken. Because if we don't mitigate today, as we have just heard, in future it is going to be much most costly, not only in mitigation but also in adaptation, because we'll have to adapt a lot more. The society has to pay a lot more, somebody has to pay. And as we know, it's often the poor who pay, because rules of the game are set by a very golden rule, and the golden rule says "One who has the gold makes the rules." That's how the golden rule plays out.

So in adaptive capacity in major cyclones in Bangladesh has been shown that every ten years [inaudible] there has been a order of magnitude decrease in the number of deaths for the same set of events, because the society was better mobilized. So if 100,000 people died in 1960s, by '70s it was 10,000 people dying for the similar event, by '80s it was 1,000 people give and take, plus minus factor of three or four. So adaptive capacity remains very, very important and societies must have to start adapting and adaptation doesn't mean doing infrastructure only. It means institutions, it means building up the type of system that we need.

Now as we all know that the Climate Convention was established and food security and ecosystem issues became the central issue in the objective of Climate Convention, as you know, that in Article 2.4 those are the . . . and there are large number of issues, the whole rate issue, how rapidly things are changing. What is equity fairness between groups of people, groups of communities, that becomes the mechanism. You know, the Kyoto has given three pretty awful mechanisms, but that's all we have. We don't have any other options. The whole Kyoto was about solving the problem in the countries who agreed. For the first time in human history a group of countries agreed that we have done something for which we must take responsibility. And the biggest of the group then decides it's going to hurt me a little so I'm not going to do anything, I'm going to drop from the system. When I went to all the five women and the man that I've said that if you signed on a piece of paper if you withdraw, is that acceptable? And all of them said no. It is perfectly acceptable when the United States walk out of an agreement that they have signed the first bit, they don't agree to the second bit where action comes in.

And then of course the whole "not so" debate, it has been a "not so" debate, but neither is north homogenous nor is south homogenous. Group of 77 does the negotiation. What is common between China and Bhutan? What is common between, you know, Korea and Burkina Faso, is all a package, is all a package where even in those package the biggies, they make the decision for everybody else. And who do they make the decision for? Not even their own population. They make the decision for a small elite of their respective countries. That happens in U.S. as much as happens in India, Brazil, China, Bangladesh, everywhere. So those governments who go to the intergovernmental process do not, and let me emphasize the *not*, do *not* represent their people; they represent an elite interest. So some people say these governments are client states of the corporate sector, maybe so, and I'll just stop immediately, I can see that.

I will come to the last . . . well, let me skip all that . . . and say that the responses are taken across by a number of stakeholders, which was discussed this morning, the governments, the nongovernment community, the private sector, the communities, the village communities, and we are now doing a study with the village communities who are willing to participate, solve their own problem. They're not waiting for any begging bowl, they said, "Don't make my problem worse. I think it's pretty fair to ask that. I'm already in trouble, don't." You know, it's that additionality, the addition straw that broke the camel's back. So climate change isn't a big deal, but it is that additional deal which breaks those communities and breaks those systems, and the main issue that we have to look at is the building of capacity across each stakeholder, and the highest amount of capacity building needed is in Washington and the White House.

Thank you.

Cynthia Rosenzweig: Climate Change and a Global City

Upmanu Lall: Thank you Dr. Rahman. I'm sorry for cutting you off a little bit. Last panelist is Dr. Cynthia Rosenzweig from the Goddard Institute of Space Science at Columbia.

Cynthia Rosenzweig: Thank you, Upmanu. I feel like I'm going to have to give this talk in a New York minute so we can get to discussion all the audience. So I'm going to have to fly through what I put together.

I've added responses to the title because of the stimulation by the challenges posed by the organizers of this symposium. Let's get going on responses, let's really start getting . . . let's get . . . let's get down to brass tacks now about responses.

So the premise of my remarks is that urban areas have a critical leadership role in responding to climate change. And this leadership role is in three different arenas. The first is in assessing the consequences, which is a response in itself, a very important one. The second is in mitigation of the greenhouse-gas emissions. And the third is in adaptation.

These responses, this leadership role by urban areas, represents an important bottom-up approach to solving the climate change issue. I believe that this regional approach is a crucial bottom-up approach which then complements the top-down approach of the Kyoto Protocol and the UN Framework Convention on Climate Change.

Urban areas have been neglected tremendously in all the work in the IPCC and U.S. national assessment, etcetera. And it's actually astonishing because urban areas are so important. As we all know, they are soon going to have over half the world's population, they have a wide range of socioeconomic groups, they're often located on coastlines which are tremendously vulnerable to the sea-level rise and associated effects, tremendously multiple complex environments. We have to start studying climate change where it's hard, not where it's easy. And I've done a lot of work on agriculture, which is I believe relatively easy compared to when I started working on urban areas.

It's also hard because they're fractured and often very contentious jurisdictions. How are we going to take climate change on board in urban areas? And in this regard, they are also key linkages between global environmental effects and global forces to the local regions, and the other way back in terms of financial flows and migration patterns, for example. So for these reasons I believe that the urban areas is definitely a way that we need to go forward.

Jonathan talked about this a little bit, so I'm not going to belabor the climate stresses that impinge on urban areas. These are the main ones for the New York metropolitan region. First of all, our storms, the nor'easters, which come from November to April, and our tropical cyclones—we have them here as well, not as frequently, but they do come visit, especially in the fall. We have the link to the major climate-variability forcing factors of El Niño. When we have an El Niño, we actually have fewer hurricanes. But then we also very much have the heat waves that Jonathan mentioned, and the droughts and floods. And these are two examples from 1999. Indeed it was the hottest year on record, and we had four heat waves throughout the entire summer, and then, when the heat wave finally broke, tremendous convective thunderstorm. I've never driven in any storm more than that storm that happened right at the end of August. I'm sure some people from New York here remember that storm.

But, as Jonathan also said, not only are urban areas the recipient of climate stresses, they have a reciprocal effect on the climate as well, and that's the urban heat-island effect, primarily because of the absorption of the radiation by all the concrete and asphalt that we have in cities. So we've done studies with a number of departments in the Earth Institute and found that New York City has had—this is not a new phenomenon—we've had our urban heat island since the start of the twenty-first century. It's been warmer here. It was lower, about one degree C early on, but we still have this urban heat island in which our central parts are at about three degrees warmer than the surrounding exurban areas. But what we see also is how complex this heat island is. This is a Landsat satellite picture, which we're doing analysis of. Well where are the hot spots? And this is a key point in terms of urban areas, this unevenness of vulnerability within even one region, the New York metropolitan region. The complexities are enormous, but we need to take these on board. So we see hot spots. Of course, the airports in the region are very hot. Many of you flew into JFK, which is a drained coastal wetland by the way. I'm going to show that later. But we have hot spots in South Bronx, Red Hook, Long Island City, Newark. So right away this raises the issue of environmental justice and the interactions between our climate factors, our urban climates, and the people who live there. So how do we respond to these complexities in the cities?

So the first response, I believe, is that we need to assess climate variability and change in urban areas. Very, very neglected, as I mentioned. So I just want to tell you a little bit about the New York Metropolitan Regional Assessment, we called it the Metro East Assessment, in which we—it was part of the UN National Assessment, which divided the country into 18 regions. So the Columbia Earth Institute stepped up to being the sponsoring organization for the New York metropolitan region. I'm not going to go through with everything that we did, but the point I want to make is that this is an important response to mobilize the regions to address the climate-change issue, to learn about it. And that's what we did, with the Earth Institute, having workshops, many different workshops, we made partnerships with public agencies, working with our partners on our sector teams to set the research questions, so it's shared data and models, and decide the key findings. So what we're doing is we're moving beyond academic to partnerships with the key agencies. This is I believe a very important response, an activity, that we need to take on board, and this needs to be disseminated widely.

I just want to say up on the left we also emphasized integration, because in urban areas you can not study the sea-level rise separate from what's going to happen to the energy and water supply, etcetera. So we need to put the integration challenge at the center, and that's what we did with people, place, and pulse. And everyone asks always, "Well what is *pulse*? Why did you call it *pulse*?" Of course, *pulse* is a third word that starts with *p*. However, it also stands for why do people live in cities? We live here because of the economic activity that's here and the cultural activity as well. These are reasons why the urban areas can take on the leadership role in responding to climate.

By the way, we have a report if anybody wants it on CD now. Give me your card.

This was for each one of those sectors. We worked with partners from this multiple set of agencies. You can see this illustrates the complexities of the jurisdictions, the decisions. How is this complicated group of agencies really going to start taking climate change on board?

How did we do the climate part of the assessment? First of all, we don't just go to the predictions. We have to look first at the observations, and clearly all the talks this morning very much emphasized this. So just to show you that right here in the New York metropolitan region we have our own warming over the last century. And in fact we've had more warming than the global average. So that's the top curve. The bottom curve is the precipitation trends. You see there's not too much change in the precipitation trends, but if you look at the variability it's not statistically significant yet. But you see in the recent decades there appears to be the beginning of that intensification of hydrological events that the climate modelers and the IPCC project as one of the main consequences of global climate change. So before we get to the climate projections, we have to work with the observations—what's going on right now and what can we learn from our observations and trends?

Then we come to the challenge of taking the global climate models and the projections, and we had a very good discussion this morning about some of the strengths and weaknesses of the models, and then from those extracting a set of scenarios—never choose just one, but a set of scenarios—that is appropriate to use at the regional level. So this is a big challenge for the climate modelers, and the global climate modelers, and then now we're doing a lot in developing ATKIS, as Jonathan mentioned, regional, finer scale models as well to improve the predictions. But we always have to be very up front about the uncertainties, and I echo all the speakers this morning who brought this forward. But I also believe that we on the impact side can not be paralyzed by those uncertainties. We need to bring forward the uncertainties, but we need to deal with the potential for a changing climate right now and in the future. And as we go to the regions that's what we are really bringing forward.

I'm going to very, very quickly go through and just tell you three integrating lessons that we learned. The first one is, and this has been made before, that we have uneven variability in urban areas, from where the blackouts occur. That's in 1999. The blackout that we had just north of here in a lower socioeconomic neighborhood, and as Jonathan mentioned, these are the asthma hospitalization data, which have a relationship to ozone, which has a relationship to temperature, as Jonathan pointed out. And then two, the per-capita income distributions across our region. So the first key integration point is uneven vulnerability, and we need to look across our sectors to be able to understand this, and across our region.

The second is that the integration point is . . . there's a lot of hand waving about integration. We don't do integration because it's nice, we're all having such a great time working together. We reason why we have to do integration is that if we don't integrate, especially in urban areas, we are going to get the wrong answer. And this demonstrates this. Our water sector leader said, "Oh, don't worry. When there's a drought we can use our Chelsea Pump Station and take water out of the Hudson." Dr. Vivian Gornitz, who asked a question earlier and may still be here, yes, Vivian's here, she raised her hand in our meeting, which we were having integrating discourse, and she said, "Our back-of-the-envelope calculations on sea-level rise showed that the salt water intrusion is going to extend with sea-level rise." And I am not joking. She said they had made the calculations up to Chelsea. Unless we integrate, we are going to get the wrong answers, and we're not going to be prepared.

The third integrating point is that when we think of urban areas it is a mistake if we only think about infrastructure. We always think cities, oh, it's a bunch of buildings. That's not true. In all cities there is an underlying, highly damaged, often disrupted natural set of ecosystems as well. So we need as we're thinking about urban areas to integrate across our built environments and our underlying ecosystems. And what this shows is the vulnerability in terms of topography, our built critical elevations in our major transportation facilities. But on the right is Jamaica Bay, which we, and scientists at Lamont as well, identified in the work the accelerated loss of our coastal salt marsh that we have within the boundaries of New York City.

And this is just showing the actual observations and evidence of change. Again, we're not saying that this is caused only by the sea-level rise and the enhanced sea-level rise that we're having, but we are raising the issue of that enhanced sea-level rise as a factor.

Turning now to the other responses, the assessment is one type, very important. All the speakers have mentioned mitigation and adaptation. So what are we going to do? Are we going to mitigate, adapt, or both? Clearly the answer is going to be both. And then why is that? Because on the one hand we're going to be living realistically in a world that is going to be warmer than it already is, with our committed warming, but at the same time we have to work very hard to bring down those ultimate levels.

So in New York, in terms of mitigation, there's a real leadership role for cities to play. Of course, we have very high absolute values of electricity use, a lot of automobiles. But at the same time cities are more efficient in terms of their energy use because of stacking people up in the high-density buildings. That's very important. We have to promulgate that. And we have the best and the most expensive public transportation in the world. These are elements that we need to spread to other areas of the world.

And I know that Governor Pataki is coming tomorrow, so I'm sure he's going to be telling more about this, but this is at the New York State level we have already, with Governor Pataki's leadership, taken on board mitigation activities for the state. And the role of New York City in this, these are the state mitigation activities. Just want to highlight two mitigation activities that are important in New York City. The first is the establishment of shadow carbon trading markets, because we're great at markets downtown, we have experts on every kind of market, and we already have in the companies, Natsource and others, we have those carbon trading markets already to go.

The second is our corporate leadership here. I'm going to give just the example of Swiss Re, with their New York office, is doing a tremendous amount to bring mitigation activities to the forefront and taking a leadership role at the corporate level. These are elements that New York is doing, but other cities can do as well.

Now moving onto adaptation, what's New York doing? Following on from the metro east coast, remember we worked with all these different agencies. They are beginning now to take on the climate-change problem themselves, so it's incipient, it's beginning, an acceptance of the responsibility for dealing with climate change and climate-change adaptation at the regional level. So again I won't go through all the list, but these are descriptions of ongoing projects that we are still doing, very often initiated by regional entities that are beginning to be serious about climate change in our region.

And my final response is an actual set of projects that combine both mitigation and adaptation. And this is work that we're doing with a whole coalition of different institutions, both academic, research, and NGO in the region. And this is to actually do some demonstration projects on actual projects that can both mitigate and adapt, and solve a multiplicity of environmental problems as well. So I just want to end with the potential to tell about this project that we're working on right now, and we are looking at the potential for green roofs, which are vegetated roofs, a new form of roofing material. Instead of using the black tar that most roofs have in the New York [area], this is the idea of putting semi-arid vegetation with a very narrow soil layer to actually help to deal with the urban heat-island effect global climate change because we cool the surface of the roof and therefore first of all the people in the rooms underneath are cooler, less heat stress, that's the adaptation side, but also then it takes less energy to air condition those floors in the summer. And it also helps with the combined sewage overflow that Jonathan also mentioned.

So the idea in terms of our responses, let's be as creative as possible. Let's look for solutions that solve multiple problems, that are really exciting and wonderful. These are also tremendously aesthetic as well. And these are the kinds of responses that I think urban areas, with their people, place and pulse can really bring forward.

So what's the role of the Columbia Earth Institute here? It's to establish a research station to really document what those functions are. There's a lot of great enthusiasm about green roofs, How do they work in New York? That's the role of researchers, and so we're very excited about putting a coalition together to actually have the Earth Institute sponsor, perhaps, put a green roof on a Columbia building. This is the experimental design. These are the actual possible buildings that are owned by Columbia University. Most, the top ones and at midway, that's in the Manhattanville site. We'd love to put one on top of GISS, our building, because we feel it would be of great symbolic value where so many of the global climate-model projections have been made. But we are working with Columbia facilities, the Office of Government and Community Affairs, the Earth Institute, Earth Pledge, to let's get going on some projects that we can say we in urban areas are beginning to respond.

And I think the last one is this, which is that we need also to move beyond New York and establish networking—Atiq and I were just talking about this—we're going to get going on working to have a network of global cities to take on this challenge and really play the leadership role that urban areas I think need to, can, must, should. I think it's a tremendous contribution, and necessary.

Thank you very much.

April 22, 2004

Session 2 Q & A: Responding to Climate Change: Living in a Greenhouse

Question 1: Remote-Sensing the Urban Heat Island

Upmanu Lall: I would like to thank all panelists for four very informative presentations. Since our optimism about keeping on time was equal only to our optimism about the future of the planet, we are going to forego the panel discussion and move directly to the questions from the audience which Mike Purdy will orchestrate.

G. Michael Purdy: Okay we've just got a few minutes here for three or four questions from the audience to the panel. If you'd like to go to the microphones. I'm going to have to brutal I'm afraid to keep us on time this afternoon. Please go ahead.

Woman: Thank you. I was wondering if the remote sensing . . .

G. Michael Purdy: Could you identify yourself?

Woman: I'm Judith Weiss of Rutgers University. I was wondering if the remote-sensing look at urban areas such as Manhattan shows cooler temperatures in Central Park, for example? Can you see that the urban heat island is . . . if you had more parks, you would have less heat-island effect? And is there any possibility of increasing, you know, turning lots of empty lots and, you know, buildings can get demolished, you know, uninhabited buildings, and just have more park land and help the situation that way?

Cynthia Rosenzweig: The answer very definitely is yes. The remote sensing clearly shows that the vegetated areas are indeed cooler because of primarily their evaporation transpiration, which is a cooling process. And we are actually in discussion right now on your second part, in terms of urban forestation, vacant lots, etcetera, we are in conversation right now, in discussion with NYSERDA, New York State Energy Research and Development Agency, to really do research around the potential for street trees and vacant lots and the role—and green roofs—that they may play in cooling.

Question 2: Keynes and Economics

G. Michael Purdy: Thanks, Cynthia. Please go ahead, sir.

Man: My question is for Mr. Dasgupta, who is from Cambridge. Since he's from Cambridge I'm interested is he still interested in Keynes? During the '90s we had about half a decade of prosperity, and we had economists predicting infinitely large surpluses for an infinite number of years, which was reversed in the space of about six months to infinite debts for an infinite period almost. Now what is his view on the cyclical concept of Keynes, which means of course that the remedy for the depression or the recession actually lay in the period of the bubble before. A little bit of activity should've been done surely to shave the bubble down a bit, which would've averted the recession. It seems to me Keynes has got the answer to all this. What is his feeling about it, please?

Sir Partha Dasgupta: I really don't want to be supercilious about it. You're asking an extremely important set of questions regarding important insights about Keynes. He looms large, so don't worry, he's still there in our consciousness. But it's interesting that you ask about Keynes because the subject of this workshop and this symposium and this panel is really about the long run, and when economists talk about the long run, we talk about 100 years, 200 years, and that's really stretching it. And it's interesting that Keynes was very much concerned with the short run. His work, as you probably know, was really targeted at trying to identify the reasons for the depression that Europe and the United States suffered from, and so in a way Keynes doesn't have very much to say, except when he addressed the apostles, he doesn't really have very much to say in his economics about the questions that we are interested in here today.

Question 3: Climate Predictions and Financial Markets

G. Michael Purdy: Thank you. Yes sir.

Man: Hello. It's another question for Dr. Dasgupta. First of all I must confess absolute ignorance of all economic matters, but it is my impression that no political course of action will be taken that will harm growth. It seems to me the paradigm here is that anything that harms growth is to be avoided above anything. So as a climate modeler I'm asking how scary do we need to make our predictions so that financial markets will finally consider this is a possible bad outcome on growth?

Sir Partha Dasgupta: That too is a terrific question, and I'm going to do injustice to it, no matter how hard I try. One way of looking at your question and the way you posed it is that you're making a prediction this is going to happen; that is to say, policymakers are interested in GNP growth. You didn't say what growth in what, by the way. And implicit in your question is a very, very rich set of issues that many of us have worked on.

The target really is growth in GNP, which will be missing huge amounts of the items that really should be concerning us, because we could be running down things and so forth, and it wouldn't be picked up by GNP. So there is work on that. Now what are asking is suppose, however, we don't live in utopia, we don't live in Agathatopia, which by the way is an expression that was used by economist James Meade to describe the good enough society. We are not even there, we are in a rotten situation. In that world, what I was arguing was that if you are a public policy maker somewhere or the other, or at least . . . put it this way, the arguments that you need to bring to bear on the public policy makers is in line with what I was suggesting. They may go for growth but then say, "Well if that leads to potential hardship and to the vulnerable, in which case that hardship would loom large in our consideration, then the way to assess those projects you really ought to look at very low discount rates, possibly even negative discount rates, depending on what the forecast is." So the structure that I was suggesting is consistent with moral thinking or ethical thinking in a world which has gone mad.

Question 4: The Role of the Public Health Community

G. Michael Purdy: Thank you. Okay, one last question. Go ahead, sir.

Man: My name is Roger Ladell and I'll address the question to Dr. Patz. And my question arises out of my frustration at the resistance of so many elected officials to everything that we're talking about, and despite an almost unanimous scientific community position, these elected officials don't want to hear about it, and many of the electorate therefore don't want to hear about it. So on the thesis that physicians tend to be respected more than scientists, is there a role that the public-health community and physicians can play in trying to drive change?

Jonathan Patz: Well sure, I think that one of the first things we learn in medicine is first do no harm. And so I think simply by example physicians should lead their lives and do no harm, so you know, I drive a Prius, so things like that. I don't think there's much that physicians can do in the office because physicians are dealing with acute issues, and they really don't have time for these . . . necessarily for more population-wide, longer term issues. On the other hand I argue that every physician should have a master's in public health anyway as a requirement, and look beyond individual health, family health, community health, but also population health. But the other answer I have for you is that there's always an argument about triage, and we have so many acute, pressing health problems today, how can we even think about the future? And my answer to that is that we do need a priority on the current acute problems of today, and yet all of these acute issues—poor water, air pollution, infectious diseases—every single one of those, climate change can build on the current problem and exacerbate it. And I would make the argument that the issue of long-term climate change is actually a problem that cuts across problems of today that we really need to be building that extra bit of prevention into. So you need to juxtapose the argument that climate change is not far off in the future. It's climate variability, it's extremes—we have them today, even though you can't say that flood, that heat wave is related to global warming, although climatologists do argue about Europe last summer as being such an abnormal event that maybe it is climate change, but juxtaposing the acute with the long-term and realizing that they're one and the same really.

EARTH'S FUTURE: TAMING THE CLIMATE SYMPOSIUM
April 22, 2004

Session 3: Responding to Climate Change: Can We Stop It?

Introduction by Christopher Field

G. Michael Purdy: I'm sorry that we don't have time for a break, but we are targeting a prompt ending at five o'clock, if that brings you any solace. And I welcome our third panel for the day onto the stage. This panel will be entitled "Responding to climate Change: Can We Stop It?" We've already heard some comments on this issue. This panel will dig into this in more depth as we move increasingly towards the controversial topics that we're hoping to tackle here. The chair of this panel is Chris Field, who is the founding director of the Carnegie Institution's Department of Global Ecology. He gained his PhD from Stanford and has led research into the quantification of ecosystem processes from satellite data, leading to global-scale studies of primary production, forest management, and agriculture. I introduce you Professor Chris Field.

Christopher Field: Thank you, Mike. I'd like to start by congratulating Columbia for the leadership that organizing this session demonstrates, and I'd also like to congratulate all of you for obviously making the topic a priority.

Before I introduce the distinguished colleagues who have agreed to discuss the challenging question, Can we stop climate change? I'd like to make three quick points. The first point is that what we're really talking about is the global energy system. Now we live in a world where primary energy use is something like 400 exajoules, 400 times 10^{21} joules, a vast amount of energy, but if we look at any kind of a realistic projection in the future, we're looking at a century where primary energy use will be substantially more than it is now. In a future with more or less business-as-usual type perspectives, we could be looking at anywhere from six to eight, even ten times current primary energy use by 2100. What we're really talking about when we're talking about stopping global warming is coming up with another kind of a model for the future, a future with much more emphasis on non-emitting technologies, on conservation practices, and on technologies for removing CO_2 from the energy system before it gets to the atmosphere, and these are the processes that my colleagues will be discussing today. We need to discuss the underlying technologies, the mix of them that makes the most sense, and the geographic and economic distribution that makes the most sense.

We also need to be acutely aware of the fact that we're dealing with processes with very long time lags. In principle we would recognize that climate represented a problem we wanted to solve, [so] we would solve the problem immediately at the point of stasis, but there are a number of factors that are incredibly important that extend out the time frame, placing really unparalleled challenges on a decision-making framework that lets us get ahead of the problem rather than behind it, and that concerns issues with how long it takes to quantify the problem, something we heard about this morning, how long it takes for the international community to come together and formulate agreements, how long it takes to develop the technologies in order to address the problem, and then finally how long the natural system takes to respond to the issues that have already been entrained. And this involves everything from decline of forests that have been impacted to issues about the lifetime of power plants.

What we hope to reach as an outcome of this session is something about a trajectory of carbon emissions that is consistent with a future world that we want to live in. And then we need to reconcile that with whatever development trajectory we get on, and it's likely that there's going to be a gap between whatever the development trajectory is and the carbon-emissions trajectory that's consistent with where we want to be. And that's the challenge of policy.

And the final thought that I want to leave you with is that with many development trajectories, we look at gaps that are scary in size, gaps that are on the order of magnitude of the entire size of global carbon emissions currently. But when we look at those, even though they're scary, they typically have large amounts of technology improvement already built in, so I've sketched here a 550-ppm constraint, not to say that that's where we want to get, that may even be more damaging than we're willing to accept, and the well-known IS92 scenario above that. But if we look at the IS92 scenario without endogenous technology improvements, we're looking at carbon emissions that are many, many fold greater than those that we experience today, and it means that the challenge of the policy process has to be eliminating not only the leftover emissions after technology improvements have occurred, but the courage and the forthrightness to look at this whole gap and close it down to the level where we're on a future that we're willing to accept. And my colleagues have graciously agreed to address this challenge in a substantive way.

We'll start with Professor Jorge Sarmiento, professor of geosciences at Princeton University. Jorge's PhD is from Columbia. I believe he was a student of Wally Broecker's, and he's been a real leader at integrating biological, chemical, and physical aspects of the ocean carbon cycle and climate. He's a past director of Princeton's Atmospheric and Ocean Sciences Program, and he's the current director of the Cooperative Institute for Climate Science. His title is "Carbon Dioxide and Climate Change." Jorge.

Jorge Sarmiento: Carbon Dioxide and Climate Change

Jorge Sarmiento: Well the first time I heard about climate change was when I started my graduate studies here in 1973, and as Chris said, Wally Broecker was my advisor. I lived here in the city, by the way, on the Upper West Side, and I just loved it. It was so hard to get used to living anywhere else after being here those years. But I was standing in the hallway, and I overheard Wally Broecker talking with somebody, this is 1973, saying, "We should all be investing in land in Canada." And I said, "Well what's this all about?" and he told me, you know, about global warming, and I said that was my first experience.

I have just a very simple message I want to get across, which is that we should tackle this problem sort of one step at a time, starting now, and actually in fact we have been tackling the problem pretty well for the last thirty years, not intentionally. So what I want to talk about is carbon dioxide and climate change, and the topic of this meeting is how can we tame climate change, and I want to talk about how we can tame carbon dioxide.

And I want to begin by talking about the last thirty years which have given us a great start, and then talk about the next fifty years, defining the nature of the problem in terms of this sort of wedges-and-slices concept that my colleagues at Princeton have introduced, and then talk about some difficulties, and then say a little bit about what we need to think about for the next fifty years.

So this is a logarithmic plot of fossil-fuel emissions starting in 1800. And on a log scale like this, an exponential increase comes out like a straight line. And what you see here is that over most of the history of fossil-fuel emissions, the growth rate of emissions has been about four or four and a half percent per year. There were little pauses in the First World War, the Depression, and the Second World War, and then during the energy crisis of the early '70s, there was a really significant change to a growth rate, which has been about one and a half percent per year.

So what sort of difference has that made? Well a colleague, Fortunat Joos, from the University of Berne did this calculation ten years ago—we should update it because it goes only through 1990—but the results are pretty much the same. And what this is is it shows what the world would have been like if we hadn't cut back the growth rate from four and a half to one and half percent. The atmospheric carbon dioxide between 1973 and 1990 actually by 24 parts per million. It would've grown by 36 parts per million. So the reduction in increase of the atmospheric CO_2 was 33 percent.

The growth rate of CO_2 in the atmosphere in 1990 was almost 2 parts per million per year. If we hadn't reduced the growth rate of emissions, it would've been in excess of 3 parts per million per year, and so the reduction was 45 percent. The annual fossil-fuel emissions, which today are up around 7 gigatons or petagrams of carbon per year, in 1990 were around six. They would've been 10 petagrams of carbon per year, so two-thirds higher than the actual emissions rates. So this change in growth rate that occurred following the energy crisis has had a really major impact on where we start from today.

So what about the future? There are two lines shown on this slide here going out till 2150 and starting in 1950. The top slide is basically an extrapolation of the one and a half percent growth rate from the first transparency, so we could call this a business-as-usual scenario. People argue as to whether it might be greater than that, but the scenarios in general tend to fall more or less around this value, one and a half percent per year. And the other line shown on this diagram here is the emissions that would be permitted if we decided that we wanted to stabilize atmospheric carbon dioxide at 550 parts per million. So those are the permissible emissions. And the gap between these two is the challenge that we face, as identified by Chris Field. But I would like to suggest, following the sort of consideration of this issue by my colleagues at Princeton in the Carbon Mitigation Initiative, that we ought to think about this problem in sort of two timescales, one of them being a time scale of fifty years when many if not most of us will hopefully be around, and then beyond that. As I say, it's two separate issues.

So this is a detail of that fifty-year timescale that I identified in the previous transparency. Here is that business-as-usual scenario. These are the fossil fuel or the fluxes due to fossil fuel. So what we have here is the business-as-usual scenario again reproduced for the next fifty years, starting this year, 2004 to 2054, and then we have the stabilization scenario at 550 parts per million. And basically these are the allowable emissions, given the permissible atmospheric growth rate which would stabilize us at 500 parts per million, given an estimate of oceanic uptake using ocean models, and then given an estimate of land release into the atmosphere of about a gigaton of carbon per year, rather of land uptake, net land uptake, of about a gigaton of carbon per year, which is actually a pretty large number, which I'll say something about in a moment.

So the idea is that we have essentially this wedge, and to give some numbers to it, which I'm going to call a stabilization wedge, and to put some numbers on it, present emissions are about 7 petagrams of carbon per year, and under this one and a half percent per year growth rate would grow to about 14 petagrams of carbon per year. So the wedge that we have to do something about basically grows from zero today to 7 petagrams of carbon per year. And these, if you take 7 petagrams of carbon per year over fifty years that amounts to 25 . . . sorry, if you take . . . so what we're going to do here is if we divide the wedge up into seven slices, each of which has an emission of 1 petagram of carbon per year at the end, it's sort of hard to resist the temptation to do it that way, and then each of these slices of the wedge is responsible for a cumulative emission of 25 petagrams of carbon per year over the next fifty years. So essentially what we're doing here is we're taking the problem of stabilizing atmospheric CO_2, which defines this wedge of emissions of CO_2, net CO_2 emissions to the atmosphere that we have to reduce, and we're breaking it up into seven pieces.

And so we need seven slices of 25 petagrams of carbon per year. How can we actually satisfy those? And there are a long list of technology options that are available now, each of which could probably account for an order, one or two, slices of this gap fairly easily. And these include things such as increased energy efficiency, carbon capture and storage, fuel shifting to displace coal, using other kinds of fuels like methane and so on, wind and solar sources for electricity generation, renewable or nuclear energy. And David Keith, who will be giving his presentation next, will be discussing three of these topics in more detail. So in principle we have here five to maybe perhaps ten or even more of these slices. We also have slices that come from the possibility of enhancing natural sinks, in other words, the land or the ocean. And on land the baseline we've assumed is a constant uptake of 1 petagram of carbon per year net, and that's equivalent to two slices. But it may be that that is an overestimate, and perhaps we should make that more like one slice which would mean then that we have to do eight slices.

We've ignored CO_2 fertilization. There is increasing evidence that the fertilization of plants on land, which has been thought to be a major mechanism for uptake of carbon in land, does not appear actually to be increased carbon uptake on land. If indeed there were a CO_2-fertilization effect, that would be equivalent to approximately two more slices over the next fifty years. An additional one or two slices may be possible by such things as aforestation, reforestation, plantations, and soils, agricultural soils, and so on. Our group has done a considerable amount of research on oceanic sequestration of carbon dioxide by injection of CO_2 into the deep ocean and by fertilization of the surface ocean by iron. There are large parts of the ocean today which have high concentrations of nutrients. If you add iron to those areas, the hypothesis is that you will get carbon-dioxide uptake, and there's been lots of research done on this issue.

We tend not to be particularly enthusiastic about these scenarios. I should say that injecting CO_2 into the deep ocean, if you inject it deep enough, around 3,000 meters, in fifty years only 1 or 2 percent of it comes out. So anything that you put into the deep ocean will actually stay down there. With iron fertilization, if you did large-scale iron fertilization, for example, around the entire southern ocean, that could give you approximately two slices. So in principle the potential for CO_2 injection is unlimited, as long as you strip the CO_2 out and pump it into the deep ocean, and iron fertilization in principle could account for as much as two slices. But the environmental impacts of both of these options are probably prohibitive. The CO_2 pumped into the deep ocean locally would cause enormous damage to ecology. There have been several attempts to actually carry out experiments. All of that have had to be canceled due to environmental objections and so on. It's hard to see how this would actually become an option that people would use in the future. As regards fertilization, iron fertilization, we've done a series of simulations looking at fertilization, for example, in the tropics, and it's very, very difficult to verify that you've actually taken up CO_2 because the perturbation of the atmospheric CO_2 flux is really very small. What you're doing when you're fertilizing is you're actually transferring nutrients from the upper ocean or thermocline down into the deep ocean, and that reduced biological productivity in the surface ocean. We made some estimates of the impact of this on fisheries, for example, off Peru, and the costs of sequestration, which might be of order perhaps two or three dollars per ton ends up being more like fifty to a hundred dollars per ton if you start to take the impacts on fisheries into consideration.

In addition there are certain areas where the fertilization leads to anoxia, and anoxia leads to production of another greenhouse gas, nitrous oxide. And in the tropics the release of nitrous oxide to the atmosphere is almost equivalent in its greenhouse impact because it's a much more powerful greenhouse absorber than carbon dioxide, to the carbon dioxide that's removed from the atmosphere. So on the whole we're not particularly enthusiastic about these carbon sinks, and tend to look more towards the upper parts of the diagram, and perhaps biological sequestration on land.

