PART 6

Energy, the Environment, and Global Change

Overview

It is often said that energy is the lifeblood of modern societies, but energy in one form or another has always been critical to human activities. We should also acknowledge that energy is important only as it allows us to provide the services that improve human welfare — illumination, heating and cooling, communication, transportation, manufacturing, and other industrial and commercial processes. It is a means to an end, not an end in itself.

Nonetheless, modern societies, which provide a high level of services to their members, are totally dependent on energy sources. Industrialization required the use of wood-powered steam engines in its initial stages, gradually switching over to dependence on coal and oil. The twentieth century saw a rapid rise in electrification, and no end is in sight. Electricity generation, originally based on coal and then oil, still depends on coal, but increasingly on hydropower, nuclear fission, natural gas, and in time, on renewable energy sources, such as wind and solar power.

Population growth, rising economic expectations, and scientific and technological developments have dramatically increased the global demand for energy in its various forms, and increasing energy demand is likely to be a defining characteristic of the twenty-first century. However, this progress in providing enhanced levels of human welfare comes with a price: Energy production and use based on the consumption of fossil fuels can harm environmental and human health and has the potential to increase global warming through changes in the atmosphere's concentration of carbon dioxide.

The panel discussion that follows focuses on these issues, and the role that scientists and technologists, along with other societal contributors, can play in maximizing the benefits and minimizing the risks of the world's steady trend toward increasing demand for energy services. It is illuminated by the thoughtful perspectives of acknowledged experts in the fields of energy, environment policy, future studies, and religion. These include Neal Lane, now a professor at Rice University and formerly director of the National Science Foundation and adviser on science and technology to President Bill Clinton; Donald Boesch of the University of Maryland Center for Environmental Science; Mohamed El Ashry, former chairman of the Global Environmental Facility; David Rejeski, former official in the White House Office of the Council on Environmental Quality and now director of the Project on Foresight and Governance at the Woodrow Wilson International Center for Scholars; Ted Gordon, codirector of the Millennium Project and founder of the Futures Group, the largest private sector organization performing futures-oriented research; and Mary Evelyn Tucker, a professor of religion at Bucknell University, codirector with her husband of 10 conferences on world religion and ecology, and a former member of the Earth Charter Drafting Committee.

Together, our panelists make it clear that we are facing serious issues of global sustainability. Although science and technology will be guiding us into the future and can be helpful in addressing these issues, much more is needed if we are to ensure that our path in the twenty-first century is not just an extension of our path in the twentieth century.

Introduction: Neal Lane

Neal Lane, Edward A. and Hermena Hancock Kelly University Professor at Rice University, holds appointments as Senior Fellow of the James A. Baker III Institute for Public Policy, where he is engaged in matters of science and technology policy, and in the Department of Physics and Astronomy. Prior to returning to Rice University in January 2001, Dr. Lane served in the Clinton Administration as assistant to the president for science and technology and director of the White House Office of Science and Technology Policy, from August 1998 to January 2001, and as director of the National Science Foundation (NSF), from October 1993 to August 1998.

Before becoming the NSF director, Dr. Lane was provost and professor of physics at Rice University in Houston, Texas, a position he had held since 1986. He first came to Rice in 1966, when he joined the Department of Physics as an assistant professor. In 1972, he became professor of physics and space physics and astronomy. He left Rice from mid-1984 to 1986 to serve as chancellor of the University of Colorado at Colorado Springs. In addition, from 1979 to 1980, while on leave from Rice, he worked at the NSF as director of the Division of Physics.

Dr. Lane has received many awards and honorary degrees and is a fellow of the American Academy of Arts and Sciences and a number of professional associations. He serves on several boards and advisory committees.

When I was in Washington, full-time, these AAAS meetings were always a special treat for me. I applaud the American Association for the Advancement of Science for having this important program and all of you for making the decision to participate in it. The nation is much the better for your commitment and public service.

Our topic is an important one, and we have an excellent panel of individuals who know a lot more about the subject than I do. We were to have Dr. John Holdren talk about energy policy. Dr. Holdren is director of science, technology, and public policy programs at the Belfer Center for Science and International Affairs at Harvard. But, the change in the date of the meeting created a conflict for John that he could not resolve. As I think you know, John was a member of President Clinton's Council of Advisors in Science and Technology, and in that capacity he chaired several important studies on energy and was called on by the White House to brief the president and vice president on several occasions and to testify before Congress. In John's absence, the organizers asked me to add some comments on energy to my introduction, which I am happy to do. But, these will in no way be an adequate substitute for what John would have said.

This occasion also gives me the opportunity to recall for you one other distinguished individual who was prescient on all matters of science and technology. I'm speaking of the late Congressman George Brown of California. In early 1994, when he was given the W. R. Grace and Company Award by the American Chemical Society, he said,

> *What we are beginning to understand is that the path to the twenty-first century cannot be just an extension of the route we have taken through the twentieth century. If our planet and its burgeoning population are to survive, a new societal pattern must replace our current trajectory. If we call that new pattern sustainability, what we really mean is a pattern that leads to a survivable future. And if that future is to be survivable, then we must heed the advice of the renowned biologist, Jonas Salk, who said, "Our greatest responsibility is to be good ancestors."*

George Brown called for an entirely new approach "a new set of values and goals that society, as a whole, is willing to accept and live by." He noted that it is "not likely to happen without strong, diverse, and inspired leadership." If he were with us today, as we find ourselves mired in conflicts in the Middle East and living in denial of the implications of the buildup of CO^2 and other greenhouse gases in the atmosphere, he would suggest some urgency in seeking such leadership.

I will begin my remarks by explaining briefly how I view the interaction of science and technology, policy, and politics and then discuss our future energy needs, the likely availability of energy, and the likely environmental concerns. Since I am a physicist, I'm fond of the three-body problem in mechanics, which can also help us understand the interaction of science, policy, and politics in the U.S. system of government.

You may recall that in the famous three-body problem of physics, even for three simple masses with all gravitational forces between them known precisely, there is no way to solve for the motion and position of the bodies without complex computer modeling. My three bodies "science," "policy," and "politics," which are shown symbolically as circles in Figure 1, are to say the least much more complex than physical objects. The forces between these three symbolic bodies are complex, nonlinear, dynamic, and unpredictable. In our form of representational democracy, political disagreements between the White House and Congress (or even within these bodies) can cancel out any effort to translate scientific consensus on an important issue into policy action (a law, regulation, budget initiative, or government program).

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It is not surprising, then, that the usual outcome of government's attempt to deal with a problem is inaction, as is the case with CO^2 emissions and our withdrawal from the Kyoto Protocol and related international discussions. Current U.S. policy is "we don't know enough to do anything!" I hope to hear some words of optimism from our panelists about future policy directions and, perhaps, some suggestions as to how we can begin to make some progress.

To comment on energy, I'll ask and suggest answers to a few questions: How important is energy on the list of human needs? How much energy will we need and where will we find it? What are the implications for humanity and the environment?

First, let's consider how important energy is on the list of human needs. My Rice colleague, Nobel Laureate Rick Smalley, co-discoverer of C_{60} buckyballs and other fullerenes, has looked pretty carefully at the energy situation. I will borrow some of his figures.

Most of us would agree with his list of the top ten problems of humanity for the next 50 years (see Figure 2), as the world's population grows from 6.5 billion to 8 billion or more. We might not all list items in the same order, and we might add or subtract an item, but we'd all find Dr. Smalley's list is pretty much it. He argues,

FIGURE 1. A Three-Body Problem in Society (not to scale)

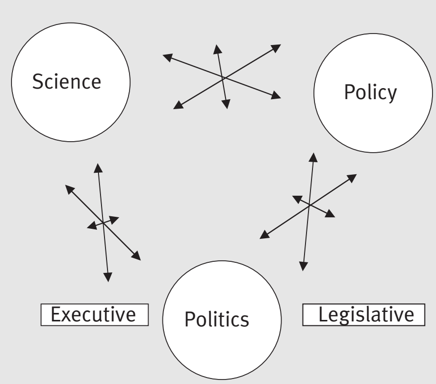

FIGURE 2. Humanity's Top Ten Problems for the Next 50 Years

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism and war
7. Disease
8. Education
9. Democracy
10. Population

Source: Rick Smalley, Rice University.

and I tend to agree with him, that energy is number one, in part because all of the others are affected by the availability, the cost, and the use of energy.

One problem in particular, the environment, is tightly coupled with energy. Humanity needs energy, but the production and use of energy is damaging to the environment. John Holdren puts it simply in a memo he wrote to President Clinton, in connection with a study he chaired for President Clinton's Council of Advisors in Science and Technology:

> *In short, energy is the most difficult part of the environment problem, and environment is the most difficult part of the energy problem.*

How much energy will we need, and where will we find it?

Yogi Berra once said: "It is tough to make predictions—particularly about the future!" Unfortunately, there is no good news regardless of whose predictions you use. John Bookout, the former president of Shell USA, used projected the future supply of energy using a method similar to that used by M. King Hubbert, a geologist with Shell Oil, in 1956 to predict that U.S. oil production would begin to decline in the early 1970s. According to the book *Hubbert's Peak* by Kenneth Deffeys, Shell executives tried to get Hubbert not to make that prediction right up until the time he was to give his talk. He was a gutsy guy and gave it anyway. Apparently there was a saying around the Shell Lab in Houston, "That Hubbert's a bastard, but at least he's our bastard!" As it turns out, he was right! So Hubbert became famous, and the maximum in the energy supply curve is known as Hubbert's peak.

Bookout's projections show a widening gap between demand and supply over the next several decades. Today, most predictions give an even higher demand curve and a larger gap. The problem is that we have depended on fossil fuel for a long time, and now we are running out. Moreover, continuing to rely on oil, gas, and coal causes the buildup of CO^2 in the atmosphere, which results in global warming and climate change.

Rick Smalley projects a huge increase in nonfossil energy needed by 2050 (see Figure 3). Right now, the world uses energy at the rate of about 14 terawatts (14 x 10^{12} watts) a day, mostly produced by fossil fuels: oil, coal, and natural gas. By 2050, the majority of projections show a doubling or tripling of this energy demand, with a much smaller fraction coming from fossil fuels, due both to dwindling supplies and environmental concerns. Smalley suggested how the distribution of sources might look in 2050. Note that these numbers are a percentage of the total.

The result is a need for greatly expanded supplies from solar and other renewable energy sources. However you might choose to draw this diagram, perhaps raising or lowering the bars for particular energy sources, it still shows a big gap in energy supply and demand. By 2050, we likely will need at least 10 terawatts (the equivalent of 150 million barrels of oil) each day, and some of it will have to come from sources not yet identified. Furthermore, as the world deals with global warming, carbon emissions will have to be cut back through carbon sequestration and use of renewable energy sources. Of course, the other possibilities for

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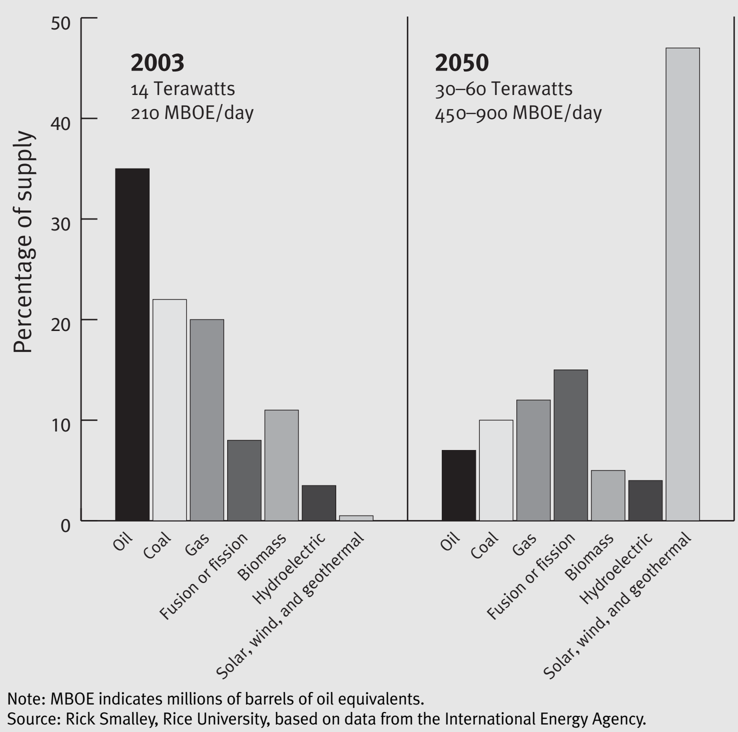
FIGURE 3. Current and Projected Energy Demand and Supply, by Source, 2003 and 2050



Note: MBOE indicates millions of barrels of oil equivalents.
Source: Rick Smalley, Rice University, based on data from the International Energy Agency.

Einstein gave us *$E = mc^2$* a century ago and, with that discovery, the expectations of limitless energy by fission and fusion. Instead, we face a huge energy shortage in the next century and, as we burn more and more fossil fuel, the Earth continues to heat up.

carbon-free energy, besides renewables, are nuclear fission, which has a whole set of environmental and security problems, and nuclear fusion, which so far has not yielded to technical challenges.

Most of the energy we use today came from the sun, but in the case of oil, gas, and coal it took a long time to convert solar radiation to fuel and cost the lives of a lot of prehistoric creatures. Solar energy (including biomass and wind) is our most likely future energy source. We need only a small portion of the 165,000 terawatts that hit the Earth each day. But, we will need new breakthrough technologies, including new materials, to produce the needed energy from these renewable sources, particularly solar. One possibility is nanotechnology. That's one reason President Clinton singled it out as a budget initiative for increased research investment in his FY2001 budget. Funding for the National Nanotechnology Initiative continues to grow, with the United States investing over $800 million a year in nanotechnology research. And the rest of the world is doing the same thing.

What are the implications for humanity? The question is difficult to answer, but one impact is becoming increasingly clear: global warming and the resulting climate change. The Earth will continue to warm, but how rapidly it will warm and how that warming affects the climate in various regions are still unknown.

Future warming predictions also depend on the scientific computer model chosen. We are confident that most global warming is due to human activity and that the atmosphere will continue to heat up in the future, but we don't know the science well enough to predict the future in detail. Another reason the rate of future warming is so difficult to predict is that we don't know how much energy the world will use and how much buildup of CO^2 the atmosphere will experience in the coming decades. That depends on how people live, particularly in the developing world. Even given these uncertainties, none of the models has any good news for humans.

One way to think about these uncertainties is to look at how energy is now being used in various parts of the world. Then, we can each have our own opinion of what is to come.

There are large disparities in energy consumption, hence in carbon emissions. The United States has contributed about 25 percent of all the CO^2 that is currently in the atmosphere. Our emissions per person are the highest in the world, because our energy consumption per person is the highest in the world. We and the other wealthy nations have only 20 percent of the world's population, but use 80 percent of the world's global goods and services. So, it is understandable that other nations look to us for leadership, at least cooperation. We had a start in that direction with the Kyoto Protocol, but after pulling out of Kyoto, we are stuck in an awkward position.

In addition to climate change, of course, there will be other problems related to energy demands. When we do begin to run out of fossil fuel, as the Hubbert analysis suggests we will by the middle of the century, we will have serious conflicts over the dwindling oil, gas, and coal supplies. It will be dog-eat-dog time. The price of energy will go up rapidly. We will be pumping unprecedented amounts of CO^2 into the atmosphere; we will be even less able to control greenhouse gas emissions; and there will be "energy wars" on many fronts. Every U.S. president then will be a "war president."

