Old Mission Point, 2005. Warmer temperatures lead to reduced ice cover on the Great Lakes, evaporation of the water during the winter, and lower water levels in the lakes. Photograph by Todd Marsee, Michigan Sea Grant Archvies.

Energy and Climate Change

Rosina M. Bierbaum, William K. Reilly, and Richard L. Revesz
Introduction by Richard A. Meserve

This panel discussion was given at the 1916th Stated Meeting, held at the House of the Academy in Cambridge on October 7, 2007.

Richard A. Meserve

Richard A. Meserve is President of the Carnegie Institution of Washington and former Chairman of the U.S. Nuclear Regulatory Commission. He has been a Fellow of the American Academy of Arts and Sciences since 1994.

We have an opportunity this morning to have a far-reaching discussion about climate change with three extremely knowledgeable individuals. My role is to set the stage for them by laying out a few facts.

Figure 1 shows the exponential growth in world energy usage from 1850 to 2000. That growth will extend into the future; energy consumption is expected to increase by as much as 50 percent over the next 25 years, with disproportionate growth in the developing world. The different wedges in the figure indicate the various sources of energy. Fossil fuels meet 80 percent or so of energy demand; an additional 10 percent is derived from biomass. Because we are burning biomass at a rate faster than replenishment, it too is adding a carbon burden to the atmosphere.

Not surprisingly, as shown in Figure 2, the growth in energy usage resulted in an enormous parallel increase in global carbon dioxide emissions. This has caused, of course, increased concentrations of carbon dioxide in the atmosphere. In Figure 3, we see the concentrations of carbon dioxide in the atmosphere as measured in Hawaii from 1960 to the present. CO_2 concentrations have increased from about 280 parts per million (ppm) in the pre-Industrial period to 380 ppm or so today. The annual oscillation in the figure arises from the fact that most of the landmass on Earth is in the northern hemisphere; we see a downward cycle in the spring as photosynthesis takes carbon dioxide out of the atmosphere, and a corresponding increase in the fall.

What does all this mean? Everyone has heard about global warming. Figure 4 shows the global average temperatures from 1600 to 2000 and then a projection into the future. Scientists have developed several different but generally consistent ways to estimate global temperatures in the past. The data show a slight increase up to the present. The gray area shows the range of estimates for the future based on various scenarios involving economic growth and energy supply. The estimates are from the Intergovernmental Panel on Climate Change, a world consensus body that is studying the climate change problem. They show a stark increase above the historical baseline.

Climate change will have many effects beyond temperature change. Unfortunately, many of these effects are now already being observed.

The range of estimates for the future is broad: from the relatively small increase of two degrees at the low end up to much higher average temperatures at the upper end. Unfortunately, experience suggests that we are moving toward the upper end of the range rather than the lower end. And although these numbers may not seem large, it must be remembered that these are global average temperatures. The temperature increases are much larger at high latitudes than they are at low latitudes. So relatively small changes in the global average can mean very large changes at high latitudes.

Climate change will have many effects beyond temperature change. Unfortunately, many of these effects are now already being observed. No one can say whether a particular hurricane, for example, is the result of climate change. But one expects that the average hurricane will become more violent, and we are starting to see that. All over the globe, glaciers, ice caps, and sea ice are melting. This past summer the sea in the northern latitudes was as open as it has been in recorded history.