I'd like to give three sort of warnings about this sort of scenario approach. The one and a half percent growth rate per year scenario—basically this is how much emissions is allowed in the next fifty years if we want to stabilize at 550. This is how much we emit if we go at one and a half percent per year. And so the wedge is 181 petagrams of carbon, which gives seven slices. On the other hand, if we take two other very popular business-as-usual scenarios like the IS92a and the stress a2, we're talking about 11 or 15 petagrams of carbon, or rather slices, so four more slices than this to here, and then four more in addition down there.

Another point I would make is to emphasize one that Chris made, which is that the IS92a and all of these emission scenarios actually already make some assumptions, very, very dramatic assumptions, about energy efficiency. And so if the economy grows along a trajectory where with present energy efficiency we would go along this line, the actual scenarios that have been published all over the place already assume endogenous technology improvements that bring us along this line. And so if those things don't work out, that could present some issues.

The third warning I would like to make in regard to the impact of global warming, and in particular Steve Wofsy mentioned this morning this Hadley model where the Amazonian rainforest collapses as a consequence of warming. He argued that the mechanism in the model is probably incorrect, but the possibility still exists of major changes in terrestrial biota. And if we estimate the magnitude of the carbon sink that is given up by the collapse of the Amazonian rainforest, then here also are the warming impacts. We're talking about seven to, in this case one and a half, additional wedges or slices that would be required.

Well beyond fifty years things get a lot tougher. But if we get going now during this first fifty years and we have an emphasis . . . we essentially gain time for fundamental research, which would then really enable us to deal with this bigger problem that comes in the longer run.

The next slide I think is the sort of summary slide. I'll end here so as not to take time from the other speakers.

David Keith: Technology and Climate Change

Christopher Field: Our next speaker is Professor David Keith, who has just assumed, or is in the process of assuming, the Canada Research Chair in Energy and the Environment at the University of Calgary. He has a PhD in physics from MIT, and his original research life was in atmospheric chemistry. Later he came over to the good side, and focused on energy and environment, where he's made fundamental contributions to energy technology, hydrogen transportation, and carbon disposal in geological formations. David's title today is "Technology and Climate Change."

David Keith: As we know, technology always works.

Industrial civilization rests on abundant fossil energy. In Britain, the cradle of the industrial revolution, fossil fuels became the dominant energy source around 1700. The fossil-driven economic expansion far outstripped the rise in energy use, producing a steady decline in the amount of fuel used per unit economic output. In countries that industrialized early, the last two centuries have seen a tenfold or greater improvement in the efficiency with which these fossil energies are transformed into useful work or final products. The increased prosperity has ignited a population explosion. That, in combination with the increase in per capita energy consumption, has driven fossil-fuel use up by more than a hundredfold since 1850. Despite this, there is no sign that we are running out of fossil fuels. We have enough for centuries at twice our current burn rate, so we will not solve this problem by running out.

Use of fossil fuels will, if unchecked, risk dramatic climate changes within this century, as you've heard throughout the day. Can we stop it? We cannot prevent some human interference with the climate because we are already interfering. Even were we to devote several percent of world GDP to an optimally managed crash program aimed at reducing greenhouse-gas emissions, we would still see emissions rise for several decades before they began to decline, and concentrations, which drive climate change, and which depend on the sum of emissions over time, would rise significantly before declining on a timescale of centuries. So we can not avoid some interference with the climate.

Now let's try a more nuanced version of the question. Can we change course, can we leave the path of ever-increasing emissions, which will eventually lead to dangerous interference in the climate system—for example, an ice-free Arctic Ocean in my children's lifetime is entirely conceivable—and instead bring emissions down towards zero over this century?

The answer to this, at least my answer, is much more heartening, it is yes. There is no reasonable doubt that we have the technological capacity to achieve very deep reductions in emissions without sacrificing access to abundant energy. So what I'm going to do essentially is to describe three kind of double-sized slices, each of which might be a useful tool to tackle this problem in a specific sector. And here I'm going to take a kind of diverge from what Wally Broecker said. I myself work mostly on CO_2 capture and storage, but I in no way believe it is the only tool at hand that could deal with a large chunk of this problem. So I'll describe three technologies that could be widely implemented over the next few decades, just a few decades, each of which could enable us to cut CO_2 emissions from electric power generation in half or more. Why electricity? It accounts for 40 percent of CO_2 emissions, that's both the U.S. or the global figure, and it's the easiest sector in which to make very deep reductions in emissions from primary energy use.

First, wind. Wind power currently supplies a mere .7 percent of global electricity, but the amount of installed wind power capacity is growing at an extraordinary pace, equivalent to the construction of several king-sized coal-fired power plants each year, a development spurred on by the European Union's commitment to reduce CO_2 emissions. At the best, that is *windiest*, sites the average unsubsidized cost of electricity at the turbine is now roughly equivalent to the cost of fossil-fueled electricity. Moreover, the cost for electricity for wind has fallen dramatically in the last two decades, and there are very good prospects for continued decline as the technology matures. We have innovations around the corner that can be applied. I should say these things are getting huge. The wind turbines are not your sort of father's wind turbines. These things now stand 150 meters to this height. That's the height of a really tall skyscraper, and they're going to go up another fifty or more meters in the next decade.

The effective cost of wind in real-world electric systems exceeds the average cost at the turbine, because of the intermittency and location of wind resources. Wind does not yet, thank goodness, blow when we tell it to, and the location of the best wind resources is often far from population centers. Thus, while some advocates claim that the cost of electricity from wind is now equal to that from conventional generation, this is an exaggeration based on underestimating the cost of intermittency and location, the costs these things impose on electric power systems.

Skeptics of wind, on the other hand, often say that these limitations are insurmountable and that wind can never account for more than a small fraction of electric power generation, a small fraction meaning 10 or 20 percent. Engineering-economic models constructed by my collaborators and by other folks around the world suggest that this is false. If the electric system adapts by adding transmission, storage, and load-following capacity, it's possible to grow electric power systems with associated markets that derive more than half of their net electricity generation from wind, at a cost increase of only a few cents per kilowatt hour.

Second, we could continue to use fossil fuels while eliminating emissions of CO_2. This can be achieved by capturing CO_2 from power plants, most obviously coal-fired power plants, and injecting it deep underground into geological formations similar or identical to the geological formations from which we now extract oil and gas. This is often called capture and storage or sequestration. We argue about what's the right word in the IPCC these days. Surprisingly essentially every piece of hardware necessary to build such a power plant without a smokestack is available today at the commercial scale, at the billion-dollar commercial scale. So the idea that we need R & D in order to do this is simply incorrect. Systems for capturing CO_2 from power-plant exhaust are already used commercially to produce CO_2 for merchant uses such as carbonated beverages. Long-range . . . that is, 1,000-kilometer pipeline transport of CO_2 already exists, and injection a kilometer or more underground is already practiced in the oil and gas industries for the purpose of enhancing oil recovery. We could build new coal-fired power plants without CO_2 emissions today, without any more R & D.

While predicting future energy-system costs is certainly a dangerous game, the rock consensus is that with appropriate R & D directed at system integration, but without any substantial new innovations, such plants would—assuming they were built in some quantity, not just one—raise the cost of electricity at the plant gate by a few cents per kilowatt hour. Sound familiar? There are of course risks and uncertainties related to the fate of CO_2 we would inject underground. If used at very large scale—imagine hundreds of such plants—there would likely be occasional accidents involving leakage from pipelines and leakage from CO_2 that was injected underground. Nevertheless experience in the oil and gas industry, experience with injection of other fluids for disposal, which is not insignificant, suggest that risks of CO_2 storage need be no larger than risks from similar large-scale industrial activities such as natural gas transportation and storage. The leak rates from North American natural-gas storage operations are less than one part in 10,000 per year, and natural-gas storage is in several respects a harder task than CO_2 storage, so we ought to be able to do better for CO_2 storage.

Let me just show you that this really exists. This is perhaps the best example that shows that every piece of technology really exists in the real world today. This is a giant facility in North Dakota that turns coal into natural gas, but if you ask the folks here to make hydrogen, that would be an easier job for them. They ship the CO_2 on a billion-dollar pipeline up to an oil field in Saskatchewan, where it's injected about a mile underground, and there's a big international monitoring effort designed to understand the fate of that CO_2.

The third option is nuclear power. Nuclear power works. It now supplies about 22 percent of electricity generated by U.S. utilities. Even counting the full fuel cycle, emissions of carbon dioxide and other air pollutants are extremely low. Current costs of electricity at the existing plants, ignoring the capital required to build them, are equivalent to or lower than the cost at coal-fire generation. The recent MIT study on the future of nuclear power suggests that the costs of nuclear electricity from new plants, that is including capital costs, would be about 1.5 cents per kilowatt hour more than new coal-fire generation with high-quality environmental controls. Again, there are risks. There seems little prospect of building new commercial reactors in the United States in the near future; the industry has lost the public' trust, and in my view much of that responsibility lies with the industry and stems from a combination of weak management and an unhappy tendency towards, to be polite, a paucity in public relations. Risks arising from operation of the reactors themselves and waste disposal are, in my opinion, small compared with other energy technologies. For me the greatest uncertainty is proliferation. If nuclear power was widely used, it wouldn't be used in just this country, to cut CO_2 emissions throughout the world; I see no way to avoid the fact that it would be materially easier to access the materials and technology necessary for making weapons.

All three of these technologies could be used to achieve very deep reductions in the electric-sector emissions within just a handful of decades, putting us on track to substantially reduce our impact on the climate system. Use of any of these technologies would likely add a few cents per kilowatt hour to electricity costs. How much is that? A glance at the history of recent electricity prices, I believe, suffices to put such a cost increase in perspective and to suggest that while clearly significant, it would not in any way result in a dramatic change to our economy or a dramatic collapse in our use of electricity. So statements that one occasionally hears that we just can't afford to this, it would sort of break the industrial bank, are just sheer nonsense. This graph here is the last, 1960 to 2000, these are electric prices, residential and industrial prices. This is, you know, what might happen in the future. I have no idea what will really happen, nobody else does either. And this is what two cents a kilowatt hour looks like. And just to take a longer perspective on history, you probably can't read the numbers here, but this is from [the] 1890s to 1973, and that top figure there, electricity prices started in real dollars at about four dollars a kilowatt hour, 450 cents a kilowatt hour, so on that kind of long timescale, adding a cent or two a kilowatt hour it's clearly not going to radically affect our economy, not to say it's not real money.

None of these is a silver bullet. Implementation of any new energy technology at large scale will have profound effects on energy systems, effects that will ripple through energy markets, producing far-reaching and unpredictable changes in economic and social systems in which they are embedded. Costs will not be, and should not be, the sole basis for decision making. For nuclear power and carbon capture and storage, at least some of the potential risks are obvious. For wind power, while wind power presents a few acute risks, its use at large scale will necessarily have nontrivial environmental impacts due to the diffuse nature of the energy source.

I am confident that the risks arising from any of these technologies are small compared to the risks arising from the operation of the conventional coal-fired power plants, which after all caused the premature deaths of somewhere between ten and fifty thousand of our fellow citizens a year today. If we are to deal seriously with the climate problem, we will, of course, have to tackle other sectors of the economy beyond electricity, and improvements in efficiency will necessarily play a vital role. But the electricity sector is in several respects the best place to start making deep reductions.

Technology serves as both villain and potential savior in the climate problem. Fossil-fuel technologies serve as a primary driver of modern industrial civilization and of human-induced climate change, yet many technologies exist that could enable us to drastically reduce our impact on the Earth's climate while continuing to provide more energy services. Thus, subject to various quibbles, my answer is yes, we can avoid damaging climate change, but will we? I wish I could be more optimistic.

The history of the ozone problem gives us some real basis for optimism. It demonstrated both that a flexible, effective, and efficient international regime can be developed to protect a global public good. And a less appreciated and perhaps more important lesson, it demonstrated that private-sector ingenuity can be efficiently harnessed to drive down the cost of pollution control. The great core success of the ozone regime was that the cost of controlling chlorofluorocarbons was much less than we expected, and that didn't just come out of the blue, it came out of the way we structured the management regime, and maybe also out of luck.

But the climate problem is harder, harder because the cost of control is higher, and harder because the impacts are both more uncertain and more unequally distributed. As you've heard before, there will be both winners and losers as climate changes. It's now been 39 years since a U.S. president first received a high-level briefing on the climate problem. The core scientific facts have in many ways changed little since President Johnson's days in office. We know a great deal more, but the core connections between burning fossil fuels, rising concentrations, and climate change have not changed, yet the global community is only now beginning to take baby steps toward slowing the rate of increase in our climate impact, and one can hardly even say that in this country today.

If the ozone story gives us hope, the failure to effectively regulate particulate air pollution in this country, the cradle of modern science-based environmental regulation, gives one some pause and cause for pessimism. On that unhappy note I close.

Michael Hanemann: The Economic Costs of Action Versus Inaction

Christopher Field: Our next speaker is Michael Hanemann. He's an economist with a PhD from Harvard, and he's currently professor of agricultural and resource economics at the University of California at Berkeley. Professor Hanemann has made key contributions to a number of areas at the interface between economics and the environment. He's worked on topics that range from fisheries to forests to climate change. His talk today is "Economic Costs of Action Versus Inaction."

Michael Hanemann: I'm delighted to be here. I have to apologize right away because I'm afraid I express myself in sentences, not in bullets, and so this is not PowerPoint, this is Word. I want to mention that I'm part of what seems quite a large group of Englishmen called Michael who have chosen to come to the United States to make their home and find better weather, if not better climate.

My talk will have four sections. I want to talk for a few minutes about climate change as an economic issue, because I think it stresses economic reasoning, and I want to talk about some of the problems that it poses for economics. And then I want to talk about the costs of inaction and the costs of action. And then lastly I'll say a few words about what I think we should do.

So the next slide. As Keith said, the question is not can we stop it but what should we be doing? And the essence of the climate problem is really one of timing, it's what action should be taken when? Let me go on to the next slide. The climate change issue is a tremendous example of an externality, and the concept of an externality in some ways is fairly recent. It dates back to around 1920, an English economist Arthur Pigou, who emphasized the fundamental point that in a situation like this where the actions of one person have a direct effect, an adverse effect, on other people, the outcome of a private market economy will not be in the public interest, and there is a case for intervention—something needs to be done to remedy the situation. And climate change is really an immense externality over space, as Professor Rahman talked about very eloquently, and also over time in terms of the effect of current generations on the well-being of future generations.

The dominant intellectual trend in economics for the last fifty years had been to separate efficiency from equity, and to try and focus on questions that can be answered purely as scientific questions, which means focusing on the issue of efficiency. My own view is that externalities are an area where that is inherently flawed, if not foolish. That is to say, externalities are fundamentally an issue of a conflict of interest between one party acting in his own interest and other parties who are adversely affected. And of course climate change is a dramatic example of that.

Partha in his remarks at one point said of something, "The problem is not with economics, it's with the way economics is done." And I think that's true here. In the case of the type of conflict of interest represented by an externality, I don't believe it is possible to frame a meaningful answer without first adopting an ethical stance because this is in a sense a judgment of Solomon. You have one party acting in his own interest, and you have another party who's being affected. And essentially you need to take a stance. I'm not arguing what the stance should be, but what I am saying is this: what is driving the conclusions of a lot of the existing analysis, economic analysis, is not the economics but the ethical stance that is adopted implicitly underlying that analysis. And the result is that the conclusions of the analysis need to be defended by defending the ethical stance, not by asserting the technical, scientific knowledge of the economic analysis.

The last point in this theme is just to emphasize that the timescale we're dealing with, fifty years, seventy-five years, a hundred years, two hundred years, really stresses, I think, economic analysis. The issue that Partha discussed of discounting is really crucial, it's the essence of the issue. And Partha's view that what is at stake here is a concept of a social rate-of-time preference, that is the basis for judging tradeoffs between this and future generations, I think is absolutely correct.

Let me move on to the next slide, and talk a little bit about the economic analysis and the costs of climate change. I'm going to make qualitative statements. I am working on these issues for California, the State of California has just created a climate change center at Scripps and at Berkeley. The Scripps center is led by Dan Cayan and is focusing on climate modeling, and the Berkeley one is focusing on climate policy.

My sense is that the existing estimates of the potential damage in the United States, which are very low, are too low. I'm not in a position to say by how much they understate the damage, but the next slide will make a point. Very few sectors of the economy are directly affected by the climate these days. Essentially most of our lives are sheltered from the climate, and the only sectors directly affected are agriculture, forestry, fisheries. Forestry and fisheries are minor at a national scale. Agriculture is important but still small. Those are the sectors that have been most extensively studied. Energy and water are receiving attention, but much more needs to be done.

Very quickly I want to talk about some work I'm doing with colleagues and about the effect on U.S. agriculture. The important point is to distinguish between the West and the rest of the U.S. because rainfall directly is the source of water east of the hundredth meridian, whereas to the west you need to look at the institutions surrounding water rights and water systems. We've looked at two recent projections and this transparency summarizes our conclusions. In the near term, there will be some effect, but it will be—there's confidence intervals so I'm speaking with excessive certainty, but their point is there can be effects on farmland profit and farmland value, which are on the order of 16 to 20 percent. If one looks to the end of the century, the possible effects are much wider, the range of uncertainty is much wider, from about 30- to 70-percent reduction. Whether these later reductions occur depends on whether there's a policy response or not.

To summarize the near-term effects are, let's say, on the order of 15, 20 percent. Those are not disastrous. They're the same order of magnitude as the depression in agriculture or the slump in agriculture twenty years ago. We can survive them, but there's hardship, there's bankruptcies, people will notice them. It's as you look out into the century that effects could be dramatic unless there are policy interventions that are taken right now.

When you deal with the West, you really need to do case studies because the water-supply situation differs state by state, and in fact within different regions of the state. I want to summarize very briefly some work being undertaken by a large number of us. Chris is involved with [the] Union of Concerned Scientists. The consensus . . . although there are different models, it's clear the temperature in California is moving outside the range of historical range, outside the range of variation. And about ten years from now there's a 95 percent chance that the temperature will be increasing, so that essentially there's no uncertainty of global warming. Within a few years, it will be 95 percent confident of some change. And in California this will have a substantial effect on the water supply and stream flow. Thirty years from now, the snow pack predicted to decline by 37 percent; towards the end of the century it will decline by three-quarters or so. This is going to create a huge change in the stream flow. Let me describe . . . we are trying to finish this paper, and we're engaged in a debate with the chief hydrologist for the Department of Water Resources. His attitude is that this is a large change, but by being very clever about reoperating reservoirs they can cope with the change and still capture most of the snow melt, even though it occurs so much earlier. And maybe that's true. You'll look out of the window, the snow will have vanished from the lower elevations of the Sierras and will be greatly reduced on the upper elevations, and the hydrologists are saying, the engineers are saying, "No problem, we can handle it." And if you believe that then the impacts will be relatively small. My assessment is the situation is different for several reasons, and it illustrates the point I want to make, which is really it's the kind of disequilibium or adjustment effects which are large and which are ignored for most of the . . . or potentially large, which are ignored for most of the economic analysis. First of all, risk aversion. If you see the snow pack vanishing there will be huge public outcry for infrastructure, for storage, and so on, to offset this. And it's not foolish, and it's entirely feasible, it just costs money. And that's a cost that's not being considered. And secondly there will be uncertainty, and the ability to use existing storage as effectively as possible depends on whether there's increased variability in rain, in weather conditions, and how much flood storage one needs. And the last point is it will have a dramatic effect on water rights, because until now people who had water before the major projects have the highest water rights and are privileged. And it's the other users who used stored water who have to defer to them. Now the natural stream flow vanishes in July, August, and September, and you can have a senior right to a stream flow which no longer exists. And the people who will be sitting pretty are the people who have storage. This is a major stress on the legal and political and economic system. It's not that it can't be resolved, these things can be resolved, but there are costs, there are transactions costs, there are stresses, these are things that are not currently factored into the analysis.

There are other impacts which are not currently well considered. Jonathan talked about health effects, Cynthia mentioned fires and so on. These are things which also are issues of disruption and involve cost.

So when one talks about the economics, in my view, the potential costs of climate change are dwarfed by issues of anticipation, issues of adaptation. If the effects are well anticipated, if the adaptation is well handled, these costs will be low. If that doesn't happen, the costs will be high. That's the enormous range of uncertainty that we face. One implication, which is something that Jonathan and Cynthia stressed, is that climate policy is going to become as much disaster preparedness, emergency-response preparedness, public-health response policy, as it is climate policy in a narrow vein.

So much for the damage. Let me be evenhanded and spend a fraction of a minute talking about the costs of emissions reduction. What I want to stress is that, also, those depend on issues, flexibility, endogenous technical change, etcetera, which economists are well aware of, but in my view are not well incorporated in the existing CG models, the existing models that we use. The existing models that we use are very aggregative, they have a single firm to represent very heterogeneous sectors. They don't have, I think, a convincing story of investment determinants at the firm level over the timing of investment, and they don't yet have a realistic story of technical change, exogenous and endogenous. That doesn't mean that the costs of emissions control will be low in absolute terms, but I think they will be lower than the current estimates of the cost.

What I see as the features of a climate-change policy—very much those that I think Eileen Claussen will talk about tomorrow. But let me just make two or three points. One is I think that until there is a commitment to reduce emissions now, it is entirely rational for most firms not to spend money now because of the time-value of money. Nothing will happen without a real commitment and a real target of reducing emissions now. The trick is to start with a modest reduction and ratchet it up over time, and let firms develop an expectation of the future value of emissions reductions. You start with a cap and a market in permits, with a modest permit price because the cap is not that Draconian. But you build in the correct anticipation that the value of permits will rise over time, and firms have that in mind when planning their investment. In other words, the goal is to give an incentive, but an incentive of a trajectory involving a rising value of emissions reduction. I'd point out two other things. One is if states chose to act, some of this could be a source of revenue. In a state like California a colleague of mine, Steven Peck, has estimated could raise perhaps 10 or 20 billion dollars annually by issuing a series of annual permits over a period of years.

Let me stop there by saying, as David did, that I think we can take action, and the time for action is now. And the trick is to design the action to avoid inefficiencies while stimulating some response of emitters immediately.

Thank you.

Ambassador Raul Estrada-Oyuela: No, We Can't Stop It, However . . .

Christopher Field: It's a pleasure for me to introduce the final speaker for this afternoon's session, it's the Honorable Raul Estrada-Oyuela. He is former ambassador from Argentina to China. Ambassador Estrada has played a . . . one of the really few people to be in a pivotal role in the development of the international agenda for climate change. He, in many roles, has included service as chairman of the Committee of the Whole for the third conference of the parties for the UN Conference on Climate Change. He's been a key player in a number of international environmental agreements, and he currently serves as Argentina's special representative for International Environmental Affairs. Ambassador Estrada's title today is "No, We Can't Stop It, However . . ." and the *however* is what I want to hear about.

Ambassador Raul Estrada-Oyuela: It is very useful to have this PowerPoint presentations if you are the first speaker. But this is not the case. I'm the last. And also it's useful if you are not going to pay attention what previous speakers say. I'm planning to answer that also. Then I'll do my best with it.

I will try to confine the question to show how International Concern works, and this will change the set of concepts that we'll consider here because I will speak a different language, I think. I will try to show the key obstacles from the political point of view. What we have ahead of us, what can we do, and what are the doubts about the possible U.S. decision.

I say that we cannot stop the climate change because there is no discussion in the international political arena of stopping the climate change. What we are trying to do is either to reach agreements in order to mitigate the climate change, because the change is coming, and to adapt to the climate change, but not to stop the climate change. And mitigation has been mentioned many times here today, mostly as sequestration of carbon. And let me say that I'm a little bit surprised because of the absence of comments on reducing emissions by introducing efficiency or other kind of reduction of emissions.

The international community is able to make some changes. This is the growth rate for the greenhouse-gas forcings. This is the accumulation of greenhouse, only the rates of growth. And you can see here that the chlorofluorocarbons were reduced very strongly because an agreement on that, the Montreal Protocol, was reached. This graphic is got to be analyzed, but I will limit myself to the chlorofluorocarbons and to mention that in that case the industry played a great role because they were substituted by other substances because the industry was able to produce that.

Climate has changed before. This is a fact, we saw it before, and I don't need to go back on this kind of graphics you have been seeing all the day, but this relationship between the increase in temperatures and the concentration of methane and CO_2 in the atmosphere, and this, which takes 160,000 years. But if that happened before, why we worry now? One of the reasons is that the present change is human induced, and this is the political concern. We are doing something, we are increasing our emissions of greenhouse gases, and that could induce the climate change. The pace of that change could be faster, adaptation consequences will be traumatic, sociopolitical stability suffers because the trauma of the adaptation, and then in this situation we have uncertainty. But we answer, we try to answer to the uncertainty with precaution, the precautionary principle. It's something [that] could happen now there's a big risk of great damage. And it possible to do something to temper it. Why don't we do that? And particularly in this area where we have a number of options to improve the situation, options that are reasonable from many points of view.

But in any case, global action is required, and that's the reason because the whole international community is called to work. You can not select what country; perhaps you could select a number no more than 20, 25 countries, and you will have 90 percent of the global emissions. But this would be unfair from the point of view that other countries with higher per capita will be excluded. And it also not totally fair because countries with lower emissions per capita, however, have a big global emission. Then you have no choice, and everybody has to be involved. And that makes the process much more difficult.

Do we have a CO_2 concentration target? We don't have. Five hundred and fifty was mentioned many times today. Who agreed on that? There was an attempt to agree on that in Rome when the second IPCC report was prepared, and that was not solved. There was a second attempt to agree on that in Geneva in '96 and was not agreement on that. And is 550 the magic number? Really we don't know. There is a meeting of the IPCC next month, May, in Buenos Aires, to try to help to define what the Article II of the convention says on that. But there is no such an agreement yet.

Well the first step of the international community to mitigate and adapt to climate change was the convention, the UN Framework Convention on Climate Change. All parties shall produce inventories and adopt and implement policies and measures to mitigate and to adapt.

Industrialized countries will lead the mitigation effort, returning to the 1990 levels of emission by the year 2000. They committed also to produce funding and technology transfer for developing countries. And the point is that industrialized parties as a whole reported that for the year 2000 their aggregate gross emissions were lower than in 1990. This is the figure of that. The green line represents emissions of former socialist countries; they have a great reduction. The gray one on the top is the countries which belong to market economies before, but the one in the middle represents the situation of the whole group. Then, in fact, the purpose of the climate convention of returning to the 1990 levels by the year 2000 was fulfilled in excess, and this referred to gross emissions, and we'll see what the difference is with the Kyoto Protocol.

Of course the behavior was different, and you could go through this charter, those are percentages, but you could see the U.S. have a 14 percent increase, and Monaco is increasing 36 percent. But there is a big difference on that, you know. And you have the UK and Germany with considerable reductions, but perhaps on another occasion we'll deal with that.

Well the second effort was the Kyoto Protocol. And caps were proposed by each concerned party, nobody was imposing a cap, and accepted by all parties. Then if U.S. have 7-percent reduction, it's because the U.S. proposed during the conference that reduction. The amount assigned to the different parties were located on historical grounds, *grandfathering* we call that, because somebody was a big emitter before has some right to keep emissions high. And this is a matter of serious discussion. We change to facilitate the fulfillment of he commitment. The baseline is taken on gross emissions, and the target line is taken on net emission, I mean reducing the sequestration. Parties with difficulty, as you know, could buy reduction from other parties, which is also a matter of discussion. And the final purpose was to reduce 5.2 overall emissions as a result of the effort by 2008–2012. And buying the CO_2 certificates is from four to nine dollars according to different possibilities today.

But all these come from a situation which have a number of obstacles to get decisions. First of all, promoting the public awareness on climate change is not easy. It's a very abstract matter, and it's difficult to get to the people. But particularly it's difficult in affluent communities with high emissions per capita, like some sectors in the U.S., and with the means to adapt after the impact, because you could think of communities which are rich enough to afford the impact and to recover from the impact. Governments have to act on the short term to mitigate, but the benefits will be shown in the long term, in any case, beyond their mandate. Then the interest of the government is difficult to realize.

Policies and measures are perceived as costly—they require investments—or unpopular because they could change lifestyle. And the lifestyle in industrialized countries, in particular in some industrialized countries, is one of the main reason of the high level of emissions. And we didn't hear anything on that during the day.

Of course oil- and coal-producing countries are always trying to delay decisions in these matters, and countries with negligible emissions, however, are involved. There are countries in Africa which have a very low contribution to the phenomenon but, however, are in the process, and sometimes you feel that they are used by OPEC countries, for instance, to stop the process or to complicate the negotiations.

What do we have for the future? What can we do? Will Russia ratify the Kyoto Protocol? I think they will do. The background is that Russia always joins environmental agreements at the last moment. The Kyoto Protocol was designed, the "entry into force" of the Kyoto Protocol was designed in such a way that it has a cost for the U.S. You need to have the U.S. or Russia. It has a cost, the Kyoto Protocol has a cost for the U.S. Is a big cost or small cost justified or not justified? Whatever you could think of, but there's a cost. And for Russia is a benefit. They have an amount of CO_2 to sell to the others. And this was understood clearly from the beginning. In my view what Russia is doing now is bargaining—what is going to be the price of that coal, and what is going to be the amount that they are going to be sell the others? And they still have time to ratify. They could do that in 2006. The domestic arrangements for the Russian federation to operate on that are relatively simple. Then I think that they will ratify, perhaps when some changes occur in other countries, political changes occur in other countries.

But may the Kyoto Protocol be implemented without Russia and the USA? In fact there are people talking now about the possibility to implement the protocol, to have provisional application of the protocol, which will create a number of difficulties because most probably we'll request if some of the measures are basis on taxes then taxes on the border will be applied in order to compensate.

But the Kyoto Protocol could be complemented with other instruments. There's no reason to have only the Kyoto Protocol, perhaps this could be complemented after 2012 or before, if these facilitate the process. What is clear is that grandfathering as a criteria can not be kept forever; it has to be slowly modified.

Another question is, Are the caps contained in the Protocol equitable? And perhaps they are not. We negotiated on caps because that was the original idea coming from the percentage reduction suggested by the IPCC. But perhaps it's not the idea, there are other criteria. Of course emissions per capita are the fair approach, but this was not accepted by industrialized countries. We have higher emissions per capita than developing countries. And perhaps efficiency standards could be more equitable, not efficiency standards taking into account the GDP, but a sectoral efficiency standards, an amount of carbon per ton of steel or amount of carbon per a megawatt of energy, thermal energy.

Should developing countries have caps and when? Developing countries—some developing countries—should at some point in time have caps, I mean limitations or comparable limitations with industrialized countries, but only after industrialized countries demonstrate the will and the decision to contribute to the mitigation of climate change, not before. And of course it will be necessary to differentiate among developing countries.

What happened with the U.S.? I came here to find the answer and I didn't find it yet. But what happened? The idea of caps and trade was an American one. It's no longer logical. Is adaptation plus sequestration the answer? I don't think so. What we are looking for is the limitation and reduction of emissions—this is the objective of the convention. These intensity targets are a better alternative? Perhaps they are. Is cost a fundamental issue? The cost, 10,000 of different figures you could discuss it, but let's presume that the cost for the U.S. will be 1 percent of the GDP. Is that impressive? If you go to the World Bank publication on world development indicators, you will see that countries like Brazil pay 9.2 percent of the GDP as services [inaudible] Mexico 8.5. I'm not going to mention Argentina—you know the situation, we don't pay anything. But Indonesia has 13 percent. Then how could we touch it, because the U.S., the biggest power have to spend 1 percent of its GDP to reduce emissions. This 1 percent are going to be investments in the U.S. itself. We are transferring money to other countries. Then the cost doesn't seem to be a fundamental issue. Are the blockages in domestic politics? Sometimes you see this, the issue came near to the elections. Is that good or bad? I don't know, it is for you. Is the protection of lifestyles the main point? Perhaps it is, perhaps it is, but there are pockets of different lifestyles in the U.S. How these commitments operate in the U.S.–European Union relations, because you could feel a kind of aggressive position from the European Union from time to time and perhaps this is not helping the process. Is international competitiveness the issue? Is the U.S. concerned because countries from Asia, like China, will have better conditions to compete in the international trade? Is that the problem?

Taming the climate sounds bombastic, this idea of having an angry beast is something which I reluctantly accept. Climate is a system, not a beast. And if we start to accumulate carbon in the oceans in fifty years we will discover that the ocean is also a beast. Climate is a not a beast, it's a system, and we have been interfering with the system. What we have to do is stop interfering with the system or to reduce as far as we can the interference with the system.

Stopping climate change is not the task. It's something which is happening, it's already a problem for more than almost two hundred years, and we have to mitigate and to adapt, which is possible. And adaptation and mitigation complement each other. The more we adapt the easier the level of mitigation will be, and the more we mitigate the less we'll need adaptation. And reaching agreements, international agreements, requires a lot of ingenuity. It's necessary to find new ideas and new approaches to this problem. But implementing the agreements demands will, and that will is lacking in some places. Developing countries, as I said before, will follow the leaders if industrialized countries take the lead, as they promise to do. I think this is so.

Thank you very much.

April 22, 2004

Session 3 Q & A: Responding to Climate Change: Can We Stop It?

Question 1: Consumption and Efficiency

Christopher Field: Time for a couple of questions from the audience, but before we do that I'd like to challenge the panel with the question that Ambassador Estrada began with, and that's the question of whether and how we should be thinking about two things that didn't really come up as a big feature on the agenda we talked about, one is decreasing consumption and the other is increasing efficiency in processes that we're already undertaking? I'll pass that to all of the speakers.

David Keith: I believe there may in fact be principled reasons to say that we might be over-consuming in the rich world that is, that it's not, say, bringing us enough happiness. But I believe that those are really quite independent from this question. We can reduce, greatly reduce, CO_2 emissions at costs that are order of a percent or two of GDP, which for sake of reference is about the total aggregate cost of all other environmental regulations today. And I think it's simply silly to harness that to the idea that people must reduce their consumption of goods and services. Arguments about reduction of consumption of goods and services need to be made on their own merits, independent from the question of how we should use tools available to reduce CO_2 to protect us from damaging climate change.

Ambassador Raul Estrada-Oyuela: I'm not talking about reduction of goods and services. I'm talking of keeping the level of consumption with a more efficient way. You know the waste of the resources in some countries, including this one, and what I think has to be considered is the possibility to reduce that waste. I was living for a semester here at a university, and you go on the street during the night, and you see all the buildings light. And this is true for all the City of New York. And I don't go to make the list of waste because I'm enjoying your cordiality to inviting me here, but there are a number of things to reduce. What about cars?