In closing, I'd like to returning to what George Brown had to say:

There is no question that we need new models for economic development both in the wealthy industrial nations and the poor developing nations. These models should recognize the need for continued growth, but not for the few at the expense of the many, for that will produce intolerable tensions in global society, or for any of us at the expense of the environment, which would destroy the Earth's support system on which we all depend.

We will not be able to develop such models without the involvement of scientists from many disciplines—social sciences, natural sciences, mathematics, and engineering—working together in ways we have never done before. Mr. Brown often called on scientists to turn their attention to the problem of continuing to improve the quality of life of all people in the world, thus finding the energy required while ensuring our survivability as a species. He was really the founder of the "civic scientist" idea.

If there is any problem that science and engineering ought to be able to solve, it is energy. Einstein gave us $E = mc^2$ nearly a century ago and, with that discovery, the expectations of limitless energy by fission and fusion. Instead, we face a huge energy shortage in the next century and, as we burn more and more fossil fuel, the Earth continues to heat up, changing the climate in ways humans have not experienced before and will be unable to reverse for centuries.

It seems that the world has a challenge. It's harder than physics, and even harder than science. And it's not too early to start thinking of what we might do to help.

Donald F. Boesch

Donald F. Boesch is a professor in and president of the University of Maryland Center for Environmental Science. He earned his B.S. in biology at Tulane University and Ph.D. in oceanography at the College of William and Mary. Before moving to Maryland in 1990, he was the first executive director of the Louisiana Universities Marine Consortium and professor of marine science at Louisiana State University. An internationally known marine ecologist, he has conducted research in coastal and continental shelf environments along the Atlantic Coast and in the Gulf of Mexico, eastern Australia, and the East China Sea.

Dr. Boesch is particularly active in extending knowledge to environmental and resource management at regional, national, and international levels. He is a science advisor to the Chesapeake Bay Program, to various state agencies in Maryland, and to other organizations in diverse coastal regions around the United States. He has served as a member of the Marine Board and the Ocean Studies Board of the National Research Council and on numerous federal agency advisory committees. He led the coastal sector team of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change and served as member of the Science Advisory Board of the U.S. Commission on Ocean Policy.

It is a real pleasure to be here. As a marine scientist, I have become interested in the global phenomena that are affecting the way we live and interact with the coastal environments in our own backyard. In talking about some of those global interactions today, I'm going to use the nearby Chesapeake Bay as my primary example.

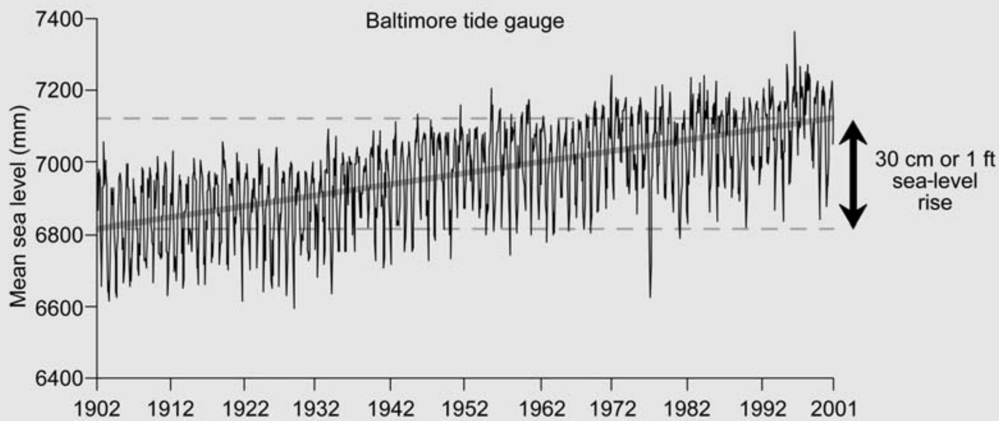
When this meeting was originally to have occurred, which was September 18 and 19, 2003, Hurricane Isabel was approaching the Chesapeake Bay across the North Carolina Barrier Islands. Isabel drove a tremendous amount of water into the lower Chesapeake Bay, with the winds initially coming from the east, blowing ocean water right into the mouth of the bay. As the hurricane progressed, ultimately passing just to the west of Washington, winds shifted from the southeast and then from the south. This created a tremendous storm surge of water up the Chesapeake Bay. When the hurricane approached Washington, the wind speeds were not particularly strong, nor was the rainfall especially heavy, so we probably could have held this meeting, had Carnegie opened up the building.

What was going on in the bay, though, was something quite different. The storm surge progressed up the main stem and lower tributaries of the Chesapeake Bay, reaching heights of almost 3 meters above sea level in some cases. As it advanced up the Potomac River, it flooded downtown Alexandria. Along the upper bay, the waterfront areas of Annapolis and the Fells Point region of Baltimore, the most historic parts of those cities, were inundated. These areas developed as colonial towns because they were near the water, not under it!

And, of course, everyone said, "Oh, my word, this is the worst flooding we have ever seen." Some of the old-timers remembered the 1933 hurricane, which had a very similar trajectory to Isabel. Indeed, one gentleman on Deal Island along the Chesapeake Bay's Eastern Shore pointed to a mark he had placed on the wall to record the level of flooding in 1933, and he said the level of flooding in 2003 was about a foot higher. So, it has gotten worse!

That may indeed be the case. If one looks at data from the Baltimore tide gauge, which has a very long record and a stable and fixed elevation, one can see that sea level has actually risen about a foot over the past century (Figure 1). Basically, the sea-level rise explains the increase in hurricane storm surge over time. More important, it serves as a wake-up call for things to come.

FIGURE 1. Relative Sea Level Rise in the Chesapeake Bay, 1902–2001



Source: Permanent Service for Mean Sea Level.

As we are busily trying to plan our lives and manage the environment, we generally assume that conditions will remain more or less constant. We are not thinking adequately about future changes.

The lesson that I am trying to communicate here is that as we are busily trying to plan our lives and manage the environment, we generally assume that conditions will remain more or less constant. We are not thinking adequately about future changes. Whether or not one believes the projections of global climate change, with all their assumptions and uncertainties, one must recognize that significant environmental changes are already taking place. More and more changes are being documented, demanding that we develop mechanisms to adapt to them. Dr. Lane made some projections about climate change for the globe as a whole; in the Mid-Atlantic region, air temperature and sea level are also projected to rise throughout the twenty-first century.

The projected sea-level rise is significantly greater than what we would expect as a result of the rise in the world ocean due to global warming. The reason is the land subsidence that has been taking place and will continue in the future. The Earth's crust in the Mid-Atlantic region bulged during the last glacial period and now is settling back down. So, we have to contend with land subsidence as well as sea-level rise. When we combine the rate of global sea-level rise with this local land subsidence, we can see in Figure 3 that the mean expected rise in sea level for the Chesapeake Bay region is almost 2 feet, or double the 1-foot rise that was seen in the past century.

This projected change has enormous implications, not only for low-lying communities, but also for critical environments that we are trying to manage and protect. For example, tidal wetlands, which occur precariously at the interface of the land and the estuary, exist in a delicate balance with the water level. To survive, wetland plants must be able to grow, trap sediments, and accrete soil material around their roots; if they accrete too much soil, the wetlands dry out, but if they do not accrete enough soil to keep pace with the sea-level rise, the wetlands are drowned. We have already seen signs of inundated marshes deteriorating, falling apart, not because of any direct impact of humans, through dredging and filling activities, for example, but because those marshes are losing that balance between soil accretion and sea-level rise. This phenomenon is also occurring in many other parts of our country and the world, most notably the coastal wetlands of the Mississippi Delta.

Sea level is not the only factor, though. All the other conditions that will change in coastal ecosystems as a result of long-term climate change have enormous consequences, including the temperature itself. Temperature influences many biological processes, but also influences where organisms are distributed on Earth. The biogeography of the world is greatly determined by temperature ranges, and it will change as temperature changes, with cold-water species retreating and warm-water species advancing poleward.

In an estuary like the Chesapeake Bay, the amount of fresh water entering the coastal zone from the land is also critical. Freshwater influx not only affects salinity gradients, but also drives circulation, because the fresh water is denser than saline ocean water. Changes in runoff and river flow affect the delivery of nutrients, sediments, and other substances. The frequency and severity of storms and the nature of coastal currents are important factors that may change as well. For example, the ecology and productivity along our West Coast is heavily governed by the California Current, which demonstrates dramatic regime shifts, as a result of decadal climatic variability, and also is susceptible to longer-term changes.

When the temperature regime changes, the door opens to other kinds of biological changes. One such change is the establishment of invasive species that might have previously been excluded. In this morning's news is the capture two days ago of a northern snakehead fish in the Potomac River just a few miles downstream of Washington. Two years ago, northern snakeheads, fish native to Asia, were found in a small pond in Maryland, but they were eradicated before they could spread. However, this was the third northern snakehead recovered from the Potomac this year, suggesting that a population of this invader has become established. So, you AAAS Fellows here in Washington, be careful when you walk down along the banks of the Potomac because this is the legendary fish that, according to the press, walks on land, breathes air, and eats small children. Although this invader was introduced by human action rather than changing climate, it is indicative of the rapidity and consequences of biological invasions, some of which are facilitated by changing climate.

Many well-meaning practitioners have difficulty adding another layer of complexity—such as what climate change may mean—to what they are already struggling to achieve.

Climate change will complicate our already challenging efforts to restore and manage imperiled coastal ecosystems. The U.S. Commission on Ocean Policy, appointed by the president to address a Congressional mandate, has just issued a draft final report that deals comprehensively with a wide range of issues related to the state of our nation's oceans and coastal resources, environments, and communities. Initially, the commission's work was seen as an effort to reignite interest in our ocean environments and investments in ocean research, but it became in the end a much more sober appraisal of the problems with which we are dealing along the U.S. coast: not only invasive species, sea-level rise, and wetland losses, but also pollution, habitat losses to development, and overfishing, which affects not only the stocks that we fish, but the ecosystem as a whole. The commission's report calls for a more integrated approach to dealing with those issues and problems, using ecosystem-based management (the final report is posted at www.oceancommission.gov).

Despite the report's emphasis on an integrated approach, one can find scant mention of the consequences of climate change as something that we have to factor into the more effective management of coastal resources. Now, this could be because the commission wished to avoid political controversy, but it is also, I think, because most people who work on the day-to-day problems we have created are preoccupied and overwhelmed by them. Many well-meaning practitioners have difficulty adding another layer of complexity—such as what climate change may mean—to what they are already struggling to achieve.

The report, which I encourage you to read, espouses a number of quite noble management principles, such as sustainability, a precautionary approach, and stakeholder engagement that, if actually put into practice, would greatly improve the effectiveness of coastal environmental protection and resource management. Some recommendations of interest to this audience are, first, strengthening the basis of science for managing the ocean and its resources, and second, applying new approaches, such as adaptive management, which involves learning by doing and puts great emphasis on understanding outcomes and using that knowledge in subsequent policy development and management decisions. Implementing these recommendations will create enormous opportunities for the scientific community.

A particularly important factor affecting coastal ecosystems around the world results from what has been called the nitrogen cascade. Loading of the nitrogen cycle with reactive nitrogen produced by human activities became a phenomenon of global proportions during the second half of the twentieth century, growing more rapidly than even the build-up of greenhouse gases. In a very short order, humankind has doubled the amount of reactive nitrogen in the biosphere. This recent abundance of reactive nitrogen cascades from one medium to another, from air to land to water, with significant consequences to ecosystems and human well-being. The nitrogen cascade has enormous consequences for the ten major issues that Dr. Neal discussed, particularly those at the top of the list, namely, energy, water, food, and environment.

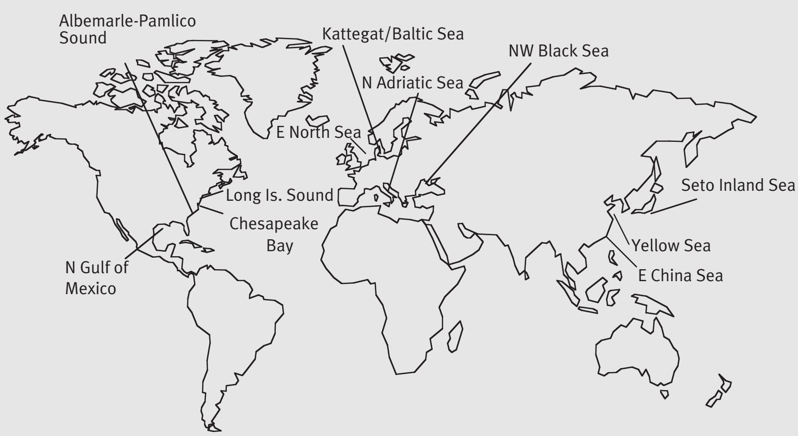
The human-fixed nitrogen comes from two basic sources: one is that needed to support food production, generally through the synthesis of ammonia for fertilizers from nonreactive dinitrogen gas in the atmosphere. The other source is that released as a byproduct in the combustion of fossil fuels, which at high temperatures oxidizes nitrogen in the air. Nitrogen from those two sources cascades through ecosystems with enormous consequences. Nitrous oxides are a precursor to the formation of ground-level ozone, thus affecting human health and forest productivity. Deposition of oxidized nitrogen from the atmosphere affects plant communities and can acidify soils and surface waters. Nitrate leaches or runs off fertilized farm fields, affecting the quality and use of both ground and surface waters. At the end of this cascade is the coastal zone, which receives the nitrogen that has not been absorbed elsewhere in the system. Excess nitrogen is one of the main causes of the coastal ecosystem degradation that we see around the world. It results in algae blooms, some of which produce toxins that are harmful to humans or reduce the light available for underwater plant growth. Degradation of the abundant organic matter produced can ultimately deplete the life-sustaining oxygen in the water. A so-called dead zone, containing very little if any dissolved oxygen, occurs every summer in the deeper parts of the Chesapeake Bay.

Excess nitrogen is one of the main causes of the coastal ecosystem degradation that we see around the world.

If we look around the world at where coastal ecosystems have deteriorated rather dramatically, we can see that they are closely related to areas where the total reactive nitrogen produced by humans has increased rapidly, particularly owing to the use of industrially produced fertilizers (Figure 2). Fertilizers, of course, have great benefits for humankind, because without them we would scarcely be able to feed the 6.5 billion people we have in the world, much less the 10 billion people that Dr. Lane showed you in the projections for later this century. But, just as we will need fertilizers, we will also need to learn to avoid some of their negative consequences.