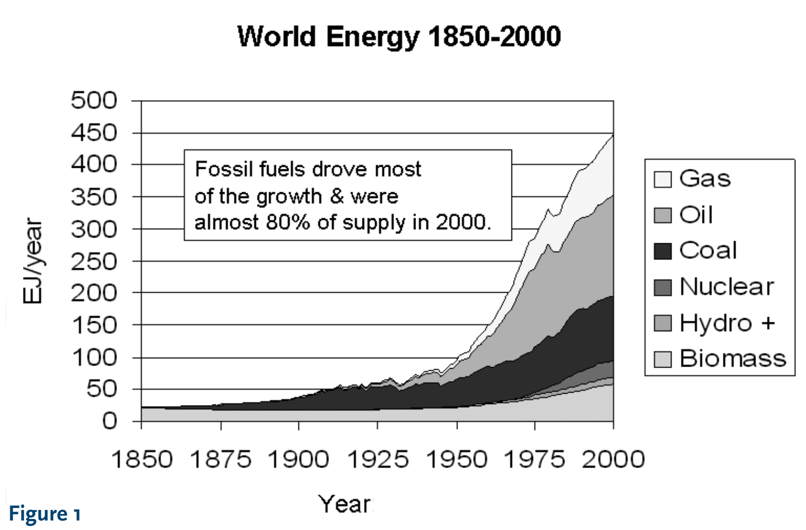

Figure 1

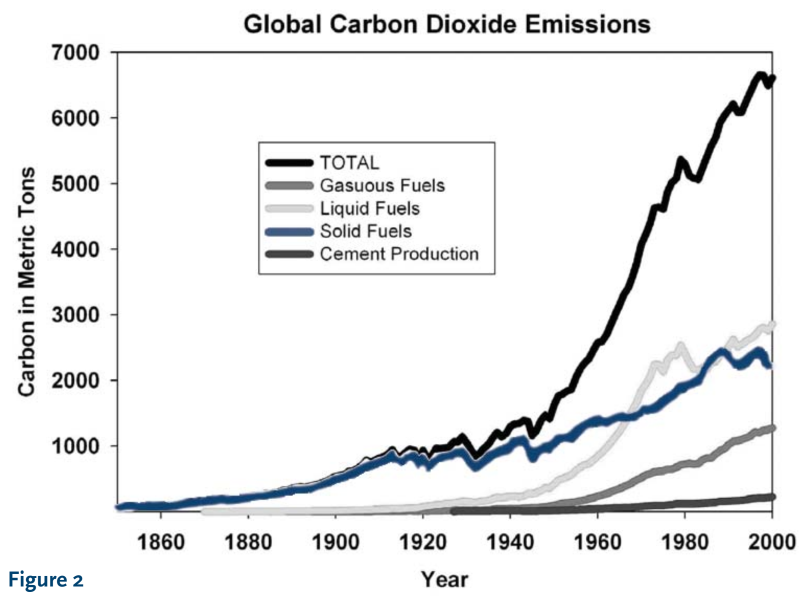

Figure 2

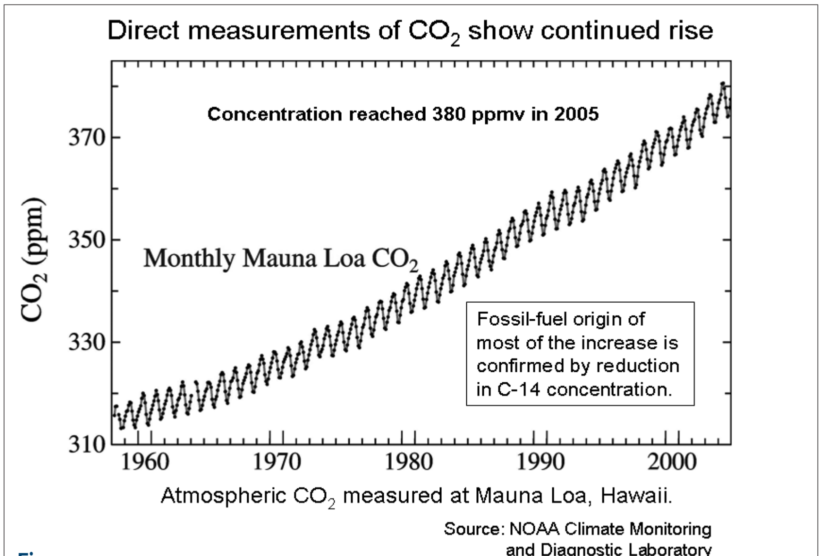

Figure 3

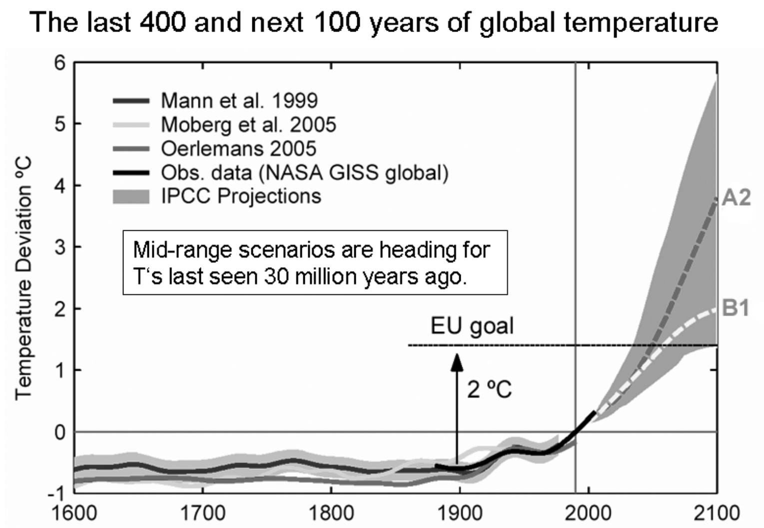

Figure 4

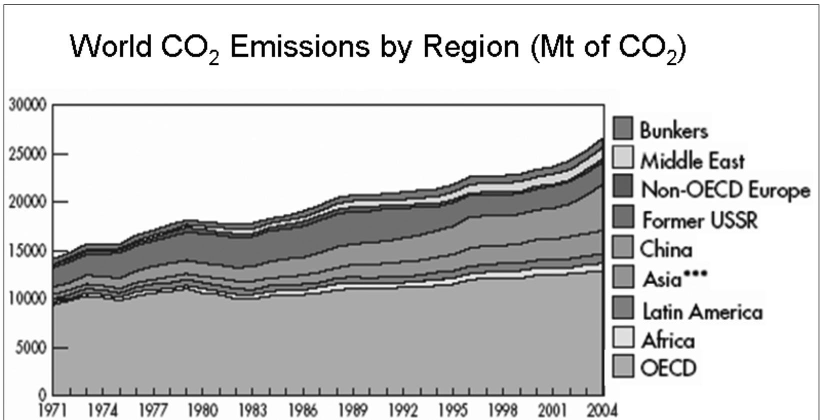

Figure 5

Source: IEA, 2006

CO_2 Data

	CO_2 Emissions (Mt of CO_2)	Population (million)	CO_2/Pop (t CO_2/capita)	GDP (billion 2000$)	CO_2/GDP (kg CO_2/2000$)
World	26583	6352	4.18	35025	0.76
China	4769	1303	3.66	1904	2.50
India	1102	1080	1.02	581	1.90
United States	5800	294	19.73	10704	0.54
OECD	12911	1164	11.09	27698	0.47

Source: IEA, 2006

Figure 6

Heat stress to crops and people is another problem. At the same time, changing patterns of rainfall will have profound effects on agriculture. The projections show that the droughts plaguing Africa will grow worse. And we can expect outbreaks of agricultural pests because they will survive future winters without the cold weather to kill them.

We will also experience increased burdens of infectious diseases as tropical vectors move north. In the United States, we are already starting to see diseases that we have previously considered tropical diseases. Climate change is threatening biodiversity as well. The changes in temperature are occurring so fast that species cannot move northward or to higher altitudes rapidly enough. They may not find niches with appropriate temperature and other conditions that they need to survive. So one expects enormous reductions in the number of species that will survive through the next century.

Finally, there is the acidification of the oceans. With increased concentrations of carbon dioxide in the atmosphere, more carbon dioxide will dissolve in the seas, producing carbonic acid. Acidification will have an impact on the many species that take calcium carbonate from sea water and use it to build shells or skeletons. We have already observed changes in the pH of the ocean. A group of 25 oceanographers published a paper last week projecting that, by the middle of the twenty-first century, the surfaces of the world's oceans will violate the EPA's water quality standard for pH.

Climate change is a severe challenge that no one country can solve. Figure 5 shows world CO_2 emissions by region from 1970 to 2004. As China and Asia grow economically, their demand for energy will increase and their emissions will go up.

In Figure 6 we have data from the International Energy Agency. Let me draw your attention to the third column, which shows estimates of the releases of CO_2 per capita. The United States has considerably larger CO_2 emissions per capita than any other country on this chart and China has about five times less per-capita emissions of CO_2 than we do. The Chinese can legitimately make the argument that they have the right to emit more. They can claim that they need more energy for their own economic growth.

But if countries at the low end use more carbon, the earth will become unsustainable for all of us.

The fifth column reflects an additional complication: the tons of CO_2 per dollar of gross domestic product. China is far less efficient in its use of carbon than we are. So at the same time that the Chinese are expanding their usage of fossil fuels, they are not doing it in an efficient manner, which aggravates the problem.