David Keith: But in fact the efficiency of energy use in industrial processes and in transportation is generally higher in the richer counties than the poorer ones, not lower, so the fact is simply Americans and other people in rich countries are extraordinarily rich. It is incorrect to say that they're extraordinarily wasteful in terms of energy efficiency.

Ambassador Raul Estrada-Oyuela: No, no, no. You could have a big car, a very efficient big car, the most efficient you like with a lady going to the supermarket to bring two bags. Is that efficiency? The car itself is efficient, but the act, the conduct, the behavior is inefficient. That is what I think should be changing.

Christopher Field: I might just conclude this with the thought that our community has the luxury to sort of set goals that aren't necessarily precisely financial in nature and are us as a community setting a goal to make efficiency a priority and, where possible, make decreasing consumption a priority certainly can yield benefits, even if they aren't strictly benefits in economic terms. I'd like to open it just for a few minutes to questions from the audience, if there are any.

G. Michael Purdy: We've just time for maybe just three or four questions. Go ahead, sir.

Question 2: Storing Wind Energy

Man: My name is Douglas Hill. I'm a consulting engineer. I have a question for Dr. Keith. If I understood you correctly, you said that you thought that more than half the electricity on a grid could be provided by wind power, provided that storage, among other things, was provided. What kind of technology could provide energy storage on that scale?

David Keith: Air-energy storage for pumped hydro are the most obvious alternatives, but in fact in at least the simulations I and several others have done, storage is not the preferred alternative. The preferred alternative is long-distance transmission to average over the variable wind in different locations and peaking gas capacity.

Question 3: Catalyzing Government Action

Michael Purdy: Thank you. Let's try and keep the questions short, but let's identify ourselves first, please. Go ahead, sir.

Man: Ted Glick. Just to follow up on the last speaker. Isn't really, when it comes right down to it, the fundamental question really for all of us in the room, How do we generate the movement to get our government to have the political will to do what needs to be done, and soon, and quickly? Without that do we have hope for a change?

Michael Hanemann: Maybe I can jump in and answer in two parts. The first part is yes. And the second part is Pigou. Let me just go back. Pigou's point was where somebody creates an external impact on other people, one logical form of intervention is what's called to internalize the cost, to make people responsible for and pay for the cost of the adverse impacts they impose on others. And we're refusing to do that so far. And if such a cost is not imposed one way or the other, you have an undesirable outcome. And so we are being selfish and wanting to not pay the costs of some of the effects that we impose on others, both other countries and other generations.

David Keith: And I might just conclude that with hope that sessions like this can play a catalytic role in developing of political will that will eventually be necessary.

G. Michael Purdy: Thank you. Sir.

Question 4: After Kyoto

Man: I'm James Wang, atmospheric scientist with Environmental Defense. I was wondering, do people have any concrete ideas for what should happen after the first Kyoto commitment and, you know, how do we get more countries involved, etcetera?

Ambassador Raul Estrada-Oyuela: Well next year we should start the negotiation for the [inaudible] and we have been considering different ideas. I think Eileen Claussen tomorrow will comment on that. There are a number of ideas to be developed, these points that I simply mentioned on efficiency are something that can be done, and there are a number of new initiatives to help the process. You could either continue with a second [inaudible] in the same line, or change totally the line, or have two different processes optional to the parties. We need, as I say, to have ingenuity to create possibilities for all, including the USA, to add to the process.

Questions 5 and 6: Wasted Energy

G. Michael Purdy: Thank you, Ambassador. Okay, we'll just do the three questions there and then we'll call it an evening. Go ahead, sir.

Man: I have a question that hasn't received satisfactory answer so far, so I think I'm going to ask it to David Keith. Start with a simple premise. I am lucky enough to be a graduate student at the Lamont-Doherty Observatory, and I'm lucky enough to have a window in my office. And not only does it bring light but it brings also the significant benefit that when it's winter I can open the window so that temperature in the room is not unbearably hot because of the heating, and in summer I do exactly the opposite so that I keep it at a comfortable temperature while the air conditioner would make it unbearably cold. And I've wondered, seeing that it's the case in most of public buildings or New York or every [one] I've been in here, What is the cost of that sheer waste of energy? Raul Estrada has said that some of the environmental policies are often perceived as unpopular because they limit comfort. I don't think it would harm comfort to live at 20 degrees all the time and not live at 15 degrees in summer and 25 degrees in winter. So do you have any quantitative estimate of how much energy is wasted and how much energy could be saved by avoiding living like this?

David Keith: Well I couldn't agree more with you about the American obsession with having the temperature inside buildings anti-correlated with the temperature outside. It's bizarre. But I think it really is important to realize that while each of us can see individual examples that really are just waste, that when you look across the economy and you ask, How much can we squeeze out without changing goods and services, without changing things we actually want? It's not as easy as you think in the real world. There are always persistent reasons why what technological optimists see as energy efficiency improvements don't tend to work out quite so well in reality. It's always harder. Say for automobiles there really are tradeoffs between weight and safety and power and safety and those tradeoffs are longstanding and will not go away. For lighting there are a series of other related tradeoffs, and there are tradeoffs in people's actions. So I in my house have some lights where I've installed high-efficiency lighting and some places where I haven't don't it because it was too expensive to do. I would've had to rebuild my house. So I push my family more to turn off the more high-energy lights than the low-energy lights. That means that I achieve less savings than an engineer would predict because my behavior changed, if they predicted based purely on naïve engineering that threw away human interactions with the technology. And in practice we find that the really extraordinary statements that were made about energy efficiency in the '70s have persistently proved to be overrated, and they were overrated because they ignored people's actual interactions with the technology.

G. Michael Purdy: Thank you.

Woman: This is just a comment, the follow-up on the previous speaker. I think it's supremely ironic that we're having this conference here on climate on Earth Day, and the room is so cold that a lot of us are putting our jackets on.

Michael Purdy: Would anyone like to comment on that?

Christopher Field: I will say that Dr. Rosenzweig made the really key contribution that there is an effort that's taking shape that involves Columbia, and if everybody lends their support to that it can address issues like this.

David Keith: And the business-as-usual scenarios we see often have twice the historical rate of energy efficiency or intensity improvements built into them.

Question 7: U.S. Electric Power Companies

G. Michael Purdy: Final question.

Woman: I would like to make a comment just going back to the question of lifestyle versus . . . I mean being environmentally conscious implying sacrifices in lifestyle for the U.S. people. And I want to just point out that I follow U.S. electric power companies, and just I think as an illustration of the rule that the economy here has to improve in terms of how efficiently we use resources to produce energy is that the ten largest European power companies produce 35 percent more energy with 35 percent less CO_2 emissions compared to the ten largest U.S. power electric companies. And I think when you compare both the thermal efficiencies of European companies are now we're comparing to developed countries in terms of power generation, which is a main contributor in terms of GG emissions, there is a lot of room to improve, and maybe one reason why that's happening is because the electric power companies in the U.S. mostly are . . . they receive the grandfathering, basically meaning they can extend the life of the asset, the coal asset, without having to invest in air-pollution equipment, and that basically means that they can keep using those assets and producing airborne externalities to the citizens, not only here but worldwide, without having to factor in other investments that companies in other parts of the world have to do.

Christopher Field: I think your comment raises two important points that maybe we should leave people with. The first is that turnover times of capital stocks are very, very important, and that if you have a 20-year-old coal-fired power plant, it's very difficult to tear it down tomorrow to replace it. And the other thing that's really important is that the natural endowment of countries really differs, and coal-rich countries will have to have real strong incentives to move away from coal or to sequester the carbon from coal if that's what their natural assets are.

Michael Hanemann: Just one thing, Chris. This is exactly the argument for an emissions tax. If you pay something that reflects in some way the externality you're causing, then you can decide whether you want it now or wait—it's your choice. As long as we say, "Oh, I should be grandfathered and I don't have to bear a responsibility that the system is distorted."

G. Michael Purdy: Thank you very much. Shall we thank the panel for an excellent session?

Time to bring things to a close here. Thank you for all your attention during the day. I think we've made a good start nibbling at some of the big questions. Tomorrow morning, 9 a.m., our first keynote speaker will be Eileen Claussen, and please remember that tomorrow immediately after lunch, 1 p.m., Governor of the State of New York, George Pataki will be here to talk to us before our final panel. Thank you everyone, and I look forward to seeing you all at nine o' clock tomorrow morning.

April 23, 2004

Eileen Claussen
Facilitating Change: A Practical Approach to a Low-Carbon Future

Introduction by John Mutter

John C. Mutter: Good morning and welcome to the second day of our conference "Earth's Future: Taming the Climate." Today we have an exciting line-up of speakers and panelists. Today, as you heard yesterday, but for anybody who was not here yesterday, we'll be honored with the presence of the governor of New York, George Pataki. George Pataki is a Columbian, but unlike those mentioned in the material you've been handed out, he is not a Columbian ahead of his time, in fact, he's gonna be late. Instead of coming at 1:00, which I think your program identifies, he will be here at 2:30, unless he's late. I don't expect he'll be ahead of his time.

So what we're hoping to do is run the program more or less as you've seen it, but with immediately after lunch there'll be a panel and then the governor will give a speech.

Like the rest of you, I sat in the audience yesterday and listened with fascination to the talks being given. And I did, since I am a Columbian myself, it says so on my badge, I read the material that the 250th people would hope I would read, and I was looking at the pictures on the bottom of the program we have that has five Columbians ahead of their time. And it occurred to me as I was reading the little quotes there that although all of these people lived well before climate issues came to the front, some of the quotes they have made are highly pertinent and echo into this debate. So, going from the right, Margaret Mead said, and I quote, "It's all one world. There are no islands any more." So although she may, or undoubtedly would have been talking about an anthropological notion, she could equally have been talking about the climate system, because we do live in one world. I had the opportunity to briefly chide Admiral Lautenbacher, who is the head of the National Oceans and Atmospheres Administration, by telling him that there are no national oceans, and there is no national atmosphere. There is only one atmosphere and there is only one global ocean. We were made significant emphasis of that several times yesterday by Mike McElroy, Wally Broecker, Mark Cane, and others. Therefore we really are all in it together.

Believe it or not, the atmosphere is so well mixed that if your nostrils were good enough, you could actually smell daffodils growing in the Netherlands today.

Maybe Sharper Image will build a machine that lets you do that one day, but if your nose was good enough you could do that.

It's fairly amazing. I didn't know this until a few years ago. I'm a geophysicist, but I'm a solid-earth geophysicist. I deal with the mantle, and the deep mantle of the Earth is nothing like that; we think it's more like a marble cake, with great streaks of material of different composition held in place. The atmosphere is truly well mixed. That means that our atmosphere is everybody else's atmosphere; we don't own any piece of it. That's why we can trade, that's why the problem can't be ours, it has to be everybody's. And Franklin Roosevelt seemed to know that, and he said, "The test of our progress is not whether we add more to the abundance of those who have much; it is whether we provide enough for those who have too little." Now I think he was talking about people in the U.S., but he could just as well have been talking about global inequalities.

So just as you and I could smell the daffodils from Holland, a child, say, 6 months old living in a country like Chad, for instance, would've been born into a world where that child's mother had 1/250th chance of surviving pregnancy as a woman in this country, and that child of 6 months old has 1/40th of the chance to reach the age of 12 months. That child, if his nostrils were good enough, would be able to smell the exhaust of the SUVs driven around in this country. A teenage girl in Malawi carrying a head load of wood, undoubtedly illiterate, very likely orphaned by AIDS, required not to go to school in order to carry the only energy product she has, that is, the biomass from the products, back to her home. She, too, could smell the smoke from the power plants that generate energy in this country, that power our televisions and our electric toothbrushes. We heard from many people on what direction the science compass points in telling us about science and how it can help us inform decisions with respect to climate change. We heard about economics, but we also heard from Atiq Rahman which way the moral compass might point. Hopefully today, by the end of the day, we'll learn that science, economics, and moral compasses all point in the same direction. I dearly hope so.

I had to skip two of the people. I didn't know how to make relevance of Paul Robeson's comment, and I didn't know how to make relevance of Zora Hurston's either, but John Jay's I think is particularly relevant. Jay was governor of New York. He was also a chief justice of the U.S., and he said, "We must teach useful truths, however harsh." And I think today and yesterday we heard a lot about truths, and some of them were quite harsh. The notion of a useful truth is interesting.

I was given some very good advice once by somebody who works on the science staff in the Senate, who no longer does, in trying to explain how it is that scientists should engage with the public. Most scientists think that this is a difficult job. Most scientists think that it's very difficult to communicate the subtleties, the nuances, of science to people who don't know it. And he said, "Look, it's not difficult at all, but there's something you must do." He said that knowledge as perceived by him falls into three categories. There are things that one can regard as facts: an asteroid is going to hit the Earth, it's simple, it's a fact. There are things that are immediately derivable from those facts, a fact: if an asteroid's going to hit the Earth, people in the way are going to die. So there are simple facts and things that are immediately derivable from them. But then there are things that one can say that are consistent with the facts but not required by the facts. So an asteroid is going to hit the Earth, some people will die, but perhaps there will be the equivalent of a nuclear winter and everyone will die. Well that's consistent with the facts but it's not required by them.

I think one of the things that we have a problem with is that almost everything we talk about is in this third area of knowledge, because nothing about the future can ever be a fact, it is always in the third area. But what we believe the future could be like, consistent with the facts, is very dark, particularly for those people in the poorer parts of the world. So if dire consequences can be derived from a plausible analysis of inferences from facts, then we must pay attention. What this person told me was that you don't need to dumb it down, you don't need to be clever, you just need to be clear. Tell people what are the facts, what derives from the facts, and what is not a fact but is a useful conjecture based on those facts.

There is probably nobody who has brought more clarity to the climate change debate than our speaker this morning. This is Eileen Claussen. She is president of the Pew Center on Global Climate Change and [also] Strategies for the Global Environment. She's former assistant secretary of state for Oceans and International Environmental and Scientific Affairs. Prior to joining the State Department, she served for three years as special assistant to the president and senior director for global environmental affairs at the National Security Council. She also served as chair of the United Nations Multilateral Montreal Protocol Fund. In your materials you'll a find much-extended biography that gives many more of her achievements, accomplishments, but for us the most important thing she will do is provide clarity and insight into the consequences we must listen to with respect to the climate-change debate. Eileen Claussen.

The Excuse of Scientific Uncertainty

Eileen Claussen: Thank you very much. It's a great pleasure to be here to celebrate Columbia University's 250th anniversary, so let me begin by saying happy birthday to one of the world's finest institutions of higher learning.

Yesterday, as we all know, was Earth Day, or as the Bush administration referred to it, Thursday, April 22. The 34th anniversary of Earth Day, I believe, provides an important opportunity to acknowledge how far we've come since the 1970s. But while we have made progress we have obviously not made enough, and I commend you for commemorating Earth Day yesterday in such an appropriate and public-spirited way by focusing your attention on an issue where we really have not made significant progress, global climate change.

During the first day of this symposium, you heard from a number of distinguished panelists about the state of our knowledge regarding the climate-change issue. You heard about trends in global temperature and what this means for the climate, you heard about ways we can possibly adapt to the predicted changes, and you heard some ideas about what can be done to slow down or stop climate change.

My job in this symposium is to try to explain why we are doing so little to prepare for the certainty of climate change, and because I'm genetically programmed to focus on solutions, I will also lay out some ideas for an overall approach that might help us to chart a productive path forward on this issue. But first a very brief refresher course on why we are here.

We are here because there is overwhelming scientific evidence on three basic points. One, the Earth is warming. Two, this warming trend is likely to worsen. And three, human activity is largely to blame. And so the question is, If we know these three things, why are we not acting on that knowledge? Why are we not doing more to limit those human activities that are driving force in climate change, namely our emissions of greenhouse gases, stemming primarily from the burning of fossil fuels?

The answer, very frankly, is because we have allowed ourselves to be swayed by a number of tired excuses, excuses put forward, for the most part, by people and interests who plainly want nothing to happen to address the problem of climate change. The reason more often than not is that they have an economic interest in the status quo.

The first excuse for inaction usually revolves around the issue of scientific uncertainty. Even though we may know that the climate is changing, the fact that we can not accurately predict exactly how much warming we will see or how quickly it will happen is used unfailingly as a reason for inaction. But I submit to you that uncertainty in the science is not a valid reason to hold off on addressing this problem, given what we do know. The fact that we are uncertain about exactly how climate change will proceed may actually be a reason to act sooner rather than later. So let me tell you why.

First, current atmospheric concentrations of greenhouse gases are the highest in more than 400,000 years. This is an unprecedented situation in human history, and there is real potential that the resulting damages will not be incremental or linear, but sudden and potentially catastrophic. Acting now is the only rational choice under those circumstances. A second reason to act now is that the risk of irreversible environmental impacts far outweighs the lesser risk of unnecessary investment in reducing or mitigating greenhouse-gas emissions. Third, it's going to take time to figure out how best to meet this challenge, both in terms of technology and policy. We must begin by learning now. Fourth, the longer we wait, the more likely it is that the growth in greenhouse-gas emissions will continue and that we will be imposing unconscionable burdens and impossible tasks on future generations. Fifth, there is an obvious lag time between the development of policies and incentives that will spur action and the results, so even if we do not wait, we will be waiting. And last but not least, we can get started now with a range of actions and policies that have very low or even no costs to the economy.

The Excuse of High Cost

And this brings me to the second tired excuse that is used to argue for inaction in the face of climate change: the costs will be too high. This argument ignores the fact that if we do this right and if we start sooner rather than later, we can minimize those costs, and more important we can minimize the very real economic costs of doing nothing. Next week the Pew Center will be releasing a report that weighs the potential costs of climate change in relation to the potential benefits. Yes, in the short term there may be scattered economic benefits in sectors such as agriculture resulting from higher temperatures and more rainfall. However, research shows that these benefits begin to diminish and eventually reverse as temperatures continue to rise. In other words, the potential economic damage from climate change far outweighs any short-term economic gain.

What kind of economic damage are we talking about? In 2002 the United Nations Environment Program released a report done in collaboration with some of the world's largest banks, insurers, and investment companies. The report found that losses resulting from natural disasters appear to be doubling every ten years, and if this trend continues will amount to nearly 150 billion dollars over the coming decade. Over the last two years alone we have seen wildfires in the western United States and devastating flooding in central Europe and China. These are the kinds of events scientists predict will occur more frequently or with more intensity in response to climate change. Of course it's impossible to conclusively link any one of these disasters to the broader warming trend, but we may be getting an idea of what's to come, and we can not allow those who argue that addressing this problem will cost too much to ignore the potentially devastating costs of allowing climate change to proceed unchecked.

What's more, the costs of acting to address climate change can be kept at a manageable level if we use economic instruments wherever possible, if we act thoughtfully and in phases so that we allow for capital stock turnover in the development of new technologies, and if we provide certainty for the private sector to make wise investments and create new climate-friendly businesses.

Responding to climate change does not have to wreak economic havoc. A recent MIT study assessing the costs of the Lieberman McCain Climate Stewardship Act found that a modest national emissions trading system would cost less than twenty dollars per household per year. In addition a significant number of companies are showing that they can meet ambitious targets for reducing their emissions, targets of 10 percent, 25 percent, even 65 percent below 1990 levels, at minimal or no cost. I repeat, at minimal or no cost. Some companies are even saving money. BP, for example, recently announced that it had achieved its target of a 10 percent reduction in emissions eight years ahead of schedule and at a savings of roughly 600 million dollars, due to more efficient energy use and streamlined production processes. So while I would not argue that addressing climate change over the next fifty years is free, I do believe that with care and pragmatism we can do what we need to do without breaking the bank. Cost should not be a reason not to act.

The Excuse of Disproportionate Burden

A third excuse that we have allowed to stifle action against climate change is that the United States should not be asked to bear the economic costs of reducing our emissions while other countries, notably China and India, get a free ride. In other words, why should we have to do all this hard work if other people do not? This argument is weak enough when you consider that we can consider our emissions in economically feasible ways. It's weaker still when you recognize that the United States already is lagging behind the global technology race with implications for U.S. jobs. Our dallying over climate policy is ceding to Europe and Japan the lead in developing climate-friendly technologies. And it seems to me that we should worry less about China and India attracting the polluting technologies of the twentieth century and worry more that we won't be selling them the technologies of the twenty-first century.

The fact that developed countries should act first to reduce their emissions is enshrined in the United Nations Framework Convention on Climate Change, to which the United States is a party, thanks to the signature of our first President Bush, George H. W. Why did the United States agree to this? Because developed countries are responsible for most of the greenhouse gases in the atmosphere and therefore should reduce their emissions first. And because developed countries are far wealthier than developing countries, we have the means to take action now. This is not to say of course the developing countries should have no responsibilities. Just as the United States and other developed nations will need to become more carbon-friendly as we turn over our capital stock, so must developing countries develop in more carbon-friendly ways. But to expect or even to wish that developing countries should face emission limits at the same time and on a similar scale as we do is folly.

We have now touched on three main excuses for doing nothing: science is uncertain, the costs of addressing the issue are too high, and developed nations should not be asked to bear this burden first. All of these excuses are used to delay action on this issue. In pushing for such a delay people often resort to a fourth excuse that underlies all of the others. We can solve this problem if and when we really have to, but until then leave us alone. This is what I call the silver bullet defense. Americans by nature are an optimistic people who have a deeply held faith in their ability to apply their down home ingenuity to solve every problem that comes along. We live in a world of wrinkle-erasing Botox injections, iron-free shirts and cellular phones with cameras built in. We've got to be able to come up with an equally wondrous technology to solve this problem of global warming, just tell us when.

There are two problems with this argument. First, we don't have time. You can not launch an industrial revolution overnight, and that is exactly what we need, another industrial revolution. And second, climate change is too big a challenge for any one solution. It's going to take a wide ranging portfolio of technologies from energy-efficiency technologies and hydrogen to carbon sequestration, renewable fuels, coal-bed methane, biofuels, and biotechnology. Developing these technologies and getting them to market is going to take a lot of hard work. We cannot just snap our fingers and make it happen. What we need to do is replace our existing energy system. Businesses, however, continue to receive mixed signals from policy makers about whether or not we are serious about getting on with the challenge of moving to a low carbon economy. What's more, the federal government spends even less than the private sector on energy-related R D & D, which is particularly disappointing when you consider the importance of energy to our economy, our security, and our environment. We must be clear about where we are headed, and we must begin to develop the full complement of technologies that will begin to deliver real reductions in greenhouse-gas emissions. And in the same way that we need a broad portfolio of technologies, we will need an array of policy solutions as well.

Among the most important of these is an economy-wide cap-and-trade system. This is a policy that sets targets for greenhouse-gas emissions and that allows companies the flexibility to trade emission credits in order to achieve their targets in the most economic manner. This is the approach used in our acid-rain program, and also taken in the Climate Stewardship Act introduced last years by senators Joseph Lieberman and John McCain. Their bill garnered the support of 43 U.S. senators, and prompted the first serious debate in Congress about exactly what we need to be doing to respond to the problem of climate change. A companion measure was introduced in the House of Representatives just last month by ten Democrats and ten Republicans. But a cap-and-trade policy alone is not enough. We also need an aggressive R&D program, government standards and codes, public infrastructure investments, public-private partnerships, and government procurement programs, and I'm sure that there are policies and approaches we haven't even thought of yet.

However, despite needing all these policies, we still seem to be waiting for an easy catchall answer that will get us out of this mess, just as we are waiting for a technology silver bullet to make the problem go away overnight. And waiting itself becomes yet another excuse for doing nothing. But in doing nothing we are making a choice, we are choosing to ignore what we know to be true about the reality of climate change. We are choosing to leave as our bequest to future generations a world that will in all likelihood be very different from the world we live in today. We are choosing to saddle our children and our children's children with an array of problems that may well be beyond their ability to solve. This is not a case, in other words, where inaction can be explained in terms of benign neglect. We just didn't know. Atmospheric levels of carbon dioxide, the major greenhouse gas, have reached an all-time high according to a report last month from the National Oceanic and Atmospheric Administration. By putting off serious action, we are essentially making a conscious decision to make the problem worse. And for that there really is no excuse.

Smart and Inexpensive Steps to Reduce Emissions

Of course it doesn't have to be this way. There are indeed many smart and inexpensive steps we can take beginning right now to reduce our greenhouse-gas emissions and start developing the low-carbon energy technologies of the future. How do we start? Well let me give you a few ideas.

Number one, we can require companies to track and disclose their greenhouse-gas emissions. If it is true, and I think that it is, that what is measured is managed, then this is an essential step if we ever want to move forward with any kind of program for reducing emissions. Number two, we can use a standard-setting process to set practical but progressive goals to improve the efficiency of our vehicles and our appliances. Number three, we can make significant and strategic public investments in promising technologies, working with the private sector and providing them with the certainty to make investments as well. Number four, we can provide incentives for farmers and foresters to adopt practices that take carbon from the atmosphere and store it in soil, crops and trees. Number five, we can step up efforts to determine whether we can safely and permanently sequester carbon in geologic formations deep underground at a reasonable cost. Number six, we can build an economy-wide system that sets modest but mandatory targets for reducing emissions and uses market approaches, like emissions trading, to meet them at the lowest possible cost. And seven, we can build a global framework that will move all countries toward a low-carbon global economy at a pace that reflects each country's emission profile, what its opportunities are, and what costs is can bear. That's just a random assortment of things we can do right now, and none of these activities, not one, would pose any kind of serious threat to U.S. economic performance. Indeed by creating the conditions for a new industrial revolution that encourages the development and deployment of low-carbon technologies, we can create new opportunities, new jobs, and new wealth. The key as we move forward is to set a clear long-term goal of where we want to be on this issue and then to figure out the short- and medium-term steps that will get us there. At the Pew Center we call it the 10-50 Solution. By 10-50 we mean that we believe that this is a fifty-year issue, and we should be thinking ahead and envisioning what our society and our economy will need to look like if we are to significantly reduce our emissions, that's the 50 part. Then in order to make it manageable we break it down into ten-year increments and we identify the policies and strategies we can start pursuing in the next ten years and the decades to come so we can achieve our long-term goal. That's the 10 part.

The 10-50 approach takes a long-term view because we know it will take time to achieve the result that we need, a low-carbon economy. At the same time the 10-50 approach enables us to identify the practical steps we can take in the short-term and in the decades to come so we can achieve steady progress. If we do this right, one step at a time with a long-term goal it'll be like Calvin from Calvin and Hobbs who said, "Know what's weird? Day by day nothing seems to change, but pretty soon everything's different."

In closing let me say again that I greatly appreciate the opportunity to be here today, and I ask all of you to join with me in saying that the time is passed for making excuses about why we should not or can not take serious action to address the problem of global climate change. With an approach based on sound science, straight talk, and a commitment to working together to protect the climate while sustaining economic growth, we can achieve real progress on this issue, and we must. Columbia University is 250 years old this year. Let's work together to ensure that 250 years from now there will be a symposium at this great university on what happened at the dawn of the twenty-first century to finally get a handle on this enormous problem.

Thank you very much.

Question 1: Renewable Energies

John Mutter: Thank you so much. We do have time for questions. The drill is that you go to one of the two mikes in the aisles. Please identify yourself and your affiliation, and ask a question meaning a sentence with a question mark at the end, rather than give your own speech, please.

Man: In the last two days we've heard a lot more about carbon sequestration than anything else. Obviously I think there's general agreement that that needs to be part of the mix given the huge coal reserves, but I don't know why there's all this attention paid to this when wind is already here. We heard from one speaker yesterday that it could provide more than 50 percent of our electricity. We've haven't heard anything in the last two days about solar. Why is . . . you make one of your seven points carbon sequestration, which is still on the drawing boards, and we heard you say nothing about wind and solar.

Eileen Claussen: I did actually talk about renewables, in which I put that. I mean I tried to make clear, and maybe it didn't come across, that I think we need a portfolio. I think it does include wind, I think it does include nuclear, I think it does include carbon sequestration if we want to keep using our coal reserves. It's only one piece of a lot of different things, so I don't know. I wasn't here to hear the discussion yesterday, but I think it's an important piece for political reasons as much as it is for economic reasons.

Question 2: Educating about Climate Change

Woman: Good morning. Thank you very much for your incisive comments. My name is Jessica Green. I'm from United Nations University, and I wanted to make a brief comment and with a question, per the instructions. I think one of the other low-hanging fruits that needs to be examined is education at all levels, from the very beginning to postgraduate. Obviously here is a brain trust of people who know a lot about climate change, but there are many who don't. And so my question to you is, How can we as scientists and as researchers and also as educators incorporate these difficult and complex problems, as Dr. Mutter pointed out, into a more common curriculum for all people to understand the gravity of this problem?

Eileen Claussen: I don't think I have a really good answer for that, but there are a lot of educators in the room who probably know more about it than I. It seems to me that the greatest difficulty . . . there are two difficulties, I should say, with this issue. The first is that it's very complicated, and trying to boil it down into five points that are sort of takeaways is hard. The other thing that I think is difficult is that people view it as a long-term problem, which it is of course. It's also, however, a short-term problem, and if we don't start now I don't think we deal with it as a long-term problem. But I think the general perception is that it's way out there. It's part of what I was saying before, if you just think it's way out there, you just wait and then something will come up, and we'll do it, and that's not I think the right message. The right message: we have to get moving now and let's start with the things that we can do now. How to embed that in the minds of young people . . . as I said, I try but why don't we ask some of the professors here how to do it?

Woman: I invite anyone who has comments. Thank you.

Questions 3 and 4: Corporate Reductions, and Nuclear Energy

Woman: My name is Beth Browdy, and actually you and I spoke two years ago when I was doing an article, at which time you talked about your work with . . . I think you had thirty corporations signed on to reduce, voluntary reduction of emissions. I wonder how that project is going, what kinds of obstacles you've encountered to gaining more support for that program?

Eileen Claussen: What you're referring to is what we call our Business Environmental Leadership Council. It's now 38 companies. I think it'll be 41 in about two months, so there continues to be growth in the number of companies who believe this is a problem and would prefer to be part of the solution, rather than just part of the problem. That said, I think there are two sets of things for them to do, one of which is easy and one of which is very difficult. The part that is relatively easy is getting them to set an emission-reduction target and meet the target. And we've actually got about 27 targets set. Some of them have already been met, as I mentioned some of them are quite ambitious and still have been met. So that part is actually not that hard because there appear to be lots of efficiency opportunities that people haven't taken advantage of and they can get moving. The more difficult part I think is getting companies to be advocates for public policy, which is critical because I don't see how you move the political process without sort of some voice from the private sector saying, you know, this is . . . it's okay, regulate us, you know, provide incentives for us, do things for us. And that is harder, although there are some who have sort of crossed that line, they're not very comfortable with it, and I think the politics of this year are particularly bad. The politics in general are so divided that it's very hard for these guys, no matter what they may think, to get out there or go up to the Senate and say we need this bill right now. So a work in progress is maybe the best way for me to put it.

Woman: Thank you.

Man: My name is John Cummings. I'm a Columbia graduate from farther back than I care to remember. I want to thank you for your comments and I think what you've said has been the most interesting so far. And I preface my question with the fact that nuclear energy has been proven to be a potential disaster for everyone. Why do learned people like yourself keep coming back to this as a solution, which is far worse than any problem we have now?

Eileen Claussen: I guess there are also learned people who disagree with you, and I don't know if I'm learned enough to have a real debate on it. I think it is possible to solve some of the problems with nuclear, just like I think it is possible to solve some of the problems with all the other technologies, and that to remove it from the range of possibilities is a mistake. I actually think we need to pursue everything we can, because we don't actually know what the right mix will be or should be. And so I don't want to pick all the winners. I just think we need to move ahead with everything, and I wouldn't exclude that, and I recommend that you look at a study that just came out of MIT, which I think is very good on nuclear and this problem, and it's quite balanced. There was a very diverse group of people working on it. I think maybe it's not quite as bad as you might think. It may not be quite as good as some others think. I don't want to exclude anything from the mix.

Question 5: Individual Action

Woman: My name is [inaudible] and continuing on the young lady's question about education for the future, I'm simply asking as a mother what message or how I can impress by 8 and 9 years old about this huge problem for them to understand?

Eileen Claussen: Again let me leave for a second the issue of how to describe the problem and maybe spend a minute on things that you can do or that they can understand and that they can do. Because one of the things that I think we forget in this debate is what individuals can do, what citizens can do, so let me offer a few thoughts there. The first is the choices you make are actually very important—whether it's the car you decide to drive or what other form of transportation you use, or what washing machine you buy—because there's a huge difference in what is out there in the marketplace, and if everybody thought that they didn't make a difference we'd have a problem. You can make a difference, and so just by the way you live your life I think you can start to move things in the right direction. The other thing that people can do, and your children are too young but you may not be, is vote, make sure that this issue is on the political agenda, which it isn't really but could be if enough people wanted it to be. And then you can make a choice when you make a vote as to whether you want to move forward on this or whether you don't. So I think there is a real role for citizens, not only in the individual choices they make but in who they vote for, and for some people who they invest in. Why not invest in the companies that are making this a priority and doing things and not invest in the companies that have decided that they would like to postpone action as long as possible?

Question 6: Considering Environmental Costs

Woman: Hi, my name is Mikaela Bisutima, postdoc here at Lamont in climate research, and I'm as fond of the climate problem as any other person. But I do think that we have an ecological problem that is much bigger, and one thing that has been bothering me through the last couple of days is that we keep talking of cost in terms of GDP. And there are economists who have stopped doing that, who have started incorporating the environmental cost in the cost. And I would hope that everybody who is involved in this debate and who talks to the politicians, who talks to the media, the public, will start actually moving away from that box of thinking of cost just in terms of money moving around and incorporate in the losses of species, everything that is going along our means of production and our trades. And I wonder whether the Pew Institute has been thinking about it, whether you think it's a good idea, whether there are ways to do it, or if it's just such another huge piece of education that needs to be done before that it's not feasible to do it now.

Eileen Claussen: I actually think you have to deal with both. I mean I think it is important to look at sort of the market consequences, which is why we did this report. What it basically comes out and says is that even if you only consider the market consequences, the things you can easily quantify, it's pretty clear that climate change is negative and doing something about it is a net positive. If you add to that all the things that we don't really know how to quantify, like loss of species and a lot of other things, it's overwhelming. But I actually think you need to make the first point first as a political matter because people look at it that way, but then you can continue to make the other sets of points, which we don't know how to describe very well, which we can talk about but which we can't quantify. Maybe I'm not answering your question, but I think you actually have to do both. So we started off with the market stuff, although if you read the report you'll see that there's a lot of discussion about the non-market consequences as well.