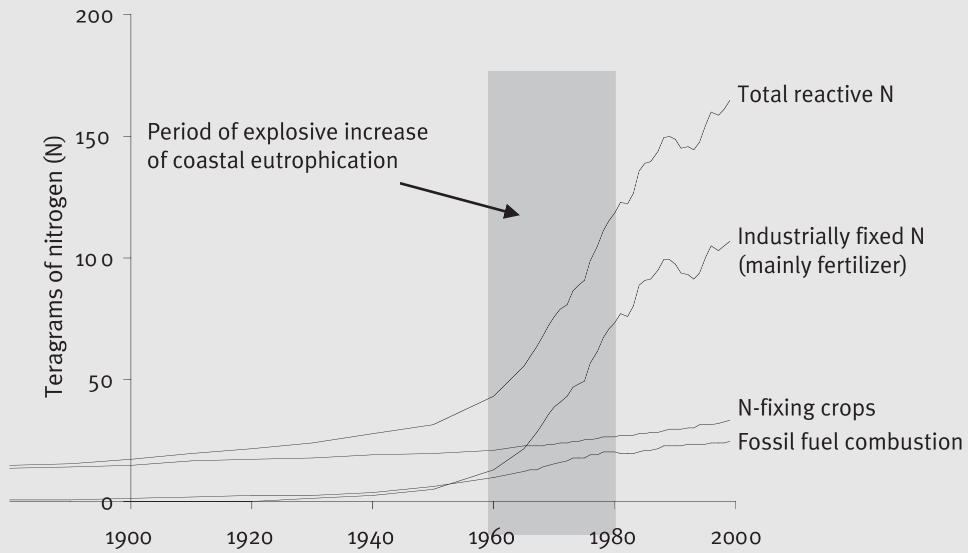
Atmospheric discharges of oxidized nitrogen are clearly related to industrial development, power gener-

FIGURE 2. Coastal Seas Experiencing Large-Scale Nutrient Overenrichment



Source: D.F. Boesch, "Challenges and opportunities for science in reducing nutrient over-enrichment in coastal ecosystems," Estuaries 25 (2004), pp. 886–900.

FIGURE 3. Coincidence of Degradation in Coastal Ecosystems around the World and Global Increases in Production of Fertilizers and Combustion of Fossil Fuels



Source: D. F. Boesch, "Challenges and opportunities for science in reducing nutrient over-enrichment in coastal ecosystems," Estuaries 25(2004), pp.886–900.

The Chesapeake is leading the world in trying to figure out how to reduce these excessive nutrient inputs in order to restore the coastal ecosystem.

ation, automobile emissions, and the like (Figure 3). This worldwide explosion of coastal overenrichment is presently evident mainly in North America and Europe, and it affects rather large systems, including the Gulf of Mexico, the Baltic Sea, and portions of the Mediterranean.

Almost two-thirds of U.S. estuarine and bay environments have been degraded as a result of overenrichment with nutrients, particularly nitrogen. This is the cause of the so-called Gulf of Mexico dead zone or hypoxia, which is related largely to the agricultural inputs of nitrogen 1,500 kilometers upstream in the Mississippi River, from Iowa, Illinois, Minnesota, Wisconsin, and Ohio. When Dr. Lane was the president's science adviser, there was an assessment of Gulf hypoxia, and a multistate agreement was reached at the end of the Clinton Administration to reduce the sources of nutrients in order to mitigate the effects downstream. However, little has yet been done to implement this agreement.

So, what does this mean for the world, looking ahead to 2033? One of the indicators we can project globally is the demand for cereal crops (Figure 4). That demand will grow rapidly in developing countries over the next 30 years, because of the growing populations and the growing desire of developing populations to live our lifestyle. Although we may hope that they will not eat as much environmentally costly and unhealthy animal protein as we in the United Sates now do, the rising demand for food and, therefore, fertilizer is clearly a trend with which we will have to contend. And, interestingly, as one can see in the projections, developing nations will continue to fall short of meeting their own demands from their own production. This shortfall has implications for the United States, as the increased demand for agricultural products drives our exports and, therefore, has consequences on our domestic environment through the nitrogen cascade.

Another global indicator is the projected level of NO_X emissions, as demand for energy rises. In Asia, for example, as people use more internal combustion–powered vehicles and demand more electrical power, the emissions of NO_X are projected to increase dramatically in the 30-year time horizon (Figure 5).

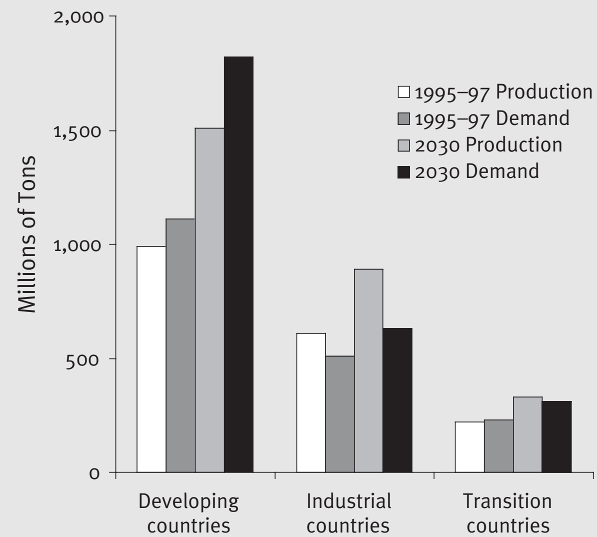
Bringing these projections again closer to home for the Chesapeake, we have developed plausible scenarios to reduce nitrogen loading over the next 30 years. The Chesapeake is leading the world in trying to figure out how to reduce these excessive nutrient inputs in order to restore the coastal ecosystem. Through an effort that we call Chesapeake Futures, the scientific community in the region asked: What are the changes in technology that we could apply? What are the changes in lifestyle and development patterns that we could propose as options that would reduce the nitrogen inputs into the system? We examined three scenarios (Figure 6). The first scenario basically assumes that recent trends will continue unchanged, meaning that we're doing about as much as we can do. Under that scenario we will actually lose ground as nutrient loading increases as a result of population growth and unabated sprawl. The middle scenario assumes that we achieve the management objectives that were in place in 2000.

The third scenario introduces what we thought were feasible alternatives. These might not be accomplished right away, but over the next 30 years could well be accomplished. For example, atmospheric emissions of NO_X could be significantly reduced through developing the kinds of energy alternatives that Dr. Lane mentioned, such as greater use of hybrid vehicles, and maybe even hydrogen fuel-cell vehicles. Through such feasible innovation in agriculture, waste treatment, and growth management, we could significantly shrink the dead zone, the volume of hypoxic water, in the Chesapeake Bay.

Whichever outcomes could actually be achieved—either losing ground or, in the most optimistic case, gaining substantial ground—nitrogen inputs would remain well above those experienced by the pristine bay. Nonetheless, the feasible alternatives scenario would yield significant improvements in the environmental quality of Chesapeake Bay.

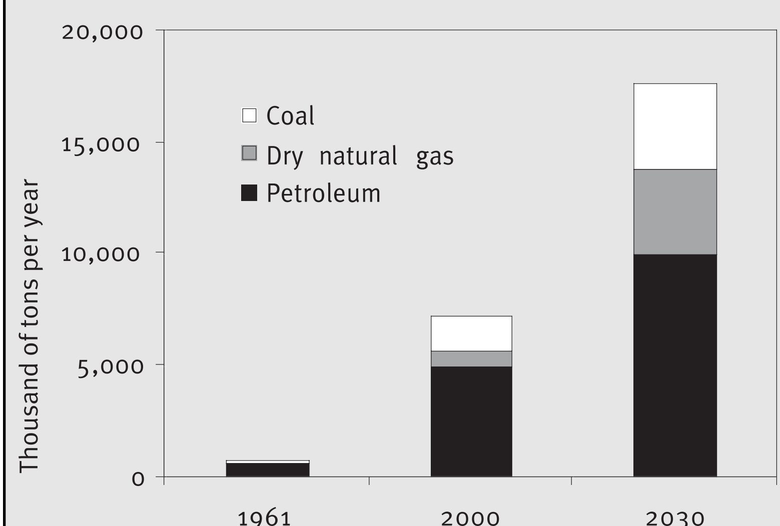
Undoubtedly, we as scientists have some formidable challenges ahead contributing to the improved management of coastal ecosystems. Perhaps our first step is to develop the right mindset to facilitate change. Let me call this the "Pasteurization" of our science. That notion comes from a book entitled *Pasteur's Quadrant,* by

FIGURE 4. World Cereal Demand and ProductionProjected to 2032



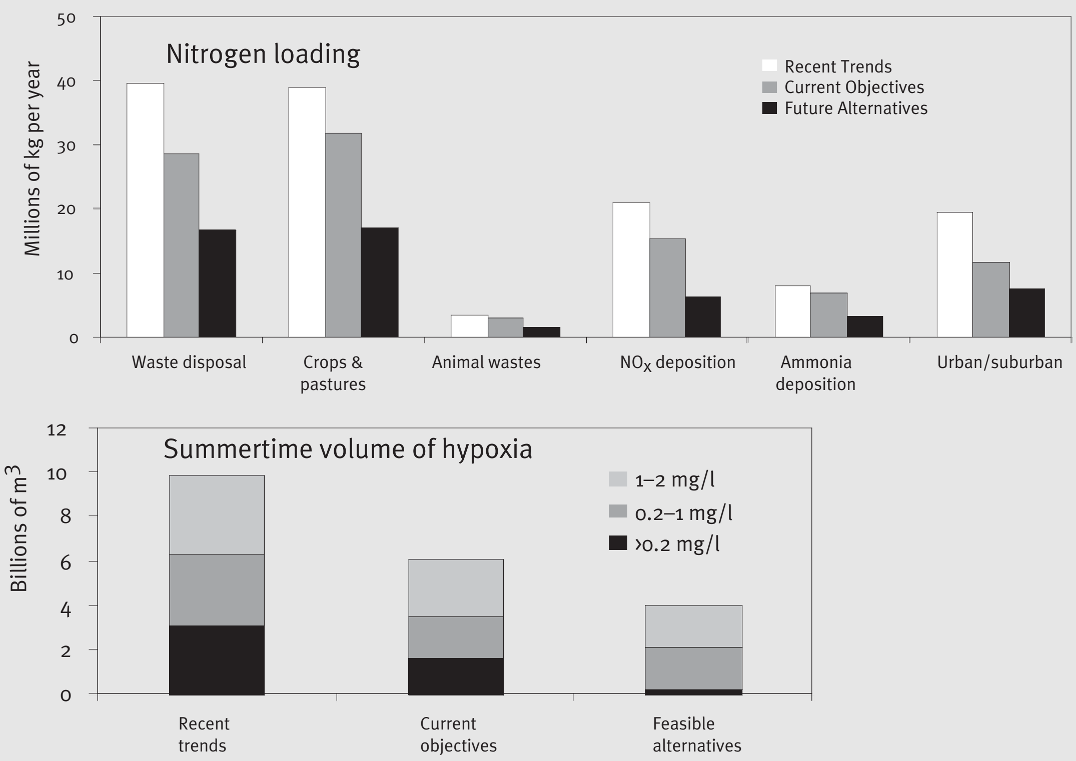
Source: R. N. Roy, R.V. Mistra, and A. Mntanez, " Decreasing reliance on mineral nitrogen —yet more food," Ambio 31(2002), pp. 177–83.

FIGURE 5. Emissions of Nitrogen Oxides in Asia Projected to 2030



Source: M. J. Bradley and B.M. Jones, Ambio 31(2002), pp. 141–49.

FIGURE 6. Nitrogen Loadings to the Chesapeake Bay by 2030 under Three Scenarios and the Effects of These Scenarios on the Oxygen-Depletion of Bottom Waters



Source: D. F. Boesch and J. Greer, Chesapeake Futures: Choices for the 21st Century, Edgewater, Md.: Chesapeake Research Consortium, 2003.

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Donald Stokes (Brookings Institution Press, 1997). Stokes observed that some scientific advances driven solely by fundamental curiosity (think of Nils Bohr) eventually resulted in useful applications and that society can also benefit from a rather uncurious technological application of scientific observations (think of Thomas Edison). However, the simultaneous quest for scientific knowledge and practical application can create marvelous synergy. That was Louis Pasteur's approach. Pasteur was very strongly driven not only by basic curiosity about the way the world works and the understanding of basic principles and processes, but also by his very fervent desire to use this knowledge for the benefit of human society. I think that approach is a model not only for our own individual ways of thinking about these environmental problems, but also for our institutions to foster more use-inspired research as we move forward.

Mohamed T. El-Ashry

Mohamed T. El-Ashry is the former chief executive officer and chairman of the Global Environment Facility (GEF). He served in that capacity from July 1994 to July 2003. He also served as chairman of the GEF during its pilot phase (1991–1994). Before joining the GEF, he served as the chief environmental adviser to the president of the World Bank and the director of the World Bank's Environment Department, as senior vice-president of the World Resources Institute, and as director of environmental quality with the Tennessee Valley Authority. He has held teaching and research positions at Cairo University, Pan American-U.A.R. Oil Company, Illinois Geological Survey, Wilkes University, and the Environmental Defense Fund. He also has served as senior environmental adviser to the United Nations Development Programme, as special adviser to the secretary general of the 1992 United Nations Conference on Environment and Development, and as a member of the World Water Commission.

Dr. El-Ashry received his B.S. degree with honors in 1959 from the University of Cairo and his Ph.D. in geology in 1966 from the University of Illinois. He has received numerous international awards and honors and is the author of three books and more than 200 papers and articles. Dr. El-Ashry is a fellow of the Geological Society of America and the American Association for the Advancement of Science. He is a member of the Third World and African Academies of Science and is listed in *American Men and Women of Science and Men of Achievement*.

Humanity, greater in number and more economically active than ever before, is increasingly playing havoc with Earth's life support systems. Our actions are giving rise to a multitude of critical threats: the degradation of soils, water, and the marine resources essential to food production; health-endangering air and water pollution; global climate change that is likely to disrupt weather patterns and raise sea levels everywhere; the loss of habitats, species, and genetic resources, which is damaging both ecosystems and the services they provide; and the depletion of the ozone layer.

Scientists warned about many of these problems long before the general public and politicians became aware of them. For example, on a human-induced greenhouse effect, it was Svante Arrhenius more than a century ago; on acid rain and its ecological consequences, it was Svante Oden in 1968 in Europe and Gene Likens and Herb Bormann in 1972 in the United States; and on ozone, it was Mario Molina and Sherry Rowland in 1974. By pushing at the frontiers of science, we have been able to reach a common understanding of many of the fundamental threats to Earth's natural systems and, in some cases, a consensus on the necessary solutions.

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Climate change, perhaps the most serious of these environmental challenges, is the global environmental concern that I will address here. I will examine how the lessons from the successful control of acid rain and ozone depletion could help guide the United States and the international community toward collective action for reducing greenhouse gases. In analyzing these lessons we will be able to see that there is really nothing unique about the arguments against CO^2 control—similar arguments were made against SO^2 control and the phasing out of chlorofluorocarbons (CFCs)—namely, uncertainty, natural variability, quality of science, cost of action, cooperation by all parties concerned, available technologies, role of special interests, and so forth.

In the seven years from 1985 to 1992, the status of the global-warming issue progressed from a consensus among scientists that the "greenhouse" threat is real to a consensus among governments that responsive action should be taken. The scientists who met in Villach, Austria, in 1985, under the auspices of the World Meteorological Organization, the United Nations Environment Programme, and the International Council for Science (ICSU) concluded that human releases of greenhouse gases could lead in the first half of the twenty-first century to "a rise of global mean temperature … greater than any in man's history"(1). They also concluded that "understanding of the greenhouse question is sufficiently developed that scientists and policymakers should begin an active collaboration to explore the effectiveness of alternative polices and adjustments." As we will see later, it took 12 more years of scientific research and assessments by the distinguished group of international scientists known as the IPCC (Intergovernmental Panel on Climate Change) to arrive at the same conclusion.