Let me return to Figure 1 and flag one additional issue that deserves to be on the table: the increase, from 1925 to the present, in the size of the wedge from oil. Beyond the climate change problem, the world's dependence on petroleum creates the special problem of energy security. It is hard to beat gasoline as a transportation fuel because of its high energy density. Yet, as we see in Figure 7, about 60 percent of the world's oil supply comes from the Middle East, the former USSR, and Africa. So for reasons completely independent of climate change, we need to be concerned about dependence on oil from unstable areas, in particular from countries who might use oil as a tool for international influence.

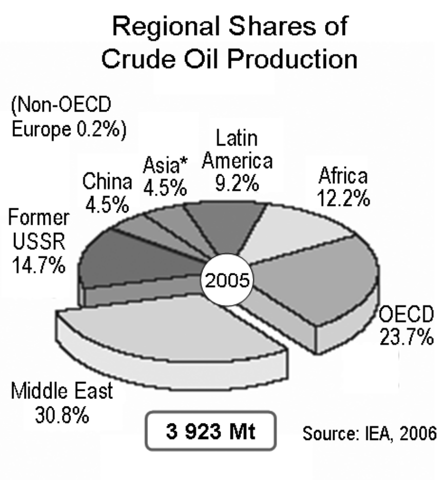

Figure 7

My comments merely set the stage for today's discussion. I hope that our three speakers this morning will reveal a path out of the dilemma in which we find ourselves.

Rosina M. Bierbaum

Rosina M. Bierbaum is Professor and Dean of the School of Natural Resources and Environment at the University of Michigan. She was elected to the American Academy of Arts and Sciences in 2007.

Time is short, both for my presentation and for humanity to confront this problem. The range of temperatures that Dick showed for the next century, up to 6 degrees Celsius, or 11 degrees Fahrenheit, is a phenomenal increase to occur in 100 years, which is a geological blink of an eye. So I want to start by saying that we need to begin thinking about climate change in a different way. It is certainly "a matter of degrees," as depicted by the thermometer, but we also have to think about climate change as the "degrees" or composite of environmental insults, including habitat fragmentation, biodiversity loss, pollution, and coastal erosion. We must consider the impact of all these interacting problems simultaneously, and try to solve them together, because by addressing just one problem, we may unwittingly create or exacerbate another.

We also need to think about climate change in terms of "degrees" of latitude and longitude. Where you live on the planet determines how climate change will feel to you. It also determines what resources and capability you have – economic, scientific, and technological – in order to address those changes. We, as a society, have spent a lot of time studying climate change as a matter of degrees of temperature, and far too little time understanding composite stresses and regional impacts.

My take-home messages are four points. First, the degrees of warming matter. Mitigation will make a difference: the more we can control and slow the increase in temperature, the better the possibilities for coping with the changes. Second, we are already committed to further climate changes. Temperatures have already increased 0.8 degrees Celsius, and another 0.4 to 0.5 degrees are in the works from greenhouse gases already emitted. Significant change is under way. The rate and magnitude of these changes make achieving the Millennium Development Goals, which were set by the United Nations in 2000, much more complicated. Third, it is not just the average changes that are of concern, but how climate change affects the vulnerability of particular regions, concomitant with multiple stresses, and the manifestation of extreme events (heat waves, floods, droughts, and hurricanes). These impacts cause great economic and human pain. Fourth, to effectively tackle climate change, I would argue for a portfolio approach. We need mitigation – that is, to reduce the emissions of greenhouse gases and slow the rate of temperature increase – but we also need adaptation to cope with the changes already under way and the impacts that are in store.

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Dick showed us that the temperatures have already increased 0.8 degrees above pre-Industrial levels. Mountain glaciers are already disappearing. As the average temperature rises to about a degree and a half, we will start seeing more extensive damage to coral reefs. As the average temperature rises to two and a half degrees, another 2 billion people will likely experience water shortages, and between 20 and 40 percent of the world's species will be at risk of disappearing. At three and a half degrees, all sectors of society across the globe are projected to be experiencing significant impacts. And remember that fully half of the projected range of tem-

Climate change will impact all sectors and regions. Source: OSTP, 2000

Where you live on the planet determines how climate change will feel to you. It also determines what resources and capability you have – economic, scientific, and technological – in order to address those changes.

perature increases that Dick showed us for the next century is above this level. So the odds of going beyond three and a half degrees are very high, unless immediate reductions in greenhouse gas emissions begin.

What happens as temperatures increase? The water cycle of the planet speeds up, which increases precipitation and raises the sea level, both from melting mountain glaciers and from thermal expansion of water. Those changes in temperature and the hydrological cycle alter the ideal range where species live and flourish. They certainly change the availability and quality of water for our crops and forests, the sea level at our coasts, and the integrity of our ecosystems as a shifting climate map moves over them and the parts that swim, crawl, and fly try to keep up with the changes. The resultant heat waves and change in distribution and extent of disease vectors also affect human health (see illustration above).

Certainly, we have studied the effects of climate change to some extent but we have tended to do so sector by sector. Unfortunately, climate change is occurring simultaneously to all sectors. Further, we have not analyzed to any great degree how climate change will affect the livability of our communities, or our ability to provide energy services, or the impact on commerce and trade. I would argue that we best get on with understanding the character and magnitude of changes to our ecological, economic, and societal systems.

I had the honor of cochairing a United Nations report that came out earlier this year entitled *Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable*. "Avoiding the unmanageable" means trying to mitigate climate change or reduce emissions, and "managing the unavoidable" means trying to cope with the harm. We concluded that most impacts of climate change will be negative, especially for the poorest and most vulnerable nations. Achieving the Millennium Development Goals will be difficult because climate change will affect all resources in all regions. Our city, state, national, and international institutions are ill-prepared to cope with these changes, so we need to enhance our preparedness. Both mitigation and adaptation are needed: mitigation will not work alone because it is too late to avoid substantial climate change; adaptation alone will not work because adaptation measures become more costly and less effective as the magnitude of the changes to which one is trying to adapt increases.