Question 7: Economic Feasibility of Reduction

Man: I'm Brian Weiss. I'm a student at Columbia, and I just wanted to ask considering that it would take a 60-percent or so reduction in carbon-dioxide emissions to stabilize the climate, do you think that the costs are still manageable at this society, and do you think that current policies which call for modest reductions are a feasible step on the road to eventually stabilizing climate?

Eileen Claussen: Do I think it's economically feasible? Yes. But it's in part because I think you have to start with what you can do. You have to send a signal that you're really serious, and then you have to sort of move into the things that will over time become more expensive, although I also believe that if you time it right, they're not as expensive as it would be if you had to do it all at once. I mean one of the things that sort of frightens me the most is that we sit around and wait, and then all of a sudden it becomes really obvious that we have to do something here, and we do it all at once really fast, probably not very thoughtfully. And then the costs I think are huge. So I am for modest beginnings, sending a signal, getting people to internalize the fact that they've got to deal with this, and then moving in a very deliberate way down a path to get to whether it's 60 percent or 80 percent or whatever it turns out to be as the right number. But yes, I think it can be done if we do it thoughtfully. I can remember one senator when I said this is a hearing saying, "Do you think we can do it thoughtfully?" And I do, I do think we can.

Question 8: Low-Energy Consumption

Man: I'm Roger Ladell. I'm a Columbia business-school graduate, a Wall Street executive, and an environmental activist with a suggestion in terms of education and the low-hanging fruit. I would like to see Columbia and other educational institutions that have dormitories require the students to use compact fluorescent lightbulbs as a way of educating them every time they turn them on—in that one-fourth of the electricity consumed, peak load drops, air conditioning loads drop—it's so rare that we can find instances where you get paid to do the right thing, and compact fluorescents are the most obvious, the lowest-hanging of all fruits for us to start educating people.

Eileen Claussen: Actually there are some universities that have taken this on and set their own target, so that could be a challenge for Columbia too.

Question 9: The Voice of the United States

Woman: Thank you very much. My name is Alla Maylou Iyengar. At the outset I'd like to thank you about your comments on India and China. We do have a problem. Although there are developing countries supposedly, the wrongness of anything is wrong, whether you're developed or not. We have problem of a large population who really admire the United States so much they want to do everything that's done here. So considering even if one-fourth of the population of a billion people, we waste one plastic bag a day. That'll be 250 million plastic bags a day. So how can we convince the rest of the world that America is a great place, but just do as we say, don't do as we do?

Eileen Claussen: You hit the problem right on the head.

Woman: There must be some way that the missionaries from this country should go everywhere, because we do listen to them, United States.

Eileen Claussen: I mean I have to say I think people listen less when we behave the way that we do. And that is why much as I want to see a global framework that includes everybody in a reasonable way, I think the voice of the United States is not heard on this issue because we have such a terrible record here at home. And that is why I think we have to start doing some things here at home so that any kind of a message that we have or any kind of a cooperative venture that we enter into is done knowing that we ourselves are doing what we need to do. So the policy of speaking abroad one way and not behaving consistent with that at home, which was sort of the Clinton administration policies, is not the right one. I'm not of course saying that this administration's policy is the right one. They don't talk about it anywhere or want to do anything about it anywhere, but I think the point is we have to do something serious here at the same time as we try to figure out how to get the rest of the world to do something serious.

Woman: Maybe we should get the MTV to help us out or something. Thank you very much.

John Mutter: This I think has to be the last question, but it looks like it is anyway.

Question 10: American Consumerism

Man: Hi, my name is Eric Hooks, and I was fortunate enough to attend here some years back. But to quote E. O. Wilson who appeared here several weeks ago, thank you for helping to polish the brief on behalf of life on this planet, and that I was wondering what you think about . . . you're clearly in the forefront of a very important advocacy here, but what about helping to find ways to attack the soft underbelly of American consumerism? I appreciate what you were suggesting about, you know, making it beneficial for companies to be associated with something as positive as this, but I don't know if there's any kind of corporate or institutional money out there to start with a drum beat in the background about the existence of this as an issue itself. Thank you.

Eileen Claussen: I mean it's really hard. I can remember a conversation I had sort of in the very beginning of the founding of the Pew Center, which is six years ago, with a manufacturer of appliances who was manufacturing by far the most efficient appliances out there, and we were talking about washing machines where there was a very good product, and the guy said to me, "Well, you know, we tried to do some advertising saying this would save water and it would save energy and it would be good for the environment, and consumers didn't go for it. As soon as we started saying this will give you the best wash you can get, people started to buy it and they took along all the ancillary benefits." But if that was the message people weren't quite ready to do it, and I wonder whether we don't need a different way of dealing with this that incorporates a lot of things into one and tries to push something rather than just sort of saying it's good for the environment, because I'm afraid we don't have enough people who will make those kinds of choices.

John Mutter: Let's thank our speaker once again.

April 23, 2004

Session 4: What Limits Our Ability to Respond to or Stop Climate Change?

Introduction by John Mutter

John C. Mutter: Good morning. Welcome again to the second day of our conference on the future of the planet. I'm about to introduce the first panel of the day. For those of you who didn't come early, let me make you aware that there is a small change to the schedule today, that while Governor Pataki will be attending and giving a speech this afternoon it will not be until, we anticipate, about 2:30. So that this afternoon's panel will begin immediately after lunch. The way this works is that I will introduce the chair of this panel, and the panel chair will introduce the panelists. They will each give remarks, there will be a discussion among members of the panel, and then the floor will be open for questions. We will try to keep those remarks among the panel and questions from the floor in about equal proportion. We have not been able to do that so far, but we should try.

Our panel chair is Scott Barrett, who is professor at the School of Advanced International Studies at Johns Hopkins University. He has written extensively on international cooperation and is the author of *Environment and State Craft: The Strategy of Environmental Treaty-Making.* He's also written specifically on the design of the Global Climate Change Treaty and has been the lead author on the Intergovernmental Panel on Climate Change, the IPCC. In addition to doing research in this area, he has advised a number of international organizations on climate-change policy and other international issues. He's currently an advisor to the International Task Force on Global Public Goods. For his research he was awarded the Eric Kempe Prize and the Resources for the Future Dissertation Prize. He taught previously at the London Business School. He's Research Director at the University College, London, received his PhD from LSE, the London School of Economics. It's my pleasure to welcome Scott Barrett to the stage.

Introduction by Scott Barrett

Scott Barrett: Well thank you very much. The session that I am chairing has the question, What limits our ability to respond to or stop climate change? and I'm going to come back to questions in just a minute.

Let me first of all tell you what the arrangements will be. After I've finished the introduction, I'm going to turn to our first speaker, Profession Daniel Schrag who is professor of Earth and planetary sciences at Harvard University, and he'll be speaking to us about the science of climate change. Then after Dan we'll turn to

Klaus Lackner who's a professor of geophysics in the Department of Earth and Environmental Engineering here at Columbia, and then finally to Geoffrey Heal, a professor of public policy and corporate responsibility at Columbia Business School.

I do want to take a few minutes at the beginning to mention and to comment on some questions that were put to me in [an] earlier phone call when the organizers of the conference were trying to get the . . . in this case, myself as chair, kind of on the mark about what the organizers were hoping to achieve in this session, and there were some questions that were said to me and I want to share those with you. The first was, Why are we not making, why haven't we been making progress on this issue? That's like the fundamental question. And then there are these sub-questions that come under that. The first one is, Is it because we don't know enough about the science? And we're going to hear about that from Dan. Second question, Is it that there are no engineering solutions? And we're going to hear about that from Klaus. The third, Is it that the costs are too high and/or the benefits too low, or that the benefits are distributed in such a way that the countries most able to do something about this problem also have the smallest incentive to do something about it? And that will be a question which I think Geoff Heal will touch on. And then finally, Is it that there's a lack of political will?—when we've kind of exhausted all the other possibilities is the explanation that we often come to. And I wanted actually to bring all those questions together because I think they're quite important to be kept together, and to comment on them, but not just to comment on them with respect to climate change. Last night the speakers for this conference were treated to a lovely dinner and also a terrific presentation by Richard Alley, and one of the things he did in this presentation was to mention another global environmental problem—stratospheric ozone depletion—to remind us that we actually dealt pretty successfully with that problem, and basically to inspire this that we could do better, we can address this problem. And I wanted to comment briefly in the introduction about what the experience dealing with ozone depletion has to tell us about this particular problem, climate change. And I think you actually learn more about this problem by thinking about it in the context of other problems that we've had to address.

So let me start with that first question: Is the reason that we haven't done much so far because the science is uncertain, that we don't know enough about the science? I think the answer to that is no. Now we don't know enough about the science, that's true. But it turns out that if you go back to the history of the negotiations over the ozone-depletion problem, you also find that when countries decided to do something about that problem and actually began doing something about it, the science of ozone depletion was also uncertain. In fact Richard Benedict, the chief negotiator of the Montreal Protocol, the treaty governing protection of the ozone layer, reminds people pretty regularly that this was true, that the science was uncertain when countries decided to take action on that particular problem. So the scientific uncertainty I think is not the reason that we haven't been making progress.

Now the second question: Is it that there are no engineering solutions? I think the answer to that also is no. We heard yesterday from David Keith that there are engineering solutions, and I think we're going to hear much more about that from Klaus Lackner, particularly about possibilities for the future. Now if you're thinking about a technological revolution, which is something that Eileen mentioned earlier, we do need to have new kinds of technologies, and we also need to figure out how to get these technologies diffused throughout the global economic system. And that's a major challenge. Now if you look back on the history of the ozone story, it also turned out that the technical solutions were not available at the time that countries agreed to move forward and do something about that issue. One thing that the treaty on the ozone layer helped to do, though, was to create a kind of a bandwagon where once enough companies and countries started doing something about this problem, there was a positive incentive for others to want to do more. You had a positive feedback that meant a kind of a bandwagon got rolling. We don't have that for climate but that's something we're going to need.

The third question is, Is it that the costs are too high and/or the benefits too low? I think this is part of the problem, not all of it but part of it. Let me just tell you a little briefly about this. It turned out that for the ozone depletion problem the benefit/cost ratio to the United States of the world as a whole doing something about this problem at the initial level at which action was taken based on studies that have been done was something like, I don't remember the exact number, but something like 180 to 1. When normally when you look at public investment the ratios you would see are something like 1:1 or 1:2. And by the way, that benefit of doing something about this problem is a calculation of the damages that would be avoided because of doing something, okay, the action. So the concerns that were voiced earlier are being taken into account here. Now for the climate problem, just to give you one sort of set of numbers developed by Professor Bill Nordhouse at Yale University, he finds that the optimal policy on climate would have a benefit/cost ratio for the world of about 3 to 1, so very different kind of order of magnitude for one kind of problem than for another.

Now the secondary question here was, Is it the case that the benefits are distributed in such a way that the countries most able to do something about climate also have the smallest incentive to do something about it? That is a problem. It turned out with the ozone issue the rich countries, who were the main polluters, were also the ones most likely to gain, especially in the short term, because that problem of ozone depletion would cause skin cancers and would kill people, and people in rich countries are willing to pay a lot to avoid that. With the climate problem, the countries most vulnerable are the ones that are not contributing much to the problem, and so there is an issue there about the distribution of benefits and costs.

Let me now come to the last question, the one that we always come to at every meeting, which is, Is the problem the lack of political will? Of course. We already heard Eileen Claussen's wonderful opening line about Earth Day. Was it Earth Day or was it Thursday. So that goes without saying. But then you have to ask the question, "Well, why isn't there more political will?" And I think one reason for that has to do with these benefits and costs and as they apply to a whole nation, but I don't think that's enough. I think another consideration is how those benefits and costs are distributed domestically, in terms of domestic politics. And Eileen mentioned this in her talk, and in general to get something to move forward, you must have not too many big losers, which is why the sequestration as a technology is something to take quite seriously, because it takes away the coal lobby and so on, as arguing against doing something for climate change. And it turned out that on the ozone-depletion problem, again, you had a positive influence here where companies did see that new markets would be created, and as the companies said that they would reduce their production and consumption of CFCs, that emboldened government to reinforce that with stricter regulations, which in turn got more companies to want to take action and so on, and you had this positive feedback, much like the one I mentioned earlier. And we need to create something like that for climate.

The final thing about all this is that climate is a global problem, and while we can and need to take action locally and nationally, it also has to be addressed at the global level. And the Montreal Protocol, the treaty that was designed to address the ozone-depletion problem, did that very successfully by creating the kinds of incentives for research and development, for diffusion of new technologies, incentives for bringing developing countries into an agreement in which real things are done and so on. And the agreement we have now for the climate unfortunately has not succeeded at that. And so we also need to think not just about how to deal with these issues at the domestic level, but also having to design more effective international agreements that will achieve what we really want to see achieved.

So that's my kind of quick response to the questions that were set for us, but let me now turn over to Dan Schrag to begin a much more considered discussion of these issues.

Daniel Schrag: Ancient Perspectives on the Next 250 Years

Daniel Schrag: Thanks, Scott. Thank you, the organizers, for inviting me here. I also want to apologize to the speakers yesterday because I was teaching and I couldn't be here. I'm probably going to say things that people said yesterday, and so I hope that won't offend any of you.

So I was thinking about the question that was asked for our panel, What limits our ability to respond to or stop climate change? And I thought really the best, the way to do it, is to start with the obvious. I was thinking about Columbia and what kept coming into my mind was Thomas Hobbs, who wrote the *Leviathan*, and he's one of the most misquoted people. People are all familiar with his famous quote that life is nasty, brutish, and short, which is the thing that most people remember, but here at Columbia, they have a real Core Curriculum, unlike the watered down version we have at Harvard, and so they probably know the difference. In fact that's really not what he said, it's quoting him very much out of context. In his book *Leviathan* he writes, really he's talking about lack of natural order that creates a situation which he calls war. So he says that without a common power to keep them in awe that we would have war, and he actually makes an analogy to the weather, which I thought was particularly interesting. He says that "for a the nature of Foul weather lieth not in a shower or two of rain, but in an inclination thereto of many days together: so the nature of War consisteth not in actual fighting, but in the known disposition thereto during all the time there is no assurance to the contrary." So I guess, you know, war on terrorism is a continuous state of war from now until eternity. In that context that's where his famous quote was, it really was in discussing this condition of war. If humans were in this condition of war, then life would . . . the life of man would be solitary, poor, nasty, brutish, and short. He wasn't saying that all our lives were this way, he just was saying that in a state of war this was the way it was. Interestingly he also noted what would be required, that "the Passions that incline men to Peace are a Fear of Death, Desire of such things as are necessary to commodious living, and a Hope by their Industry to obtain them," and that's really at the core of what we're talking about today.

But I want to use another example from Hobbs as well, because he's writing about the leviathan, the giant whale. I mean we'll get there in a second, but from this sort of nasty-brutish-and-short analogy, one could simply answer the question that we were asked by the panel, that humans are nasty, brutish, selfish, shortsighted, irrational, violent, and cruel, and that's why we're not doing anything about climate change. And I look at the world today and, you know, there is something to be said about this argument, but I'm pretty sure the organizers didn't invite me to come to talk about my politics, and so we'll get rid of that. But aside from human nature, are there qualities of the climate system or carbon cycle that will limit our ability to respond to or stop climate change?

I'm not going to talk about whether we know enough about the climate change. People have talked about that ad infinitum, we don't need to hear about that again. The important point is that we're performing a grand experiment that we haven't done . . . we haven't had CO_2 above 300 parts per million for at least 400,000 years, and probably it hasn't been much above 500 parts per million for something like 30 million years. So we're performing an experiment that hasn't been done for millions of years, and no one knows exactly what's going to happen. It's not about scientific uncertainty, it's about putting the Earth in a condition that it hasn't been in for millions of years, and do we really want to roll the dice? That's the question.

And the important point that I want to drive home is that the response time of the system . . . what I consider the most serious obstacle to action is that the response time of the system is very long, both because of the lifetime of energy technology and because of the lifetime of CO_2 in the ocean-atmosphere system. Wally uses the wonderful analogy of poking the angry climate beast, and there's the picture of

. . . I wasn't able to put it on this overhead for this presentation, but poking the dragon with a stick. But again the point is that there's enormous amount of momentum in the climate system. You're not poking this repeatedly. The important point is that the beast's wounds are cumulative. We keep sticking the sword in and the swords stay in, the carbon dioxide stays in the atmosphere and builds up. It's not just poking him again and again, it's accumulating, and that's really the problem. And I think the important thing is at some point the beast is likely to poke back. And that's really what we're worrying about here, right? Okay, enough gore.

I want to show you something that I . . . I did something similar for the "State of the Planet" meeting here a few weeks ago, but I want to show something very simple here, which is a carbon-cycle calculation which illustrates this idea of momentum, of the great, the long response time of the climate system, why this is a such a difficult problem to deal with, and what the real obstacle is here. We're going to do a few simple calculations, and this is something you can do just on a spreadsheet yourself, a simple carbon model with carbon dioxide coming out, and the base assumption we'll do, the business-as-usual, is that the global economy grows at 2.5 percent a year, but that energy efficiency improves at 1 percent a year, so the net increase in energy use is 1.5 percent a year. And we're going to raise CO_2 emissions by 1.5 percent a year, a very simple way of just looking at it.

In our second scenario, we're going to look at carbon sequestration, and by the way, I really mean just a reduction in carbon emissions. You could have this be done by replacing fossil fuel with wind or nuclear, or you could sequester the carbon. It's not any specific technology I'm invoking. It's just reducing carbon emissions starting in 2015, increasing by 200 million tons of carbon per year, so if you think about it in terms of actual carbon sequestration by the end of the century, you're sequestering something like 17 billion tons of carbon per year. Okay? That's the scenario number two.

Scenario number three is that we wait until 2050 and do the same thing. But it still means that by the end of the century we're sequestering 10 million tons of carbon per year, still quite a lot. Okay? And this is what you get when you look at the graph. Here is carbon dioxide on the left, parts per million, and this the year from 2000 to 2100. There's our business-as-usual scenario, 1.5-percent increase gets you somewhere between 900 and a 1,000 parts per million. Again, this is something that we haven't seen since a time when there were crocodiles in Greenland and palm trees in Wyoming. We really don't know how the Earth's going to respond to that. I don't think we want to find out.

There's our scenario if we actually began ten years from now sequestering carbon at a rate of 200 million tons additional added sequestration each year. And this is the impact on carbon dioxide. We still get almost to 600 parts per million, so it's still an enormous rise. That's double the preindustrial level, so that's still massive climate change. A previous questioner asked about, you know, said that we would need to reduce by 60 percent to stabilize the climate. This isn't stabilizing the climate, this might be stabilizing CO_2 in the atmosphere, it's not stabilizing climate. Climate is going to . . . changes from this is going to be massive.

Here's what happens if we wait fifty years. And so the question is—you see now where at sort of 800 parts per million—Is this difference between 580 and 800 parts per million significant? Is this something we should worry about? To me this is the heart of the question. But the response time of the system is so long that we don't have the choice of waiting fifty years and changing our minds, "Oh, this really is a serious problem, now let's do something about it." Well it's too late.

And I think this has been left out of a lot of the economic discussion and policy discussion of this. The long response time is absolutely the core of this. And by the way, this whole calculation here, the point is that the consequences of waiting are significant, and this calculation doesn't even consider the enormous cost of changing energy technology, for example, after China has already built pulverized-coal plants. The inertia in the climate system is what we're seeing here in terms of the carbon cycle. But there's also enormous inertia in our energy technology. It's more expensive to change our technology after we've already built coal plants for the next thirty years, saying, Oh, maybe that wasn't such a good idea." So economically the calculations I don't think have been done correctly. And of course there's other factors.

So here's Antarctica. Actually I know probably Richard Alley talked about this yesterday, I don't exactly [know] what. People have talked about the possibility of the west Antarctic ice sheet going into the ocean. I think it's a remote possibility, but again we've never done the experiment. You know, it took 10,000 years for the last deglaciation, the Laurentide ice sheet on North America to melt away completely, but that was only a small change in CO_2 and a small warming. We're talking about over a few hundred years warming by maybe four or six degrees, and changing CO_2 by much higher amount. We have no idea how an ice sheet is going to really respond, and the question is if we were monitoring the west Antarctic ice sheet and it suddenly began showing signs of collapse, could we stop it? This is a massive change to the planet, and to think that we can suddenly turn on a dime and fix the problem if we suddenly decide it's catastrophic is silly. That's the really important lesson I think in all of the science of climate change.

So when you ask, What are the biggest obstacles to taming the climate beast? Aside from human nature, which is I think a very serious part of this, it's the long response time of the carbon cycle, the climate system, and the energy infrastructure. And I think profoundly affects the discounting argument the economists use. And I know Partha talked about this yesterday, but the economic argument for discounting essentially says that we should invest our money in our economy, grow our economy, and then we'll be richer and more prepared to do something about it in the future. But this long response time really undermines that whole discussion, because not only is it vastly more expensive to do something in the future, it's not even clear that it's possible. So we have to make some decisions now, we just don't have the luxury of waiting. It of course also places much more emphasis on catastrophic outcomes.

Another issue that one could think about in terms of Kyoto and the type of treaties . . . lots of people bash Kyoto for all sorts of reasons. There is a good part of it, which is that it was an agreement. Just getting an agreement between different countries is so difficult that one should be careful just bashing it because it doesn't include one thing or another. But a more serious issue that I think needs some discussion is that the first step towards a solution, say a 10-percent required reduction in emissions, lead you to invest in the technology or in the types of behavioral change that really are going to solve this problem. And I think that's an open question. We need to do a little bit more long-term planning. So that's my perspective.

Thank you.

Scott Barrett: That was terrific. The first atmospheric scientist I've seen quote Thomas Hobbs. Well done. Let's turn over now to Klaus Lackner and hear about new technologies.

Klaus Lackner: Today's Limits to Climate Engineering

Klaus Lackner: So I was asked to give an engineering perspective on all of this, and the first thing I realized, calling myself a climate engineer I would feel silly. It's very rare that climate and engineering is mentioned in the same sentence. The normal thing is to talk about climate research— you make predictions, you analyze, you try to understand, and ultimately you try to make predictions. So the applications in climate science are not so much what do we do about it at this point and this stage in the game, but much rather the application is forecasting.

And if you look at the weather, in particular, we spend an awful lot on forecasting the weather, which tells you at some level we deeply care, we need to know what is going on, we want to understand where it goes. And in some ways, the best thing you can do if you can't change things is at least to be prepared. So in many ways we are not yet ready, I would argue, to tame Wally's angry beast. The best we can probably do, and I will conclude with that, is to not poke it and put that stick away.

But I think a lot of engineering, a major role of engineering in a very real way for people, is to gain control over their environment in one form or another, whether you build a house, which gives you sort of a local microclimate, or air-conditioned skyscraper, whether you move yourself from one place to another, or even if you do military designs for the purpose of controlling your neighbors, in any case one of the engineering efforts is about gaining control over your environment. And I would argue that's a very strong human drive, so we will like to do that. And it's quite likely that we will tempted to do the same in climate at some point in the future, but we are not ready yet because I think at some level this is where the science at this point is still a little too weak. We can't really predict what we would be doing. And so as a result we are very reluctant to get involved of this.

But look at, for example, damming up rivers for flood control. The moment we had figured out how to do that, we were happily getting engaged in it, sometimes with great success, sometimes with side consequences we really hadn't anticipated when we got going. So I would argue at this point we are probably not there yet. But the systems we can control are getting bigger and more complex. And there are two reasons we can do this: the machinery we can put to work on it is getting bigger, and the energy we are willing to invest into it is getting bigger. And at the same time our understanding of how things work is getting better, and that makes it easier. So I would argue you could well see in the future a fairly sudden transition where we suddenly feel comfortable with it, and over the next hundred years, we will learn an awful lot about the climate, so we might be thinking about this. But I think for the foreseeable future, prediction is sort of the best substitute we have. We will look at the system and say, "Okay, failing control, I'd like to know what will happen, so I can either get out of the way of it or adapt to it or protect myself against what's going to come." The one exception . . . so therefore we do weather forecasting, and you can see how valuable this is in examples of tornadoes, hurricanes, and severe storms and droughts. Knowing what will happen puts you in a much stronger position to begin with. But as long as our predictions are too poor to understand what we are doing, we sort of probably follow this principle: if you break it you own it. And so we are very careful and reluctant to make drastic changes. And in the climate debate those changes have been suggested, for example, it has been suggested to very directly influence the radiative flux onto the Earth either by intercepting it in the stratosphere or going even out into space and putting a screen up. I think the reason we are not willing to look at these in earnest is not so much that these are particularly expensive solutions—it turns out they are not—but because we really don't understand what would happen. So for the time being the only change I think we are willing to look at is a change which says, "Okay, let's not poke this angry beast, let's stop making changes inadvertently to the system and try to clean up after ourselves so that that wouldn't happen." On the other hand I would argue could we affect the climate? Of course we can. We are doing it by accident, so nothing would really stop us from doing it on purpose, but we are not quite sure where that would go.

So if you really in the immediate future only deal with eliminating our inadvertent impact, then you really have three options to solve the problem. Either you can forego the use of energy, or you find alternatives to fossil fuels which don't have the associated emissions with greenhouse gases, or you by engineering means figure out ways of closing the carbon cycle. And I think at some level, all of these three options will have to be looked at seriously and have to be pursued and pushed forward.

On the other hand, I would argue energy consumption is very hard to reduce to the level we would have to reduce it to to have dealt with the problem successfully just through that route. Roughly speaking in the U.S., our energy consumption is about a hundred times our own metabolism, and if you look at species that are in the 75-, 70-kilogram range, you can sort of support empirically a population density of about three per square kilometer. We are way, way above those kind of numbers, and so as a result, we will have to use excessive energy, additional energy, to maintain, if not our lifestyle, at the very least the way we are going about it and maintain that kind of density. On the other hand, I would argue there is no fundamental theorem which says that energy consumption and lifestyle have to be one-and-one related. Quite the contrary, I would argue it's sort of a hallmark of technologically advanced societies that they can do the same thing with much less energy, like we raised productivity, we will lower energy intensity or raise energy productivity over time. So this is a good thing to do.

We also should look at alternatives to fossil fuels. This includes solar energy, this includes wind. You have heard about this yesterday. But at the same time, I would argue we have done this for thirty, forty years, and have looked at it, and we have made quite a bit of progress. I mean otherwise David couldn't have stood here yesterday and said, "Well, we could have 50 percent of our energy from wind at a price we could afford." This is thirty, forty years of research which has gone into it. But I would argue we haven't quite gotten there yet, and I think we are tying our hands behind our back if we say this is the only options we have left.

I'll give you a somewhat crude analogy to say, "Well in the food sector, we also have to feed ten billion people by the middle of the century, and for some reason I'll leave unspecified now we have decided to accomplish this goal by eliminating all cereals, no more wheat, no more rice, no more corn. I don't know whether we could do this, but certainly it's obvious to everybody it would be a very hard and a very ridiculous challenge. But in many ways if we take the 85 percent of energy which is currently taken up by fossil fuel out of the picture, we are posing a challenge which is just as dramatic as that, and just like we need food I would argue we need energy. It is unavoidable and we can't get around this.

So we are coming back then to the immediate approach to the problem that we have to keep Wally's beast calm, and the way we do that is we don't poke it. So for that I would like to put a few words on the capture and the disposal of the carbon dioxide. And I would argue—and you have heard this already yesterday—that can be done. The question is, Can we do it at the scale we need to do it? And to put it in perspective, I just wanted to give you a perspective where this picture was taken, and I'll come in a second to why. But we will need somewhere on the order of 10 to 30 terawatts of carbon-neutral energy, and that is the challenge. We are going to fill roughly Lake Michigan with liquid CO_2 over the next hundred years, and on that scale it becomes challenging where to put all of that carbon dioxide. On the other hand, I would make the point we can start today. There is nothing that prevents us at this point to put carbon dioxide under the ground. We can inject it. It is done 20 million tons—or even more than that by now—in the U.S. go underground for the purposes of bringing oil up. And that CO_2 stays down there. So we can start rather immediately moving forward by injecting carbon dioxide underground. I think there is no question that once these reservoirs have filled up—and there's no debate that this will never hold a Lake Michigan—once these reservoirs have filled up, there are other reservoirs. We don't get an economic benefit by using the CO_2 so now it starts to cost us money to put it underground, but we can do that at a larger scale. I think the honest debate about this is, Is that enough? I just saw a German report, a recommendation to the German government, saying don't rely on that because you have at a maximum 300 gigatons, and if you follow Dan's numbers at the end of the century, you needed more that that. It just won't last. So for that reason, I believe we need to look at other options, and ultimately we have to put that carbon dioxide away in a form which doesn't store it as a gas, but we have to neutralize the carbonic acid and turn it into a solid. And this was what I was showing you before. This solid here, the alma mater out there, is serpentine, it's a magnesium silicate. And if you look at the white veins in there, they are carbonates which happened to have formed spontaneously. So I believe you can take mineral silicates, magnesium silicates, and react them chemically with the CO_2 in an exothermic reaction to form carbonates, solid minerals. And at this point you have eliminated the limit of 300 gigatons. Now you can put all the carbon you had ever had away permanently and safely. The hitch with this idea is at this point we can not do this at this point economically. This process is at least three or four times too expensive. On the other hand, fuel sales are probably a factor of forty, fifty too expensive, and people are optimistic that as we move on technologically, we can make progress. I would argue this is still in the nineteenth century as far as the technology development goes, and we can make progress, and we would have to make progress to make this technology one we can say we can rely on. At this point it is still too expensive.

If you have a way of putting the carbon dioxide away in the end, you also will need a way to collect that carbon dioxide. You will collect it from concentrated sources, and you then can put it away permanently. Such concentrated sources are obviously the big power plants. In the future, these could be plants which can generate hydrogen, but in any case, here you have big sources, you can collect the CO_2.

I don't want to say very much about it, but just make one comment that this has a synergism with other things. We have in the past burned coal in homes. We still do this in countries like in China, and it's an absolute disaster. And doing it in a big power plant is a lot better, but it is still a bad idea. In the long term you want to have smarter ways of getting your energy out of your fossil fuels, and not emit anything to the atmosphere. By collecting the carbon dioxide which is the one gas you couldn't help but make in the first place, you can literally close the stack of a power plant. And there are a number of designs out there, and I can't get into the details here in 15 minutes, which basically would allow you to collect that CO_2 and put it permanently away while at the same time have capped the smokestack and have reached efficiencies like 60, 70 percent from a power plant. So if you look thirty, forty years out, there is no reason to believe that these technologies have to remain as dirty as they are today.

But I put a third leg into this net-zero carbon economy, which is to pull carbon dioxide back out of the atmosphere. And if you look at that, that is possible too. If you know from high school and you bubble it to a calcium hydroxide solution, it clearly gives up its CO_2. So the real question is not, Can it be done? But the question is, Can it be done affordably? And I would argue to begin with simply the size scale you need for that is actually surprisingly small. If you think of such a design here, which I drew where the air goes through something akin to venetian blinds, such a system where a 60 by 50 meters would pull roughly 3 kilograms of CO_2 per second out of the air. Just to give you a feeling this would be equivalent to 15,000 cars. So a small town which has a water tower of this size would also need a air collector of this size, but obviously you would put it in another place, you would collect them at some remote site where you have them together right at the point where you would put the CO_2 away. The scale of that can be reached at some level in the future. At this point the cost for that is probably still too high. On the other hand, there is no fundamental reason why this cost can not come down drastically. If you look at the areas involved here, they are very small. Per person the CO_2 emissions on such a unit, which I assume to be 50 by 60 meters . . . every person has a piece of that approximately the size of a big color television. So that would be scale through such an area the wind carries as much CO_2 as one person emits over the course of a year, namely 22 tons per person per year.

If you put this together out of pieces we have right now based on what we can do, probably the price is still too high. I have been saying for some time, ultimately we can drive this price down in the order of 25 cents a gallon of gasoline. So I believe if we push this further, there's a fair chance that this can be done. And by the way, there's a small outfit in Tucson who has just started to build a prototype, and I think after they have managed to do that we can talk much more intelligently and in much more detail about where the costs of such a system will be.

But it opens a number of interesting doors. The first one is, Why is a hydrogen economy so exciting and interesting? Well a hydrogen economy is exciting and interesting because it collects its water from the environment. It uses presumably renewable energy to break that water up into hydrogen and oxygen, it releases the oxygen to the atmosphere, and then sometime downstream, the consumer takes that hydrogen and combines it with oxygen and releases the water back into nature. That is a nice and in itself closed loop.

Okay, if I can collect CO_2 out of the atmosphere, I suddenly opened a door because CO_2 and hydrogen can do Fisher-Tropsch reactions, which have been well established for the last eighty years or so, and with those kind of reactions I can take CO_2 and hydrogen and turn them back into a fuel. So air extraction in the short term will allow us to collect the CO_2 back from the air and close the carbon cycle with fossil fuel as input. But in the long term, it also will allow us to put that CO_2 back into use and close the cycle just as you would in a hydrogen economy. So it opens the door to connecting back to a renewable energy system, and you could phase it in without at any point in the future having to replace one infrastructure with a brand new one. That is its advantage.

Finally let me close and come back to this climate engineering question. If you were to succeed with the air-extraction system, and you posit at this point that some 30 percent, let's say the transportation sector, of all the energy is being dealt with, with pulling CO_2 back out of the air, nothing really would prevent you from letting that part grow by another 10 percent. At that point you would have a net reduction in the atmosphere, and at this moment you actually have to start to ask a question about climate engineering in the long term because now you will be asked the question, What is the CO_2 level we ultimately should settle on? Are we willing to pay to drive it back down to 280, or will we stop at 250? And David Keith once said geoengineering isn't geoengineering unless it is done on purpose. I would argue once you have this option, all of our inadvertent emissions of CO_2 in the atmosphere may turn retroactively into geoengineering because now we have to decide whether we pull it out, and it is now done inadvertently, one way or the other.

So let me close with this. To give you a feeling and summary, yes engineering can come up with a number of solutions, and as David said yesterday, they will not be so expensive that they break the bank. The big issue is that we find the will to do it.

Thank you.

Geoffrey Heal: The Limits of Economic Policy Making

Scott Barrett: We now introduce our last speaker, Geoff Heal, from Columbia Business School.