At the Earth Summit in Rio de Janeiro in June 1992, following 18 months of very difficult negotiations, more than 150 counties, including the United States, signed the United Nations Framework Convention on Climate Change. The framework convention does not mandate specific reductions in greenhouse gases—it only obliges the industrialized countries to "adopt national policies and take corresponding measures" with the "aim of returning" emissions by 2000 to their 1990 levels. In the negotiations leading to the convention, developing countries argued, and rightly so, that the primary responsibility for action on climate change falls on the shoulders of the industrialized countries, which with only 20 percent of the world's population have contributed about 75 percent of total CO^2 emissions.

As we now know, very few countries adopted the necessary policies and measures called for by the convention, and greenhouse gas emissions continue to increase. Because energy consumption is so vital to industrialized countries, the barriers, both economic and political, to adopting the necessary policies and measures have been very high.

With implementation of voluntary measures faltering, the Kyoto Protocol was agreed upon in 1997, setting an initial target and a timetable for reducing emissions by industrialized countries. Industrialized countries were to reduce greenhouse gas emissions by 5.2 percent below 1990 levels during the first commitment period of 2008–2012. For the United States, the commitment was 7 percent. Since U.S. emissions in 1997 were already 12 percent above 1990 levels, the reductions required to meet that commitment would have amounted to more than 20 percent.

While the Kyoto Protocol was intended as a first step in implementing the climate change convention, it would not have materially altered the long-term atmospheric concentrations of greenhouse gases. Although U.S. ratification of the Kyoto Protocol was always considered unlikely, few observers expected the Bush Administration's outright rejection of the Kyoto Protocol and the global concern over climate change. Rejecting Kyoto's provisions as they apply to the United States and proposing viable alternatives is one thing; taking several steps backward and arguing that we do not know enough to take action is another. The Bush Administration's position was taken in spite of the IPCC's 2001 assessment report, which concluded that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities," and the National Academy of Science report in the same year saying that "greenhouse gases are accumulating in the Earth's atmosphere as a result of human activities, causing surface temperatures to rise. There is general agreement that the observed warming is real and particularly strong within the past 20 years."

Responding to national and international criticism, the White House announced a $1.7 billion climate science program to improve knowledge about climate change and its impacts and to reduce uncertainty in projections of future climate change. By July 2003, the Bush Administration released a research plan to mixed reaction from the scientific and environmental communities. As one critic put it, "the push for more basic research is only a stalling tactic." Another described the emphasis on "natural variability" as a code for "global warming is natural—it's not us"(2).

In a way, history repeats itself. Two decades earlier, mounting evidence showed that acid rain, from fossil-fuel combustion, was damaging aquatic and terrestrial ecosystems in the eastern. United States. In 1980, President Ronald Reagan, who believed that trees, not people, cause pollution, decided that we did not know enough to control SO_X and NO_X emissions, the precursors to acid rain, and that more research was needed. Hence, the National Acid Precipitation Assessment Program (NAPAP), a ten-year, multimillion dollar research program on the causes, effects, and controls of acid rain, was born.

Less than a decade later, President George Bush (senior, that is), campaigning in New England before the New Hampshire primary, promised that, should he become president, he would work with Congress to enact acid rain legislation. In 1990, Congress passed the landmark Acidic Deposition Control Program as Title IV of the Clean Air Act Amendments. It mandated a 40 percent reduction in SO^2 emissions by 2010 from a 1980 base and imposed a national cap of 15 million tons of SO^2 emissions annually.

Two features of the control program are worth highlighting since, in my opinion, they provide lessons for a future climate program. They are (a) an innovative, market-based trading and banking system of emission allowances and (b) flexibility in the choice of technologies to reduce emissions. These two features alone have reduced compliance costs significantly below initial estimates. For example, NAPAP's own 1990 report predicted that a 10 million to 12 million ton reduction of SO^2 emissions would cost from $800–1,200 per ton. The actual per ton cost of controlling those emissions ended up being less that $100(3). Flexibility in the choice of technology allowed large utilities to decide which power plants were to be fitted with scrubbers and which would employ cheaper technologies—yet the system in totality would be in compliance. This was our experience at the Tennessee Valley Authority, which prompted us to adopt and implement in the early 1980s the first acid rain policy in the country, committing the agency to a 50 percent reduction in SO^2 emissions.

Two things need to be emphasized before leaving this point of the discussion: (a) a market-based approach cannot function without an overall cap on emissions and (b) there are secondary benefits to pollution reduction, which do not enter into the calculus of costs. In this case, NAPAP's 1996 report suggested that human health and visibility benefits from SO^2 reductions alone could exceed the cost of compliance.

Let us now examine the lessons from the Montreal Protocol on Substances that Deplete the Ozone Layer, a landmark international agreement originally signed in 1987 and amended in 1990 and 1992, which phases out the production and consumption of ozone-harming compounds such as CFCs, halons, carbon tetrachloride, and methyl chloroform. Like the Kyoto Protocol, the Montreal Protocol is an international agreement to implement a convention—in this case, the Vienna Convention on the Protection of the Ozone Layer. Unlike Kyoto, however, it enjoyed the support of the U.S. administration at the time. The Reagan Administration, which had previously opposed acid rain control, used U. S. prestige and leadership in 1987 to leverage consensus on this successful yet contentious agreement at the time of its negotiation.

"Entrenched industrial interests claimed that new regulations would cause immense economic dislocations. Technological solutions either were nonexistent or were considered unacceptable by most major governments. The scientific positions taken by some parties were influenced by commercial self-interest, and scientific uncertainty was used by some as an excuse for delaying hard decisions. Many political leaders were long-prepared to accept potential future environmental risks rather than to impose the certain short-term costs entailed in limiting products seen as important for modern standards of living." These are the words of Ambassador Richard Benedick, chief U.S. negotiator of the Montreal Protocol (4). They are the same arguments being made by opponents of effective action on climate change. The Montreal Protocol is considered one of the major environmental successes of our time. The ozone layer is beginning to recover; by 1995, the industrialized countries had largely eliminated CFCs and halons—the two major ozone-depleting substances—and many developing countries are now ahead of the timetable that gives them until 2010 to phase out these substances.

A crucial difference, however, between the ozone and climate issues is the degree of public concern over

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the potential dangers. In the ozone case, public concern reinforced the warnings of scientists. For example, consumer demand for products utilizing CFCs in spray cans fell by two-thirds even before the U.S. ban on these products. Contrast that with consumer revolt in the U.S. over the rise in the price of gasoline that fuels gas-guzzling sport utility vehicles, even though the average price of a gallon of gasoline in the United States is less than half that in Europe and in many developing countries. Would heat waves similar to those experienced in Europe last summer, where close to 15,000 people died in one month in France alone, wake up American public opinion?

Support for the Montreal Protocol was bolstered by other factors in addition to public opinion. Market mechanisms encouraged technological innovations, just as they had in the case of acid rain, and emission targets signaled to the private sector that alternatives would be profitable. Political leadership was also crucial. As the largest emitter of ozone-depleting chemicals, the United States took the lead in pushing for the Montreal Protocol and could bring other nations along by example. Although it is the largest emitter of greenhouse gases as well, the United States has avoided such a role in the climate negotiations. Developing countries, which as in the case of climate change did not cause the problem in the first place, were provided incentives to participate through the Montreal Protocol's Multilateral Fund. Similarly, developing countries were provided financial assistance to participate in the Climate Change Convention through the Global Environment Facility (GEF), which was recognized as the financial mechanism of the convention.

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To summarize the lessons for next steps beyond Kyoto, I would like to highlight eight points: First, the Kyoto Protocol, if fully implemented, will have negligible effect on the climate system. Second, no effective action on climate change can be achieved without the participation and the leadership of the United States—the largest emitter of greenhouse gases. Nor can any long-term solution can be achieved without the participation of major developing countries, such as China, India, Brazil, and South Africa, whose population and emissions are growing at a much faster rate than those of developed countries. The U.S. Government Accounting Office recently reported that, in the past two decades, energy-related carbon emissions from several Asian countries, including China and India, have almost doubled, while Europe has reduced its output of greenhouse gases by 14 percent. U.S. emissions increased during the same period by almost 25 percent. The report predicts that China's emissions, which are now about half the U.S. output, will reach more than 80 percent of it by 2025 (5).

Third, mobilizing public opinion is crucial to help bring pressure on politicians who lack the political will to act on their own. Fourth, setting a target, a timetable, and a cap on emissions is essential to drive technological development and dissemination. Fifth, to ensure the cooperation of the business sector, any emission control system must provide incentives to industries in the form of market-based instruments, like emission trading and banking, and must allow some flexibility in the choice of technology to reduce emissions. Sixth, providing incentives from rich countries to developing countries by facilitating the transfer of cheap and affordable clean energy technologies will ensure the participation of developing countries in future agreements. Developing countries' top priorities are economic development and poverty alleviation, not climate change.

Seventh, future climate research should increasingly focus on meeting the information needs of decision-makers for action. As Pielke and Sarewitz put it in a recent article in *Issues in Science and Technology,* "the types of knowledge we have been emphasizing for the past decade or so, despite their significant scientific value, are not those we will most need in dealing with the challenge of climate change. It's as if the National Institutes of Health focused its research on making better projections of when people will die, rather than seeking practical ways to increase health and life expectancy"(6). Eighth, since science tells us that as a result of current and near-future accumulation of greenhouse gases in the atmosphere a certain amount of warming and accompanying climate change is to be expected, research should also focus on adaptation measures to reduce societies' vulnerability and enhance preparedness to respond to climate impacts.

So, what does this mean in terms of a realistic "Kyoto II," and the leadership role that the United States can play in its own self-interest and for the sake of global sustainability and future generations? A future technology-based agreement could have the following features:

1. Governments agree on a cap-and-trade scheme to control emissions, as well as technology-forcing targets and timetables.
2. Developed countries commit to reduce their emissions by10 percent from 2000 levels by 2015. At least 50 percent of the required reductions would be accomplished by 2010, and at least 50 percent would be achieved by domestic measures.
3. Developed countries agree to reduce by 20 percent the cost of clean energy technologies by 2015 through research and development and other measures. Countries that meet this target would receive credit toward their emission reduction.
4. Developing countries can increase emissions up to 2010 to meet their immediate economic development needs, but agree to stabilize emissions at 2010 levels and begin to reduce emissions by 10 percent starting in 2015. Developing countries commit to increase their energy efficiency as they pursue economic development.
5. Developed countries agree to provide the kind of financial incentives and technical assistance that will encourage developing countries to adopt affordable, clean energy technologies to stabilize and then reduce their emissions.

The focus on technologies, policies, and measures to achieve a global goal, with regular reporting and updating under public scrutiny, may offer the best hope of achieving near-term emissions reduction, while new research improves our knowledge and reduces uncertainty about the climate system.

In my view, it is in the self-interest of the United States to reestablish its leadership role in the global environment and technology arenas. The self-interest lies in pursuing a path that enhances national security by reducing reliance on imported oil, supports economic growth and reverses the current trend of job losses in the manufacturing sector, and improves the global environment, all at the same time.

In 1991, I was asked: "If you have one piece of advice on the environment to the incoming administration, what would it be?" I said, "Launch a public works program for clean energy. Such program would set the U.S. on a sustainable energy path; it would create jobs; it would enhance national security; and it would reduce air pollution, acid rain, and greenhouse gases." Since the Clinton Administration did not heed that advice, I offer it to the incoming administration. In my view, a public works program, in partnership with the private sector, could embark on large-scale manufacturing and application of existing and proven clean energy technologies, especially renewables. Such an effort would lower the costs of these technologies and reduce the amount of carbon emitted per unit of primary energy. At the same time, the program would support advanced energy research for improving the efficiency of existing technologies and for the development of next-generation technologies, particularly hydrogen and fuel cells.

A transition to renewable energy and hydrogen is inevitable, not because fossil fuel supplies will run out, but because the costs and risks of using these supplies will continue to increase relative to renewables. Costs will increase with security concerns. They will also increase as the environmental effects of fossil fuel use are internalized in the cost of the energy produced and as the cheapest reserves are depleted.

Worldwide, renewables accounted for 2.4 percent of the total primary energy use in 1998, but the share is constantly increasing due to growing private sector investments, particularly by big oil companies such as Shell and BP Amoco and particularly in developing countries. Recently, at least 30 major firms and the GEF have given indications that they will invest $10 billion–$15 billion in renewable energy over the next five years.

Research should focus on adaptation measures to reduce societies' vulnerability and enhance preparedness to respond to climate impacts.

I, for one, remain optimistic that one day there will be global sustainability, with needed sources of energy virtually pollution-free and affordable, without abject poverty, and with all nations promoting peace and stability.

In the United States, the use of solar and wind energy and fuel cells is growing, too, particularly in California and Texas. In a letter dated September 14, 1999, responding to my letter of congratulations on his signing into law of a bill that requires Texas utilities to increase their use of renewable energy sources to generate electricity by 2000 megawatts over the following ten years, then Governor George W. Bush wrote: "I am encouraged by our state's renewable energy potential and am pleased to see Texans pursuing those opportunities—with wind power projects in West Texas; solar panels in homes, offices, government buildings, and schools."

With strong political commitment and the right incentives, Texas's renewable energy program can be scaled up and multiplied many times throughout the United States. Some environmental regulations will also need to be revised to encourage technological change. "Best available technology" standards, for example, tend to entrench existing technologies at the expense of new cleaner ones. Yet, recent relaxation of clean air rules will neither help technological change nor the environment. In the summer of 2003, the Bush Administration decided to allow thousands of the nation's dirtiest coal-fired power plants and refineries to upgrade their facilities without installing pollution control equipment as required by the Clean Air Act (7).

Speaking of coal, the United States and major developing countries, such as China, India, and South Africa, have large resources that will continue to be utilized for some time to come. The U.S. Department of Energy (DOE) expects that the share of coal in U.S. electric generation will increase from the current 50 percent to 54 percent by 2025 and projects CO_2 emissions to increase by an annual 1.5 percent through 2025 (8). That, in my view, will require the development of cheaper and more efficient technologies for the capture and sequestration of CO_2 as well. Underground injection is a proven technology that can be expanded greatly, so that a substantial volume of CO_2 could be sequestered in deep unminable coal deposits, in depleted natural gas fields, and in saline aquifers. In Texas, about 200 million tons a year of CO_2 are being injected into reservoirs to enhance oil recovery. A Norwegian carbon tax has prompted Statoil to pump CO_2 into a deep saline aquifer under the North Sea since 1996 (9).

Without a comprehensive energy plan that would point the country toward a brighter, sustainable energy future, we will not have the technological advances and penetration of those advances into the economy at a magnitude that would significantly lower emissions of greenhouse gases and address U.S. dependence on foreign oil. Foreign oil now constitutes more than half of all U.S. consumption (57 percent as of July 2003) and is projected by DOE to rise to 70 percent of demand by 2025 (8). Since President Jimmy Carter made energy a national priority in the 1970s, every administration has tried to tackle the critical issues, but without success. Some blame this failure on the lack of imagination, others blame it on the lack of political will, or both. In contrast, the Energy Future Coalition, a bipartisan group of former government officials, academic experts, environmentalists, and energy industry representatives, released a report in July 2003 that sets out a detailed strategy aimed at balancing national security, energy, and environmental concerns. Their ideas go far beyond what Congress and the administration are currently considering. Clearly, the time has come for a national debate on energy and the environment.