The Millennium Development Goals (listed at right), which the world pledged to meet, address poverty, education, equality, childcare, maternal health, disease, environmental sustainability, and development. At first blush, it might appear that only number seven, "Ensure environmental sustainability," is linked to climate change. But, as agricultural lands shift, water availability changes, and disease vectors move, our ability to provide food, improve health, provide clean water, and sustain natural resources will be degraded. As climate changes, the baseline against which we intended to measure progress on these goals shifts, and so climate change becomes absolutely central to goals one, four, five, seven, and eight. However, all the Millennium Development Goals will become difficult to achieve as climate changes because economic, ecological, and sociopolitical stability are inextricably interlinked.

Millennium Development Goals

1. Eradicate Extreme Poverty and Hunger
2. Achieve Universal Primary Education
3. Promote Gender Equality and Empower Women
4. Reduce Child Mortality
5. Improve Maternal Health
6. Combat HIV/AIDS, Malaria, and Other Diseases
7. Ensure Environmental Sustainability
8. Develop a Global Partnership for Development

I mentioned that we need to understand regional impacts and the interaction of multiple stresses with climate change. To give you an example, the map on the left in Figure 1 displays ozone concentrations in the Eastern United States with today's climate and air pollution. The map on the right shows ozone concentrations with the climate and emissions projected for 2050. Note that there could be increases in ozone levels of more than 10 percent across much of the North-

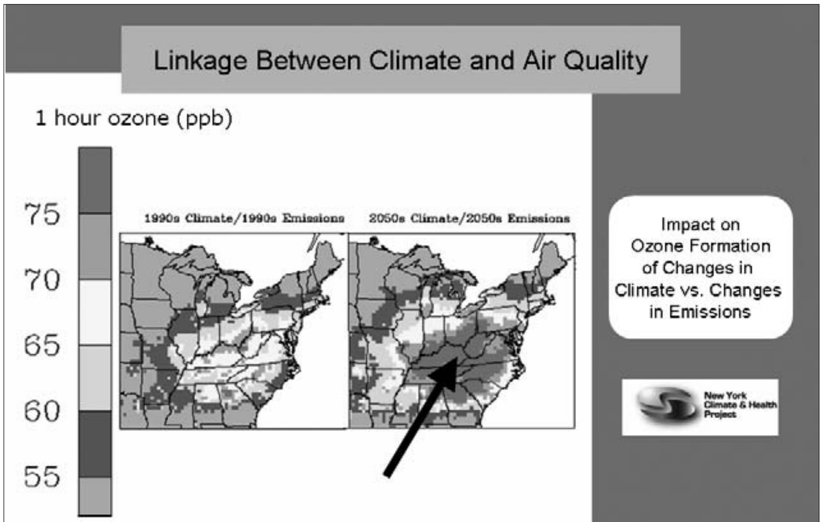

Figure 1

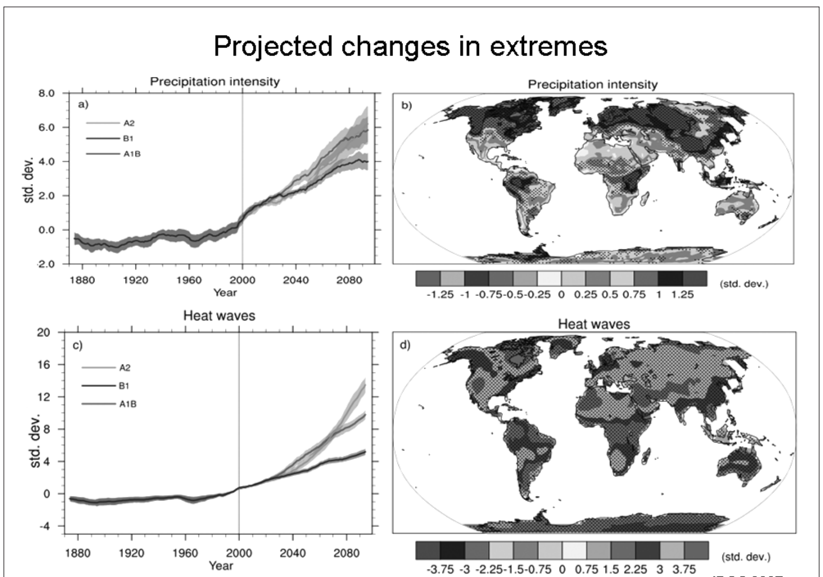

Figure 2

east (indicated by the arrow). If we do not think about how climate change and air quality interact, or more specifically how warmer temperatures enhance smog formation, we might not be able to achieve the standards we have set to protect the health of the most sensitive populations.

Understanding how climate change will impact extreme events is a high priority. Extreme events are increasing, and the human pain and economic cost are enormous. We do not handle droughts, floods, heat waves, and hurricanes well now, and, as Dick said, more are in store in the future. The upper panels in Figure 2 show the change in precipitation intensity over time. Such downpours cause floods, erode our soils, wash pollutants into our waterways, and damage crops. Rainfall intensity has already increased, and by the end of the next century, it is projected to increase greatly in many parts of the world. In the Midwest, where I live, we have already experienced a doubling in intense precipitation events from 1950 to now, and we expect that they will double again over the course of the next century.

The bottom panels in Figure 2 show the change in heat waves, which have increased slightly in recent decades. But we are headed toward a huge increase. The heat wave in 2003 in Europe, which killed 35,000 people in a rich part of the world, could become the norm as frequently as one out of every five years. Clearly, we have to learn to adapt to such dramatic increases in extreme heat and extreme rainfall. In fact, worldwide weather-related disasters in 2005 cost $375 billion, a third of a trillion dollars. That kind of cost will continue to increase, and surveillance, preparation, and response strategies are necessary in order to cope.

Even as this challenge is growing, adaptation research is lagging. A National Research Council Report (NRC) from September 2007 shows that while we are making some progress in understanding the physical climate system, we are losing the capacity to observe it, principally via satellites. Of the $1.7 billion that we spend on climate research, only $30 million is currently spent on understanding human dimensions – clearly incommensurate – and the NRC warned that we are not making progress in understanding vulnerability to climate change and its potential impacts on humans, conducting risk analysis, or understanding what stakeholders want from science to aid decisionmaking.

It is essential that adaptation options be developed rapidly. The list below is an example of some adaptation needs that came out of the First National Summit on Coping with Climate Change, held at the University of Michigan's School of Natural Resources and Environment in May 2007. Adaptation options can include wise management, new technology, changed institutions, monitoring, and research and development. For example, management of natural resources could be designed to be "robust" over bigger spatial and longer temporal scales. New design criteria may be needed for levees, reservoirs, and dams. Species preservation may require active facilitation of migration or "banking" of genetic material.