Geoffrey Heal: Can we go to the first slide, please?

Okay so my . . . looking at the beginning slide, I can give you an outline of what I want to talk about. I want to talk about the kinds of steps we need to take in order to tackle seriously the problem of greenhouse gases. I'm going to start off by talking about some easy steps and move on into some somewhat more difficult steps. I want to talk about the implications that this has for the Kyoto Protocol and for the kinds of changes that need to be made in that protocol. And I finally want to end up talking about the question—which I guess is the one we've really been asked to look at in this panel—which is, What are the obstacles to taking moves in these directions? Why haven't we taken some of these steps already?

Now there is a number of steps that we can take that are very straightforward and will make a significant impact on the climate problem. And Eileen Claussen, in fact, outlined some of these this morning in her talk, and I'm going to repeat some of these. There's a number of existing technologies which, if properly implemented, really will make a significant difference to emissions of greenhouse gases. We can look for significant contributions from better building insulation, the use of more efficient automobiles, and a range of things like this. As Eileen mentioned this morning, there are a number of large corporations which have undertaken to make significant reductions in their CO_2 emissions and have managed to do this at little or no cost, or even in some cases at negative cost. And she mentioned the example I have there in the second bullet point, which is British Petroleum, which has cut their . . . in the last four or five years have cut their emissions of CO_2 back to significantly below their 1990 levels, and claim actually to have made money—in fact to be precise 630 million dollars—in the process of cutting back CO_2 emissions. And there are actually interesting and very similar stories from a number of other large corporations. I mean Dow Chemical is one of the most widely quoted. And continuing on the line of existing or available technologies, Toyota Motor Company will shortly have available hybrid drives for all of its vehicles, from the small ones like the Prius all the way up to the big SUVs and the luxury cars in the Lexus range. So if we were all to switch over the driving Toyota hybrids, we would be able to cut our emissions of greenhouse gases in the transportation sector by 50 percent, and that will be an available technology in the relatively near future. So there are quite a number of ways in which we can cut greenhouse-gas emissions quickly and at relatively little cost.

Now these don't solve the problem altogether—in fact they're a long way from solving the problem altogether—but they at least get us en route, and they get us moving, and they get us a momentum in place. Maybe they add up to 10 to 20 percent of the solution overall. And the first thing we have to do from an economic perspective is to make certain that these low-cost, low-hanging-fruit-type measures are implemented.

I just wanted to make a just brief remark about why some of these things don't in fact happen. It's a question that a number of people have posed from the audience. So I want to take a very concrete example, an example that I had in a class I'm teaching this semester. I had a lady come and talk to the class—who's the manager of a large apartment building complex in New York, seven hundred apartments built for low-income families. And in that apartment complex, the heating and cooling systems are all centrally controlled, and they're all on or off together. So you either heat every apartment simultaneously, or you cool every apartment simultaneously. There's no individual control of the temperatures in the apartments. And as a consequence . . . some of these apartments are south facing, some of them are north facing, so consequently some of them are over hot, and other ones are comfortable and vice versa. So you've got an enormous amount of energy wasted. The question obviously everybody asked was, Why don't we stop doing things like that? And the answer is in that particular case when the building manager discussed what it would cost to change the control systems in the building the answer is it would cost one and a half million dollars to change the control systems in that building and make it possible for each individual apartment to control its own temperature. And as this was in a building specifically for low-income people, that was just not feasible. I mean the people in that building couldn't between them raise a million and a half dollars. So that's the kind of obstacle you run into when you talk about implementing some of the low-hanging fruit. In that particular case there was a happy ending. A rather interesting recent startup company called Consumer Power Line came along and volunteered to install the control equipment free in exchange for 50 percent of all the energy savings that the building could make through more efficient control systems. And that's now being . . .

Can I have the next slide, please?

The complete solution to the problem of greenhouse-gas emissions is going to require much more than the kind of things I was just talking about. It will require, as several speakers have emphasized, development of significantly new technologies, and not just their development, which is perhaps sometimes relatively easy, but their implementation on a really large scale, and that is actually quite a challenge. And we have to find ways of reducing very significantly emissions of carbon dioxide, which are compatible with the energy needs of the industrial countries but more specifically and more perhaps pointedly, we have to find ways of doing this which are compatible with the energy needs of the developing countries. And in the developing countries we have 4 or more billion people who currently consume little or no energy, and, as one of the questions this morning indicated, would just love to consume energy on the level at which we do. And if they were to start doing that, then the worldwide consumption of energy would increase by a factor of forty-, fifty-fold, enormous increase. So the challenge we face is finding ways of generating energy on a large scale, a very, very, very large scale, much larger than we are at the moment while controlling greenhouse-gas emissions.

Now this almost certainly means continuing the use of fossil fuels. That's the point that Klaus was just making. I mean fossil fuels are the most abundant energy source that we have worldwide, and in particular a number of the big developing countries have very substantial reserves of fossil fuels. India and China both have enormous resources of fossil fuels, for example, and it's natural to expect that they will want to develop by using those reserves of fossil fuels. They're far and away the cheapest and most cost-effective method of economic development for them. So ultimately solving the problem means that we have to find technologies that let us and the developing countries burn fossil fuels on a very large scale without creating greenhouse gases.

And in light of those observations, I just want to look briefly at the Kyoto Protocol and some of the issues that that raises. The Kyoto Protocol obviously is a great step in the right direction, and it's the only step we've made so far, so I don't want in any sense to knock the Kyoto Protocol. But it really doesn't go far enough in a whole range of very important directions. Specifically it doesn't tackle what I call the India-China problem, which is the problem that I just mentioned, that developing countries need a mechanism for generating energy on a really large scale, at the same time not producing large-scale greenhouse-gas emissions. If India and China, for example, were to sign and to implement the Kyoto Protocol as it currently stands, effectively they would be signing away their rights to economic development. That's obviously something they're not intending to do. They have no intention whatsoever to do that, and if India and China and countries like those have no intent to participate in the Kyoto Protocol, then the fundamental problems of greenhouse-gas emissions will not be solved in the long run, and other countries also have relatively little incentive to take part in the Kyoto Protocol either. So the unwillingness of large developing countries to take part in this protocol, which is a totally natural unwillingness, really effectively undermines the point of the whole exercise.

Let me give you an example—I guess in a business school what we would call a case study—which I think sheds some light on how we need to tackle this problem. And that's the example of the introduction of unleaded gasoline, which is an unsung environmental success story on a global scale. It also happens to involve two of the key protagonists in the climate-change issue, which is the auto industry and the oil industry. A number of years ago, the United States mandated the use of unleaded gas in automobiles. That was actually not an easy thing to do. At that point all automobiles were built to run on leaded gasoline, and all petroleum refineries were designed to produce leaded gasoline, so we had a very significant investment in technologies on the production-consumption side that really depended on the presence of lead in gasoline. In order to get that change through, the auto and the oil industries had to get together. They had to agree on what would replace lead in gasoline. The auto industry had to redesign their engines, and then redesign the manufacturing processes to make these new engines, and the oil industry had to redesign some of the stages of their refineries and rebuild parts of their refineries.

Now this measure didn't only affect the U.S. auto industry. Although it was implemented in the U.S., it affected any auto company wanting to sell its vehicles in the United States, and that includes pretty much every auto company in the world. So as a result of the measures that the U.S. took, every major auto company in the world had to develop engines that were capable of burning unleaded gasoline. So, effectively, a regulation passed in the U.S. drove changes in vehicle-engine design worldwide. Now once the U.S. had made these changes and had mandated the use of unleaded gas, it then became far, far easier for other countries to mandate the same change. The U.S. already had developed the technologies and for an automaker to have these technologies in place. So for countries like the UK or Germany or France to follow suit was then far cheaper, far easier, economically and politically than it was for the U.S. to make the first move.

What this case illustrates is a number of things that I think have in common with the greenhouse-gas problem. It illustrates the need for new technology. It illustrates the central role played by a couple of key industries, the auto and the oil industries, and the utility industry of course one would have to add to that in the case of greenhouse-gas emissions. And it also plays the critical role played by a first mover, in this case the United States, in the development and introduction of a new technology.

Now it seems to me likely to for a greenhouse-gas control agreement to be successful, the U.S. will again have to play a central role. What is it that has stopped the U.S. from playing a central role in this area so far? There's a couple of things. One is the opposition of the oil, the auto, and the utility industries to what will be a significant economic upheaval in their businesses. And this I believe instantly can be overcome, and I believe there are ways of designing the kinds of policies one would implement here which would look after the economic interests of those three industries, and could conceivably actually make it profitable for them to adopt greenhouse-gas-friendly standards of production. And indeed there's an interesting series of papers by Professor Larry Goulder of Stanford University which look at exactly what kinds of policies the U.S. would have to implement in order to make it in the economic interests of the oil, auto, and utility industries to move in the direction of significantly lowering greenhouse-gas emissions. We know how to do that. I mean we know what technologies would be needed there and we know what kind of economic policies would be needed to make it financially in these people's interests to move in that direction.

I think another big obstacle towards movement in this direction has been the unwillingness of developing countries to get involved in this area and to make significant commitments. They've held out on this on a couple of grounds. One of the grounds that the problem is not theirs but ours, we being the industrial countries. And they've also held out on the grounds that implementing anything like the Kyoto Protocol on their part would deprive them, as I said a couple of minutes ago, of the right to develop economically. And that second argument I think is a very compelling argument. Now I think holding out on these sorts of grounds, while very understandable, is probably not practical politics from their perspective.

I think what we can hope for in terms of support for developing countries joining something like the Kyoto Protocol, from the industrial countries, is significant transfers of valuable new technologies. I don't think we'll ever see significant cash payments, for example, from industrial countries to developing countries as a quid pro quo reductions in greenhouse-gas emissions although there've been a lot of discussions of that, and that was one of the hopes that people had a number of years ago.

The development of significant new technologies could in fact be of enormous value to countries like India and China, and specifically, as I mentioned a couple of minutes ago, both China and India have very, very large resources of coal. And a natural route towards industrialization, or in the case of China further industrialization, for those countries is to make use of those reserves of coal which are accessible, low cost, and so on.

Now a country like China at the moment, for example, faces an enormous dilemma in this area. Their natural route, as I said, to energy intensification is to burn their own coal, but it generates enormous amounts of pollution, and here we're not talking just about greenhouse gases but a wide range of domestic pollutants, to the point where atmospheric pollution in China is now a major domestic political issue, and one of the principal sources of that atmospheric pollution is the combustion on a large scale of low-quality coal. On the other hand, if they stop burning their own coal and they import oil, their energy-production costs rise very significantly, and that has a negative impact on their economic growth. So the development of technologies of the type that Klaus and others have spoken about which facilitate the combustion of coal and other heavy fossil fuels, while making that a relatively clean process and cutting out a lot of the emissions, including the greenhouse-gas emissions is actually of immense economic value to a country like China and a country like India.

So my thought here is that the development of appropriate technologies in this area by the industrial countries is of great value to many developing countries and could be sufficient incentive for them to participate in some extension of the Kyoto Protocol, on the understanding that tight emission standards in the area of greenhouse gases would only come into effect once these new technologies are actually available and accessible to them.

So my conclusions overall on this. The principal reasons we've had a lack of progress in this area are not, I think, as other people have emphasized, not a lack of scientific understanding. And we have far more capacity to predict the future in this area than we do in many, many other areas in which we undertake significant investments. For example, I'm the business school and many of my students in the portfolio-management school, portfolio-management area, portfolio managers regularly commit billions and billions of dollars on far less information and far more uninformed guesses about what the future will bring than we have in the area of climate change. Climate change by the standards of many areas in which we make economic decisions regularly is actually quite a well-understood field. We know what the risks are, and we have reasonably good estimates of the magnitudes there. So the issue is not uncertainty that's an excuse rather than a reason. I think the fundamental point is that we haven't crafted a deal on this issue which is attractive to all the key parties to the industries involved and the countries involved and so we've run into a lot of unnecessary political opposition, domestically here in the U.S. from the industries, and internationally with some of the countries that will be involved by this. And I think we've probably those interested in and concerned about the environmental issue and the greenhouse-gas emission issue in particular are just focused too much on the Kyoto Protocol in its current form. Kyoto Protocol in its current form, as I said, is a good start but it certainly isn't anything remotely like a solution. We need to revise and restructure that in significant ways, and I believe it is possible to do that, to construct a deal which is attractive, as I said, to all of the parties involved here.

Let me end with one final point on this. It's conventional and in fact the Kyoto Protocol does this to set targets. The Kyoto Protocol has emission targets, reducing emissions to 1990 levels by specific years and things like that. From an economic perspective, the key thing is not to get involved in the minutiae of setting targets like this. They're in some broad sense irrelevant. The key thing is to provide economic incentives and financial incentives to individuals and to corporations to change their behavior and move in the direction of using less greenhouse-gas-intensive technologies. And if we provide strong enough incentives we will get eventually very significant reductions. But without providing those incentives and we have almost none of them in place at the momentwe will get no response whatsoever, whatever the targets we choose to set.

Thank you.

April 23, 2004

Session 4 – Panel Discussion and Q & A
What Limits Our Ability to Respond to or Stop Climate Change?

Panel Discussion

Scott Barrett: All right. Well, the microphones are switched on here, and at this point we're going a chat, a public chat among ourselves about the issues that were just discussed, and then after we've had this chat we'll open up for questions from the floor. I think at least Dan Schrag wants to make a comment. Did I hear you correctly? And Klaus as well.

Klaus Lackner: Having listened to your arguments, I would say it's absolutely central to have these incentives in there, and I agree with you, you may not understand or predict the trajectory how reductions phase in, but if the incentive is there, it happens, and I can take the air extraction as an example. It cannot work unless somebody gets paid for it. But by the same token if you manage to build an industry which has suddenly as its business core the idea of collecting CO_2 and putting it away, either to sell it in the short term in enhanced oil recovery and coal-bed methane, or later to safely sequester it, that industry will go out and lobby and will say, "Look, you should tighten the standards. We want more of that because we have a business in there." If on the other hand you leave it to regulatory rules which say you must deal with the problem inside your own plant, then you will always view it as a drag on your system and consequently try to get out of it by putting political pressure on the system not to regulate you.

Geoffrey Heal: That's absolutely right. A good example of that is what happened with the 1990 amendments to the Clean Air Act, which ironically were enacted by Bush One and were a very effective piece of environmental legislation. And did exactly that—they put clear financial incentives in place for reducing SO_2 emissions without specifying how it had to be done, and leaving it to corporations to develop new technologies, which they've done on a large scale and the costs of that have come down enormously.

Klaus Lackner: And you can see it in the new plant concepts, which are being bandied around right now. If you have it driven by the regulatory side, where you gave the old plants, grandfathered them in as an exception, now anything which sits in the same place is considered an old plant. And it was just the natural driver which happens as soon as you open that door.

Geoffrey Heal: No, we need to tilt the playing field economically in the direction of cutting back emissions. What I was saying is we need to tilt the playing field economically so it is much more oriented in favor of reducing emissions of greenhouse gases. And I've just given the example what happened with the emission of SO_2 as a result of the 1990 amendments to the Clean Air Act, enacted by our present president's father, somewhat ironically I think, which in fact had a very big impact on the emission of SO_2 and encouraged people to develop radically new technologies for controlling SO_2 emissions.

Daniel Schrag: I want to come to the point you made about Kyoto. I mentioned it briefly in my conclusion. I agree with you on all the deficiencies of Kyoto and certainly Kyoto, if we were to plot it on the carbon scale that I showed, does almost nothing. It's almost irrelevant to the future, except that maybe it puts some economic incentives in place to begin to invest in other alternatives. And in all the public talks I've given over the last several years, I've bashed Kyoto for all the problems it has. And last week Vice President Gore actually came and taught my class at Harvard and spent two hours with the students, and they asked him, they just heard economists and technologists and myself bashing Kyoto for the previous week and they gave him a hard . . . the students really gave Gore a hard time about Kyoto. And he, I think, was very eloquent and said, "Look, you know, you go try to convince China to sign onto a treaty, think about what diplomacy and negotiation is really about, and try to get an agreement out of all these different countries. And this is what we could get. The whole thing almost fell through. It's amazing that we came away with anything." And I'm not sure that's a complete defense for anything, but I think we have to be very careful to undermine some kind of agreement because it's not perfect. That's the nature of world politics. I mean it's actually remarkable when the world agrees to anything. In that context I think it comes back to thinking about what's really missing from this discussion, which is leadership which we're sorely lacking right now. If what . . . if solving this problem requires global action, as we've just heard, U.S. influence and diplomacy is . . . I haven't . . . I'm not that old, so I don't remember when it was really profound, but I've got to say I can't imagine us having any less influence in the world given how powerful and rich we are. It just seems really out of proportion. I think we have a profound lack of leadership here, and that's really at the core of what we're talking about.

Scott Barrett: If I could comment on some of this. We are definitely lacking leadership, but I think Geoff Heal is exactly right that, like it or not, big things don't change in the world without the United States behind it. And we do need, it's kind of a necessary condition at the least, to get the United States to take this issue seriously, to show leadership. My view about the Kyoto Protocol, this is an incredibly complicated problem. I mean not only is the science complicated, it's overwhelmingly complicated, but the economics, the politics, the international relations aspects of how to put together a treaty that's going to actually change behavior, it's incredibly complicated. And I look at the Kyoto experience as being at the very minimum a learning experience because we've been sort of groping and feeling our way about how actually to deal with this problem. It's not easy. One thing I think to have in mind is that this is not the first time we've done that. There are other complicated problems we've tried to address, and we've had similar experiences. The one that I find the most interesting to hold up against Kyoto is an agreement to reduce the release, the deliberate release, of crude oil in the high seas, which is a problem dating back over a century ago, and countries started to actually negotiate agreements on how to address this problem beginning in the 1920s, believe it or not. Well an agreement was finally negotiated, which had sort of similarities to the Kyoto Protocol in the 1960s, and it never went anywhere. It never entered into force, it didn't attract strong support. And then what countries did is they kind of reorganized, and they came up with a totally different approach to address exactly the same problem. The original approach was to focus on restricting, setting quantitative limits on the amount that could be released into the seas in certain zones over certain periods of time, so it's a kind of a quantitative approach, very similar to the way that Kyoto is structured. The new regime that was developed in the early 1970s was to focus instead on a technology, and the technology was to segregate the ballast water in the ships, the oil tankers, from the cargo holds that were holding the oil so there was no mixture between the two. This changed absolutely everything because it was very easy to verify whether a ship had been in compliance with this regulation, and you had these positive feedbacks that I mentioned earlier, that Geoff was really also mentioning in his talk, that the more the countries adopted this kind of technology and restricted entry into their ports of ships, tankers, that didn't comply with that technology, the more that others want to adopt exactly the same technology. Well today you've got 97 percent of global world tonnage in this treaty, and it's been an extremely effective treaty. Compliance, by the way, is 100 percent. So I think we need to . . . it's not that we should dismiss Kyoto as being not serious, I think the people negotiating Kyoto were extremely serious, but it's a difficult problem, and it's not necessarily the case that our first crack at it is going to be right. We've made mistakes before and I think we just need to learn from those mistakes.

Klaus Lackner: Let me just a comment in as a harmless engineer. If you look at the problem, you are going to avoid one ton of a CO_2 at a time, and that is a local problem. So yes, I do think we need these international treaties and these international agreements, but we could in the State of New York, in New Jersey, on the U.S. scale, decide to put the right incentives into place. We could tilt the playing field in the right direction, and we could not make it so dramatic that our economic disadvantages are horrendous. We could have a cap and trade with a pretty lax cap to begin with, with an understanding we will tighten it. But if we don't lead in that way, and say we go forward, we actually develop technology, we actually put it in place, we will never get anywhere and it is much easier to get a small group with a more homogeneous interest to sit down and say we can agree locally to make this happen. And as long as you don't push so far that your disadvantage is so large that you can't handle it anymore, you can make the first step, and you can then wait for the others to come on line. And if you look at the developing countries, an obvious observation is we are putting out far, far more. If we all were to meet at 3 tons per person in the middle, they have a long way to grow on average. And so we have to make the first step in many ways, and we can do that by organizing things locally. It does not all have to happen on an international scale.

Daniel Schrag: You know the engineering perspective is an important one. I think it also points to a . . . in some ways I think a poor framing of this problem. Many of us . . . many people talk about climate change and demonize the oil industry or demonize the coal industry. And the irony is that if you're serious about sequestering carbon in any of the ways that you talked about, the industry that has the most technical knowledge about how to pipe gas around in vast quantities and then inject it in the ground, the only industry that really knows how to do that is the oil and gas industry. And moreover they're one of the few industries that has the capital to actually put infrastructure in, unless we decide to have another, like a highway program for putting an infrastructure for sequestration. And so we have to sort of redefine this problem where the oil companies aren't necessarily the bad guys. They've behaved badly, some of them at least have behaved badly, but we need to get them involved because they ultimately have to see this as a business opportunity.

Scott Barrett: And one thing there is that that experience of the ozone problem that I mentioned before . . . one of the interesting features of that was that the would-be losers from controls on chlorofluorocarbons also saw that they could be the winners. In other words they had a competitive advantage, certain advantage, in wanting to develop the new kinds of technologies, and we really do need to think about this not just from the scientific point of view, but we want somebody to actually change, feel your way about how you actually can get kind of coalitions on board that will be in favor of doing something while at the same time muting the dissident voices on this issue.

Klaus Lackner: One of the reasons I'm pursuing the mineral sequestration is precisely that. I don't think this is the technology of choice in the immediate future because underground sequestration, underground injection, and wind energy are probably cheaper in the short term. But if you can go to the industry and say, "Look, you can compete on that playing field, and you don't have to phase out, you may end up being at a competitive disadvantage if you don't get your act together, but you could well keep playing," I think you have a much stronger message to go out and say, "Look, this can be done," than if you tell them first you have to sequester and then within fifty years we have to phase out.

Geoffrey Heal: I think Dan is absolutely right that we have to work hard to bring the auto, oil, and energy industries on board here. They have to solve the problem ultimately. We as individuals don't. And we have to show them that their business is not going to be destroyed in that process and that their responsibilities to their shareholders are not going to be incompatible with taking the kinds of measures the society needs.

Question 1: Choice of Technology

John Mutter: I'd like to congratulate Scott and these panelists for staying on time, for having a discussion among panel members and allowing enough time for the audience that I'm sure has questions to participate. We have the best part of 15 minutes in which the audience can engage. Please do as before: identify yourself, the organization you work for. If you have a question for one of the panelists please say so, but I don't think that's required, you can ask a general question and perhaps one or more of them will pick it up. So beginning on this.

Man: Michael Bobker from the Association of Energy Engineers and also affiliated with the New York Academy of Sciences. And my question really is for the whole panel and is really about the choice of technology. It seems that sequestration is very attractive. It offers very positive horizon on energy usage in our society and globally for developing countries. I have two questions about it. The first is with respect to time frame of deployment, what's realistic? As we saw from Dr. Schrag's curves, a delayed deployment of sequestration is really not much of a solution. It's very time sensitive because of the momentums involved. So that seems to me a critical question to discuss. And the second question is how the choice of a technology affects the other technologies. We heard from Eileen Claussen this morning about needing a diverse portfolio, but really we try to choose single modes of production by and large. And I wonder if we focus on sequestration, what impact does that have on the perhaps closer term investment while we wait? What impact do we have on nearer term investments in efficiency and renewables that really don't have the vested interest, don't have the power of the major industries behind them? Those are my questions. Thank you.

Klaus Lackner: First let me say while I'm working on mineral sequestration and carbon sequestration in general, I do think there's a difference between saying we will end up with one or two technologies which solve the problem and that we want a portfolio of options. I think we definitely need a portfolio of options. I personally picked this one to work on because I feel it's really neglected, and we create a real problem if we have to pull the rug out under this big industry. So I felt this is a necessary ingredient, but I'm realistic enough that I'm agnostic who will be the big player in 2070. I think that's the beauty of the market. All I can do is open doors and say, "Look, this is a way for fossil to stay in the game, and it's important that we have that door open." But at the same time we have to open the other doors. Now you say, "Well, resources are always limited." I would argue we have taken a point of view over the last thirty years that energy is something we have well in hand. There is no big national program in building cars because the car companies have that in hand. We had a similar attitude to energy, but if you think about it, we don't know how to provide sufficient energy for ten billion people without creating environmental havoc. So we have to treat this problem differently and at a much, much bigger scale than we have in the past.

Daniel Schrag: I will also just add that the different parts of sequestration can be done differently. There may some very small investments we can make now that will be very important for the future. And what I'm thinking about is coal burning in China, which to me is really one of the huge motivations for thinking about carbon sequestration. The investments right now, encouraging China to build coal gasification plants which create a concentrated stream of CO_2 as opposed to pulverized-coal plants, that difference . . . we're not talking about transporting the CO_2 or pumping it into the ground, so there's no sequestration involved, but at least you allow the future opportunity for capture and storage. So that choice of technology today might allow sequestration in ten or twenty years, and remember these power plants last for forty or fifty years, maybe even longer in China. So again there's some very short-term decisions that we need to make. The sequestration doesn't need to be put together. There are little bits of it that we can do right now.

Geoffrey Heal: We ought to emphasize Dan's point about the time lags involved here. I mean even if we want things to happen in 2030, 2040, we actually have to start doing them today because it typically takes five years to build a power plant, and once it's built it may last for thirty or forty years. So what we're building today can be impacting CO_2 emissions in 2040, even 2050, if they prove particularly durable. So we need to get the playing field, as I was saying, tilted and tilted in the right direction quickly, and then things will actually start running downhill. Once we've got the playing field tilted, and they'll run downhill in the right direction if we put the right tilt on it.

Klaus Lackner: [Inaudible] this growth at 5 percent a year in carbon reductions and the problem will solve itself.

Question 2: Nuclear Energy

John Mutter: A question on this side.

Man: My name is John Cummings, and I want to applaud all of you for your comments today, I thank you. And you mentioned a lack of leadership, which of course is appalling at this point in time, but I'd also like to ask each of you when we were running Russia headlong into nuclear energy, with some notable exceptions, there was very little said by the scientific and academic community about the downside to this. And I would like to know how you gentlemen feel about nuclear energy in light of your topic. Thank you.

Scott Barrett: Just a quick response to that. I'm not going to tackle the whole nuclear issue. But what I would say is that we do tend to think about the consequences of climate change. We should, there's no question about that. Doing something about climate change, however, also has consequences, and we need to think about that as well. There may be environmental consequences associated with it. And the choices we make about how we move forward basically involve trade-offs, not only in terms of money but also in terms of risk. And the risk is not only on the side of what happens if we don't do something about climate change, but there may also be a risk on the other side about the nature of our response. And my only comment really is to say that we should be consistent and address both the issue of the cost, but also the risk on both sides.

Klaus Lackner: Some ten years ago, I decided to look at sequestration, and my first check was that I believe that I can convince myself that I can be cheaper than nuclear energy. So I feel nuclear energy is too expensive, and in my mind the biggest risk is the proliferation risk. Now five years ago people would've said otherwise, but we have demonstrated in the last few years that there are countries who start with their commercial nuclear power plants to go into nuclear weapons.

Geoffrey Heal: Can I just add to that that I think I totally agree with that last point that Klaus is making. The biggest single risk associated with nuclear power is just proliferation. If you imagine really widespread use of nuclear power stations all over the world then the proliferation of nuclear weapons is almost an inevitable consequence, and in the present international climate I find that a horrifying thought, frankly.

Daniel Schrag: Even within China, though, even within China where China already has nuclear weapons, why doesn't China just build massive nuclear and solve the climate problem? It's too expensive. They're actually planning on increasing I think their nuclear capacity by a factor . . . I hope I don't get this wrong . . . I think it's a factor of ten over the next thirty years, which many engineers don't think they'll be able to do it. And it'll grow from something like 6 percent of their energy capacity to 15 percent. It's still not going to solve China's energy needs. Their growth is so high that nuclear isn't the answer for them.

Question 3: Decision Making Under Risk

Man: My name is Paul Thompson. I'm a health economist by training and a retired Wall Street professional. Talking about risk is exactly where my question is. Portfolio managers do take a lot of risk based on a very limited amount of information. But if they make a bad decision, they're able to get out of it and sell what they bought. The twin problems of catastrophe and costs of following the path to a stable climate make decision making under risk a very different thing, it seems to me, in this area. I direct this primarily to Professor Heal, but anybody can comment on that.

Geoffrey Heal: Yes, you're right, portfolio managers can dump their mistakes. Venture capitalists can't, private equity investors can't, that's probably a better . . . you know, you're locked in there for good or evil, so those are better analogies probably. The fact that the decisions are effectively irreversible over a significant period of time does give another dimension to this, yes absolutely. It effectively gives you a . . . there's an option-value calculation that you need to take into account associated with this, and this is probably not the forum to discuss exactly how you'd formulate that option value calculation, but if you've been in the business you can see where it's coming in intuitively I guess.

Question 4: Investment Incentives and Universities

Woman: Carlotta [inaudible] research analyst [inaudible]. The panel has mentioned the need to put the right financial incentives in place to encourage corporate change behavior and also the lack of leadership. So I was wondering do you think that universities can also take the leadership in paying more attention to the way that they're investing their endowments, for example, trying to make or to buy stocks and to invest in companies that have relatively more sophisticated carbon-management strategies in place, do you think that will be helpful? I was wondering if you think that universities can help facilitate the process in terms of providing financial incentives by the way they choose to invest their own money?

Geoffrey Heal: That's an interesting question. It's much . . . we much debated on university campuses, and it goes back to the whole issue of disinvestment from South Africa, which was such a hot topic back in the 1980s. So the question would be asked here is whether we think universities should use the leverage they have for their quite significant portfolios to try and move funds away from companies that are negative in the climate dimension and towards companies that are positive on climate-related issues? In principle that's an attractive idea. As an economist in a business school what I have to say on that is that it's not unfortunately clear to me that the movement of funds in this sort of way, through the socially responsible investment movement, actually has much impact on corporate performance. There's a lot of studies of what this does for your rate of return as an investor. There's relatively few studies on what it does on the behavior of the corporations. And on most of those that there have been suggests it doesn't have a huge amount of leverage. Maybe that's going to change as more and more of the big pension funds get involved, but I suspect that Columbia on its own doesn't have enough impact in these markets to have a big effect. But I'm certainly mildly positive about the idea, but I don't think it's going to have . . . I think a lot of people rather oversell what this type of thing can do for us.

Daniel Schrag: Divestment from South Africa was the political issue when I was in college. And there were Sullivan Principles. The Sullivan Principles were very clear and were a guideline, and you could say that either you followed the Sullivan Principles or you didn't as a company. It's not so clear what that should be for climate. I'm not sure how to evaluate an oil company or a technology company on whether they're pro- or anti-climate. It's not clear we have those sort of standards, so I don't know how that would work so well.

Woman: One clarification. In terms of South Africa, maybe that was more related to negative screening which basically will inflate a portfolio management, will reduce diversification sectors as some investors do currently with tobacco companies or nuclear weapons. But what I'm suggesting is you can incorporate those criteria and take the leadership even within any particular sector, just identifying what are the companies that have more sophisticated management in terms of carbon strategies but not exclude any of the companies, for example, in the energy sector. You don't need to exclude any industry in particular, just identify companies that will be left in a better position to address the risk.

Daniel Schrag: I'd settle for any kind of student activism and agitation. I don't think we have anything like that today.

Woman: But the key point here is not activism, it makes economic sense.

Daniel Schrag: I just don't see much of it these days.

Question 5: A Hydrogen Economy

John Mutter: I think we can take questions for those people already standing, but please nobody else. Maybe that's even too many. One on this side.

Man: Ross Benson. I'm a recent graduate from MIT. This is a question for Dr. Lackner. This is about . . . you brought up hydrogen economy, and I was wondering how a hydrogen economy is actually going to be feasible given that we don't have enough platinum, which is a required material for hydrogen economy in the first place, even with the technology improvement to decrease platinum loading?

Klaus Lackner: I would argue you are asking wrong person because I'm quite skeptical that we will go to hydrogen in cars and move to a hydrogen economy. One of the reasons I'm interested in the extraction of CO_2 from air is that it allows us to avoid to get there.

Question 6: Redeploying Subsidies

Man: My name is Greg Landel I'm a graduate student in Dr. Lackner's department. My question is to Geoffrey Heal. It seems to me like the need for new technology which everybody seems to be acknowledging here would provide a huge opportunity for massive subsidies to the oil and gas industries, which are such friends of our current administration. And so the question is two ways. First why have they not taken up the opportunity to do this, starting some sort of a pilot program, if you will, for clean energy and reducing CO_2 emissions, and second given that the oil industry already is the recipient of massive subsidies in the form of wars in Iraq or various different things that we do for them, and that there are a lot of people who dislike the oil industries in part because of these massive subsidies that they get, how do we then include the oil and gas industry and the auto industry, etcetera, into Kyoto and into changing their ways without lavishing more money on them than we already have?

Geoffrey Heal: There were several parts to the question. The first part asked me to explain the current administration's policies. I'm afraid I frankly can't do that. I don't know whether I can put myself inside the mind of the current administration. It's too alien a beast as far as I'm concerned. So let me deal with the second issue. It's a question of redeploying the subsidies, and currently there are, as you say, significant subsidies of various types going into the energy industries. What I really meant when I talked about tilting the playing field in a different direction was using the subsidies that we have at the moment in more effective ways and more focusing them on the problems we really want solved, including this particular problem here. At the moment there are a series of rather indiscriminate historically determined subsidies going to most of these industries. We need to collect those together, point them in the right direction, and they may be quite adequate or they may need some supplementing. But at the moment, as I said, they're there more by historical accident than by economic intention, the nature of the subsidies that are being received.

Question 7: Renewable Fossil Energies

Man: A question for Professor Lackner also about the hydrogen cycle slide you put up, so maybe you don't feel comfortable answering it, but [in] the slide you showed, the hydrogen cycle implied a non-remitting and renewable method for hydrogen extraction, and then right afterwards you introduced some sort of a reprocessing cycle for CO_2 that, at least from what I saw, yields no net sequestering of CO_2, so why would you introduce that second loop in that I could only imagine would introduce inefficiency in the energy production?