Let me close in the same way I started my remarks, by talking about science. Scientific research, nationally and internationally, should continue to refine our knowledge about climate change and help narrow the uncertainties. But beyond better understanding of sources, impacts, and natural variability, we need science that addresses solutions to the problems of global change and sheds light on how the transition toward global sustainability might be achieved.

Bob Kates, together with 22 international scientists, utilized Science Magazine's Policy Forum in April 2001 to discuss "sustainability science"(10). They argued that "a new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society." They also argued that the difficulties of the situation in developing countries, particularly weak scientific capacity and vulnerability to rapid changes in social and environmental systems, are aggravated by resource and knowledge differences and a widening digital divide.

Sometimes in light of all the challenges we and the rest of the world face, there is the temptation to say "stop the world, I want to get off." As scientists, however, we can pause and take stock of problems, as well as progress and solutions. I, for one, remain optimistic that one day there will be global sustainability, with needed sources of energy virtually pollution-free and affordable, without abject poverty, and with all nations promoting peace and stability. In many ways, we have entered one of the most creative phases in human history. Science, technology, and communications are advancing at breathtaking speed and offering unmatched opportunities for responsible action. We have new tools and vastly increased understanding that our strength lies in working together across the globe—if we can muster the political will.

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Questions and Responses

DR. LANE: We have time for a few questions before our discussion panelists make their remarks, so here's one for Dr. El-Ashry: It would appear that the earth is engaged in a giant experiment called global climate change. Do you see any prospects that significant steps will be taken by the world to limit greenhouse gas emissions in the next 30 years?

DR. EL-ASHRY: Just one quick comment about public involvement. The public puts the pressure on the politicians, so not much can happen without public understanding of the issue. In the case of climate change, we talk about conditions likely to be happening in 2050 or 2100. That's such a long timeframe for anybody who is worried about today's issues or even tomorrow's issues. We can, however, bring more immediate consequences to people's attention, such as the notion of stronger and more frequent hurricanes or rising sea levels. For example, I recently heard a radio advertisement to encourage people to visit the science museum in Baltimore; it said that, if we continue to produce carbon dioxide, sea level rise will put you right on the beach, rather than having to go out to visit the beach now a two-hour drive away. Images like that help the public to understand the issue and start to put pressure on politicians, as they did for air pollution and water pollution back in the 1970s.

The case of the ozone hole is the best example of all. The public understood the skin cancer risk, and they actually stopped using the fluorocarbons and the canned sprays before regulations were instituted in the United States. When the public is mobilized, then we can really hope to have effective action—not just political consensus, which tends to be at the lowest common denominator of understanding—but effective action through public participation and public pressure.

DR. LANE: I have a question for Dr. Boesch: What do you see as the future development of fission power? Are we going nuclear?

DR. BOESCH: Well, I'm not an expert on fission power, but, if we look at the curves on energy resources that Dr. Lane showed and even the optimistic estimates of the various sources of supply, we are going to have to be very resourceful to meet rising demands. We will have to make better use of the energy of the sun, which is new energy arriving at Earth, and I think we probably are going to be revisiting nuclear energy as well in various ways around the world, as well as in this country. It's hard for me to predict exactly how much or what kind of nuclear power will ultimately be produced, but I think that it is probably going to be part of the mix of acceptable energy sources again.

DR. LANE: Let me just add that one of my hobbies is to chair a National Academies National Research Council panel on transportation of radioactive waste material to Yucca Mountain. It's a huge public opinion issue. Many people in Nevada don't want it, and one gets the impression that nobody so far wants it coming through their state. Even the most optimistic folks that I talk to about nuclear power are still projecting that it would remain about 20 percent of our electrical power generation. Of course, we're going to need more power down the road, so that share is going to have to be a bigger number, which means more nuclear power plants and more radioactive waste.

One of you has rejected my list of humanity's top ten problems. This questioner makes a very important point: So long as we continue to look at each of these as separate problems, we are not going to get anywhere. I totally agree with that.

Here is a question about whether our federal agencies are really structured to deal with a lot of these crosscutting problems, and of course the answer is, No. Even the internal parts of our agencies don't interact so well together. That's a huge, huge problem.

One of the questioners asked about the three-body diagram, wondering, Where is the public? Where is society? Well, of course, I should have said that all three bodies exist in the context of society, but the questioner rightly points out: Isn't it perhaps more important than I emphasized that scientists get in touch with the public, that they spend some time reaching out to the public? I couldn't agree more with that.

So let me pose another question from the audience: The policymakers have asked us to take on faith the idea that a transition to hydrogen is around the corner and is the solution of all our energy problems. Given the challenges posed by developing clean hydrogen sources and the implied complete change in infrastructure, do you truly think hydrogen is a feasible solution, and why and how? Would either of you like to comment on whether hydrogen is our future or not?

DR. EL-ASHRY: I'll take a crack. You know, I believe that hydrogen can be one of the means to a sustainable energy future. Hydrogen has been investigated for many, many years, and it's still a dream. I remember, when I was at the World Resources Institute back in 1987 or so, we issued a report on the feasibility of hydrogen as a future fuel, including the cost of the infrastructure, the safety issues, and so on. We released it on the Hill, since we were a policy research center and we had some friends on the Senate and on the House side who hosted us there. We knew that Daimler Benz and Volvo had already manufactured cars that could run on hydrogen, and we contacted them. Daimler decided to ship over a Mercedes that ran on hydrogen and fuel cells, and we used it in the parking lot to give senators and congressmen the chance to open the trunk to see what it looked like and how it worked. That was almost 20 years ago, and we haven't yet gotten out of the parking lot.

The important thing is that we have to wean ourselves off fossil fuels. There are a number of feasible options, whether it's hybrid cars or, ultimately, hydrogen as a fuel. I believe hydrogen as a fuel not only is feasible, it probably is the right way to go. In terms of infrastructure, it does not cost as much as other alternative fuels, because you can use the same pipelines that are being used for natural gas, as natural gas starts to dwindle. You can modify existing engines and filling stations to use hydrogen instead of gasoline.

But we have to start. We can't just keep doing little piddly research projects here and there and then all of a sudden expect that we can scale it up. It does not work that way. We have to start by demonstrating the feasibility of these technologies, so that the public and governments around the world will ultimately have a choice.

DR. BOESCH: I would just like to add that, as Dr. Lane pointed out in his remarks, moving to the hydrogen economy doesn't by itself solve the energy supply issue, because one needs an energy source to create the hydrogen. In the short run, that source is primarily going to be fossil fuels. Nonetheless, I think there are some very interesting prospects for increasing the efficiency of energy use, whether it's renewable energy or fossil-fuel energy in some applications. And there could also be some potentially very significant environmental benefits in terms of where energy is used and what the impacts are.

DR. EL-ASHRY: What I had in mind is using renewable energy, not fossil fuels, to produce the hydrogen. Otherwise, it would be self-defeating.

DR. LANE: Thank you very much. I think we have to move on. It was pointed out that we didn't mention fusion energy. I believe it was mentioned in passing, but we still don't know how to crack that nut. There are no fundamental problems with fusion; it's just much harder than any of us anticipated. It clearly is the ultimate source, but we don't know whether that's 50 years out or 100 or even longer. I hope you will join me in thanking our panel.

Discussion: David Rejeski

David Rejeski directs the Project on Foresight and Governance at the Woodrow Wilson International Center for Scholars and is an affiliated adjunct staff member at RAND. Most recently, he was a visiting fellow at Yale University's School of Forestry and Environmental Studies and an agency representative (from the Environmental Protection Agency) to the White House Council on Environmental Quality (CEQ). Before moving to CEQ, he worked at the White House Office of Science and Technology Policy (OSTP) on a variety of technology and research issues. Prior to his time at OSTP, he was head of the Future Studies Unit at the Environmental Protection Agency. He has graduate degrees in public administration and environmental design from Harvard and Yale. Information on the Foresight and Governance Project can be found at www.foresightandgovernance.org.

It is really a pleasure to be here. I am here as a nonscientist who has had to make extensive use of scientific information. I was thinking back six years, back to a time in which I was trying to get up to speed on a number of scientific topics, including genomics, nanotechnology, and cognitive neuroscience. In each instance I depended on a AAAS Fellow to point me to the literature and help me find the right people to talk to in the science community. That help was invaluable to me as a policymaker trying to unravel very complex scientific issues.

So, I'm a living example from the policy community that the AAAS fellowship program has tremendous value, because I couldn't deal with a lot of the scientific issues that I have had to deal with without the help of AAAS Fellows. I believe in the program; I know it works; and I just wish there were more AAAS Fellows out there.

I'm a living example from the policy community that the AAAS fellowship program has tremendous value, because I couldn't deal with a lot of the scientific issues that I have had to deal with without the help of AAAS Fellows.

I would like to start off with two short quotations. The first one comes from a short essay by Richard Feynman on science and values, in which he quotes a Buddhist proverb. He says that "every man and woman is given a key that opens the gates of heaven. That key also opens the gates of hell." The other quotation is from a great little essay by Francis Bacon on innovation, and it goes: "Those who avoid new remedies must expect new evils, because time is the greatest innovator."

Both quotations point to a situation that we are in right now: characterized by a constant tension between remedies and evils, and the one thing we do not have is time. Time will either be our enemy or our ally. From a policy standpoint, it is often the enemy, because it is very, very difficult to actually think about policy when everything is speeding up. I was thinking about what has changed since last September, when we were originally supposed to be holding this symposium. We have seen a 50 to 100 percent increase, for instance, in the amount of computing power per unit cost, and similar gains in display resolution, available bandwidth, the cost of sequencing a DNA base pair, and the amount of useful genetic knowledge. And that rate of change will go on into the future as fast and as far as the eye can see.

That is what makes public policy in our present era very, very difficult. If I were to look back from the year 2050 as an environmental historian I might see two possible scenarios leading out from the present time: One is that the next 10 years are a time of incredible environmental progress; the other is that they are a missed opportunity, a period characterized by a massive failure of human imagination combined with a lack of political will.

Let me take you on a little trip into those two scenarios. I have a morbid habit of collecting headlines. This is just a fairly recent collection of what is out there; not much to be optimistic about:

- EPA Eases Clean Air Rules on Power Plants (*Washington Post,* August 27, 2003)
- Senate Rejects Bill on Fuel Economy

(*San Francisco Chronicle,* June 30, 2003)

- Utilities Aim to Postpone Mercury Emissions Targets Until 2018 (*Washington Post,* June 29, 2003)
- TVA Is Free to Ignore EPA Rules (*Washington Post,* June 26, 2003)
- Seven States Vow to Sue U.S. on Pollution Policy (*Washington Post,* February 1, 2003)
- Lead Hazards Brushed Aside (*Boston Globe,* February 1, 2003)
- Efforts to Ease Air Rules Decried (*Washington Post,* October 19, 2002)
- EPA Drops Chemical Security Effort (*Washington Post,* October 3,2002)
- EPA Seeks Leeway in Rules About Dirty Water (*Washington Post,* August 8, 2002)

On a more positive note, some of you may remember that we recently decided to regulate diesel emissions. Now the interesting thing is that, in the year 2004, we passed regulations to begin to deal with a piece of technology that Rudolf Diesel rolled out in 1893. I want you to think a little bit about that. This is a technology from the First Industrial Revolution that we are still grappling with 100 years later. And it's typical. Whether you look at chemical synthesis, transportation technologies, food production technologies, or any other technologies, once they are put in place, they affect our environment for a long time.

This picture could make you depressed, I suppose. But I look at it a different way. I spend a lot of time in another universe that the environmental policy people don't go into much, one that's loaded with scientists and bleeding heart techies who see something that is very different in the current turmoil. They see enormous change taking place, and that makes me very optimistic. A lot of the change is hidden behind a veil of jargon, but all kinds of things are going on that will change the very nature of production–forever.

People have referred to this period as "the little BANG," characterized by a convergence of bits, atoms, neurons, and genes, or informatics, nanotechnology, neuroscience, and genomics. Actually, if you read science fiction, you saw it coming 20 years ago. Today, people are talking about Michael Crichton's book, Prey, right now as a nanothriller, but if you look at the literature, there are close to 30 science fiction books that have dealt with nanotech since 1983. Go back to Greg Bear's 1985 book, *Blood Music,* for instance, or Michael Flynn's *Nanotech Chronicles* in 1991. You will begin to pick up a lot of the signals about this emerging world in the sci-fi literature. Eventually, those ideas make it into *Wired* magazine, and before long they get into the staid *Harvard Business Review,* and people in corporations are actually reading about them, thinking about them, and talking about them.

The Next Industrial Revolution [is]... not going to be driven by environmental lawyers, but rather by science and technology people.

What is happening is that we have entered what some people are calling the Next Industrial Revolution. And what does that mean? Does it create an opportunity? I think it does, one that's not going to be driven by environmental lawyers, but rather by science and technology people. They will be the ones who see change first, probably not as fast as the sci-fi people, but they will see it before the lawyers and the policy wonks.

So imagine we wake up in 2033 and find that the First Industrial Revolution is over, and we have passed through another kind of revolution. What's different? Environmentalism, as we have known it since the 1970s, will probably be very different. Until now, we have spent most of our time dealing with the byproducts of the First Industrial Revolution. We are cleaning up rivers polluted by decades-old production processes; we're taking emissions out of the air. As policy has progressed, we have shifted our focus from the byproducts to the products themselves. In the U.S. we have moved in that direction a little bit, but not as far as the Europeans who have gone far beyond us in recycling and product take-back schemes.

Until now, we have spent most of our time dealing with the byproducts of the First Industrial Revolution. We are cleaning up rivers polluted by production processes; we're taking emissions out of the air.

Now, if you believe that we have essentially passed over into another industrial revolution, then it is time to focus on the new means of production. We have gone from byproducts to products, and now we must turn to production itself. Everything is on the table: how we produce, where we produce, whether we produce, and whether we choose to substitute bits for atoms, for instance. This is an incredible opportunity! The envi-

For every thousand dollars we invest in science, we probably now spend a penny or two thinking about how to manage science.

ronmental people should be jumping up and down at the prospects. They aren't yet, but it will happen.

In the First Industrial Revolution, we were essentially forced into an adaptive position. That was a world of boundaries, incremental changes, and the science of discovery. Now, we are facing a very different world. It's a world where scientific disciplines converge; everything is fluid, mobile, and interconnected; and change is exponential and highly disruptive. Our old approaches won't work well now, or won't work at all. There is only one option for the Second Industrial Revolution: we are going to have to figure out how to shape an emerging technological and scientific infrastructure, and we don't know how to do that. I can tell you after working in a policy environmental that the policy people have no answer here. The environmental community hasn't thought this through at all.

It is an incredible opportunity, and essentially there is no alternative. There's a concept that was developed by the scenario planners at the Royal Dutch Shell Corporation, and it applies here. They talk about TINAs, meaning the acronym for There Is No Alternative. We can't go back. We can't wait for this world to happen, and in 20 years say we're going to regulate it. There's only one option, and that is essentially to shape it on the run as it emerges.

So here is the big challenge and opportunity: Can we shape the next industrial revolution to co-optimize for environmental and social benefits and mitigate environmental harm? I realize it's a nontrivial task. It involves rethinking a lot of what we call science and technology policy. What are the existing technology trajectories? Are we going to go to a hydrogen economy? And what is the underlying science?

We will also have to consider how we manage science. For every thousand dollars we invest in science, we probably now spend a penny or two thinking about how to manage science. If we're going to manage science effectively in the future, we will need to rethink the appropriateness of our institution and the nature of public dialogue and education.