Adaptation options include:

- Prioritize Lands to Preserve
- Design Migration Corridors for Species
- Create Infrastructure to Withstand New "Extremes"
- Link Reservoirs to Enhance Supply
- Seed Banks, Mass Propagation Techniques
- Create Emergency Response Plans
- Design Early Warning Alert Systems/ Surveillance

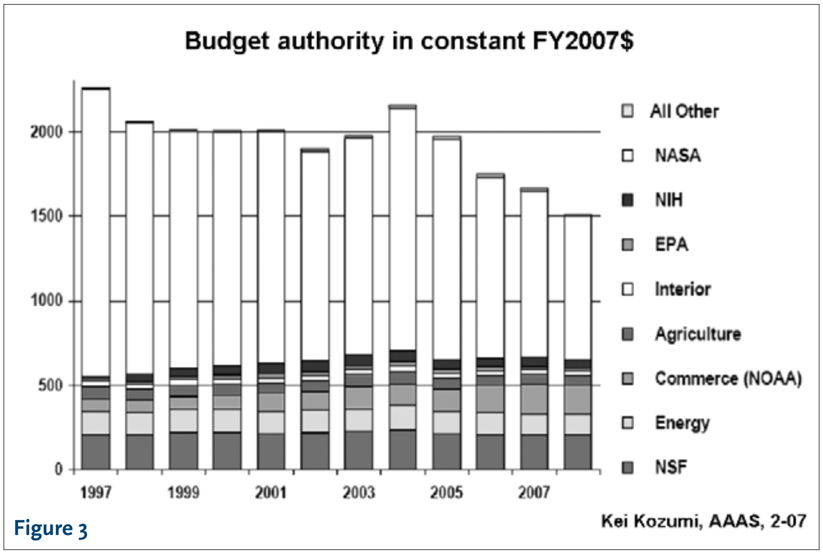

Figure 3

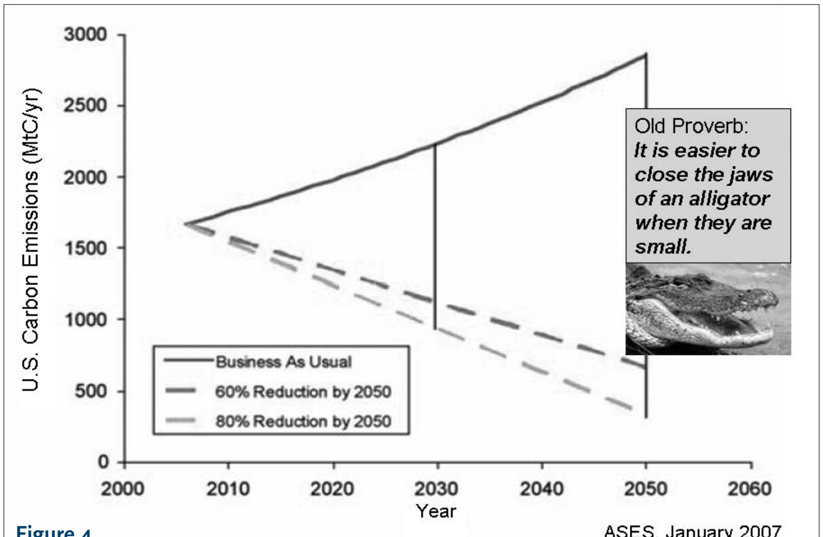

Figure 4

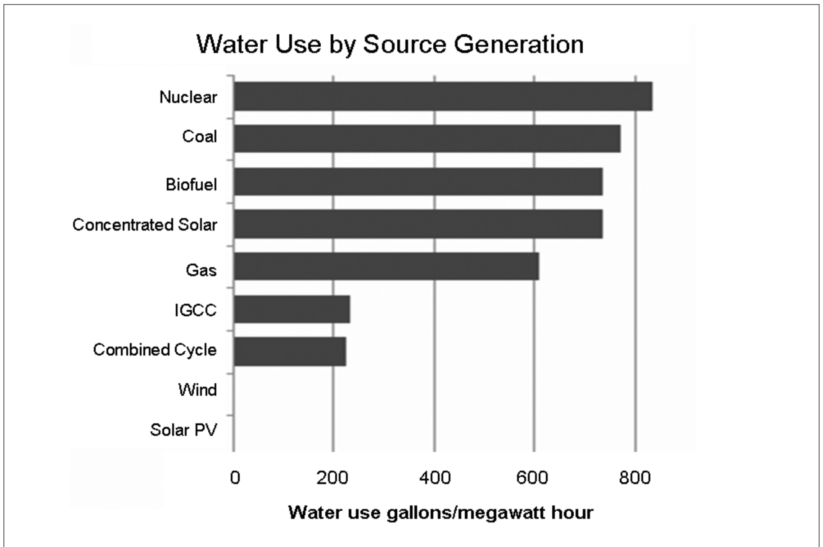

Figure 5

The degrees of warming matter. Mitigation will make a difference: the more we can control and slow the increase in temperature, the better the possibilities for coping with the changes.

This country also needs to conduct Integrated Assessments that not only synthesize the available scientific and technological information, but also identify near-term actions that make sense to implement, while also laying out short-term and long-term strategies and research needs. The United States has not published an integrated national report since the first National Assessment mandated by Congress was published in 2000. And, even as these issues become more pressing, the federal budget for this work is declining. It was $2.5 billion at its peak in 1997; it is down to $1.5 billion now. If you think about ecological impacts and infrastructure planning, the agencies that need to be involved in addressing these issues have extremely modest budgets to do so. In Figure 3, the slivers representing the Environmental Protection Agency and the departments of Agriculture, Energy, and Interior are incommensurate with the task.

Potentially good news is on the horizon, though. A memorandum from the Office of Management and Budget and the Office of Science and Technology Policy outlined the President's FY'09 priorities to the Federal agencies. It states: "Agencies should continue to make investments to improve our ability to observe, model, assess, and adapt to impacts of climate change, particularly on a regional scale, and to assure the availability of critical long-term climate data." So as agencies put their budgets together and submit them to Congress in February 2008, they should reflect these priorities, and I hope both Congress and the community will insure that they do.