Klaus Lackner: The idea behind it is to make the point that technologies which you start introducing for the purposes of carbon capture and disposal can also move on into a future energy economy where you have renewable energy. I want to make the point that renewable and fossil energies are not mutually exclusive; like hydrogen can be the exchange, the currency of exchange, for energy, so can be carbon. And the advantage of going that route is we can do that without upending the existing infrastructure. So yes there is a certain inefficiency, but if you have to store hydrogen on board of a vehicle, you have at least a comparable inefficiency, and as things move forward I'm not arguing that we are wedded to internal-combustion energy. Fuel-cell technology could work with carbon just as well as it can with hydrogen.

Question 8: Impacts of CO_2 Sequestration

Man: Hi, my name is Jeremy Barth. Carbon sequestration sounds like a very promising technology, but it seems to me it's being invoked as a talisman that's going to solve many problems without creating others. And I'm wondering if perhaps Dr. Lackner or anyone else could address the question of the environmental impact, the side effects. Just as with nuclear technology, there's the question of the long-term storage of the waste. Could you just address the question of what is the impact of storing Lake Michigan—sized body of liquid CO_2 in the Earth? It has to have some consequences. Thank you.

Klaus Lackner: I think it would be foolish to assume that any technology has zero impact. I think as you alluded earlier we have to compare the risks of different options. Now we have a pretty good idea what the risks are of putting CO_2 into the atmosphere. My argument is sort of as a guiding principle, and that's why I ended up with the mineral sequestration, as ultimately you want to put things away in the most benign possible form, which is a thermodynamic ground state usually. But don't kid yourself, this is a big mining operation, which is implied by that, and that's a big effort. And it is as big as what we are doing on the other hand, we do something comparable in order to have coal and in order to have oil and gas already, but we have to find out where the optimum in that space is too, and that implicitly brings in energy conservation. And I also would argue if you go long enough you will run into the next problem; as things grow by another order of magnitude, we will start worrying about things we haven't worried about. But yes, there are environmental impacts, but I could speak an hour on those.

Question 9: Increasing Public Awareness

Woman: I'm Vivian Gornitz from the Goddard Institute for Space Studies, and my question is for Dan Schrag, and it's about the inertias that are built into the climate system that you referred to, and how best to increase the public awareness of the consequences of inaction due to potentially irreversible changes? And one that I have in mind that has not really been mentioned at this meeting is the issue of possible Greenland meltdown from a temperature increase of only 4 to 5 degrees that is not beyond the realm of some of the IPCC projections, and the sea-level rise consequences thereof.

Daniel Schrag: Jim Hanson, as you know, has been very concerned about this recently. I showed a picture of West Antarctica, but it could have been Greenland. The truth is that we have an ice sheet. We have an ice sheet in Greenland, we have a big ice sheet, a couple of big ice sheets in Antarctica, and we're suddenly warming the climate far more rapidly than those ice sheets have ever experienced. Richard Alley is probably most up to date on exactly this is going to change, but as far as I understand it, every time the glaciologists take a new look, they get surprised by what they see. And therefore, I'm actually horrified by the lack of deep understanding of how ice sheets work. It's a very hard problem, I understand that. It seems to me that it's the one part of this, an abrupt rise of a meter or even 6 meters of West Antarctica goes, over a few decades would be catastrophic to anyone. I mean no economist would argue that that sort of sea-level rise over a few decades is absolutely game over. And so it seems to me that we really . . . that's the really critical part of this doesn't seem to excite people. You know, and maybe this crazy movie that's coming out this spring is going to do something to capture the imagination that people have. Maybe we need some science fiction in here because the science doesn't seem to be capturing people's imagination. Oh, it's called *The Day After Tomorrow*, and it's based on bad science but it's going to be entertaining.

Geoffrey Heal: Can I just make one remark on that issue, which is that it's a question of awareness here. I'm involved as a director of a thing called the Union of Concerned Scientists, and one of the things that we do is try to make people more aware of issues relating to climate change. And recently we held a meeting down in Florida where we publicized—which Richard Alley was actually talking about last night at the dinner—which is how much of Florida would go under water, and specifically how much high value property in Florida would actually be under water, under various scenarios about the melting of the ice sheets, the glaciers, and things like that. In what are significantly conservative regions of Florida, politically conservative, socially conservative regions of Florida, we managed to get substantial interest in the whole issue of climate change as a result of pointing out to these people that they were 30, 40, 50, 60, maybe if they're lucky a hundred centimeters above sea level, and that the property that they had saved for for so many years and paid millions of dollars for was likely to go under water at some point within the next fifty to a hundred years in the event of some of these scenarios occurring. That connection with everyday life just hasn't been made enough by the people who are concerned about climate change and its consequences, I'm afraid.

John Mutter: Well on those somewhat alarming thoughts, we should break for lunch. I'd like to thank Scott and his panel for doing a fabulous job. I'd like to have you back by one o'clock. We have heard nothing different from the governor. We expect he'll be here at 2:30.

April 23, 2004

Session 5: Findings: The Way Forward

John Mutter: This is the final panel. The afternoon, if it goes as we think it will, is the following. This panel will conduct its deliberations. At 2:30 our expectation is New York governor George Pataki will arrive, give remarks, and after which Jeff Sachs will sum everything up and point our way to the future. This panel . . . you will see if you've been with us for the last two days, you'll see only one new face, because we've collected together the chairs and others from previous panels to try to draw things together, suggest where the common themes are, identify where the needs are, and perhaps make some recommendations of where we might go in the future.

To chair this panel we have Dr. Robert Pollack. In putting this conference together, we deliberately tried to view the climate problem from as many different perspectives as we could. Of course it's a scientific problem, of course it's an economic problem, and of course it's a policy problem, and we have had people representing those fields.

Bob Pollack is professor of biological sciences, but perhaps more importantly for this deliberation he's adjunct professor of religion and lecturer in psychiatry at the Center for Psychiatric Training and Research. And at our Earth Institute, he directs the Center for the Study of Science and Religion. He is also professor of science and religion at Union Theological Seminary. For the last decade, since 1999 it says here, Dr. Pollack has concentrated his efforts on questions that lie at the margin of science and religion. His latest work is called *The Faith of Biology and the Biology of Faith: Order, Meaning and Free Will in Modern Science*. Bob has also been dean of Columbia College, the undergraduate college at the university. So perhaps where we're at has a point at which we need to discuss what the climate problems are at the boundary of science and religion. Bob will lead the panel as before, introduce the other panelists to make their remarks, and then conduct the deliberations and dialogue among the panelists, as you've seen before. At some appropriate moment I will come and conduct questions from the floor. If our governor comes early, we will probably interrupt the panel. It's unlikely that he'll come early. If he comes late we'll wing it somehow. Bob.

Robert Pollack

Robert Pollack: Thank you. I have no PowerPoint slides, having seen the torture that that imposes on speakers here.

I want to begin this way. This session is called "The Way Forward." In Mike Purdy's original charge to the chairs of panels, we are now to identify key conclusions from all previous discussions, and summarize these conclusions in a way that will provide guidance to decision makers on research directions, technology development, economic national and international policymaking, and most importantly educate the lay public concerning the actions that should be taken in coming years to prepare our planet with all its living systems for the certain changes in climate.

To do this we bring back the chairs of the four earlier sessions as well as the eloquent economist Partha Dasgupta and the prolific paleontologist Mike McElroy. This will allow me to make only the briefest of introductions for each speaker as all introductions will be redundant, and to turn instead to the question at hand for some personal observations of my own.

The title of the session embeds a tacit assumption, or if you will, a working hypothesis; that is, that there is a single direction to be preferred and that it is in some way aligned with progress. I want to argue for very much more modest set of presumptions, that is, that there is a single matter for scientists and social scientists to concentrate on before they can accomplish anything of lasting value here, and that in doing so they will not at all be aligned with progress but rather with a backward-looking conservative professional attitude.

I'll begin what I mean by starting where Wally was yesterday, fifty years ago. I was in high school then. The Abraham Lincoln High School in Coney Island, famous as the alma mater of Nobel Laureate scientist Paul Berg and Knicks star Stephon Marbury. When I got a letter from a friend with a three-cent light-blue stamp on it that showed a noble pillared, domed building and the slogan, "Man's right to knowledge and the free use thereof"—this was the bicentennial postage stamp of Columbia University. That slogan was instrumental in convincing me that somehow I was going to wind up studying science and doing science at the place that could make that notion its mission. I did, and I think that the mission then remains the mission now for us here today. So let's unpack that phrase. Today I'd rephrase it slightly. "Humanity's right to knowledge and humanity's right to the free use thereof." In terms of this event I think we can agree, we have become inundated, swamped, immersed, waterlogged—you get the picture—with knowledge. We have seen laid out in great clarity the sum of a vast amount of science, the data, and the hypotheses these data confirm, that human activity has been responsible for the recent rapid and unprecedented rise in greenhouse gases, and at least in large part responsible for a rapid warming of the planet's surface climate.

We have seen, as well, a vast amount of knowledge about the local consequences of global warming as measured over a vast range of periodicities, from seasons to eons. In sum, we have shared with each other the knowledge that ecosystems, species, cultures, and families like ours all will be dying at an accelerated rate from now on. Our obligation now then is plain to me. First and foremost we have to assure that humanity will be able to exercise its right to the free access of this knowledge so that our fellow citizens and the citizens of the other nations of the world as well will have at least the chance to make their choices informed by our knowledge. Assuring that they will then choose as we would choose is not, I would argue, our first nor even our primary job. Our own job is big enough. It is to assure that the knowledge we create is not hidden from the view of humanity, nor distorted, nor censored, nor mocked in such a way that humanity does not in fact have the free use of it. In short, our job is to protect the truth in our data, and do so with something of the personal commitment conveyed by the founders of this country when they closed the Declaration of Independence with, "We mutually pledge to each other our lives, our fortunes, and our sacred honor." Our lives and our fortunes are precisely what our data tell us are most at risk already. All that remains is to remember our sacred honor. That, I would argue, requires us—the *we* of the meeting, the body of professionals held together by societies of peer-reviewed publication and promotion—to take the personal risk of defending our colleagues' data in public over and over again, every time that data is dismissed, mocked, ignored, or distorted, whether by private or public agency, for reason of profit, reason of state, or any other reason at all.

As a scientist I had an unbroken run of NIH grant support for thirty years, which I chose to end when I decided that to study the system I grew up in required me to take leave of its largesse. In that time and since then, I have observed that scientists often do not speak out in public in defense of their data. Meetings like this one today therefore are necessary but not sufficient because all it takes is the whiff of reprisal for peer review to become self-censorship, and I am afraid we all know of cases where this has occurred.

The editors of *Scientific American* give us a good, short roster of such examples of what they call "Bush league Lysenkoism," in the June issue just out. We should contemplate the meaning of the remarkable peer silence that has followed after each of these. To quote, "The administration misrepresented the findings of the National Academy of Sciences and other experts on climate change. It meddled with the discussion of climate change in an EPA report until the EPA eliminated that section. It suppressed another EPA study that showed that the administration's proposed Clear Skies Act would do less than current law to reduce air pollution and mercury contamination."

Now if we were to recall and muster our sacred honor, the professional pride scientists might once have had when Wally was young, what would we do first? That is, what do I think we should do today? I think we should prepare a public declaration in defense of the right of humanity to have unfettered, unfiltered access to our data, especially when, as now, our data speak to the great likelihood that we are on the cusp of an avoidable global disaster, and to the even greater certainty that our silence today as our data are denied or distorted assures an extra dose of suffering for everyone's grandchildren fifty years from now. We should make that declaration in a formal sense, ask for signatures to it from every externally funded scientist and social scientist here and elsewhere. We should address that statement to our political leadership, and in particular to the very parts of our government that up to now have acted with impunity, judging all too correctly that they own us through our grants.

I'm sure that if any palpable fraction of you will agree to this, such a declaration will begin at least to open the gates of obfuscation and denial that now bar any imaginable way forward based on the principles of good science. It would be a tribute to Columbia University on our 250th birthday as well. If you disagree, well it won't be a shock but it will be a shame.

And now to our colleagues to learn what they think we should do next. As John said, I'll ask them each to limit their remarks, as I have, to ten minutes at most. I'll be no more pushy than necessary in enforcing this limit. Then we'll open it up for a focused discussion of what to do next, until John Mutter says enough.

Thank you.

Richard Alley

Robert Pollack: Our first respondent will be Richard Alley, the Evan Pugh Professor of Geologic Sciences at Penn State.

Richard Alley: Thank you. I have perhaps the easiest task as I'm summarizing the deliberations of the physical sciences panel, and I think the deliberations were probably the easiest ones because we were primarily summarizing a well-established body of research. I believe that I will be accurate in characterizing the panel if I say that we have sort of four bullets with fairly high confidence. Bullet number one: that humans are changing the atmosphere and so we're changing the climate. Number two: if we continue with business as usual, it will cause these changes to become large in comparison to past climate changes that have greatly affected ecosystems and societies. Number three: if this projection is in error, it is more likely that the changes will be larger, faster, or less reversible than projected rather than they will be smaller, slower, or more reversible than projected. There's a lot of room out there for bad things, and there is much less room for really good changes. And fourthly: that these climate changes will affect ecosystems, often in difficult-to-predict ways, and that they may in turn accelerate those climate changes. So that if you were to synopsize: yes, it's highly likely that we are changing the climate; that these changes will become very large if we do not change our behavior; if there are errors, they'll be larger, they'll be less reversible, they'll be less expected rather than more so; and that this will affect the way things and probably people live. This is not truth with a capital *T*. I fully recognize that the students that work with me will find things that I have done wrong. They already have, and I will guarantee you that they will again, so this is science but this is very good science. There is nothing that is fundamentally flawed with this, it is sound, it is solid, it a useful bedrock on which to build what one might wish to do next. And so the science is not the problem.

Thank you.

Michael McElroy

Robert Pollack: Our next summarizer is one of our plenary speakers, Mike McElroy, the founding chair of the Harvard Department of Earth and Planetary Sciences.

Michael McElroy: Thank you. I thought I might . . . I think it's been a very exciting day and a half so far, and I think we all owe a debt of gratitude to Mike and John for the hard work they did to put this together.

I'd like to basically make three points. One is that I think that it's important for us to try to see the problem that we've been discussing here, climate change, in a broader context. I mean much of what we've talked about has involved CO_2, it's involved energy, policy, and I think it's very important to recognize that there's a real need for a national energy policy that brings the climate issue into play, in which the climate issue is at least a component of the discussion. And there are clear reasons why we should work on the fossil-fuel problem from the point of view of national interest. I mean we know that we're importing more oil today than we did during the oil crises of the 1970s. We know that there's a new factor in the world, namely that China is now the world's second-largest consumer of petroleum products, and China is unable to meet its oil from domestic sources so China has become a net importer. We're tripping over the Chinese in the Middle East at the moment, competing for oil, and the price of oil is reflecting that kind of pressure. So national-security interests say that we should have an energy policy that encourages conservation and alternatives. As for conservation, there's no question that we can save energy, significant amounts of energy, in the United States. David Keith referred to this quite eloquently. I don't think it's out of the question to cut energy use in the United States by 20 percent, and not to affect the economy in any way. I mean small things. Conservation . . . many people appreciate the fact that when you are sitting with your television set in your home and the television set isn't on, it's still consuming electricity. Why should it be that way? Or the computer, the same way. Suppose you had devices on major electrical appliances that ticked off how many dollars you were spending to keep them running, or the integrated dollars or the integrated watts, then you would be able to make more sensible decisions. So conservation is a no-brainer, it seems to me, and economically in our national interest and personal interest.

We've talked rather little at this meeting about alternatives to fossil fuel. Nuclear has come up several times, wind power clearly is already a competitive energy source, and we should encourage those alternatives. Solar, in terms of photovoltaics, economically not competitive at the moment. There may be difficulties for the future there, but again in particular niches, it clearly has an important role to play. I'd like to mention one that has not come up and that is the possibility of using cellulose or using biomass and converting it to an energy-efficient and convenient fuel. In this way we essentially recycle carbon: we take carbon out of the atmosphere photosynthetically to make cellulose, then we burn the cellulose, we put the CO_2 back in the atmosphere. It's clear it seems to me that there are real potentials to do things there with modest investments in research, and several groups have argued that we should do that.

Second point I'd like to make is that it seems to me that we must be careful to recognize major inconsistencies in our national statements about climate, the climate issue, major inconsistencies. Now what do I mean by that? The Kyoto Protocol is really authorized under something called the Framework Convention on Climate Change, and the Framework Convention on Climate Change, Professor Estrada mentioned some of the elements of that. It explicitly stated that it is the responsibility of developed countries to go first; it explicitly made that statement. Now the United States ratified the Framework Convention on Climate Change. It is the law of the land that commits us to this principle of having developed countries taking the first step. How then can we sort of walk away from Kyoto on the primary grounds that China and India are not obligated? It's an inconsistency that I think needs to be pointed out.

Third point I want to make again in terms of the generalization here is that we must do everything we can to encourage a view that there is one humanity and not individual rich and poor countries, and that the likelihood is that the impact of climate change is going to be most serious for those least able to cope. And it seems to me that it is our responsibility, not just because it may be in our national interest, but because it's the right thing to do to take this more global view of responsibility, the rich should lead the way.

Thank you.

Upmanu Lall

Robert Pollack: The next speaker summarizing his panel is Upmanu Lall, professor and chair of Columbia's Department of Earth and Environmental Engineering.

Upmanu Lall: Thank you, Bob. I moderated the panel on living in the greenhouse yesterday so ostensibly I should report on that. And the summary for those of you who were not here is that we learned from people that if the scenarios of climate change play out, there are severe consequences for health, water, and other sectors. We learned that there are severe consequences for the poor in the world relative to the rich of the world. We learned that the way we make decisions about the future, where it looks like the economics of discounting is possible flawed, and we learned of an example for how one could probably think of it in a different way. So that's the summary.

And the way I would like to editorialize this is that I would like to argue that the problem that we are looking at in the context of living in the greenhouse is not one of meeting the climate challenge and not one of carbon management, but one of survival. So if we think in those terms, the best way to illustrate this perhaps is if I start from one of the questions that was asked by an audience member to the panelists, and they hit on the issue of the conflict between environment and growth. So the way I would look at it is, What do we mean by growth? And sometimes what people think of it is increased expenses, increased capital goods, whatever. And if I think about that, I would like to take a perspective for the twenty-first century rather than where we are today. And as Mike was just pointing out, I think the world shifts to Asia. It's a question, where we would look at the growth is, what do we need to generate in terms of the markets of those places to provide the needs of people who live there, the bulk of humanity? These are the needs of survival, but also the needs of quality of life. When we think in those terms, we recognize that they have carbon implications, we recognize that they have other implications. But we also recognize that when we look at places like Bangladesh the catastrophe that would be induced by sea-level rise antecedent to climate change is just one of the major possible catastrophes. They have many other catastrophes that they have to also worry about. And that's where the development issues come up. I would submit that if we look at growth as supplying the needs of these people in an intelligent way, that is the direction we should be looking at, and that's the problem we should be trying to solve.

With regard to the issue on discounting or how do we count for future things, it's an interesting sort of thing to me because every religion, every group that is looking at a body as a survival, they always, invariably, will identify environmental preservation as one of the collective goals. This implicitly recognizes that individuals left to their own perhaps won't do it. So then I started thinking about . . . we have examples of how the rich behave and how the poor have no choices. Is there an analogue or is there an example of normal human behavior that does look at the future? And I went back to my roots for that example, and that's the example of a person growing up in a middle class family in a developing country. The behavior of such individuals is they're willing to give up meals themselves, they're willing to give up small luxuries of life so they can invest, they can invest in the education of their children so that those people can have a better life. This is explicit investment in the future, not even their own future. But this is part of human behavior, we have seen this, we don't need to generate new examples, new language for this. I think the question in our context is, How do we take such an example and convert that into group behavior? That's the first message that I would like to put out.

The second message, which is short hopefully because I know others need to talk here as well, is, How do we translate all that we talk about here into finite pieces—as was pointed out yesterday—that translate into actions? Who should be doing those actions? One mantra clearly is the rich should be doing something more than the poor. But if I put the development and if I put the growth in Asia, then my mind goes to what is happening there, and what I'm observing is that given the local constraints on resources, the local strong degree of environmental degradation, the dimensions of which far exceed those of climate change in the local sense, these impacts are there today. What you're seeing happening in places like India and China is innovation from the bottom up. There are people who are building houses, where they're building water-collection systems, where the water is reused three or four times in just that one building complex. There are people coming up with local solutions to energy. Is that all that should be done? Clearly that's not what I'm arguing. But what I'm pointing to is something others have said, this is the century of Asia, this is the century of those continents that have been downtrodden. That is where the hope is. It's not where the fat cats such as us sit in New York.

Thank you.

Christopher Field

Robert Pollack: Our fourth summarizer is Chris Field, the founding director of the Carnegie Institution's Department of Global Ecology.

Christopher Field: A critical starting point for making progress with the climate challenge is the clear commitment of people like you, so I'd like to start with congratulations and with my thanks.

The challenge that we face is how we're going to grow that commitment to something that becomes socially, politically, and economically dominant. And in that spirit I want to offer three additional bullets that mainly came forward in the session I chaired, "Can We Stop Climate Change?"

The first is that we clearly do not have a single comprehensive solution that's technologically ready. We need to move forward with a portfolio that includes at least four prongs. These prongs need to be conservation, increased efficiency, new technologies for non-carbon-emitting energy sources, and finally carbon storage or sequestration. It's really important to remember that in the technology area, we can't envision a technology future at 2100, for example, that doesn't require fundamental advances in technologies. So even though we've heard, for example, that solar cells aren't price competitive now, it's very difficult to imagine a 2100 energy environment that doesn't have a very large contribution of large-scale solar. So commitments to technology development definitely need to be part of the package.

The second point I want to make is that we've heard a lot about opportunities, opportunities that are available now at very low cost, that in many cases are win-win where addressing the climate problem helps solve another problem, air quality, water quality, empowerment.

And third there are opportunities for leadership and many of those opportunities are fundamentally more available in university communities than there are in other places, and at the level of universities, that kind of leadership can extend to thinking creatively about the kind of environment that the university occupies, to thinking creatively about how the university portfolio is invested and what the leverage on that portfolio is.

The final point I want to make is that we've seen profound motivations for action now, rather than action that's delayed into the future. Part of the reason for this is that the physical climate system has long time lags, and if we delay action it becomes fundamentally more difficult and more expensive. Another part of the problem is that the economic system and the political system has large time lags, and that if we don't begin action now, we won't be able to bring the technologies and the necessary changes in the system into play. Third, we've seen that the political system is essentially tilted in favor of interests that are stacked against addressing the climate problem, and it's going to take time to level the playing field or even to tilt it in the direction of effective action on climate.

Finally one of the questioners said, "Why don't we have something that really inspires young people, something like an MTV for climate action?" And in the *New York Times*, I think it was on Wednesday, I read this article about how restaurants in New York City are starting to have water sommeliers and that you can now have someone advise you on your selection of waters with individual bottles of water costing up to $20. And I guess the thought I'd like to leave you with is that if we live in a society where marketing can instill intense desire to pay up to $20 for a bottle of water, I think we can devise incentives to tackle what is unarguably one of the biggest problems of our era.

Thank you.

Partha Dasgupta

Robert Pollack: I say data, he says marketing. Partha Dasgupta is next, the Frank Ramsey Professor of Economics at the University of Cambridge.

Partha Dasgupta: Thank you very much. Part of the art of understanding phenomena and then possibly trying to arrive at their implications for public policy action and then coming to grips with them at the emotional level has to do I think with packaging. We very often have an intuitive understanding of something, and very often the intuition is actually right, but we're sometimes floored by experts who will arrive at it, use terminology which will jar us. There is something profoundly wrong, in my intuition. One of the things I tried to do yesterday—and you'll probably notice from the talks of so many of the other scientists—was to show that our intuitions are those in this somewhat self-selected group, this audience here, those intuitions are not misplaced, have not been misplaced. So obviously we are in a sense fellow spirits here. What I want to do is to use five minutes to recount some of the points that have been made by other panelists and speakers, but phrase them in a language which might be slightly off the way we usually use our language, simply so that we all here are prepared when we meet the next expert who tells us that we should wait. So it's really repackaging, and nothing really fundamentally new.

Professor Hanemann rightly pointed to the public-goods nature of the problem of climate change, the fact that the commodity in question, the good in question, is a public one. That is to say, each one of us is contributing to its enhancement as well as its detriment. But the implication is felt by all, regionally affected of course. And that creates serious problems of collective action, and I'll be coming back to that point right at the end. He alluded to the need for possible taxation in the case of the pollutant or by implication subsidization of alternative. But the hard part is to get that to happen, and that's where the collective action problem comes up, and that was eloquently discussed at the previous panel.

Dan Schrag pointed to the phenomenon which has been lurking in our discussions since yesterday, which is the long lead times involved, potential and actually observed irreversibilities. Climate is a very, very big and complex structure, obviously, but the next time you hear somebody say, "Well look, where is this big irreversibility, or where is the big change here, that kind of phenomenon is not all that common," use your small experiences. I have in Cambridge in the back lawn a small pond which can switch from clear water to opaque water in a matter of hours if the temperature is wrong, if you like, or right, if you like. Lakes have been known to switch within weeks—small lakes, ponds in Bangladesh—from drinkable water to completely covered with algae in a matter of weeks, months. Those are flips. The reversal takes time, effort, and so forth. Grasslands have been known flip into bush land with shrubs, which makes life more difficult for the nomads, in a matter of years. It depends, of course, on the extent of the ecosystem in question, but we have observed flips. So the next time you're asked where have we seen flips, well we have actually observed them.

The effort required when you get near flips, of course, becomes progressively harder, and there is one implication, which again I'm going to rephrase to conclude my point, which is that often we are told that not to do something and postpone a decision buys us time and therefore options. There is a literature on the value of keeping your options open, and that is correct. But in this case it seems to me, at least what I've learnt since yesterday, is that keeping the option open requires this activity, this investment, the kinds of policies that have been suggested. So the option value here will be to do something as opposed to not doing it. Again, it's a repackaging of what's already been mentioned, but we are often told otherwise.

So it seems to me at the end of the day . . . I come back to Michael Hanemann's observation that we are looking at a massive public-goods problem. Collective action is difficult, obviously, we know that, but it seems to me that the more consensus there is built through the use of different languages, then the greater the chances of collective action. At the end of the day it seems to me the problem of climate change, as with so many other public goods problems, rests in us as citizens.

Thank you very much.

Scott Barrett

Robert Pollack: Our last summarizer is Scott Barrett, professor of the School of Advanced International Studies at Johns Hopkins, and then we'll have a group discussion. Scott.

Scott Barrett: Well Professor Dasgupta, my teacher, left us with a thought of the responsibilities of individuals, and I want to take this up to a higher level, and the arguments I'm going to make are not at all to contrast with his, but that this issue is one fundamentally of scale. One of the things that's so impressive about it is that we have one Earth, and we're basically experimenting with one Earth. We don't know what the full consequences will be, and if the problem is one of scale in terms of climate change, the response to it by us, I think, also has to reflect scale. And scale really does raise this problem that Professor Dasgupta discussed of collective action. Let me just say first that I'm not saying that we shouldn't do things ourselves. Yes we should. Our communities, of course we should. States, yes. We should be acting at all these levels. But fundamentally we also have to be able to direct action at the global level, and one of the big challenges for us is how to do that. That is the collective-action problem, and it has a number of different dimensions to it that need to be reflected upon.

One is this problem often mentioned of free riding. What that basically means is that the actions that any of us, any country, may take to address the climate-change problem does have benefits for many other countries, and even if we all agree that we should all act and do something about this problem, there is this constant niggling temptation not to quite carry through. And I'm going to elaborate on that very shortly. But free riding is not the only issue with collective action. There are also important issues about the morality of moving forward and doing something about climate change, about having serious deliberations about obligations and responsibilities, and having a discussion about who, which countries ought to do what, and when, and so forth. And that needs to be handled not just entirely in a decentralized way, but by thoughtful processes.

And finally the last aspect of this that's significant is a competitiveness issue. And it was raised actually by Ambassador Estrada when he mentioned countries moving forward even if Kyoto does not enter into force, and raise the specter of possibly using border-tax adjustments as a means of insulating the countries that are acting from the kind of less cooperative behavior of other countries. And that's a natural thing to want to do. So there are a number of reasons why the collective-action problem is important and also difficult.

Now in my own panel, Geoff Heal mentioned a piece of domestic legislation called Title IV under the Clean Air Act Amendments, which were adopted in 1990 under the first Bush administration, and that is a pretty remarkable piece of domestic legislation that basically caps the level of sulfur-dioxide emissions allowed by power plants throughout the United States, allocates responsibilities for meeting a cap to individual plants, and then allows the companies that own these plants to trade them throughout the country. It's been quite a successful program. There are two features of this program that really need to be considered, and that is, first of all, participation in this law, this regulation, is not voluntary. Utilities are required to participate—they didn't have to opt in, and they weren't allowed to opt out. And the international system is not designed that way. The other aspect of that that's, I think, pretty important has to do with compliance, that is, getting the utilities to do what they're actually required to do. Well it turns out that the compliance mechanism for Title IV is pretty blunt. You have to pay a penalty of roughly 2,500 dollars per ton if you don't meet your allowances. Now the current marginal cost for complying with Title IV is on the order of about 180 dollars a ton. So you have a choice: you can either meet the law and pay about 180 dollars, or you could violate the law and pay 2,500 dollars. Now I looked into this and it turns out to be interesting that compliance the last year I checked, 2001 I think, was exactly 100 percent, but it was 99.999999—I think about six nines—percent, so it's a very effective piece of legislation, not only for the reasons that Geoff Heal mentioned but for these other reasons.

Now when we deal with a problem like climate change at the global level, which is a problem requiring scale and our response, we do not . . . you see it in the Kyoto Protocol, which is designed in some respects a little bit like Title IV, partly because of the influence of a number of Americans at an earlier day, an earlier administration, and how we might move forward globally to deal with the climate-change problem. But the task for us at the global level really is quite different, and we don't have the institutional apparatus that we rely upon domestically. And you really see that in what's been happening with Kyoto. There has been all . . . Kyoto's trying to lift us up so that we reduce emissions, but every time we try to push it up, it gets knocked down a bit. What are examples of that? United States doesn't ratify Kyoto. Other countries don't ratify because we're not ratifying. Kyoto is in a sense renegotiated through the back door, diluted to allow for extra allowances, in a sense, for forestry and so on, for other countries. Then there's even discussion by some countries that they may not really comply with Kyoto, but that doesn't matter because the main thing is that we ratified Kyoto and we made, you know, some kind of effort to move forward. Well if you understand the scale of the climate-change problem that's not enough, we have to do much better than that.

Now in terms of a way forward, I think what we have to do is think about a different way of skinning the same kind of cat, and I alluded earlier to this agreement on oil tankers and tanker design. And actually the process that was followed in that episode of history is illuminating and I think informative to the climate problem.

If you learn the lessons from that, I think there are a number of things that we can do to move forward, and I just want to leave you with some thoughts about what those things might be.

One is I think we do need to require domestic action, and we should encourage and promote domestic action, including short-term action. But what we should do, I think, is also drop the pretense that there's going to be global enforcement where we're not able to muster it. If we looked at an agreement kind of like Kyoto, which basically allowed countries or asked countries to actually come forward and say, "This is what we are going to do about this global problem, this is our contribution to the global effort to do something about it, and we're going to do this on our own, and we want that to be acknowledged publicly and internationally, and also to be reviewed in the international kind of forum, a basic kind of approach, pledge and review, that was fashionable many, many, many, many years ago," it actually has some logic to it. We also need to have substantial research and development into new technologies.

We need to act in the short term, but we need substantial R & D into new technologies that are going to lower the costs of doing something very big about this problem even in the distant future. That's part of what it means to take out an option. It's not just in responding now, but it's taking steps now that will allow us to respond even better also in the future.

The third thing we need are to spread, to diffuse, the kind of global response. We need to think about protocols that will exploit some of the aspects that Geoff Heal spoke about earlier, basically trying to get these kind of positive feedbacks, where the more that some of us act in a positive way toward the climate, the more others are encouraged to want to act. And there are ways of doing that, much like I discussed in the case of the oil tanker, of exploiting things that economists call both economies of scale and network externalities. That's a kind of a strategic approach because if we're able to do that, we can address the climate-change problem in a very big way without the need for enforcement. And remember, that is the thing that distinguishes from an institutional perspective the climate problem from so many of our other environmental problems.

The last thing I think we need also—and there is this in the current Kyoto Protocol—is a fund to address adaptation. We need a fund to finance the use of new technologies in developing countries—that's something I omitted mentioning before. But allied to that, if you take the climate-change problem seriously, we are going to experience it, and therefore we also need to consider assisting countries who will be most affected by climate change because we are responsible for causing it. And that kind of response adds legitimacy to the overall package, legitimacy as well as effectiveness.

This may not be the roadmap that needs to be considered, but I think the perspective that informed the development of this roadmap does need to be taken very seriously. If climate is a global problem it does require a global solution.

Thank you.

April 23, 2004

Session 5 Panel and Q & A: Findings: The Way Forward

Summary by Robert Pollack

Robert Pollack: Okay, I want now to shift the tone of this to an operative one, in which the six of us, seven of us, will attempt to talk through the details to a list of points that would serve in a short document which was a report out from this conference on these matters, its intention being to change things for the better, as well as simply to report what we know.

I will just summarize for you my summary, as everybody else gets their little microphones on, and then I'll go sit down and join them.

I think for a background, it is essential that we find ways to say that as climate is global, matters of right and wrong must be judged in global terms, that we have a crisis of the commons like no other, and that anything short of a global solution is a parochial one. And at the same time, we have to say, although it seems paradoxical I think equally true, that in human terms, the family and not the flag is the model of hope for the future. We must be straight about our own investment, and we must understand we share a common human need to protect our children and grandchildren, and not become so elevated by our data as to forget that.

In terms of politics I think it is clear that whatever we may be in this room, we are not in national or international terms a majority, and that that should inform any political agenda. Political action, I think, has to begin, as I said in my opening remarks, with the simpleminded idea that we have to defend the truth of our data. Without our work in other people's hands, we have no reason to be heard. In addition I think in general, political action must always be direct. We have to teach by what we do as well as by what we say. A green university is a good place to start.

I think it is clear to me, although I'm no economist, that matters of common good do not align simply with a pure free market. But it's equally clear that though they don't they can be marketed, and we should be very sensitive to language and to how we appear in public. We have to develop a politics of our science that scales up from local to global as quickly as possible, and that makes use of the notion that an incentive is as good as an enforcement, much less expensive and in human terms less offensive.