Finally, we will have to come up with really new ways to think about having ethical dialogues. What kind of ethical frameworks are applicable to the emerging and future science and technology challenges? We won't resolve these tremendous challenges here, but we have two great discussants to help us think about them.

Discussion: Theodore J. Gordon

Theodore J. Gordon is a futurist and specialist in planning and policy analysis. His current professional activities include serving as senior fellow of the Millennium Project for the American Council of the United Nations University. He is founder of the Futures Group, now the largest private organization performing future-oriented research for private organizations and government agencies. He is also senior advisor to the Futures Group International. A consultant, author, and lecturer, he has served on the boards of several companies, including Apollo Biopharmaceutics, Rolodex, the Institute for Global Ethics, and others.

It is a pleasure to be here as your token futurist, and my topic in fact does deal with the future, particularly the management of science and technology in the future. The Millennium Project that I have been associated with for the past few years is a global network of people interested in the future. It is a project that accumulates information about the future, tracks certain global issues over time, and searches for answers to those challenges by asking chosen experts what they think about these issues and potential solutions. The list of issues is not very different from Professor Lane's list of the ten major problems facing the world. The objective of the project is to seek a broad range of international perspectives on the emerging issues and forces.

Inevitably, as we seek answers to some of those issues, science and technology (S&T) come up as the mechanism for a cure, the therapy for addressing social issues, and incidentally the source of much havoc. So, three years ago we began to look more seriously at the question of whether and, if so, how science can be steered. Is it possible to manage science without destroying the spark of innovation that has given us the great accomplishments that characterize our age? Our Planning Committee decided, with funding from the U.S. Department of Energy, to tackle this issue in an open-ended, three-year study of the future management of science and technology.

Is it possible to manage science without destroying the spark of innovation that has given us the great accomplishments of our age?

We started with a blank slate and began the work by convening science and technology attachés in Washington. We asked them to help us identify the important questions to ask about the future of management of science and technology. We followed that with two rounds of questionnaires with our chosen experts around the world. The implications of the first year's research were studied in more detail in the second year, in which we conducted interviews with managers of research facilities, managers of science projects around the world, academicians, and policy-makers. In the third year, which I'll be describing in more detail, we created a series of scenarios about how S&T management might evolve and drew some insights from those scenarios.

The Millennium Project is run under the auspices of the American Council for the United Nations University. In operation since 1996, the project now has 20 nodes from 50 countries around the world that conduct research in local languages by distributing questionnaires, conducting interviews, translating them, and analyzing them. All in all, we have had more than 1,500 participants from all around the world. Our coverage in Africa is meager, but everywhere else it is fairly good. Europe is heavily represented, as is Latin America and North America. Academic institutions, and nongovernmental organizations (NGOs) are all included.

This project is not based on opinion polling. Rather we ask our nodes to identify specific experts in their area who could best address these questions because of their experience and interests.

The questions that came out of the first year's work included these:

- How can S&T help improve the human condition?
- What research has the greatest potential risks?
- What catastrophes can science help avoid?

Synergy is an engine for change in science.

- How can ethical factors be considered in S&T management?
- What are some seminal scientific developments?
- How can science become more important to the decision process?
- How can interdisciplinary research be strengthened?

Across the whole spectrum of questions, there seemed to be a subtext on scientific sovereignty. Scientific sovereignty is an important issue that encompasses questions such as: Under what circumstances can the body politic intervene to steer scientific research? Should these important decisions be left to the scientists, the disciplines, the committees, or others? These questions pervade many of the points that I will be making.

By the end of the first year, we were seeking answers to some of these tough questions. For example, in asking how ethical consequences could be more thoroughly considered, some of the answers generated by our group included:

- Understanding the causes for unethical behavior
- Establishing ethical market economy systems (that suggestion arose particularly out of South America)
- Finding means for reducing corruption
- Including in large science budgets funds for the study of ethical implications (as the National Science Foundations is now doing)
- Conducting research into global ethics and promulgation of values.

These are just examples of the kinds of answers that were generated to our study questions. A whole area of research opened to us. Is there a global ethic? Do ethics cut across nations and groups, and how do values, once established, move from those value innovators to others?

One thing that came out of this process was the perception that synergy is an engine for change in science. This is the "little bang" that David Rejeski was talking about, and it can also be represented by a Venn diagram with the overlapping of cognitive science, nanotechnology, and computers (see Figure 1). As a means of exploring the future intersections of disparate technolo-

FIGURE 1. Representation of Synergy among Cognitive Science, Nanotechnology, and Computers

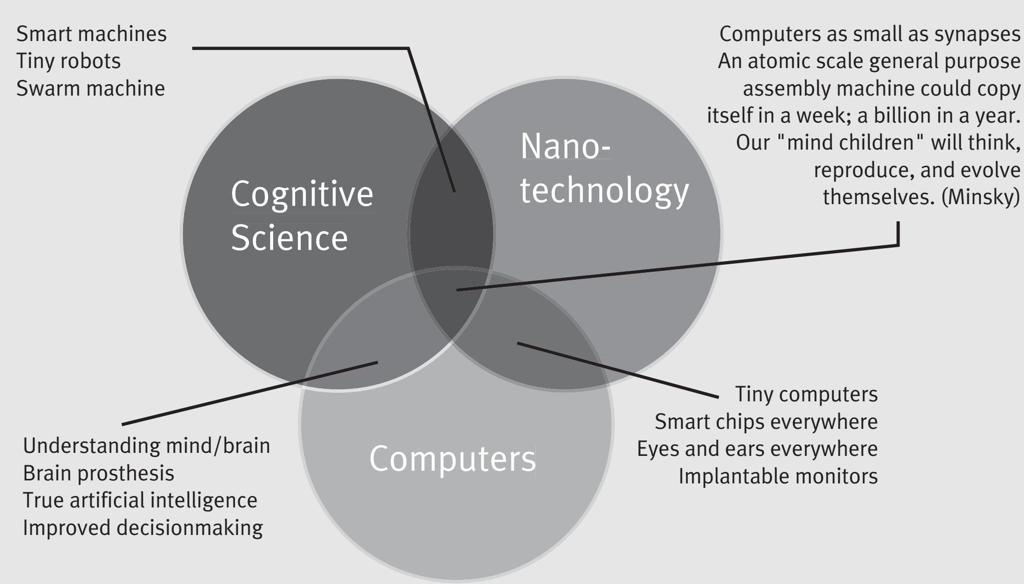

TABLE 1. Four Scenarios for Science and Technology Management

	Scenario	Centralization of science		Public support		Functioning of regulation		S&T speed	
		High	**Low**	**Pro**	**Anti**	**Works**	**Fails**	**Accelerates**	**As now**
1.	S&T Develops a Mind of Its Own		X	X		X		X	
2.	The World Wakes Up	X		X		X		X	
3.	Please Turn Off the Spigot	X			X	X		X	
4.	Backlash		X		X		X	X	

gies, these overlaps become areas of pregnant change.

Between cognitive science and nanotechnologies, we can expect to see the growth of smart machines, tiny robots, and swarm machines. The overlap between cognitive science and computers locates greater understanding of the mind and the brain, as well as brain prosthesis, true artificial intelligence, and improved decisionmaking. What a black art that is. How is it that some people can make good decisions with hardly any information, through intuition? What do they know that we don't know? What do they practice that we ordinary mortals don't? There's a whole area of research coming from psychology, economics, and policy research on how to make good decisions.

In the intersection between nanotechnology and computers, we can expect to see the development of tiny computers and smart chips, which will monitor everything, everywhere.

Right in the middle, we will see the greatest synergy of all, as computers become as small as synapses and atomic-scale machines copy themselves by the billions. Marvin Minsky at MIT asserts that these "mind children" will think, reproduce, and evolve by themselves.

As we looked at the answers generated by our respondents, we saw that the contributors could be grouped into two schools of thought. The first school said, Regulations will drive research underground. Don't regulate. If you regulate, the research will go to other countries. The regulators are never as good as the scientists they are trying to regulate. Regulators cannot keep up with the advances. Therefore, minimize regulation and control. Instead, train the scientists in ethics and to self-manage risks.

The other group, very vocal, said the scale of impacts is now so large that global systems are required to assess the risks. We must design regulations and enforce agreements. The dangers are global, so the control must be global. Some threats should be banned, others controlled.

We couldn't resolve the strong differences of opinion between these two camps. So, we developed four scenarios that played out various views. In response to the group that argued that for an international system of regulation, we sketched out an international science and technology organization, called ISTO in our scenarios. It's the U.S. Office of Technology Assessment revisited on a global scale. It evolves from an information system and becomes a de facto regulator, as it draws its guidelines from communication with experts in the various fields that it is called to comment upon.

The scenarios were constructed in a rather conventional way. That is, we decided on a framework, and we permuted the extremes of the framework to create the geography of the scenarios. There are three dimensions that distinguish each of the scenarios from the others (see Table 1). First, will science become centralized or not? Is the centralization of the future high or low? Second, is public opinion for or against science? Third, does the regulation that is established in the scenario work, or does it fail?

We had a fourth dimension, which was S&T speed, from low to high, but as we built our scenarios, we found that was not a very useful, because no matter which scenario we built, the speed was always high.

I'll give a quick sketch of the results for each scenario:

FIGURE 2. Novel Concepts Presented in the Scenarios

Agent of God (a SIMAD)
"Unplug-and-Relax" movement
Connections between education and security
Corruption in the S&T regulatory agency
Early detection of intolerance
Electronic psychotropes: escape but entrapping
Entertainment/ education systems including "You Were There"
Global projects for energy, water, and diseases
Memes (influential contagious ideas) for tolerance and to stamp out stupidity
Rise of neo-McCarthyism in science
Development of Scientist's Oath
Nanotech viruses
"Off switches": nano and genome
Policies for control of publication of dangerous research findings
Principles of inviolability of science autonomy
Telomerase dispersal as a weapon
Intervention of UN Security Council
Uneasy relationship between SIMAD prevention and transnational crime
Utilization of artificial intelligence programs to minimize corruption

SCENARIO 1: S&T DEVELOPS A MIND OF ITS OWN. The focus here is machine-human interconnection. The rate of scientific discoveries and advanced technological applications explodes. A global science–social feedback system is at work, so that people are smarter because they have better access to information; smarter people then make better and faster science; and better and faster science opens new doors to discoveries and synergies. The speed of decisionmaking and the excellence of decisionmaking accelerate. Even though decisionmakers are better, they are left behind by the scientists. The roadblocks are removed; new science is created at an increasing rate. The regulators are left in the dust.

Is it plausible that weapons of mass destruction will be available to single individuals? Seventy-two percent said yes.

SCENARIO 2: THE WORLD WAKES UP. In this scenario we introduced the notion of a SIMAD, which stands for a single individual massively destructive. This is a single terrorist, but not a terrorist of the sort we know now. This is an individual who is a working scientist, but a mad scientist, who has access to weapons of mass destruction. In this fictional case that weapon is a genetically modified Congo virus, with which the SIMAD kills 25 million people. We noted here that the conventional techniques used for identifying terrorist organizations do not work to identify and control a single person, who may be a self-proclaimed agent of God but who is also producing as a scientist, working at the bench with respect, and publishing papers. Education is the answer in this scenario. Profiling individuals to find tendencies in this direction becomes part of the society, and it is a pretty bleak picture.

SCENARIO 3: PLEASE TURN OFF THE SPIGOT. Science is attacked as being pompous and self-aggrandizing, encouraging excesses in consumption, raising false hopes, and failing to recognize unexpected consequences that can destroy us all. Again, the key to hell opens, and somehow, intentionally or accidentally, genetically modified organisms with the potential to be weapons of mass destruction are released. But in this scenario a science guru arises and galvanizes the public. He or she is the leader, the Gandhi of science, who offers to lead science in a direction that will be more promising for society. A commission is established to listen to and follow the guru's lead, but it turns out in this scenario that the commission is not isolated from the corruption that has destroyed the government.

SCENARIO 4: BACKLASH. Control is low and science moves fast, but negative consequences cause public alarm. Some of the most valued discoveries and new capabilities have downsides, and surprises abound. Terrorists take advantage of some of these shortcomings. The level of concern rises, and the media, once the friends of science, now attack it. Mobs form in front of university and government research labs, as they once did in protest of globalization. Progress stalls, poverty continues, and the conventional tools used to analyze technology, such as cost-benefit analysis, don't work because the stakes are so high. How can we trade off the possibly terrible risks of creating a black hole in the laboratory against the possibly cosmic knowledge benefit that comes from the experiment?

All four scenarios incorporate many novel concepts, including the connections between education and security; the early detection of intolerance; the spread of global projects for energy, water, and disease control; the use of memes (influential, contagious ideas) to spread the notion of tolerance around the world; the rise of neo-McCarthyism in science, when scientists would be ostracized for pursuing certain kinds of research; the potential for turning off questionable developments, if things go wrong; the involvement of the United Nations Security Council in science; and the use of artificial intelligence to minimize corruption. Figure 2 provides list of some of the novel concepts presented in the scenarios.

As we passed the scenarios around for comment, we asked our panels and others some specific questions about plausibility of some future developments. Are dramatic increases in the collective human machine intelligence plausible? Seventy percent said yes. Will regulatory organizations fail to keep pace? Seventy-eight percent said yes. Is it plausible that weapons of mass destruction will be available to single individuals? Seventy-two percent said yes. Is it plausible that advances in cognitive science and educational systems will improve tolerance? Sixty three percent said yes. Will international treaties and regulations have provisions for police enforcement, or military intervention in scientific pursuits? Two-thirds said yes. Can S&T regulators be free from corruption? Seventy percent said no. That's a disappointment, isn't it? The results are summarized in Table 2.

So we concluded that:

- S&T management happens at several levels simultaneously: globally in global organizations; nationally in advisory commissions, agencies of government, and in the disciplines themselves; and finally individually as the researchers themselves select and manage what is done.
- Forecasting and risk assessment are needed.
- Funding of S&T should be linked to the needs of humanity.
- The possibility of a SIMAD, a single individual bent on massive destruction, is plausible.

TABLE 2. Survey Responses to Key Scenario Questions

Question	Percentage responding yes	Percentage responding no
1.2 Are dramatic increases in collective human-machine intelligence plausible?	70	30
1.4 Will regulatory organizations fail to keep pace with advances?	78	22
2.2 Is it plausible that WMD will be available to single individuals?	72	28
2.3 Is it plausible that advances in cognitive science, information technology, and new educational systems will improve tolerance?	63	37
2.4 Is it plausible that international S&T treaties and regulations will have provisions for police enforcement or military intervention?	67	33
3.2 Can S&T regulators and commissions be virtually free from corruption?	28	72
3.3 Is it plausible that an anti-science movement will be as or more powerful than the environmental movement?	37	63
3.4 Is it plausible that international systems will be established to monitor and regulate biotechnology, nanotechnology, with enforcement powers?	75	25
4.2 When extreme unintended consequences are involved, can a cost-benefit trade-off be logically made?	41	59
4.3 Might scientists in the future unite into a global labor organization?	29	71
4.4 Can science disciplines effectively self-regulate?	42	58

S&T management happens at several levels simultaneously: globally in global organizations; nationally in advisory commissions, agencies of government, and in the disciplines themselves; and finally individually as the researchers themselves select and manage what is done.

- The relationship between S&T and policy-makers has to change.
- Interdisciplinary research is likely to lead to synergies.
- The globalization of science without global ethics could lead to disasters.