On the mitigation side, or the energy technology side, things are not much better. Energy research peaked at about $6.5 billion, and we are down to just a little bit above

$2 billion. So what we are spending on all of climate science and all of energy research amounts to less than $4 billion a year. This drop in funding is happening worldwide, too. A 2006 Organization for Economic Cooperation and Development report said that the world public funding for energy has dropped from about $11 billion to $8.3 billion, and private investment in energy has dropped from about $9 billion to $4.2 billion. Yet if you look at the prodigious growth in energy supply that will occur in developing countries, there are going to be hundreds of billions of dollars in infrastructure built in the coming decades. I would argue that with this kind of investment, the United States is certainly not positioning itself to capture that new energy technology supply market. These expenditures are simply incommensurate with the task.

If we want to get down to the two to three degrees that Dick mentioned, this is what the United States would have to do to contribute its share. Figure 4 shows our "business as usual" curve. We would have to be on one of these two curves to head down, by about 2050, to a 60 or 80 percent reduction – our share of holding average temperature increase at two to three degrees. The Senate bills that are appearing – the McCain-Lieberman, the Kerry-Snow, the Saunders-Boxer, the Bingham-Specter, and the Lieberman-Warner – would all put the United States in this range, which is quite phenomenal. We should pay attention to the old proverb that it is easier to close the jaws of an alligator when they are small – and begin to make progress now.

But as clean energy solutions are sought, we have to be cognizant of the intersections between energy choices and natural resources. This is an area that has received very little attention. Figure 5 shows water use by source, in gallons per megawatt hour. Notice that biofuels, coal, nuclear, and concentrated solar all use a lot of water per megawatt hour. And just yesterday, a new Fellow of the Academy and my former boss, Jerry Melillo, reminded me that biofuels production might also lead to massive nitrogen fertilizer use that could then contribute to runoff, eutrophication of our water bodies, acid rain, etc. So there are "devils in the details" of mitigation and adaptation options that we need to consider together.

However, we can produce wise integrated mitigation and adaptation strategies. For example, sustainable land and water use policies serve multiple purposes – they are vital for agriculture, forestry, energy production, and biodiversity preservation. Renewable energy sources can be new income streams for communities that are currently importing and paying for oil, coal, or gas. Building efficient and healthy buildings that can withstand increasing floods and storm surges is a win-win.

To conclude, the past is not prologue. Basing the management and planning of energy and natural resources on the climate of the last hundred years is wrong. Adaptive management will be needed in all sectors, in all regions, to cope with changing averages, extremes, and composite stresses. Our current investment is simply incommensurate with the urgency of the problem. We need integrated science assessments and serious research development and deployment in both mitigation and adaptation.

Our generation is leaving the next generation a great challenge: sustainable management of our ever-changing planet. In order to give the next generation a chance to achieve this, we must rapidly stem the rate of growth of greenhouse gas emissions into the atmosphere, principally from energy use, and learn to cope with the changes already under way in our lifetime.

William K. Reilly

William K. Reilly is Senior Advisor to TPG Capital, Founding Partner of Aqua International Partners, and former Administrator of the U.S. Environmental Protection Agency. He was elected to the American Academy of Arts and Sciences in 2007.

I have, I think, a hopeful message this morning. One of the more encouraging developments of the past year has been the commitment by a number of our leading corporations to public policies regulating carbon dioxide in the United States. This commitment has been most notable in the 13 companies and nonprofit organizations that form the United States Climate Action Partnership. They include DuPont, Pacific Gas and Electric, Johnson and Johnson, Duke Power, General Electric, and others. This group has ambitious goals.

One of the more encouraging developments of the past year has been the commitment by a number of our leading corporations to public policies regulating carbon dioxide in the United States.

Now, why would a company commit to carbon regulation? I think of my own association with the DuPont Company, on whose board I have served as Chairman of the Environmental Policy Committee since 1993. DuPont underwent a transformation when they discovered that chlorofluorocarbons, a product that generated $800 million in revenue, contribute to upper atmospheric ozone depletion. It was a stunning development for a science-based company that had considered itself responsible and mindful of the public good. This realization sensitized the company to other aspects of its operations and how those aspects related to the climate. The company changed drastically. Ed Woolard, the chairman at that time, began to refer to himself as the Chief Environmental Officer, CEO; and the company has, since 1990, reduced its greenhouse gas emissions by 72 percent. In the process, it has saved $3 billion in energy costs and has begun to transform itself from a chemical to a biological company, producing seeds that are designed to withstand droughts and lower frost intervals and generating other products, like non-fossil fuels that help us adapt to climate change.

Conoco Philips, another company on whose board I have served for a lesser period of time, recently became the first U.S. oil company to support the United States Climate Action Partnership. In that case, the decision rested upon two judgments. First, the Chief Executive Officer, Jim Mulva, and the senior management came to believe in the science that Rosina just presented. That belief, together with a sense that if the science was correct and the country and the world were headed in the direction it suggested, prompted the company to undertake to transform itself from an oil company into an energy company. It also recognized that profound new public policies were likely to impact the economic sector in which they worked, and that those companies that embraced progressive public policies earlier would be more likely to be taken seriously in the design of those policies.

One of the most notable responses to the company's promise to support California's new low-carbon energy commitment came the day after the company announced it would support the partnership, when the governor of California called the chairman and invited him to help design the low-carbon fuel standard for the state. This task is going to be highly complex, but it seems it will bear fruit for the company. Company insiders still refer, however, to CO_2 elimination as "demand destruction" with respect to its product, oil and gas. And obviously that presents particular challenges to an oil- and gas-producing company.

I would like to turn to a deal with which I have been extensively involved: the acquisition of Texas Utilities Company by TPG Capital, KKR, and to a lesser extent, Goldman Sachs. About a year ago, Henry Kravis and David Bonderman went to Texas to propose this deal to John Wilder, the chairman of Texas Utilities. The proposal was to acquire and take private a public utility, the largest electricity-generating company in Texas, with a 37 percent market share in the fastest growing electricity market in the United States. It also had some $11 billion in revenues and $2.6 billion in net income, with a share price that increased from $5 to about $60 over the last four or five years.

What I think it means to China is we will not let the lights go dim and the air conditioners go off. We will meet demand, but we will do it in a much more moderate and responsible way.