And finally in terms of my own specialty as a biologist, I think it's essential to remember always that we are dealing with discontinuity. Our own mortality teaches us that discontinuities will occur even if they are denied. And it's worthwhile, in my opinion, that we keep sensitive the reaction humans are known to have ubiquitously and transculturally to the news of their own imminent demise. Kübler-Ross's five stages. First the denial, then rage, then negotiation, then despair, then acceptance. I think we're someplace between denial and rage right now, and that we have to get to the point of negotiation if in fact we are going to head off what will otherwise be a serious problem of mortality. And now I'm going to sit down and we'll talk. Thank you.

Now I'm new at this, but I think what we'll do is we'll talk amongst ourselves toward the point of what would be in such a document. Unless John comes up here to stop me, that's what we are to do. So would someone else, not me, please say something.

A Strong Scientific Consensus

Richard Alley: Just to start off, and again I think I have in some ways the easy one, and in some ways a very difficult one. I stood up there and said the science is good. I still believe the science is good. I believe if you look at the effort that the United Nations puts in through the Intergovernmental Panel on Climate Change to find out what the future would hold, it is an immense effort, and it does involve scientists from around the world, it does involved nongovernmental organizations, it does involve governments, industry has input to it, and it's a broad consensus. It's not perfect. I think all of us who have worked on it could complain about particular pieces and often have, but it is a very good, solid, sound scientific consensus. If you were to read many publications in this country, if you were to listen to many discussions in this country, you would get a different view of how strong the consensus is. There exists almost a requirement to say, "Some scientists think the climate might change," or something along this line, and the degree of dissonance on this subject, I believe, appears very much larger out in the real world than it does within the narrow confines of client scientists. And so in some sense I do believe the science is not perfect. The science is very good, but there is still a very large job waiting to make that clear beyond our confines.

Ethics of Climate Change

Christopher Field: We've focused in this session on the scientific evidence for climate change, on the implications, and on strategies for the way forward. We've mentioned, but we haven't really emphasized, that climate change also involves vast ethical issues. Many of these are issues of equity, equity across generations, equity that links people in different parts of the world, and we need to recognize that as we move forward with some of the strategies that we've discussed and that I think we've demonstrated are practical, that we need to address these ethical issues in a very serious way. Each of us needs to reflect on how much we care about the profound questions that climate change raises, and I hope that as we move ahead that everyone strives for the appropriate balance between the technical aspects and the ethical aspects.

Misuse of Economics

Partha Dasgupta: I'm just wondering whether I could reflect on a couple of points that come forward. I think one of the problems that I face, but I'm not sure that we could put this in a report, is that economics is so miserably misused systematically that [it] lends resistance to collective action, at least at the individual level, and yesterday I tried to give you, well I did give you, an example, of how it can be misused and how the general intuition that we have about the situations that I put up on the screen are right, and to be confounded by the argument that if you use any sensible discount rate, the benefits look very small is a wrong argument. So it's more the misuse of economics. And I don't know whether in a report we can say economics is systematically misused when applied to climate matters, but there we are. That's one observation.

The Costs of Abrupt Change

Second is I think related to the point that you've just now mentioned, Chris. It's that occasionally there is the thought that while some regions will suffer if rapid climate change [occurs], other regions will prosper. And then again a smokescreen is offered because well, now you want to suppress Siberia? Do you? Is that what you want to do? I think it's well worth recognizing that very rapid change in the environment, if you like, in which we operate, even if in the medium and long run, the environment improves through certain types of economic activity, agriculture, it takes quite a while before you can adjust to it. In the long run, the move may be beneficial to a particular region, but that region has actually faced itself through hundreds and hundreds of years of a particular style of environment with an infrastructure which is adapted to it. This reorientation of the infrastructure can be costly, and can be hugely costly. So the idea that the moment the rainfall improves or the mean temperature increases, immediately there'll be bushels of wheat coming out is, I believe, something that needs to be thought through very carefully because these are huge fixed costs—roads, dams—up into how many things we have built to adapt to the environment we have been used to. And an abrupt change is very costly, both . . . the flip side obviously, but even for the beneficial side.

Robert Pollack: I believe E. O. Wilson at a previous conference made a point that in addition if one broadens one's scope to all other species, rapid and sudden change has unpredictable but usually species-diminishing consequences.

The Obligation of the United States

Michael McElroy: I agree with the points made by the previous speakers, but could I just again emphasize the . . . I would suggest that our report should emphasize the specific obligation of the United States in this area. After all, 5 percent of the world's population produces 22 percent of the world's greenhouse gases. After all, we did agree and formalized that agreement that developed countries have a responsibility to go first. It's notable that neither leader, neither the Democratic prospective candidate or the Republican president apparently understand[s] that commitment. I think it would be good to state the responsibility of the United States in this area, and the need to provide leadership.

Robert Pollack: Do you think it's worthwhile to consider being asked to be given the opportunity for a Congressional briefing of the sort that we see has a certain positive effect on foreign policy, there being two serious senators from New York?

Michael McElroy: I think it would be a good idea.

Helping the Poor

Upmanu Lall: Given what was last discussed, I wanted to add a couple of remarks to what I said earlier. Implicit in my remarks was the idea that can we use the projections of [inaudible] to actually improve the environment. So what that translates into is that if we are going to come [to] new technologies, reengineering systems that are out there which have positive environmental benefits while meeting things, the direction in which one goes is the current developing world, because that's where that market would be. So now if I add one more thing to it to close that loop, there's the issue of that the rich should pay the poor. How should the rich help the poor? And I'm suggesting that that is indeed the direction, through investments in improving the survival of those people, with new technologies that are beneficial.

Robert Pollack: Okay, John, we've run out of things to say. But I think that we have a fairly straightforward consensus that we're not done when we're right, but that . . . nor are we so unsure of ourselves that we have nothing to say. And I think that that is not a trivial accomplishment, as we are often pictured from outside as either having nothing to say or of simply being satisfied to be right with nothing further to follow. And so I think if we fight both of those, we've made some progress.

Question 1: Comments from Atiq Rahman

John Mutter: **Okay. This gives us the opportunity to engage the audience once again in this final discussion. The job is the same. There are microphones in both aisles. If you could identify yourself, your organization, and actually you don't have to ask a question, you can make a statement if you want to.**

Atiq Rahman: My name is Atiq Rahman. I'm at the Bangladesh Center for Advanced Studies. I spoke earlier. The three quick points I want to make following from the . . . coming straight from the last point of Professor Lall, that industrialized countries need to help developing countries. Developing countries do not need your help—you behave yourself, you reduce your contribution to carbon to the atmosphere, that's good enough. Don't need help, don't hurt. Stop harming the planet in the industrialized countries, that'll be enough contribution that you have done. So this idea of charity that rich countries can do, forget it. You are interfering in others' environmental space, others' right to survive. That's where it must be done. So it's not a moralistic issue of trying to help others, it's behaving yourself better. That's the first point.

The second point is, during the discourse here—and I have attended at least 500 meetings on climate change in my lifetime—and I was pretty amazed to hear the emphasis on sequestration. This is useful, sequestration will be needed, but there will be so much more emission coming out. If that is the signal coming from these countries, the industrialized countries, that all can be absorbed then you have no right to tell the developing countries not to keep automating. If you want them to reduce emitting, which is a political stance, there has to be reduction of emission here. So it's a simultaneous action of reduction of emission and absorption and encasing sequestration. Sequestration is not the only solution.

Third point, coming back to Professor Robert Pollack, is the whole issue of data. The [inaudible] in the hierarchy of data, information, knowledge and wisdom, if that is the hierarchy of decision making, of using data, then wisdom is grossly lacking, and the leadership, the issue of leadership. Knowledge maybe somewhat . . . IPCC is a set of knowledge, but I think scientists have been struggling in the area of data to information, that's where we are struggling. The issue is not just management of information, the issue is the wisdom which drives which is the path to take, and that part has to be done in a very concerted way. And if we don't go down that route, certain people in certain countries will be so badly affected that it will be no more their own security, it's security of rest of the planet, as we have seen in the last years. That is what be a threat. So I think it's a very serious issue. The action has to be much faster and is has to be starting from USA

Thank you.

John Mutter: Wasn't directed in anybody in particular, but is anybody willing to . . .

Robert Alley: Actually I may just say something about the United States and leadership. Because whether you like it or not, globally things happen when the United States leads, things don't happen when the United States doesn't lead. And a lot of people don't want to hear that, but it just happens to be something that holds true regularly. The United States has a real problem right now, of legitimacy, because it negotiated in good faith, [but] it did not take this agreement to the Senate for ratification, and it's really done nothing on its own, apart from sponsoring some important research, which is a substantial contribution. Other countries have been much stronger in the way of rhetoric, but also haven't done so much. But the United States has really, I think, failed on the leadership front. And I think it's true that unless we do something domestically, we're not going to have legitimacy at the global level. One of the big challenges, I think, to us is to get the attention of this country, not so much the administration perhaps, but the country at large, about how important this issue is. And it's not just an environmental issue. When President Bush rejected the Kyoto Protocol and the manner in which he did that, that upset an awful lot of countries, and people who had invested their political careers in this effort. And again I think the issue here was so much about the manner in which that was done. And that's been damaging to the United States even today as we try to get things from the rest of the world that we would like to have them help us with. So it's simply turning our backs on the rest of the world and saying we're not convinced by the science, we're not going to do anything about it, that really is not sufficient. I think the leadership issue is really quite fundamental.

Question 2: Controversy Over Temperature History

John Mutter: I'll go to the next question. I'll go from side to side.

Man: As a former self-employed currency trader who had a background in sciences and who was forced to learn a lot about the way the world wohistoricalrks actually, I have not been terribly impressed by the state of the world in general. And I think that it's probably good to note that, you know, in terms of Gore talking to students at Harvard or whatever, that whatever it was he thought he was negotiating there was voted against by 97 to 0 by the Senate when this came up for a vote in the
late '90s, so this is clearly not just an administration issue. But in terms of trying to propel us from the level from information, you know, to perhaps some meaningful knowledge here, as a lay person I want to see if I understand this correctly. I was very interested to follow the issues of Björn Lomborg and the scientific response, you know, to him. And unfortunately looking at the *Economist* and the *Wall Street Journal* and things like that, I've gotten the impression that he gets a lot of legitimacy due to the fact that the temperature variations we've seen so far are not outside of historical norm. But I don't think that enough attention has been given—and this is perhaps, you know, a beautiful springboard hopefully to get people's attention drawn to this, is to show the graph with the increase, you know, in atmospheric gases right now in terms of greenhouse effect. I think if you combine the current temperature increase with that obvious scientific-appearing fact, that that might be something that people would be very mobilized by. Do I understand that the reaction from the scientific community correctly about that is Björn Lomborg being considered because he falls within the historical norm of temperature variation?

Richard Alley: I don't know exactly how to address *historical norm*. The temperature that we have now is safely, notably, significantly higher than anything in the instrumental record. The evidence from thermometers, including thermometers far out of cities as well as those in cities shows, a warming trend. The evidence from melting of glaciers that are known to be temperature-sensitive shows a warming trend. The evidence from ground warming, the evidence from ocean warming, shows a warming trend. To date, my understanding is that no one has found a plausible natural explanation of this, but the magnitude and the sign are completely consistent with what one expects from carbon-dioxide forcing. The physics of carbon dioxide bringing warmth are physics. This is very straightforward, it's very easy. If one looks at geologic time, the high-temperature times went with high CO_2, over 100-million-year timescales, over 100,000-year timescales, and over the last 100-year timescale. So the data are not . . . again it's not perfect. Could I absolutely 100 percent guarantee you that it couldn't be something weird in nature? No I can't. Is everything consistent with yes, CO_2 is making warmth? Yes it is.

Man: Well sadly all that enthusiasm is usually dismissed in the lay community by pointing out
that within historical global temperature ranges, regardless of how we're getting there, that's where we are, it's within normal ranges.

Richard Alley: Well what we call historical where we actually measured it with a thermometer, no there have not. We are outside of the measured-with-thermometer range.

Man: All I'm simply suggesting is . . .

Richard Alley: If you look at the world of the dinosaurs of 100 million years ago, where continents are in different places, CO_2 is higher and yes, it was warmer. But . . .

Robert Pollack: I'll add to that that separate from issues of data is the obvious similarity to me of this response and the emotional content of it to the wish one has when one has a bump on one's skin that someone say it's nothing. There is an enormous emotional value to being reassured, and one looks till one finds someone who is reassuring. Actuarially that's a stupid thing to do, and I think what we're trying to say in our own different ways is that if you have a doctor you listen to your doctor. And here I think the doctor is physics and geophysics, and it's making a simple statement.

Michael McElroy: On the Lomborg business. Lomborg is actually relatively silent on the climate issue. It's a fairly brief part of his book. Where Lomborg gets traction with a lot of people who like the message is his emphasis on the positive achievements of society in dealing with serious problems. I mean he has the ability to state those achievements in a way that makes it look even more significant than it actually is. I mean by talking about how much less sulfur we're emitting relative to what would have been the case, how much less NO_x we're emitting relative—he gets traction in that particular sense. If I could just comment, I really think that one should be very careful in assuming that two variables, temperature and CO_2, which co-vary, necessarily implies that the CO_2 is causing the temperature change. As a matter of fact, if you look at the long geological record, my reading of that record is that to a large extent the CO_2 is following the change, and that's what you would expect, given the way in which the ocean biology, chemistry, and dynamics responds to warming or cooling.

John Mutter: A relation doesn't imply causation.

Question 3: Using Information Technology

Man: My name is Bill Russell. I'm with SKN Worldwide, and I've been spending most of my time working on how we can use technology to accelerate the implementation of sustainability solutions and, of course, climate change being a primary one. And so I had a couple of observations, and then I wanted to ask a question of the panel. One is that I attend many of these things, and there's always this sense of everyone preaching to the choir. And I just wanted to tell everyone that I've really enjoyed being part of the choir here, and that you guys have done a great job, and I need to hear it every now and then so that I can get out of the despair that I sometimes fall into. So I just wanted to mention that. But in all seriousness, we discussed over the last couple of days a lot of very real ways of dealing with climate change, but I didn't hear much discussion about business as usual not being available anymore because of the Internet and because of the changes in information technology today. And my question is really within each of your solutions, How might they be a little bit different today because of their ability to be disseminated more broadly, more quickly, more effectively, with information technology? And I do comment that I do know that we are recording this session, it will be available via the Internet to some broad audience, and I think that that's a very great start, and I just wanted to see a little bit more thought about how the solutions are slightly different because of their implementation within a much more rapid and accelerated world with the Internet.

John Mutter: Can I just interject that all of the Columbia's 250th anniversary symposia like this are being preserved in the same way and are available on the Web. So if you missed anything you can go back to it.

Robert Pollack: I would like to just try and answer to that, and it goes back to what Upmanu Lall said, which was criticized by our colleague from Bangladesh. I think that developed countries can and should provide useful tools for undeveloped countries in their efforts, and I would say the figure of merit there is scalability. I'm struck by the intrinsic scalability of biological solutions for the fixation of carbon, for instance, as against large-scale industrial fixation of carbon into either liquid CO_2 or into minerals. And I see Klaus is here, I'd really like to hear something about biological fixation of CO_2 as a model of something that can move very rapidly and locally as well as by big national decisions.

Christopher Field: The potential for information technologies and service economies to be effective is illustrated in the IPCC Special Report on Emission Scenarios, where the IPCC scientists went through a set of internally consistent assumptions and said, "Well, where might we be at 2100?" And the difference between a fossil-intensive high-economic growth trajectory and an information/service economy-intensive growth trajectory over the next century with essentially equal rates of growth of GDP was approximately fourfold in 2100. So I think that the answer is that, at least as far as we can track the consequences now, we're looking at massive impacts of decisions about technology with information technology leading to the potential for high-economic-growth sustainably.

Question 4: Making Local Assessments

Woman: I'm with Action for Tomorrow's Environment, and you know, we struggle all the time up in Westchester with how to persuade people that this is true, that other environmental actions that they're taking having a real impact on the environment. And I was curious whether anybody has done the work, or could it be done, to basically create hypothetical scenarios. You know, picking up what somebody said, you know, if you know that it is going to flood in your area in fifty years, you might be motivated to action. So has anybody taken the U.S. or the world, broken it down into small areas, and said you know, these are the various scenarios? I think people are confused. Is it getting colder, is it getting hotter? Can we have somebody project out and give the percentage odds? You know, 30-percent chance it's going to be really hot, and this is what's going to happen; 40-percent chance it's going to be really cold, this is what's going to happen, and do a converse. But if we take action, here are the percentages, and this is what it's going to look like. So you can really show people, "Look, if we don't act, these are the things that might happen. Aren't we better off doing something in case it's true? And if we do act, look how much our chances are improved." Is that feasible, sort of scientifically, to do those kind of projections on a more localized kind of basis so people can see what's going to happen in their own hometown basically, you know, within obviously something bigger than a hometown area, but not, you know, the U.S., but, you know, a state, two states, whatever makes sense scientifically — is that feasible?

Richard Alley: The effort has been made. Regional assessment has been done for the United States, and it certainly is very useful in showing the sorts of things that might happen. Questions are raised because as one goes from the global to the regional, the forecasts become much less certain. And so in the case of the U.S. regional assessment, two different global models were used, and then more local things were imbedded within them. And for most of the country, there was a fair amount of agreement and for one piece of the country, there was a good bit of disagreement in the global models. And so people have been hesitant to lean heavily on local impacts or regional impacts because of the difficulty in taking the global scale and bringing it down more regionally. If you have the jet stream and you're north of the jet stream and the polar front sitting on the jet stream, it's cold. And if you're south of it, it's warm. And if the wiggles in that change a little bit, where you are in particular may see a different signal than the rest of the world. And so yes, a lot of effort has been done in this way, but it's difficult to give you something that you really want and say, you know, believe this for your area. We're really not quite that good yet.

Robert Pollack: There's a second way to look at that, and that is the question embeds a rejection of the notion of global insurance, or the notion of insurance per se in which there's a pooled risk, and you put in your resources even though you may not be the one at risk, just because you may be. And then you don't need to know your absolute risk. In fact a shared pool doesn't need any information of that sort at all, and it seems to me in a crisis of the commons, a model of insurance is better than a model of rational action. Does that make sense to you as an economist?

Partha Dasgupta: Yes. Good economics [inaudible].

John Mutter: The term of art, by the way, is called downscaling, if I understand your question correctly. And substantial progress has been made on scaling from global to regional, not to local. But it's an unstable process, it's sort of the reverse of filtering, if you will. It's sort of going the other way. And it's unstable and tricky, but there's a lot of people working on it. Klaus.

Question 5: Klaus Lackner on Uncertainty

Klaus Lackner: Klaus Lackner, Columbia University. I would like to come back to the perception that we very much emphasized the sequestration, or to put it more broadly, carbon-dioxide capture and disposal, because I think it's not only that perception is actually a very important point, and I tried to take a different tack on it, why I personally believe it is a very important thing, and that has to do with making decisions under uncertainty. And one thing which came up here very clearly is that the uncertainty in the details of the climate forecast, and the climate predictions should not stop us from moving forward. Quite the contrary, the high degree of uncertainty makes it even more important. But I think when you make the decision what to do and how to deal with this problem, you also have to put in the uncertainty in the engineering side—What can we do, how can we deal with the problem, and how can we reduce emissions? And the answer is if you limit yourself to reducing emissions by reducing consumption, by going to other alternatives, keep in mind you are talking about an 85-percent chunk of the total right now. So in order to be comfortable with the statement "Yes, we will get there," I think it's premature to say we can go on with all the carbon we have in the ground and say we have that solution in the bag. But there are a number of options available which suddenly add to the portfolio, and I think to make the statement that with the remnant uncertainty we can move forward and solve this problem, you get a lot more comfortable if you say carbon sequestration is one of the options. And by the same token I am perfectly willing to say that a country which is in the early stages of development we should not hinder their development by putting unreasonable constraints on their emissions in the short term. The obligation there is in the developed countries, not in the poor countries. So we could agree on that part as well.

John Mutter: Other responses, or was that a response? I can take, I'm sorry, only one more question. I understand the governor has arrived. He's in the so-called green room in the back. So if I can take one more question and then thank the panel and the audience. One last question, please.

Question 6: Gas Prices

Woman: Martine Rossignol-Strick from University Pierre and Marie Curie in Paris alumna and Lamont alumna. Concerning the question of energy conservation, I observe the fact that price of gasoline in the U.S. is about a fourth the price of gasoline in other developed countries. Isn't there something which could be done in the U.S. about that question?

Michael McElroy: Yes.

John Mutter: Can anybody elaborate on yes?

Richard Alley: Tax, of course, is a four-letter word in the United States, and that's part of the problem, particularly gasoline tax. The tax in Europe is addressing . . . I mean there is a kind of a green element, if I can put it that way, and it's certainly dressed up that way. But the gasoline taxes in Europe have been high for quite some time, and one reason they're so high is that people keep driving, and it's a way in which the treasury can raise money. And now that would also be true here in the United States, but the culture of the United States, it goes without saying, is quite different, but also the continental size of the United States and the way in which infrastructure has been built around cheap gasoline, these are things that have blocked I think progress on raising the price of gasoline. But there's no question that's a serious issue, and it's simply not one that the politicians seem very willing or even able to push.

Martine Rossignol-Strick: I think there you've got a point. Thank you.

John Mutter: So the answer to the question is yes, but it's not very likely.

I'd now like to thank our panel chair, Bob, and his panel. Thank you very much.

April 23, 2004

Governor George Pataki
New York State and the Climate

Introduction by Lee Bollinger

John Mutter: Ladies and gentlemen, in the 250th year of the University, it's my very great pleasure to introduce its president, Lee Bollinger.

President Lee Bollinger: It's a great pleasure to be able to be here to introduce the governor. He is really a member of our family, an alumnus of the law school, graduated in 1970, the year before I did. And it's really . . . every time I meet him . . . and now his daughter who's a student here at the law school . . . there is a sense of real lasting connection with this institution, and it's something that we value tremendously. The governor has had a very distinguished career, obviously, and has served as a mayor, member of the New York State Assembly and the state Senate. He has worked very hard and very successfully over time on environmental issues, and I know this means a great deal to him because I've seen him in the context of the River and Estuary Center on the Hudson that was set up, and Lamont-Doherty is part of this. And so I've been able to watch him in this environment, thinking about the environment, and I know that it's very meaningful to him. Also, of course, recently having set aside well over 200,000 acres in the state from development is a fantastic development for the state.

I just would like to say something again, somewhat personal, related to Columbia about the governor. As almost surely everyone knows, Columbia also needs 250,000 acres of space, and we've looked around Manhattan for that kind of property and have come up with 18 acres just north of here called Manhattanville in west Harlem. And this is really an idea for the decades; that is, it's an attempt to really unlock the tremendous space constraints that Columbia has labored under for many years. After having realized the Morningside Heights space, we have struggled to realize the full potential of the institution. The point is that right from the beginning when I met the governor and asked him about this, he was incredibly supportive, understood completely the issues and the needs, clearly believes in the role of education in the general development of the city and of the state and of society. And just as with the physical environment, the intellectual environment requires that you be able to take the long view because there's not a lot of political advantage, there's not a lot of immediate return, in trying to think about the future of an educational institution fifty years from now, rather than just three or four years from now. And it's that characteristic which I have sensed in the governor right from the beginning that I think is really most relevant to today's topic, which is really Earth's future. And it's a great privilege and pleasure to welcome the governor back to Columbia.

Thank you very much.

U.S. Dependence on Foreign Oil

Governor George Pataki: Thank you, President Bollinger, for those kind words, and it is always great being back at Columbia. I understand you've had a magnificent symposium here over the course of the past couple of days, and congratulations on that. And I guess I'm kind of the end here, so I will try not to go for a few hours. But let me begin by saying I believe my talk this afternoon will be a little bit different, because I'm not a PhD, I'm not a professor, I'm not a research scientist, I am a lawyer. So if any of you want to leave now I totally understand.

But on the other hand, when you think of the environment, when you think of taming the climate, when you think of the issues facing us in the future, we need the research scientists and the PhDs and the professors to drive the science and drive the technology. But we also need the policy setters to be able to work with them and make sure that the policies reflect the goals and the abilities that they have determined.

I wanted to come here this afternoon for three reasons. First is because it is Columbia's 250th anniversary, and this great institution means so much. It is not just a national institution, it's a global institution, and I know we have people from around the world here with us this afternoon. Second, it is also, as President Bollinger said, my institution. I am very, very proud to have gone here for law school and had a wonderful three years when I learned probably a lot more outside of the classroom than inside of the classroom, but it was still an amazing experience. And my daughter, as the president said, is now a student here in law school as well, so it's nice to come back and see her. But the main reason I wanted to come here is the importance of the topic. Not just taming the climate, but the factors that go into raising concerns about the future of our climate, how they affect our country, what our national policies should be, and how we could change the dynamic that currently is driving too much of the world's not just environmental but also economic interests.

When you think of the challenges facing the United States, now at the very beginning of the twenty-first century, there are three overriding issues. The first is our security. Since September 11, we all know that we can no longer depend on foreign borders or an army that is the best in the world to defend us from those who despise the freedoms that we take for granted. And we have to understand that every day we have to put in place not just strategic and geopolitical but other policies that allow us to protect the freedom that we and other countries appreciate and cherish so much. Second is we're in a different economic era. We are now in the era of the global economy, and we're coming out of a recession where people have been wondering how can we create jobs, how can we have the opportunities of the twenty-first century, when countries like India and China and others around the globe are no longer just distant markets but now active competitors and threatening our ability to create jobs here at home? And third is the environmental pressures that this globe and our country face, from increasing population, from increasing industrialization, from increasing expectations of a higher quality of life in the twenty-first century. How do we meet those three challenges? Is there some area where all three come together?

And in my view there clearly is one, and that is the whole question of energy, and in particular the question of our dependence on foreign oil instead of being able to break that dependency through renewable resources and energy efficiencies. This is the only area where the three of them come together. And I don't think I have to go on at length to any of you here about how these do come together. Right now, every day, the United States imports 12.3 million barrels of oil. We send one-quarter of a billion dollars a day overseas, over 100 billion dollars a year, often to unstable regimes, regimes that are not friends of those, not just the United States but those who believe in freedom and in tolerance. And in fact 85 percent of Iran's foreign exchange and exports come from the exportation of oil. In a broad sense, you could say that a significant percentage of that funding is going as a terror tax to support directly or indirectly those who detest the freedoms that we take for granted. And for those who think, "Well nature is going to take its course and things will get better," two-thirds of the world's known reserves of oil are in the Persian Gulf, so we have got to change the dynamic and make sure we do not continue to send these hundreds of billions of dollars overseas to unstable regimes that too often do not support the freedoms we believe in.

We have to break that revenue stream, and at the same time bring back those dollars and invest in the technologies that will allow us to create the jobs here. When you think about foreign oil and its impact on our economy, every single recession in the last forty years has been preceded by a hike in global oil prices. Everyone's concerned about our trade imbalance, our growing imbalances in particular with China and with India, and that is true. Two-thirds of our trade imbalance comes from importation of foreign oil. And the Department of Energy estimates that over the last thirty years, this country has sent 3.4 trillion dollars, 3.4 trillion dollars, overseas simply to bring in foreign oil, which we have already burned, and which has not only had a negative impact on our environment, but serves no useful purpose as we go forward. Three point four trillion dollars that could've been spent on jobs and investment in industry here in the United States instead of sent overseas for something that is unrenewable and unsustainable. And most of us here I believe are probably old enough to remember the Arab oil embargo, when we had gasoline lines because for geopolitical reasons they determined to shut off the supply of oil to the United States and the West. And that began what was the worst recession and economic slump in our country since the Great Depression.

What do we do to break that nexus and to create the jobs here at home? Well we've always understood how Americans have grown our economy and expanded our opportunities and increased our optimism for the future, and that's through innovation and that's through the development not just of new technologies but of new industries. The railroad industry transformed our country and the globe and became the dominant industrial force. Earlier in the last century, the automobile industry changed the way people lived their lives and created tens of thousands, hundreds of thousands, of jobs here in America. And just within the last 25 to 30 years, the Internet has again changed the way we function in our ordinary lives. And right now in Seattle, Washington, there are thousands of jobs at a company that didn't even exist thirty years ago. When we innovate, when we have the courage to invest in the R & D and break the mold and change the paradigm, we not only have the ability to end that dependency on foreign oil, but we could invest those dollars in the technology and the opportunities that will grow our economy and create the tens of thousands of new jobs we need for our children in the twenty-first century.

And we can do it, we can do it by conservation of energy to reduce our dependency on those foreign imports, and on the development of renewable sources, fuel cell technology, photovoltaic technology, wind technology, biomass, alternate-fuel vehicles, geothermal—all of these technologies that if we made the commitment we should could be used to bring those investment dollars back home here and to create more jobs in a cleaner environment for the future of this great country.

New Technologies at Work in New York

You know, there are those who . . . and I'm sure many skeptics out there, who when you talk about something like this say, "This is a pie-in-the-sky, you know, these are all things that to a greater or lesser extent have been tried, but are they really going to work, could they work?" Let me tell you what New York is already doing, because we are making enormous strides on our own towards reducing our dependency on fossil fuels and on reducing our dependency on nonrenewable energy, and in the process creating jobs and opportunity here in New York state.

Four years ago I signed the first legislation to create a green-building tax credit anywhere in America. What we did was pass laws that said if you invest in renewable technology, photovoltaic, gray water systems, energy-efficient heating and lighting, we will give you a tax credit because we know it's a little more expensive in the short term, but we know it's a lot more beneficial in the long run. And since that time we have moved our state's Department of Environmental Conservation into the first state green building on the shores of the Hudson River in New York City. In 4 Times Square, one of the new high rises in that revitalized part of this great city, is a green building with fuel cells and photovoltaic cells and the other technologies. And in Lower Manhattan just a few months ago I was down for the ribbon cutting on the Solaire, the first green high-rise residential building anywhere in America. This is a building where they were concerned that they wouldn't be able to rent it out because of the costs, even with our tax credit, would result in the rentals being slightly higher than the market. The building rented out in a matter of days at rents above market. They have a waiting list because people are delighted to be living in a building where they don't get the indoor pollutants, and they know that they are making a contribution to the future not just of our environment but of our country. The Solaire, by the way, uses 35 percent less electricity than in an ordinary high-rise building, and because of the gray-water recycling systems, 50 percent less water. Imagine what could happen if as we move forward all the high-rise residential buildings in this country used 35 percent [less] power, 50 percent less water. Imagine the impact that would have on our global economy and on our allocation of resources too often to things that produce for today and leave nothing but pollutants for tomorrow. That's just one technology, green buildings.

We are doing other things with photovoltaic cells. We passed the first ever net-metering law in America, where when you're a homeowner or an office owner and you put photovoltaic cells on your roof not only do you get the benefit of that solar power when you need it, but if you're generating more than you use, your electric meter goes backwards; it gets fed back into the grid, saving you money and allowing others to utilize this renewable source of energy. And we've seen photovoltaic cells going up around the state. And out on Long Island, a New York State authority, a new one, Long Island Power Authority, has built a 1.1-megawatt solar-powered array, the largest anywhere in America. And we are showing what can be done to break this dependency on fossil fuels and to create dependency on technologies that allow us to use renewable energy.

We're doing a lot with fuel cells. We have a great agency, the New York State Energy Research and Development Authority that is giving grants for research and development, for job creation programs, for innovative new technologies like fuel cells. And outside of Rochester, General Motors, a global giant, is working on technology to produce 10,000 units a year within the very near future. And smaller start-up companies a few years back, like Plug Power in Albany, are working to create those fuel cells that not only will allow us to avoid the need to combust to create energy, but would allow us to have distributive energy, distributive energy where you don't have to be connected to the grid because your source can be a stand-alone fuel cell or photovoltaic array that allows you to be broken off from that grid.

Another area where we're very excited is biomass. Biomass is something where when you think back on it, when Diesel created the diesel engine back in the nineteenth century, the first fuel he used was peanut oil. And yet today biomass plays an almost inconsequential role in the generation of energy. We've created a new center of excellence in Syracuse around our great universities and private-sector companies to work on developing environmental technologies including new biomass technologies. We've put in place, through a tax credit and incentive program, methane digesters on farms across upstate New York where they take the methane generated from manure, digest it, generate power on their farms, and avoid the pollution into the air. And yesterday, of course, I was up to announce the 260,000 plus acres of open space that we've preserved in the Adirondacks as part of our Earth Day celebration. But the day before I was at Hudson Valley Community College in Troy, New York, and I was there because we inaugurated a new operation. That entire community college in off-peak hours will now be fueled by methane gas coming from the City of Troy's municipal landfill. It is an incredible breakthrough where instead of just flaring that gas off into the sky, we are using it to provide energy, reduce costs, and certainly reduce our dependency on imported fossil fuels. And that one program at that one landfill is the equivalent of getting 36,000 cars a year off the highways of New York State.

We're doing other things as well. We have a new program with NYSERDA to encourage geothermal heating and cooling. This is not high technology, but under the earth a few feet down below the frost line across New York State, there's a constant temperature of around 50 degrees. If you just run a closed cycle loop of water through that earth in the summer when you're trying to cool on Long Island from 95 degrees, just by running a pump, you will have a cooling system that can take you down to 50. In the winter in the Adirondacks, when you're trying to heat from 0, instead of going from 0 to 60 by running that water through a pump, all you have to do is incremental heating from 50 to 60. It saves 90 percent of the energy cost for cooling, 30 percent of heating, and the technology is there now. What we need are policies and programs to drive down the cost differential so that consumers, whether they're homeowners or small office owners, understand that this is right for them economically as well as right for all of us environmentally.

We're also aggressively moving forward on the alternate-fuel vehicles program. It is simply wrong that in the twenty-first century the vast, vast majority of our automobiles are still powered by the gasoline internal-combustion engine. When I took office in 1995, the New York State government had four alternate-fuel vehicles. Today we have 4,000, and last year 89 percent of the vehicles we purchased were alternate fuel. Within the next couple of years our goal is to make them 100 percent. We're doing that not just to set an example, but one of the things we're looking to do with the power of state government is to create markets. When a manufacturer understands there's a demand out there for thousands of vehicles that meet these particular standards, they're going to want to be the ones who are selling the product to meet that demand. We've done that with alternate-fuel and clean-fuel buses. When I took office one of the first things I did—and you're all in the great City of New York—was order the MTA, which is controlled by the state government, to get rid of all their polluting diesel buses.