The globalization of science without global ethics could lead to disasters.

The reason scenarios are built, often, is to find policies that work no matter what extremes the scenarios describe. I would like to conclude with the policy recommendations we drew from our study: The possibility of a SIMAD should be seriously considered as a threat. When research is undertaken that has potentially negative consequences, those consequences should be made explicit. Mitigation strategies should be developed in parallel. If there is a threat, let's at the same time develop the antidote. Each level of management—from global to individual—should take responsibility for their actions. Risk analysis is important. We must include public participation in priority setting, and we must explore alternative institutional forums to minimize the chances of impeding innovation. Finally, we should encourage the teaching of science ethics. The full list of our recommendations is in Figure 3.

FIGURE 3. Millennium Project Policy Recommendations for Science and Technology Management

Consider SIMAD as a threat.
Make unintended consequences explicit.
Develop mitigation strategies in parallel.
Require each level of management to take responsibility.
Encourage high-level organizations to engage in risk analysis.
Promote full funding of multination research into nanotechnology, artificial intelligence, biotechnology, cognitive science, learning processes, and global problems, with adequate attention to future uses, ethical implications, risks, and impacts.
Include public participation in priority setting.
Explore alternative institutional forms to minimize the chances of impeding innovation, promote sharing the benefits globally, minimize risks, and operate without corruption and with wisdom.
Teach science ethics.

Discussion: Mary Evelyn Tucker

Mary Evelyn Tucker is a professor of religion at Bucknell University in Lewisburg, Pennsylvania, where she teaches courses in world religions, Asian religions, and religion and ecology. She held the National Endowment for the Humanities Chair in the Humanities at Bucknell in 1993–996. She received her Ph.D. from Columbia University in the history of religions, specializing in Confucianism in Japan. She has lived in Japan for several years and traveled extensively in Asia over the past 30 years.

Dr. Tucker is the author of *Worldly Wonder: Religions Enter Their Ecological Phase* (Open Court, 2003) as well as *Moral and Spiritual Cultivation in Japanese Neo-Confucianism* (SUNY, 1989). She co-edited *Worldviews and Ecology* (Orbis, 1994), *Buddhism and Ecology* (Harvard, 1997), *Confucianism and Ecology* (Harvard, 1998), and *Hinduism and Ecology* (Harvard, 2000). She also co-edited *When Worlds Converge: What Science and Religion Tell Us About the Story of the Universe and Our Place In It* (Open Court, 2002). She co-edited two volumes with Tu Weiming on Confucian Spirituality, published by Crossroad in the World Spirituality series in 2003 (volume 1) and in 2004 (volume 2).

Dr. Tucker and her husband, John Grim, directed the series of ten conferences on world religions and ecology at the Center for the Study of World Religions at Harvard Divinity School in 1996–998. They organized three culminating conferences at Harvard, the United Nations, and the American Museum of Natural History in New York City and are the series editors for the ten volumes from the conferences, which has been published by the Center and distributed by Harvard University Press. For information on the Forum on Religion and Ecology see http://environment.harvard.edu/religion. They also edited a 2001 *Daedalus* issue on religion and ecology focused on climate change.

Dr. Tucker has been a committee member of the Interfaith Partnership for the Environment at the United Nations Environment Programme since 1986 and is vice president of the American Teilhard Association. She was a member of the Earth Charter Drafting Committee from 1997 to 2000.

It is a pleasure to be here, and I want to thank all the organizers, especially Phyllis Windle and her committee, for the invitation to join you. Congratulations to all of you who participated in this extraordinary project of science and policy. I think there could be few things that are more important to our nation and the world, especially at present.

I understand one of the directions for AAAS is to advance science, but also to serve society. And my question is, To what end? For progress, advancement, development? Again I would ask, to what end? If the life support systems of the planet are being destroyed at an alarming rate what is the role of the AAAS? Some of the presentations here assert that what is at stake is a sustainable future— not just sustainable development, but sustainable life for the planet. If so, I think the goals toward which science and technology can contribute need to be carefully reconsidered, especially with regard to this emerging field of sustainability sciences. What I am suggesting is the need to reexamine what constitutes progress and development. Is it our myth of progress that is in fact destroying the planet?

Now, what brings together the issues discussed here of energy, environment, and global change? Certainly, they all contribute to the nature of our current planetary crisis in terms of scale, magnitude, and impact, as we have heard throughout the presentations. The nature of the crisis clearly is interrelated and complex and therefore will need bold solutions. The magnitude of our current challenges cannot be underestimated, for this crisis affects every aspect of our lives. We cannot afford to talk

We cannot afford to talk about global security without talking about the environment; nor can we talk about health and healthy people on a sick planet.

about global security without talking about the environment; nor can we talk about health and healthy people on a sick planet. So, this fundamental sensibility of the fate of the planet as a whole is at stake, and new human-Earth relations are needed.

For example, we have heard many discussions here about energy and the necessary shift from fossil fuels to alternative and renewable energy. This will be a shift of enormous magnitude. Historically we are in a "petroleum interval," which we know will be over soon. How will the termination of the age of petroleum affect every aspect of our lives, from the clothes we wear to the cars we drive to the planes we fly in?

The deterioration of the environment also poses macroscale problems, such as global climate change, as John Holdren has been telling us for a long time. The invisibility of these macroissues is one of the greatest challenges for humans to understand. When Bill McKibben wrote *The End of Nature* in 1987, climate change was an invisible issue. It is now becoming visible. The icecaps are melting, the glaciers are receding, the tundra is breaking up, and species are losing their habitat. As we know, the other macroscale problem is the loss of species, ecosystems, and habitats. Many scientists are telling us we are creating changes on the scale of a geological era because we are shutting down life support systems of the planet. We are in the midst of a sixth extinction period as Franz Broswimmmer describes in his book, *Ecocide: A Short History of Mass Extinctions.* The Hall of Biodiversity at the American Museum of Natural History, which was curated by Niles Eldredge, has a plaque in the center of the exhibit that states we are in the midst of this sixth extinction period, but we can stem the tide of destruction. What does it mean to live in the terminal phase of the Cenozoic era? And what does it mean then, if we talk about the macroscale problems we are facing, to reflect on who we are as humans? Are we a viable species? It's not just a question of whether the great apes, our closest mammalian relatives, will survive in our lifetime. Who are we as a species on this planet to cause the death of other life forms on such a scale?

There is no question that science and policy will be guiding us into the future. Nonetheless, science and policy alone will not make these shifts. They are necessary, but not sufficient.

This massive change is drawing us toward a new sensibility of human-Earth relationships. As Peter Raven said almost 20 years ago "We are killing our world." Or as E. O. Wilson wrote in an article in the *New York Times,* "Is humanity suicidal?" At every environmental conference I attend, this is the critical issue that arises, and along with it is the question of what are the sources of hope. All of you involved in education know these are real issues for students, and I will return to this point.

Consider the possible solutions. All of these problems are global, and we in the first world, especially in the United States, have an enormous responsibility, as we have heard from Ismail Serageldin and Frank von Hippel who both urged us toward an international commitment. AAAS has to expand its first letter A, from America to the world. Its first A needs to involve even more international outreach and technical assistance than in the past. This is crucial as we realize the close connection of poverty, environmental degradation, and inequity around the planet.

The solutions, then, are clearly international in conception and interdisciplinary in nature. We need fresh thinking, but we also need enormous humility. There is no question that science and policy will be guiding us into the future. Nonetheless, science and policy alone will not make these shifts to a sustainable future. They are necessary, but not sufficient. Therefore, we need, more than ever before, moral sensibilities for new human-Earth relations, a people-based environmentalism, as Serageldin said. He was urging us to embrace a new contract of science with society. I suggest that this sensibility of a sustainable future requires a change of consciousness and conscience.

These are ethical, value-related changes. They call us, as Aldo Leopold called us with a land ethic, to extend our ethics to more than the human world, to encompass the ecosystems that support the human world. This is an extension of care and compassion to the entire system of life. That is what is at stake here. The next 30 years will clearly require a dialogue between and among disciplines that allows for creative thinking and integrated solutions. And here I suggest that science and policy need to include humanities and values in discussions on the environment. They need to embrace the human. We are the species that is going to be responsible for what life forms continue, whether it is the great apes, the fish, the birds, the reptiles, or the insects.

We have certainly seen this movement toward the inclusion of values in the growing presence of civil society at the United Nations where the participation of nongovernmental organizations (NGOs) is encouraged. We have seen it in the reconfiguration of globalization, from the anti-globalization movement, which suggests that a new world of equity and justice is possible, to key economists, such as Joseph Stiglitz, who are calling for globalization with a human face. Trickle-down or neoliberal economics are not going to bring us a sustainable future because market forces alone do not produce equity. Nor do they protect the environment.

The greatest challenges for science and policy, then, are not only how to educate a broader public on current issues and how to keep Congress and government agencies up to date on the latest technologies. It's not only how to get the newest science stories out through the media. All of those things are critical, and you have spent 30 years doing a superb job on them. But I also suggest that one of the greatest challenges for science and technology is to invite into the heart of the conversation a broader range of voices—especially from the humanities. Some of these voices have been present at this conference, and I know that there are other efforts to do this, in calls for public and private cooperation around environmental issues.

Let me offer you some reflections on where the humanities might contribute to these discussions. Specifically I will talk briefly about history, literature, philosophy, and religion. Environmental history is a rich, emerging field that can provide important guideposts for the future. John McNeill, a professor of environmental history at Georgetown University, has published a magnificent book called *Something New under the Sun: An Environmental History of the Twentieth Century World.* His description of an unsustainable path is something we all need to pay attention to. More than a dozen years ago, Clive Ponting wrote *A Green History of the World,* which is also not a happy scenario about civilization's environmental mistakes.

What I am trying to suggest here is that environmental history can help us to realize that we are now involved in an effort to create a multiform but sustainable planetary civilization. This is an opportunity for both individuals and institutions to participate in creating the ethical basis for a sustainable future, which will need imagination, will, leadership, and perseverance. To succeed, it's going to require involving history and other humanistic studies, especially literature, philosophy, and religion.

Literature has important insights to offer in this regard. The environmental literary movement in the United States is in a renaissance. We have extraordinary nature writers such as Wendell Berry, Terry Tempest Williams, Barry Lopez, Scott Sanders, Richard Nelson, Linda Hogan, and others. They are giving us back the dying art of observing and understanding nature and ecosystems. We have virtually lost all of our naturalists in the academy. We are recovering those sensibilities again from the nature writers. The literary magazine, *Orion,* is helping to spur that movement. It involves quite an extraordinary group of writers, artists, and intellectuals, and I think we should welcome them into the conversation.

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Philosophy, too, has been involved in a 30-year dialogue on environmental ethics. J. Baird Callicott, Holmes Rolston, Clare Palmer, Dale Jameison, and others within environmental philosophy have been working out some of the more sophisticated ethical discussions regarding intrinsic rights, utilitarian rights, and so on. However, a number of them are suggesting that we need more than philosophical arguments to awaken people to the urgency of the environmental and social crises that confront us. They are observing that the moral persuasiveness of religious traditions and religious leaders may help in making this transition.

I come now to one of the most difficult challenges we all face in involving the humanities in these issues, namely the religious traditions. Even talking about religion within a scientific environment is problematic. However, the study of the history of religions, which is a developed field within universities, needs to be part of discussions regarding environmental problems. The world's religions are transformers of human values and behavior. They cannot be ignored, but they need to be understood in their complexities–recognizing their limitations but also understanding how they have shaped human culture and civilization for millennia. What we are talking about is how we bring in the spiritual and moral aspirations that are deeply grounded in the human soul, psyche, and personality. I'm not talking about the caricature of religion identified with rigid or benighted fundamentalism, which has entered into our discussions here in very negative ways. Instead, I am suggesting that the multiple voices of the world's religions need to come to the table, and we need to figure out ways to bring them in and converse with their representatives. We can remind ourselves that progressive religious voices have been at the forefront of many important changes such as the abolition of slavery and the civil rights movement. There are hundreds of millions of people who have embraced a spiritual life path, and they also take seriously the sense of the natural world as intrinsically valuable. We cannot ignore these potential allies in helping to create a sustainable future for the planet.

There are hundreds of millions of people who have embraced a spiritual life path, and they also take seriously the sense of the natural world as intrinsically valuable. We cannot ignore these potential allies.

Let me suggest a few basic things we can do to move this conversation forward. We need to realize that world religions are complex; they are vast; they are historical; and they are ever changing. They are changing now, in relation to pressing global issues, especially the environment. We have to attend to the huge variety of theological and ethical perspectives within each of these traditions. They are not monolithic, nor are they all involved with simplistic fundamentalisms.

In particular, we have got to understand the multiple forms of fundamentalism and what is troubling their followers. Let's go beyond our dismissive caricature of them. Fundamentalism here in the United States and in the world at large is not just the Christian right, to which we tend to equate all religious sensibilities. Yes, their political interventions in issues of women's reproductive rights or the theory of evolution are problematic and represent a resistance to modernity as it is rapidly reshaping traditional worldviews. But this is not all of what constitutes religion. There are and have been many progressive movements led by open-minded religious leaders and lay people concerned about justice, equity, human rights, and the environment.

In addition, we need to keep in mind that there are various forms of fundamentalism around the globe, as well as liberal-minded religious people trying to help create the conditions for a viable global community. Fundamentalisms are present in the Islamic world in a variety of ways. However, there are a billion Muslims, ranging from Morocco to Indonesia, including some extraordinary intellectuals whom we need to involve in the conversation of pathways to a sustainable future. Fundamentalisms are also Jewish, as we see in Israel in various forms, including the Likud Party. They are Hindu, as evident in India's political party, the fundamentalist-oriented Bharatiya Janata Party. The fundamentalisms that are sweeping the globe are multiple and complex. We have to understand why they have arisen. What are they afraid of? What are they resisting? What are they asking of us?

There are millions of people who are not fundamentalist but are open to religions. They have ethical sensibilities to be brought into this discussion of a sustainable future. That is a huge and important challenge. I can tell you that many of the 800 scholars who came to Harvard to the Center for the Study of World Religions to participate in our series of conferences on world religions and ecology would be welcome partners in these discussions. They have studied these traditions; they have lived in the countries; and they understand the complexities of culture and religion.

Now let me just bring us to some final points. I want to tell you about the conference series at Harvard and why it may be useful to your work in science and policy. It is clear that the sensibilities of people with regard to nature and other species have been shaped, for better or worse, by their culture, religion, and indigenous values. This was especially true in the pre-modern period, which is not to say that these values have prevented destruction of the environment in earlier periods. Moreover, in the second half of the twentieth century the race toward modernization has overridden most attempts to restrain development, especially in Asia.

As I have seen in over 30 years of traveling and living in Asia, the widespread degradation of the environment due to industrialization and modernization has occurred there in just three decades. The impact of such unrestrained development in Asia- especially in China and India- leaves us at the brink of an unsustainable future for the planet. If you consider that nearly two-thirds of the world's people live in Asia, over 2 billion in China and India alone, then you see the drive to close the gap between the developing and developed world has sobering consequences, as Ismail Serageldin has reminded us. Every Indian, every Chinese wants a refrigerator and a car, which will also require more energy and more oil use. How do we respond to this? Is development viable only if it is equated with increasing material consumption? How does the conspicuous consumption of the first world factor into this? We have got to respond to these issues with more thoughtful ethical, cultural, and religious perspectives. Moreover, we also need to be sensitive to the fact that Asians don't want to be told by the first world not to develop or even how to develop. This is a delicate conversation indeed.