However, a great deal of anger has been directed at Texas Utilities. Texans, who had been promised reductions in their rates as a result of deregulation, have in fact seen a twofold increase in rates. Gas prices during the period had gone up fourfold, which explains the rate hikes that angered members of the Texas legislature and the ratepayers. Environmentalists despised the company, and we resolved that if we were to go ahead and make this $45 billion investment – the largest private equity investment ever made at that time – we would have to have the active support of the environmental community. So we spent several weeks looking at all of the opportunities to improve the environmental performance of a company of this sort. Through numerous conference calls, many of those with people I did not know, we came up with a number of proposals, and it fell to me to oversee the negotiation with the environmentalists.

I selected two environmental organizations. Obviously we wanted two, so as not to expose one to the kind of criticism that a deal like this might entail. I have often been asked why I chose the ones I did: Environmental Defense (ED) and Natural Resources Defense Council (NRDC). Environmental Defense is an environmental group that does deals. They did deals with me when I was Administrator of the EPA, most noticeably one in which they insisted on a cap on sulfur dioxides in the United States, a permanent cap in the Clean Air Act, in exchange for their support of the proposed bill. They and I, on behalf of the first Bush administration, agreed to that compromise one evening, and Fred Krupp, head of Environmental Defense, kept his word to support our bill.

Fred had a representative in Texas who was not particularly popular with the energy sector there, a man named Jim Marston. He had referred to TXU CEO John Wilder as the Jeffrey Skilling of the electricity business. So there was a history of severe animosity. But since ED had made its campaign against TXU's proposed expansion of coal-fired power a high priority, and had been handing out fliers in the legislature and running television ads and the rest, they were the logical people to deal with. Natural Resources Defense Council is also a very effective and respected organization, particularly with respect to climate change, and so I also brought David Hawkins of NRDC, another longtime friend and colleague, into the deal.

The most notable problem was how to meet Texas's growing capacity need in an environmentally responsible way – without increasing carbon dioxide emissions. Texas, by the way, is first in the Union in carbon dioxide emissions. When I mentioned this to one Texas legislator as the nature of the problem, he said with enthusiasm, "Yes," and I realized I had to change my pitch.

One of the things we looked at was whether to build Integrated Gasification Combined Cycle (IGCC) plants to address the carbon dioxide problem. Gasification, contrary to some perceptions, does not itself involve the capture of carbon dioxide. It involves the generation of gases that are more readily amenable to capture, transport, and sequestration when the appropriate technology and infrastructure are in place. I do not mean to demean IGCC, but we looked at the economics of gasification carefully, and in a deregulated state like Texas, where one cannot simply pass the cost onto the ratepayer with the agreement of the regulator, economic competitiveness is fundamental. The technology providers do not offer warranties either for the cost of the facilities or for the reliability, neither of which have yet been adequately demonstrated.

What commitments did we make? I brought Jim Marston to San Francisco. We sat down at 7 o'clock in the morning. *The New York Times*, in a front page story, later reported on what we had for breakfast at that conversation. And by the way, just to give you a sense of how strong the feelings were on this, when I asked David Hawkins of NRDC, without mentioning Texas Utilities, about his views on coal, he said, "If you want to understand how bad it can get, look at the expansion plan of Texas Utilities. They're going to build 11 new coal-fired power plants in Texas, and 3 more in the deregulated states of Virginia, Maryland, and Pennsylvania. It's the *Mein Kampf* of the carbon wars." I went back to my partners and said, "I think this could be harder than we thought."

At any rate, David was one of the people who went through the long negotiation with me. We agreed to scrap all 3 of the coal-fired power plants that had been contemplated in the 3 deregulated energy states, and 8 of the 11 coal-fired power plants planned in Texas, in return for the environmentalists' agreement to support the remaining 3. We promised a significant reduction of SO_2, NO_X, and mercury in all 18 existing Texas Utilities facilities. And we assured the environmental community that the company would embrace carbon regulation and apply for membership in the United States Climate Action Partnership. This, I might add, stunned the Texas congressional delegation, and just a few weeks later, Conoco Philips, another major Texas energy company, also committed to join the partnership. So in terms of the long-term political impact, the deal may turn out to be somewhat significant as well.

We also committed to spend $400 million on energy efficiency to bring down the CO_2 growth rate and energy use over the next five years, and to make TXU the largest purchaser of wind power in the country. Texas is particularly well suited for wind and already leads the Union in production of wind power. TXU's commitment to purchase large amounts of wind power made it possible to finance more wind power in the state by guaranteeing the offtake. Finally, we committed never to build another conventional pulverized coal-fired power plant. We are betting on technology that relies on noncarbon or carbon-capture technologies to increase Texas's capacity. Texas, by the way, because of its history with enhanced oil recovery, has the pipelines and the experience of injecting CO_2. So it is one of the places where a sequestration experiment could be founded.

When major utilities and large private equity financiers engage the climate issue in a significant and innovative way, the nation's economic sector has entered a new and promising era.

In explaining this plan to members of Congress, we were largely embraced because several members of Congress had been considering punitive measures against new coal-fired power plants. One hundred fifty coal-fired power plants, by the way, are now under consideration for permits in the United States. Among the members of Congress whom I briefed, only Senator Kerry was negative. He asked me, "Bill, what does this mean for China?" In fact, the Chinese have closely followed our experience. But whereas Texas has a 2.3 percent growth rate in electricity demand, the Chinese two years ago had a 16 percent growth rate. The Chinese added 93,000 megawatts of coal-fired power to their capacity last year, significantly more than one new coal-fired power plant a week.

What I think it means to China is we will not let the lights go dim and the air conditioners go off. We will meet demand, but we will do it in a much more moderate and responsible way. We will be attentive to our carbon dioxide impacts, and we will try to bring them down. We will try to do it in an economically acceptable and intelligent way, but we are committed to do it. The net impact of all of these measures is to reduce the carbon dioxide emissions that otherwise would have been associated annually with the expansion of Texas Utilities by 55 million tons of carbon dioxide.

Based upon telephone calls I have received, this deal has had a large impact on two groups of people. One group consists of environmentalists, many of whom have called me to ask, "Why didn't you call me?" to which the answer was, "Well, I read your website, and it looked like there was no way you could ever agree to any coal-fired power." And yet, a few weeks after our deal, the Sierra Club made an agreement with Kansas City Power and Light to do something similar, though on a somewhat smaller scale. The other calls have been from power companies, particularly from AEP, the largest coal-fired power company in the country, whose CFO Holly Koeppel said, "We watched in amazement at what you did, and we want to open a dialogue with the environmentalists."