I remember when I was here at Columbia, I'd usually take the subway but every now and then I'd take the bus, and when that bus took off from the curb, you would gasp and choke and wheeze. Doesn't happen anymore because right now every single bus in the MTA fleet has either been retrofitted or is a new hybrid clean-fuel bus that uses less fuel and emits at least 90 percent less pollutants. And it's not just good for our environment and for our health. By creating this market with the largest mass transit system in the United States, we have companies, producers, coming to New York to manufacture these hybrid and alternate-fuel vehicles. The Orion Bus Company has hundreds of jobs upstate, where they produce not just for New York but for other mass-transit systems around the country. And Corning in upstate New York just invested 200 million dollars in a new plant to create a new diesel-related environmental trap, whatever they are—converters. They are selling those converters to us here in New York because of demand, but they're also selling that technology in China and in Mexico. We are not only changing our environmental dynamic here in New York and in America; we're changing our ability to compete better in the global economy.

What does this all mean? Well, couple of years back I signed the new executive order, Executive Order 111. What I said is that by the year 2010, New York State government was going to reduce our energy consumption by 35 percent. And by the year 2010, New York State was going to hit at least a minimum standard where 20 percent of our energy that we use comes from renewable sources. We're going to do that and we're confident that we can.

Setting a National Goal for Reducing Energy Consumption

But all of the things I just talked to you about are simply scratching the surface using existing technologies. Imagine what we could do if we set not a New York State goal but a national goal of reducing energy consumption by 35 percent, of making sure that our nation's energy supply from renewables was at least 20 percent. You know, we're in this great university, Columbia, and when the United States has faced crises and difficulties in the past, we have always put in place national policy that has allowed us to change the dynamic quicker than people thought. This university during World War II was a part of the Manhattan Project when the United States and the other allies said we had to develop the ability before the other side did of having nuclear capability to make sure we win this global conflict and protect freedom. In the early 1960s I remember when I was a kid, President Kennedy looking at the challenge from the Soviet Union when they had put the Sputnik into orbit and a man into space. And I remember Senator Kennedy addressing the country and saying that let's set as a goal that by the end of the next ten years, the United States will put a man on the moon and return him safely. And I remember five or six years later when I was here at Columbia sitting around with my roommates watching as Neil Armstrong got out of the lunar module and took that one giant leap for mankind.

It's now our turn. Our dependency on foreign oil, our failure to control the emissions that are affecting our global climate, are issues and crises that we have go to meet head-on. It's our turn to set a national goal. Let us set a national goal that by the end of the next decade we will break our dependency on foreign oil and replace it through conservation and through renewable energy technologies that we develop here in America.

My goal is that this environmental issue not just be another political issue, but it be an American value. Because when you talk about keeping us safe in our homes and safe from those who would take away our freedom, when you talk about creating the jobs and opportunity that will allow twenty-first-century Americans to look to the future with the same optimism and the same confidence that we had growing up and our ancestors before us, when you talk about having a healthier not just environment but climate for all of us so that we know our children can grow up in the greenest, cleanest, healthiest possible setting, it all comes together in energy. It all comes together on breaking that dependency. We're Americans, we're innovators. You're the scientists, you're the professors. Let's set the policy and work together to make sure we achieve it.

Thank you very much. It's a privilege to have the chance to talk to you this afternoon. Thank you. Thank you.

April 23, 2004

Jeffrey Sachs
The Way Forward

Introduction by John Mutter

John Mutter: So. And a privilege to have the governor of the state of New York to help us with our deliberations. A fine speech, most welcome at this time. We would now like to formally close the proceedings of the conference in a manner in which we began. I would like to ask Jeff Sachs, the director of the Earth Institute—thank heavens! —to come to the podium—you're supposed to be there—to close our deliberations. In opening, he suggested that there were ten reasons to be dismayed somewhat at the complexity of the climate system and its problems, but four reasons to be optimistic that there might be solutions. I'm not sure if he's going to amend his list, but he'll point us in the direction for the future. Jeff.

Energy for Long- and Short-Term Needs

Jeffrey Sachs: I hope the fact that I'm back here doesn't mean we're just going around in circles. We are here to close, but close by looking forward. And I think the governor just gave us a wonderful way to do that, showing what political leadership could call upon us to do, and the fact that there is a political will in this country, not fully formed yet, not a majority, but certainly one that's taking shape and that's changing dynamically that suggests that we actually can move forward on the agenda that we've discussed in the last couple of days.

The governor reminded us that we're talking about something even more complex than the enormously complex things we've been talking about. It's not only energy and environment, long-term climate, it's also geopolitics, it's an energy system, which lies at the core of so much of our whole global civilization. I've learned, while economists tend to see everything through the optic of dollars and cents, I've learned from our wonderful colleague Klaus Lackner to see everything through the optic of the second law of thermodynamics. And everything we're trying to do is to overcome entropy. Once in a while we achieve it, locally that is, we can't do it globally or universally, but that requires energy. And as Klaus has stressed to me so many times, the idea is not simply to use less energy, energy does work for us. The idea is to use energy sustainably and wisely in ways that the work that it does for us serves the human purpose and the human interest.

We could cut out all these problems by stopping the use of energy and return to a state of affairs that the human society once lived with, which was energy purely from the Sun in the form of biomass. The governor said we use almost none of it. A lot places where the Earth Institute works, I'm reminded, get about 95 percent of their energy or more from biomass. It's a terrible way to live, by the way. To have no access to fossil fuel is to live at the edge of survival every day and to fall off the edge with regularly. Places that don't have electricity, places that don't use fossil fuels today live in the most abject and almost unimaginable poverty.

The idea for us is not, therefore, to stop using energy, obviously. We can't do that biologically, but we can't do that in the economic and social sense either. It's not even to economize on energy per se, it is to use energy to meet human purposes, both in the short term and the long term. And that is the complexity of the challenge. And because energy is so fundamental, it does involve geopolitics. We do spend tens of billions, perhaps now hundreds of billions, of dollars in military spending with an objective of securing oil flows. It doesn't seem to be working very effectively anymore, but it is no doubt part of the reason why we're spending 450 billion dollars a year in military outlays this year, and that is definitely a hidden subsidy, as the governor was saying, to the use of imported fossil fuels. No doubt about it. If we give the full economic costs and benefits of what we're doing, we certainly have a lot more options and a lot more needs to rethink our general global strategy.

So I do want to say a few words about the way forward, and make a few analytical points, I hope not too repetitive, and say a word about what I think we can do, we together, we at the Earth Institute, we with the wonderful colleagues that have come from all over the world to be part of this.

The first point I want to make is that while there are certainly important moral aspects of what we're talking about, critical moral aspects, we're actually talking about a problem of inefficiency, inefficiency in a sense that an economist could understand. Inefficiency means that we could be doing better for ourselves with our own defined goals than we're doing right now. To paraphrase the famous remark of Talleyrand, what we're doing is vis-à-vis the environment worse than a crime, it is a mistake. And what that means, of course, is it's not only a moral misjudgment, it's not only the moral condemnation. We're not serving our own interests well when we think more broadly about what our interests really are. It is not in our interest to have the climate change in the risky ways, but there is nothing in our current incentive structure of markets and government programs, either nationally or on a world level, which adequately addresses the social consequences in a desirable way, so the incentives are wrong, and that leads to an inefficiency.

It's more than morals, it's practical. How do we arrange the incentives that we face in a way to serve human society's purpose? We're not doing it very well right now. Now when something is inefficient, it doesn't mean that everybody wins from every solution, but it does mean, roughly speaking, that the winners from a solution win more than the losers lose so that the winners can, and typically should, compensate the losers so that one can move to a better path, a better outlook, a better strategy, so that just about everybody is carried along in a better way than before. That's the benefit of it being an inefficient situation right now, that's the paradox I said yesterday—that the fact that we have this complicated problem also means that there are, to use the proverbial phrase, win-win solutions. But they're not quite as easy as we sometimes want to think, I believe. It may be true that we can save all the energy and just by being smart save it, 90 percent of the energy, and be renewable and be clean and so forth without any economic outlays added to that. I'd very much doubt it. I think this is going to be tens or hundreds of billions of dollars of cost, or trillions of dollars of cost, cumulated, but the point is that it's worth it because we'll be avoiding even larger losses. We'll be getting something for that.

Economic Trade-Offs

I would warn us against the purely wishful thinking . . . maybe it's not, maybe it'll turn out that the most wishful thinking is right, but I wouldn't rely on it—that there are all these easy solutions out there that if we're only clever we'd realize we can save on everything, enjoy more income and be better in all ways. There are trade-offs, but the nature of the trade-offs—I believe we've heard in the last couple of days—is that taking the necessary steps, though they are costly, are less costly than merely going along and suffering the consequences that will ensue on the business-as-usual course. It's not wishful thinking, it's very practical. It's not only a moral issue, except that morality in one sense is just very clever thinking about long-term needs. And I think that's the situation that we're in right now.

Now the third implication I thought Geoffrey Heal put beautifully in his remarks, in a very pithy way, which is the problem then is one of creating the incentives and the transfers that can move us to this kind of win-win situation. That's not so easy, this is a complicated problem. But the point that it's such a mess, the situation we're in, suggests that by there being a better path, we actually could make—if not everybody better off on that new path—by creating the incentives properly, we could make enough better off that we can actually achieve the social or political consensus to take that course, and thereby enjoy the benefits of escaping from the inefficiencies that we're trapped in right now. But this is a complicated challenge, it's not a simple challenge. Unless it's true that there are great technologies out there just to take that are for free and that will save us money, save us energy, save us everything, if it's not simply so easy, then we have to face the following issues. First, we're dealing with, as has been said repeatedly, a situation of cross-border externalities meaning that what we do affects the whole world, [and] what the rest of the world does affects us. We don't have the problem, like we do say with leaded gasoline, basically affecting the area where the cars are driven locally, where a local solution both imposes local costs and local benefits. We have a situation where you impose local costs and get global benefits, very tricky because of the imbalance site by site in the costs and the benefits, perhaps. Second, we have trade-offs between current costs and future benefits, very tricky. Third, we have huge uncertainties, as we've discussed, not a reason for inaction, but definitely a barrier to absolutely clear consensus, because there are disagreements about the underlying trade-offs, and those are real disagreements—they're not spurious disagreements, they're not purely disagreements of ill will. These are complex trade-offs that we're facing. Fourth, the benefits are difficult to measure, partly because of the way we measure things. Our gross national product, which is our headline measure of how we're doing, is an absolute indicator of almost anything we care about. And it's getting worse. It is not a measure of economic well-being, it is certainly not a measure of happiness, and it doesn't include environmental costs or benefits to a very large extent. So the headline number—the economy is going to grow 3.8 percent, reelect me—the more we go down that road without fixing the measurements, also the more difficult it is for us to even think clearly about our own inefficiencies that we're imposing in our own society, so measurement is a very big part of this issue. And then, of course, not only are there cross-border externalities, but there are huge differences of who will benefit and who will lose within countries, and across countries, and that means that while Geoff Heal said he doubted that international transfers could directly play a role, if you rule out cross-border transfers as being part of this then it isn't even theoretically clear that there's a solution in which everybody is better off versus a business-as-usual path. Of course it depends on all of the true values of those uncertain costs and benefits, what kinds of technologies and so forth. I do believe that transfers in one form or another, whether it's the hidden form that he said, of us providing technological help, or whether it's direct compensation payments, or whether it's differential responsibilities in the system of who moves first and for how many decades before others are asked to move, or who gets the tradable permits in a cap-and-trade scheme. All of those transfer issues have to be put onto the table in terms of incentive design if we're going to reach this rather complex global-scale process agreement so that we can get out of this deep global-scale inefficiency that we're stuck in right now.

Now one more point. Economists are not being merely pigheaded to say we ought to think about the minimum costs to achieving all of that. Let's say you want to get down to 550-parts-per-million ceiling for the twenty-first century for carbon concentration. It is not simply an unthinking, uncaring, immoral, economistic approach to say, "What's the minimum cost of doing that?" Which is sometimes said. "How can you even talk that way, Professor Sachs? Why don't we just stop using X, Y, and Z energy and cut back and do other things?" Because if we just do it the way that one person thinks we ought to do it or another person or one interest group or another interest group, the real costs that will be imposed on jobs, on livelihoods, on a sense of well-being, can be huge compared to doing this in a more sensible way. Minimizing costs of achieving a goal is not an immoral proposition; it's actually a rather sensible way both to try to get a consensus and, I think, if properly done with proper measurements of what we mean by costs, a rather good ethical principle as well. It's not sufficient for ethics, it is part of ethics that we're trying to not leave on the table gains that we could otherwise get by thinking more clearly about how to do these things.

Now I raise that because this particular issue has several pertinent dimensions to it. Let me just name one. It is vastly cheaper to build a carbon-sequestering new power plant than it is to retrofit an existing power plant. Is that right, my scientist group here? Yes. Okay, thank you. Economists need some validation by people who really know. I don't really know, but I'm taking the expertise—pretty damn impressive down there—for this point. Now what does that mean from an economics point of view? It means that it's not right to say, for example, "Well the U.S. caused the problem, the U.S. should fix the problem, don't ask China to do it." That's actually the wrong way to think about it. If you want to sequester the next ton of carbon, it may be vastly cheaper for China to do it because China is going to be building the new power plant, and we're building many fewer of them than China is because of the different rates of growth of our economies. Now saying that it means that the low-cost solution is build the carbon sequestration in China. But then comes the incentive and the ethical and other questions. Why should China pay for that just because it's lower cost to do it in China? The answer obviously is maybe the United States should pay for it, but what it should pay for is not retrofitting our plant, what it should pay for is fitting a new, modern carbon-sequestering coal-fired plant in China, just as an example. Well, obviously we're in a pretty complicated environment in that sense. We're not really so good or so keen at paying for power plants in China, after all. But that's the kind of problem that's raised in this challenge.

If we want to sequester another gigaton of carbon, it may be vastly cheaper to do it in twenty years than to do it today. It may not be right to say let's do everything we can right now with what we have available as opposed to saying let's invest very heavily in several promising technologies so that we can lower the cost of doing it in twenty years. We have a stock problem. This isn't to say do nothing right now, it's to say do something wisely right now.

I'm not proposing waiting to do something. I'm just pointing out that it's not right from a cost-minimization point of view to say we'll separate the problem, ten years, and then the next ten years, and then the next ten years, and keep doing the maximum. We have to think about this in what we call inter-temporal choice. We have to take into account it's much cheaper to sequester a ton of carbon in 25 years than it is today, not just because of the delay of time. I'm not talking about time discounting, but because of retrofitting versus new power plants or because of new technology. We have a timing issue, we have a location issue, we have a technology-choice issue. I do not personally like the image let's use everything we can right now.

Now in economics it often is true on the margin you do a little bit of everything, but it may turn out that there are a dominant three or four things to do and everything else is really a nuisance, a pain in the neck, on net not really helpful, doesn't really contribute. And so a quantification of these issues is not another insignificant dodge, it's actually part of doing this in a sensible and responsible way.

U.S. Politics and Carbon Ceilings

Now I think we can get there for all of this actually, and I think we're getting closer in the United States. It's not as bleak as it seems to be. This is a map of the most recent vote, the McCain-Lieberman vote, on putting ceilings on carbon. It was voted down 43 yeas to 55 nay and two senators not voting. So what do we learn from this? The red states—they are the red states also in the other political sense, very heavily—those are the states that both senators voted against. The gray states are split decisions, and the green states, including our own, both senators voted for. It was actually a rather close, rather close vote in a sense, almost coming out of the blue because we had a White House aggressively lobbying against this particular piece of legislation, so despite that several Republican senators crossed over against the White House's extremely strong pressure and voted actually for the McCain-Lieberman vote.

Well I think what it shows . . . first of all, it tells us a little bit about the nature of our own politics, and if I can find it, this morning I decided to run a regression of who voted on what side, and I only had a few minutes to do this, so this is not ready for the big time, these results. But just to tell you the two hugely significant variables are the Democrats voted more for it, and this I think is not necessarily a Republican-versus-Democratic-party division but a White House political opposition to this bill. But definitely Democrats were vastly more likely to vote for it.

Second, even independent of party, if you look back here you see something—it's fitting that I should be the last one to have trouble with this in two days also, and I apologize to all of the other speakers—the coastal states had a very strong tendency, statistically significant, to vote for this legislation, controlling for party. They're the ones that are going to be sunk [as] Richard Alley showed us yesterday. They know what they're doing. There is local politics underway. Florida kind of likes being terrestrial and so we got two votes in Florida. Basically all of New England, California. Oregon had a split decision where Republican—I think there's one Republican senator that voted in Oregon for this, and so on. So that was the second bit of evidence that being on the coast, there's some rationality in the decision that was taken.

A third element is energy-producing states, with a statistical significance of 10 percent, not usually the publishable threshold, but then again I had about five minutes to run the regression, so. The coal, oil and gas states voted against, controlling for being coastal or not, controlling for being Democratic or Republican. That's why we had an incredibly eloquent speech by Senator Byrd of West Virginia. This is what you get when you're a coal-state Democrat, you get eloquence. It said, I would love to vote for this, believe me, it's critical, it's critical for our future, it's one of the most important issues we face. I vote against. So that's what happened in West Virginia and that was the third element.

And a fourth element that's kind of hanging in there, and again once I get our climate-research institute on the data, you can barely see this, but the red states in this map are drought states, current drought states. And I thought that probably drought conditions would influence the vote, and it shows up at not a statistically significant level but in the right sign. And finally states with major ski resorts were also more likely to vote for the legislation.

Now what do I take from all of this? This isn't meant to be simply silly, although it's a little bit quick analysis. The senators are hearing something from their constituencies. They're aware increasingly of the issues. They're aware of the coastal erosion, they're aware of the risks of increased storms on the Atlantic seacoast. The ski resorts are definitely weighing in strongly because you can read that on the wire services. We know that the energy states right now are opposing this legislation quite strongly. So we can see the kind of politics that is taking place.

But when I look at it, it's not surprising to me that the nature of our public discussion now has none of considerations that Geoff Heal told us should be at the table to actually reach an agreement. We're asking politicians to buy into something very short term. We're asking them to buy into something where they know very little really about the deeper risks that their region faces, because we've only skimmed the surface in downscaling the analysis. We're only learning in the last couple of months of the horrendous cost to biodiversity that are likely to come from this. There are hugely subtle, deeply problematic costs that have not been factored in. And we have Cynthia Rosenzweig to do New York City downscaling. Most of the rest of the country has not downscaled their climate change analyses systematically to be able to inform their own Congressional delegations.

Then when I read the debate this morning about McCain-Lieberman in thinking about this voting pattern, most of the senators said why aren't China and India at the table? What about promising technologies? Why should we jump in right now? And I have some sympathy with their point of view, which is that we're asking right now to do things without the clarity of a strategy. Now I don't have sympathy with the fact that we have no strategy because we could make one. But we have not had the leadership to put that together in our country. That's bipartisan, by the way, because it's true of the Clinton administration also—they voted for Kyoto, but they had no intention of it actually going to a vote in the Senate. It is worse in a way with this administration, of course, because they have been disdainful of the science, and this is extremely dangerous. And the Clinton administration was not disdainful of the science. It was just inadvertent in the politics.

But the fact of the matter is, there is not on the table right now a sensible strategy, and a lot of politicians don't believe it's a free lunch, they want to know what the costs are, and they want to know understandably if we do 5 percent by the year 2010 what comes next, what comes next, where are we going, how big are these costs, what are we getting ourselves into, what does it mean? Those are actually quite fair questions for something as fundamental as the energy system of the

United States and the world. I'm not saying it's a cause for inaction, by any means. Of course I'm not saying that. What I am saying is that it's understandable, not merely ill will, it is understandable why we haven't reached the kind of consensus that is sufficiently complex, unfortunately, that we're going to need.

Reaching a Consensus

Now very quickly I wanted to mention a few more things. What do we need to know to reach a consensus? We need to do a much better job at downscaling the analyses to give some sense to real political leadership. What does this mean for your country? What does this mean for your region? What does this mean for your state? This is important. It's important scientifically, and it is important politically. And we know that it's not just the coastal erosion, the storms, the rise in sea level. It's the health, it's the biodiversity, it's the water flows, the hydrology, the ecosystem functioning, the fisheries. But that's what our scientists have [been] so good at doing. We need to push farther to explain what this really means.

Second, we have to explain much better the abrupt climate change risks, that is, the highly nonlinear effects. This is something we've heard a lot about in the last two days, and we at Columbia hear about every day from our science colleagues, a lot of the epicenter of the work is here. But a lot of the rest of the country, decision makers, policymakers, the broad public does not know about it.

Third, very importantly we have to hear a lot more about the technological options, and in a much more sophisticated way. Because the fact of the matter is this is one of the most promising aspects. The costs of action are lower than we think. They are not in my view negative, this is not a free lunch, this is not the right way to think about it. These technological options are costly, but the costs are less than the benefits, but they are costly. We have to understand how big the costs are. Carbon sequestration is a household phrase at Columbia University. It will no doubt be a household phrase in your household now as well. But it is hardly in the public discussion right now—merits, demerits, knowledge. And this is critical because we happen to believe—our colleagues here happen to believe—this is an essential component of a full solution. How big remains to be seen, but an essential component, let's say an essential component of a relatively low-cost solution if there is one. Because, of course, we may have to do things without it, but then the costs could be dramatically higher. But the public has not heard about this hardly at all, nor have the politicians adequately.

And finally the discussion, the way that it's been going, gets timing and scale wrong, so we have to think much more about the timing and scale. It's actually in my view not helpful to say we must act right now, we must start conserving, we must start doing this, we must start doing that. I actually think it's not analytically right, and things in this complex business that are not analytically right are unhelpful politically. What's analytically right is to spell out our real choices over time, and the understand the trade-offs that time does or does not give us. And those are complicated. It's not right to do everything we can right now, that would be hugely over-costly. It's not right to do nothing right now. It's right to be smart right now, understanding what those time-phased choices are.

Negotiating an Efficient Path

So, three more points quickly, and I am sorry to keep you, I'll try to wrap up.

First question, how do we negotiate an efficient path? First, there needs to be broad public understanding and broad political leadership awareness. Neither of those conditions applies right now. Pew has done a magnificent job in pushing it forward, but I can't say we really have the kind of broad public understanding or the broad political awareness that we need.

Second, we need to think about a long-term framework. I'd say a century scale. This is not easy, but this is the nature inherently of the issue we're dealing with. It is not right in my view analytically to say we're going to do the fifty years, even that is too short for this scale, and then we're going to do the next fifty years. I couldn't quite buy the Princeton approach of saying seven slices up to 2050, then we'll see what happens, because this is not a separable problem in time. What we do today affects our choices in 25 years, what we do in 25 years affects our choices in fifty years, and when you look at the numbers quantitatively, we're talking about a century-scale problem inherently. So the fact we can close some wedge early on in some inexpensive ways doesn't mean that that's how we want to do it, because we may want to take a more expensive way because that wedge becomes much bigger in the second half of the century and by investing in the right way now we're going to lower the ultimate costs substantially. So I want us to think in a longer term way. This is very hard. We're not so good in thinking 'til the evening, we're certainly not good at thinking past November. This is a century scale problem. We don't have to solve it next week, and we don't have to say that if we don't solve it next week all is lost, because that will lead to panic and division rather than to real solutions. But we do need to say we need to solve it, and we need to take care without taking care as an excuse of inaction, but rather setting out a course which is going to arrive at real negotiated solutions and then a time scale which means something. The Kyoto timescale does not. I would urge us to vote for the treaty, but it was not the right way to do it. And those who oppose it have valid arguments about it not being a framework even to think in. It isn't really a framework. Yes, it's a first step, but a first step without knowing something about the second step is a very frightening first step to take. And I can understand why many are not taking that first step, even though I would prefer that we do.

So, third, the negotiations have to be global. It was not right to exclude any country in the discussions, or even in the sense of obligation. Now I know that wasn't formally done in the sense that Annex II countries have their obligations later on. But the fact of the matter is we're going to have to give even better answers because China is big in this question. It may be poor relative to the U.S., but it is big in terms of the climate issue, even today, and it swamps the U.S. down the road probably, if they're successful in the way I hope they are successful.

I made some estimates. They're rough, but I just wanted to show you—and maybe I can and maybe I can't—of the total incomes of China, India, and the United States in mid-century, and that's roughly proportional to energy use. And if you look at the charts on the right-hand side, if things go well, that means we don't blow ourselves up basically. That means that China doesn't blow itself up, that means we don't get into huge conflict with China as a rising power, because leading powers have a hard time with the new kid on the block, even when the new kid has 1.5 billion people. If we're smart and wise and let China have its space for development and China handles itself well, China will overtake the U.S. economy most likely in the first quarter of the century in terms of absolute scale, not per capita income. And in a rough estimate, which isn't probably wildly wrong or wildly super-optimistic, could be as much as 70 percent larger than the U.S. economy in absolute scale, by 2050 in purchasing-power terms. That means they're going to be using a lot more energy, and on current trajectories that could mean a lot more coal, by the way, so that you'd have an added multiplier of lots of $CO_2$and lots of very dangerous black carbon, lots of mess, for China's public health and global health and global environmental health. China needs to be at the table right now. It doesn't mean they have to pay for everything early on, as I said, but they're probably the low-cost solution for a lot of carbon reduction in the future.

India, too, is a major economic force, and it's going to become an even bigger one. And in this scenario I have India eclipsing the U.S. in absolute size in 2047. Now that's only to point out India would be roughly four times the U.S. population and roughly one-fourth the per-capita income, on an optimistic but not wildly optimistic scenario. And so India and China, Brazil, Mexico, others must be part of this discussion now. Again, that's different from . . . there are three different things: who discusses, where decisions get taken, and who pays for them, and those are three different concepts that have to be kept distinct.

Two more quick points. We need systematic proposals. Even among our group, while everyone was thoroughly brilliant in what they said, and they really were, and thoroughly polite also, everyone deferring to everyone else, there actually were a lot of substantive disagreements about what to do. How much is wind going to play a role, how much renewables, how much efficiency gains, how much carbon sequestration? Do you know? Unless you're really good a differential equations, and you've done something that no one has done yet, nobody knows a good answer to that. Because this is actually a quite complicated and iterative process to understand what those real choices are. So people say, "I want to do more renewables, I don't like carbon sequestration so much. Or why don't we just do it by energy efficiency?" This is not a helpful way to think actually. It's a nice way to think, but it actually won't reach a solution because what we need to do is actually quantify these things, understand as best we can what are real choices are systematically. And no one has done that adequately. There are few scenarios out there, but they're not very good and there hasn't been the iterative processes tested one against the other. What we need is a boxing match next time, polite, with gloves. But I want Princeton to go after Columbia, and we'll go back. And Calgary's going to get into the action with David leading his team. And the Stanford modeling group and Bangladesh and TERI at India, the Tata Energy Research Institute. Let's have it out. That's going to be two or three or four years of what really are we talking about, quantitatively? Because we don't know right now actually. And that's asking a lot for our senators to take a step when they don't know what comes and what we're really saying what the real implications are. That's frightening. The truth is going to be much less frightening than it seems, because the choices are probably much better than they seem. But they haven't been laid out with much care.

What is a solution going to look like? Very quickly, it's going to be based on the UN Framework Convention on Climate Change. We actually have an international agreement. It's a good one. We're not going to give it up, we're not going to lose it. Kyoto we might lose, but the Framework Convention we're not going to lose. And doesn't have to be renegotiated. It's going to be a global agreement, it's not going to have Annex I and Annex II actually, it's going to have everybody, but with differentiated roles in a more subtle and sophisticated way. It's going to be a century timescale. For those of you who don't like technological magic bullets I'm going to apologize. It's going to be technologically based, like everything else about our modern society. It's too late to go back to the state of nature. We can't even survive on the planet with 6.3 billion people going up to nine and a half billion people without a thoroughly technologically sophisticated approach to these issues. Because if you want to do it the simple way, we have to go back to three people per kilometer doing hunting and gathering. That means mass species decline of our species. That's what we're trying to avoid. So technology can not simply be shunned or feared, it has to be embraced. It's too late with the population 1,000 times larger than in the Neolithic. Instead of six million we're six billion and rising sharply. We're going to need technologies to address these problems, high technologies.

We're going to need differentiated roles, we're going to need adaptation as well as mitigation, and we're certainly going to need compensation, cross-country transfers somehow. I don't know how, it's hard. I spend most of my time trying to raise billions of dollars for dying people only to see hundreds of billions spent to kill people. It's a frustrating world in that regard, but we're going to have to raise money to help people that otherwise can't afford to be part of the low-cost solution. And so it's going to involve a degree of international collegiality, a sense of a global system that is much more unified than ever before. Be sure of it.

Earth Institute Efforts

Finally just a word. What is the Earth Institute going to do? Let me quickly mention a few things for our great friends the alumni here and all of the public. We're very proud, I'm extremely proud as a new arrival at Columbia, to be part of this community. I'm just thrilled every day at the incredible good fortune that I've had to become director of the Earth Institute. We're doing a lot of things here, it's exciting, we'd love your participation, your engagement, your participation in conferences, your support. We're doing basic climate research. This seminar was organized and hosted by Lamont-Doherty Earth Observatory, one of the great scientific centers in the world in earth sciences. We are at the center of abrupt-climate-change research. We're at the center of modeling of long-term climate change with the global model invented and maintained by Jim Hanson and his team at the Goddard Institute of Space Studies. We have cutting-edge research on annual and interannual climate change at the International Research Institute on Climate Prediction and at the Department of Earth and Environmental Sciences. So we will be in the forefront of basic science research on the climate.

We will also be in the forefront on applied climate research, applied research. This International Research Institute on Climate Prediction works with the poorest people in the world to help them think through what it means when we have a good idea that a drought lies ahead because of the El Niño southern oscillation in the western Pacific affecting rainfall patterns in the Sahel and in southeast Africa. And we're working all over he world with poor communities to help them adapt to climate change. Upmanu Lall, who you saw several times here, is a world-class hydrologist thinking about drought and river system management and watershed management all over the world. Cynthia Rosenzweig has led a remarkable effort on downscaling global models to be true practical instruments for applied climate research at local scale. We're doing applied economics research. Geoffrey Heal leads a remarkable effort on looking at economic incentives to get these things right. And we're hoping to launch a major effort to put green into the national-income accounts because if we don't have measurements that make sense, we're not going to make the right decisions. And Geoffrey with Partha—who is on our advisory board and we're hoping will spend more and more time here—Geoffrey and Partha are the two leading experts in the world on the theory of how to do this.

We are, I'm sure you sensed, already in the forefront of engineering solutions. Even if we didn't have a great engineering school having Klaus Lackner is like having ten of them, just simply the most brilliant thinker around on the long-term carbon management issues. And we're doing a lot of research on carbon capture technologies, on thinking about how to manage the carbon problems in ways that have never been done before. And Klaus started this more than a decade ago, and now it's becoming recognized that this is a critical component of any clear thinking to this.

We're also doing public outreach. GISS, Jim Hanson's team, in an effort led by Carolyn Harris, works with the New York City schools, especially the schools in poor neighborhoods, to bring in hundreds of kids every summer to do real research projects on measuring air quality, on working with Jim Hanson, one of the greatest climate modelers in the world, on the global model. It's absolutely a thrilling thing and with Carolyn we're trying to work on expanding our capacity to reach K through 12 curricula.

These conferences, we've had two back to back, thrilling sessions, "State of the Planet" and 'Taming the Climate." They'll be on the Web site. I'm hoping we can get them out as books or as a book in the very near future because what you've heard here shouldn't just go into the atmosphere. It should be globally mixed but not dissipated, so I would like it to be sent out all over the world and we'll try to find effective ways to do that.

There's one more effort that we are going to undertake, which is extremely exciting, and I think potentially path breaking, and we'll do it with a lot of the colleagues that have come here already and in an expanded group. There is a process which I've come to really admire. I participated in it myself on two recent occasions on a significant scale, something that is called analytic deliberation. I chaired a commission for the World Health Organization a few years ago about the state of public health in the poorest countries. And we got around the table some of the world's leading practitioners and thinkers who disagreed with each other tremendously at the beginning. And after two years of talking, not every day but a series of meetings, we actually issued a unanimous and quite bold report, which changed a lot about the way that the international community is talking about global public health. It helped get the President's Initiative on AIDS started, it helped get the new Global Fund on AIDS, TB and Malaria started. It said we have to invest money in it because here are ways that it can be done.

What for me was remarkable about that effort was that it brought together leaders that did not agree with each other, didn't even like each other. But it was the analytic, the deliberation. It wasn't a one-shot crossfire of your sound bite versus mine. It was an incredibly detailed, rich scientific effort where, when there were disagreements in the room, we commissioned a paper, and then came back in three months and discussed it. And it led to consensus. Now on behalf of Secretary-General Kofi Annan, I'm trying to lead a similar effort, even larger, on the poverty-reduction goals of the international community, the so-called millennium development goals.

I believe that the climate-change issue is exactly of the character where analytic deliberation can make a fundamental difference. And I believe that if we can get around the table leaders from India, Bangladesh, China, Brazil, New York City, Europe, other parts of the world, leaders from business, CEOs of major companies, CEOs of the utility industry, CEOs of the automotive industry, CEOs of the energy industry, leading environmental activist groups, that don't like each other, cross-corporate environmental with the full dose of science and rigor and not forcing anyone to agree to anything too early, but having everyone walk into this little plot understanding that the goal is to have a serious enough deliberation that they're expected to come out with an agreement if that's possible. I think what we can show is that the major stakeholders in the world—rich and poor, corporate, noncorporate, coastal, interior, even red state, blue state—can reach a consensus about the things that can be done. And I'm absolutely thrilled to announce that a wonderful philanthropist and benefactor, the Lenfest Foundation, has given us the support and generous backing so that we can launch this process. And the pledge is that we're going to use this very generous support of a great business leader and environmentalist, Gerry Lenfest and his foundation to bring together world leaders, to use this extraordinary venue of Columbia, of the Earth Institute, and of New York City which is unparalleled in the world for this kind of process, to show that there is a sensible approach for us in this century, that human society really can find agreement on critical issues, that we can think wisely, long-term, even generously and with an open heart. And that I think will be the way forward.

Thank you very much.