When major utilities and large private equity financiers engage the climate issue in a significant and innovative way, the nation's economic sector has entered a new and promising era. While the United States awaits enactment of serious climate policy, the private sector is displaying a new and encouraging response.

Richard L. Revesz

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My talk will take off from a sentence in Rosina's presentation. She said that most impacts of climate change will be negative, especially on the poorest and most vulnerable nations. There are a number of reasons for that. Some specific problems were discussed in her presentation, but generally the reasons fall into one of three categories.

The primary beneficiaries of anything we do on climate change are likely to be future generations in developing countries.

First is differential exposure. For certain of the negative impacts, tropical areas are likely to be most affected. Second is sensitivity. Poorer countries tend to be more dependent on agriculture, and to the extent that climate change will negatively affect agriculture, they will suffer more. They also have lower levels of health and are experiencing rapid population growth. Lastly, poorer developing countries are likely to have less adaptive capacity. They may not have the infrastructure to contain rising sea levels or to deal with public health problems, or the institutional strength to deal with problems more generally.

The result is that the primary beneficiaries of anything we do on climate change are likely to be future generations in developing countries. Why future generations? As we heard earlier today, the temperature increases, which at this point have been relatively modest, are going to grow substantially over the next 50 or so years. For a lot of environmental policy, we perform economic evaluation, which has been required for federal regulations since 1981. An executive order mandates that any environmental regulation that poses costs on the economy of more than $100 million a year has to be justified in cost-benefit terms. This obviously does not apply to Congressional acts. Nonetheless, there is a strong view in the academic community that public policies should be justified by reference to their economic impacts and in terms of costs and benefits. And my view is that this requirement is actually a good thing. The only question is how you go about doing the analysis.

A problem arises when we have to figure out the benefits that accrue to future generations. The economic literature would generally discount such future benefits in light of two factors. The first is a pure rate of time preference. Essentially, you would look at this in the same way you would look at financial flows. Obviously, getting a million dollars ten years from now is not the same as getting a million dollars now. That calculation is trivial. Anyone can do it. But the question is, how do you deal with an impact on a life ten years from now or a hundred years from now versus an impact on a life now? If you use discounting at any sort of rate used in economics, impacts 100 or 500 years from now are worth virtually nothing. So we would be willing to pay almost nothing to save thousands, even millions, of lives in 100 or several hundred years.

The second component generally assumes that there should be an additional discount because future generations will be wealthier than the current generation is. The general assumption is a declining marginal utility of money – an additional dollar is worth less to someone who's wealthier than to someone who's poorer, and since we are poorer than people in the future will be, the additional dollar is worth more to us than it would be to people in the future.

Any expenditures in stopping climate change are going to be expenditures from the developed world now to benefit developing countries in the future.

This is a complicated issue, and I cannot give you the full solution. I will indicate some problems with these two components. First, the pure rate of time preference. My claim is that applying these discounting concepts to the future generation has no appeal to any plausible moral theory. I have developed this simple example, which will not answer every question, but I think will give you an idea of what I mean. Think of a world that has only two people. The first person lives from years 1 to 50, and the second from years 51 to 100. In this world there are 100 units of resources that are split between these two people. Let us also say that each of these people can transform these resources into utility in exactly the same way. These resources are not going to increase, so we only have these 100 units. The next question is, "How would you like to distribute these 100 units of resources between the two people?"

I try this exercise with my class all the time. Most people's intuition is that each person should get 50 units. But any discounting for a pure rate of time preference would give almost all the resources to the first person. Now, sometimes people say, "Well, this is a very simple world with no productive capacity, and obviously the real world works differently." But the point is that a pure rate of time preference is a pure rate of time preference, and all the other complications are just complications that are going to be dealt with eventually.

But the normal intuition suggests that there is a problem with a pure rate of time preference. The standard economic model for a pure rate of time preference is usually associated with an influential article by Kenneth Arrow. I was actually once very fortunate to discuss the problem with Arrow. I was co-teaching a course with an economist at Princeton, and Arrow was at Princeton for a public lecture. We invited him to come to our class, where we were talking about this problem. When I posed this hypothetical to him, he was extremely generous and said, "Ricky, my theory does not work well with your example. And the fact that it doesn't work well with your example does count as an argument against my theory."

Now let us think about the point relating to the greater wealth of future generations. I have said that the primary beneficiaries of climate change policies are future generations in developing countries. As you know, the differential in GNP per capita between the developing world and the developed world is staggering. It is not plausible, during any of the time frames that we have been talking about, that developing countries are going to be wealthier than the developed world is now. So essentially, any expenditures in stopping climate change now are going to

One of the beauties of climate change policies is that they are immune from the corruption of developing countries. Anything we do in the developed world to reduce our impact would result in benefits.

be expenditures from the developed world now to benefit developing countries in the future. And those countries in the future are going to continue to be poorer than we are now. So if one is worried about the marginal utility of additional money, this provides an argument for negative discounting. That is, we would want to send more resources that way because we will be benefiting people who are poorer in the future than we are now. Once that argument is made, though, there is usually a quick counterargument: "Look, why would we want to benefit developing countries in the future since we don't seem to be very willing to benefit developing countries in the present?" For this claim, I cite the very low levels of foreign aid from the United States and less so from the rest of the developed world.

I have two plausible answers to that counterargument. First, just because we have been doing badly in one area should not mean that we should use it to justify doing badly in another area. My sense – and I am not a scholar of foreign aid – is that the most plausible moral theories would suggest that we should do more than we are doing now. But leaving that aside, one of the concerns about foreign aid is the vast levels of corruption in developing countries. The claim is, "Why should we spend a lot of money to be extremely ineffective?" And a lot of foreign aid is ineffective. Empirical studies have shown that transferring money to certain African nations for health programs results in something like one cent to the dollar in actual benefits to people, and so on.

One of the beauties of climate change policies is that they are immune from the corruption of developing countries. Anything we do in the developed world to reduce our impact would result in benefits, and corrupt governments of developing countries will and can do nothing to stand in the way of those benefits actually accruing to them in the future. The question of projects that the developed world could do in developing countries is somewhat more complicated. But typically, investments in specific projects in the developing world, which are often undertaken by the private sector, are much more effective in helping the beneficiary countries than our government-to-government aid programs. So even people who are skeptical about things that we can do now to help current generations in the developing world could come to see that the situation is quite different when the question is how we can help future generations of the developing world now through the kinds of policies that this panel discussed. ■

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