Within development discussions an environmental ethic based on western values and traditions is not going to be effective in an Asian context. The Chinese have very rich religious traditions—Confucianism, Taoism, and Buddhism—and some of us are working at Harvard on how these indigenous values can be brought to bear with regard to environmental protection. The Harvard conferences and book series on world religions and ecology have focused on this. An important breakthrough has occurred in China in considering this perspective. In the fall of 2003 the deputy director of the State Environmental Protection Administration in China issued a major statement on the need for Confucianism, Taoism, and Buddhism to be brought into the creation of a Chinese-based environmental culture and ethics. In India, effective environmental restoration projects are under way at the grassroots level and with religious leadership, for river cleanup, tree planting, and so on. These have to be brought into the conversation. Over one hundred of these grassroots projects are documented on our Harvard Web site for the Forum on Religion and Ecology at http://environment.harvard.edu/religion.

At the Harvard conference series held between 1996 and 1998, we brought together scholars of the world's religions, environmentalists, scientists, and policy experts. We organized ten conferences on the world's religions and their views of nature and environmental ethics. Ten volumes of the papers presented there are now published. We also created a Web site under the Harvard Center for the Environment, as a means of fostering interdisciplinary conversations with science and policy and humanities. We are aware that, although religious and ethical perspectives are late in entering these discussions; they are necessary but not sufficient. Scientists and policy experts have been working on environmental issues for a long time. Thus on the Harvard Web site we have created significant space for "dialogue partners," so that science, policy, economics, and ethics are represented there with extensive bibliographies and introductory essays. In addition, at the end of the ten conferences we organized three major culminating conferences-one at Harvard, one at the United Nations, and one at the American Museum of Natural History-to initiate this interdisciplinary conversation and to encourage it to move forward.

Such an interdisciplinary dialogue has clear policy implications. The United Nations Environment Programme is very keen on this approach of involving the world's religions. Worldwatch Institute did their final chapter in the 2003 *State of the World* report on religion and environment, and there are other organizations that want to encourage this dialogue. The United Nations Environment Programme sponsored a conference in Iran that I attended in June 2001. This was organized with the Iranian government (including the president, the foreign minister, and the minister of environment) to discuss what Islam can contribute on environmental issues. Indeed, there is a provision in the Iranian constitution that Islamic principles should be brought to bear on environmental protection.

For those for whom religion is not their mode of

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thinking, I suggest that we need to develop a broader ethical conversation and vocabulary here, especially around the fundamental issues of the environment. If the ecosystems of the planet go down, we all go down, clearly, and the role of ethics and values may be critical to preventing such a scenario. Many natural and physical scientists are already participating in this conversation. Jane Lubchenko in her address to the AAAS in 1997 called us to implement a new contract between science and society. This is beginning to emerge with the emergence of sustainability sciences that she and others have encouraged. The Aldo Leopold Leadership Seminars that Jane has helped to organize are also inviting the sciences into interdisciplinary conversations. I want to mention as well the Biodiversity Project that Peter Raven has helped to initiate. This project is being organized with the AAAS Dialogue on Science and Religion. We hope it will be a multiyear project involving religious and ethical perspectives regarding the importance of biodiversity to a healthy environment.

Now, let me end with two stories of my students. They show why I think these are not abstract issues and why we need to find the grounds and the language for this interdisciplinary conversation, which includes inspiring images, ethical sensibilities, and spiritual energies that are going to help make the shift to a sustainable future possible. The first story is about a student in my class last semester on religion and ecology. When we were talking about the complexity and scale of environmental issues, particularly the sixth extinction that is emerging with the massive loss of species, the student said, "Why should I care if 10,000 species a year go extinct?" Now, to me, that was a horrific question, which I was glad he could ask, of course, because all views need to be represented. When other students asked him to explain his position, he said, "I'm going to Wall Street to make money. It doesn't matter to me. It won't affect me." The sense of disconnection to our life systems is very prevalent, as we know. His attitude has kept me awake at night, because I think it's a question we all have to think about, from multiple points of view. Why should we care about other species and life forms? This is a key ethical challenge for our times. Why have we not yet developed an ethics for ecocide and biocide as we have for homicide, suicide, and genocide?

The other story is about a student who is in a class of my husband's, and he was reading some compelling essays by the cultural historian, Thomas Berry, that outlined aspects of the huge environmental crisis we are facing. This student is only 19 years old. He's just beginning to take this all in. He went into total shock, paralysis, if you will. He was in his room for a day, and when he came out he said to my husband, "I really have to talk about this. I am so overwhelmed. I had no idea of the scale of these problems, and I feel helpless."

Now, between those two responses—what I call greed and grief—and between the sense of indifference and paralysis, we have to activate human sensibilities to respond. We need to assist environmental education programs that equip the next generation with the tools of scientific competence, policy analysis, and ethical sensibilities encompassing new human-Earth relations. Those sensibilities tell us that we are not apart from this magnificent life planet that holds us and holds all species into the future.

I will leave you with one of the documents that I think contains tremendous hope for us in this regard: the Earth Charter. The Earth Charter came out of the Rio Earth Summit in 1992. I was part of the international drafting committee for three years in the late 1990s, and the Charter was adopted by the Earth Commissioners in 2000 (see www.earthcharter.org). The Earth Charter was the most widely negotiated document ever in terms of environmental and social ethics for a sustainable future. Thousand of individuals, organizations, and institutions weighed in on its principles, as did the world religions through the Harvard conference series and other interventions. I want to suggest to you why I think it is so important. I worked especially on the first drafts of the preamble with Eric Chaisson, a scientist from Tufts, and Tu Weiming, a Harvard scholar of Confucianism. What emerged from this drafting process was a section of the preamble that embodied a critical contribution of science to these ethical discussions: namely, that "We are part of a vast evolving universe." In the next sentence, which was also suggested by Eric Chaisson, it states, "Earth, our home, is alive with a unique community of life." Thus the Earth Charter is the first document of its kind that contains an evolutionary, cosmological framework in it connected to a sustainable future. An understanding of this broad evolutionary framework is crucial to meeting the large environmental challenges we are facing. In addition, the Charter encompasses principles in three key areas for a sustainable future: ecological integrity; social and economic justice; and democracy, nonviolence, and peace. The Earth Charter encourages us to link care and respect for the whole community of life within a framework of the vast evolving universe of which we are a part. This marks an important new stage in the interdisciplinary conversation and expanded ethical sensibility that I have been discussing here. We can build on this for future dialogues on science and ethics for a sustainable future.

I thank you for what you are doing to invite ethics into the conversation regarding protection of the environment, and I encourage you to move into the next stage of this dialogue, which is the transformation of consciousness and conscience into comprehensive compassion for all forms of life.

Questions and Responses

DR. REJESKI: Here is an interesting question to start with. A lot of the speakers, including people on this panel, talked about this examination of ethics and values. This question looks specifically at what the AAAS can do to support this effort. It could be worth having a science, policy, and religion fellow.

MR. GORDON: One thing to be done is to understand the science of ethics and values. There is no such science now. As I mentioned, we need to ask, Where is this commonality of ethical beliefs that are universal and stable? Can negotiations be based on those beliefs? How do people describe what their values are, when they are asked, compared with how they behave? There are likely to be immense differences between what people say their values are and what they do. The whole subject of where values and ethical beliefs come from and how they are applied is virgin territory, almost.

DR. TUCKER: It is clear that there has been an effort to start off this science-ethics-religion dialogue. I think it needs to be further supported and needs to include the world's religions. Enormous numbers of people could enter into this dialogue. A special challenge for the dialogue, I believe, is the need to create a new language that doesn't polarize, but creates some kind of common ground.

DR. REJESKI: Here is an interesting question. Some say the reason that scientists are still taking so long to accept the possibility of past and future abrupt climate change is because it seems too close to creationist views. Are there any examples of scientists being unwilling to accept the implications of data because of their similarity to religious beliefs?

MR. GORDON: I can't comment on that.

DR. TUCKER: I haven't heard that idea expressed. The National Council of Churches has sent letters about climate change each year to a thousand or more religious leaders, and the council has also initiated a dialogue on climate change as a moral issue in at least 18 states. Climate change is definitely on the horizon of the churches as a moral issue.

DR. REJESKI: Here's a question about who should call the religious leaders together for a dialogue.

DR. TUCKER: That's an excellent question. The Parliament of World Religions has met several times, first in 1893 in Chicago, and then again a hundred years later in 1993, and then a third time in Capetown in 1999, and there will be a fourth one in Barcelona this summer. There is also a United Religions Initiative in San Francisco, which has been trying to convene members of the different religions, and the World Bank has also called together on the development side some of the world's religious leaders. But I would recommend a multipronged approach, involving the leaders, the institutions, and the laity. One of the things we were trying to do with these Harvard conferences was to deepen the dialogue and the discourse, so that religious leaders would not be sectarian or platitudinous about what they might offer. One of the great leaders, who is almost unknown in this country, is the Greek Orthodox patriarch, Bartholomew, who is called the green patriarch. He has led five symposiums on the issues of water, the Dead Sea, the Adriatic and the Baltic, the Mediterranean, and the Danube, bringing together scientists, journalists, religious leaders, top UN people, and EU ministers. Those symposiums have been extremely effective moments. He is speaking about conditions in those seas and rivers as crimes against creation.

DR. REJESKI: This one is for you, Ted. Specifically what are science ethics, and how do they differ from other types of ethics?

MR. GORDON: Well, I don't think there is an answer to that. It's something that has to be created. Here is an example of what the people who worked on the study meant by the term. If scientists were working on a particular project and discovered that that project may have deleterious consequences, the scientists would on their own, based on a moral decision, decide not to work on the project. Rushworth M. Kidder, who is the president of the Institute for Global Ethics and a friend, has written books on such decisions—moral courage, he calls it—where someone must exert courage to manifest in action his or her own moral instincts.

DR. REJESKI: I think this could be answered by either one of you: How should undergraduate education be changed to generate the kind of ethical discussions that you both called for?

DR. TUCKER: Environmental studies are still very nascent, unfortunately, within academia. The programs at Harvard and Columbia have grown greatly from outside funding, but they are still struggling for coherence, although some of the smaller institutions, such as Colby College, are doing very well. At Bucknell, for example, we have excellent environmental sciences; we have terrific civil engineering working in this field; and we've got economics, political science, and humanities all engaged. Now, environmental ethics have been taught in both the philosophy department and the religious studies department, and once we create an interdisciplinary conversation, both among faculty and for students, I think we have possibilities of seeing how training in the sciences and policy can be effective when ethics are also part of the conversation.

MR. GORDON: At the Institute for Global Ethics, with which I have been associated for a number of years, Rush Kidder and his staff have developed a framework for ethical decisionmaking. He points out that the tough ethical problems are not choices between right and wrong or legality and illegality. The tough problems require balancing a right decision against an alternative right decision and finding rules that we can apply across those situations. He goes back to philosophy and the Golden Rule. That is certainly one rule that can be applied. He goes back to doing the most good for the most people, in whatever form you want to talk about. Based on this framework, much more sophisticated than I have given you here, the people at the Institute for Global Ethics have written a curriculum for grammar schools, a curriculum for training female prisoners, a seminar for corporate employees who are required to have training in ethics, and their CEO desires it as well. So there is no formal program for teaching ethics that is an end-all for all situations, but at least there are beginnings.

DR. REJESKI: Here's a question that is a definitional one. You talked about the idea of sustainable life, but does this concept really address the question of what kind of life and how it is the dealt with?

DR. TUCKER: Well, it's a good question. It's a phrase that came up in all sorts of UN discussions about sustainable development, and some people feel that it's an oxymoron. Many people say that humans won't survive. Sustainability is perhaps a more encompassing term. But I'm talking about creating the grounds for sustainable life systems, for that which holds the possibility of reproducing life and sustaining life. By that I mean the tremendously interconnected systems of habitats and species, and the elements of air, earth, water, and so on, which will sustain all forms of life. I think that the large goals of advancing science and serving society have got to be integrated into the conversation, too. What is at stake is the future of life.

DR. REJESKI: Here is a follow-up, I suppose. If we are not successful at getting everyone together in the way that you have described to recognize an ecological and human link, what do we do? What are the possible scenarios?

DR. TUCKER: I'm reminded of a comment I recently heard by Peter Raven, at a Columbia University dinner celebrating the tenth anniversary of one of their institutes. Peter Raven looked around the room and said, "Well, I remain optimistic because around this table there are ten people working in very significant areas to make a difference." I do think, however, we have got to recognize that despair is widespread, not only in the younger generation. Many people have seen these gloomy projections for a long, long time, and many are on the border between optimism and pessimism. I wonder whether we are going to become self-fulfilling then, self-destructive? That's why I suggest that the human imagination and creativity have got to be drawn into this discussion. I just feel that we also have to give the next generations some grounds for hope, realistic hope, and the opportunity for engagement in the solutions. And that's why this fellowship program is so wonderful, because it shows that young people can make a difference. We have got to draw the next generation into this process. It's one of the most critical things we can do.

DR. REJESKI: Here is an interesting question going back to Neal Lane's three-body problem. Would you add religion to the three-body problem? And if so, would it be a fourth body?

DR. TUCKER: Well, I would add ethics broadly conceived—to me it was a missing link, even though I liked what he was trying to do.

MR. GORDON: I found something really interesting in one of the things that you said, Dr. Tucker, and I'll use this question as a link into another question. You asked why fundamentalism seems to be growing everywhere, and that's really important because fundamentalism is a political force as well as a religious one. The thing that worries me about fundamentalists is not the extremism of their religious beliefs, but the urgency with which they want to introduce their political notions into secular law. Fundamentalists can follow whatever rules they may want—Islamic, Jewish, or whatever—but problems arise when they try to impose their rules more broadly on their society. If we discover the reason for fundamentalism, as you suggested, would that reason lead us to a method for separating the religious and political components?

DR. TUCKER: Well, it's an excellent question, and I realize I left that rather hanging, that comment about fundamentalism. A project on fundamentalism at the University of Chicago, led by Martin E. Marty, has come out with several publications that would be significant to this discussion. I'm not saying that greater understanding could lead to the separation that you speak of, but I do think there's at least two parts to the kind of understanding I have in mind. The first is that we have got to at least say to ourselves, What's the problem here? We've got to realize that modernity has enormous challenges and that values are being constantly reformulated. Many people can't manage change as quickly as some of you here who are ready to go with the newest, the latest, and the best. And that's why I said at the beginning, too, that I think we need some humility. Just because we can do it, should we do it?

The second kind of understanding begins with the question, What is the quality of life that people are yearning for? That comes back again to this issue of sustainable life, not just the quantity of stuff that we can put out there. We need to seriously rethink the sense that we're going to bring enlightenment and progress to the rest of the world through science, technology, or economic development.

So, if you really take Islamic fundamentalism seriously, you have to listen when they say: Well, you're a drug-saturated, pornographic society where families break down and where children have very little supervision, where your educational systems are falling apart and so on; do we want to be modern like you? And do we want to not own our past of the mistreatment of slaves or indigenous peoples, et cetera? Is this democracy?

I think there are some serious questions about modernity and tradition. By no means am I suggesting this is a right or wrong issue. I'm just saying let's examine the problems. And let's also examine, as was not really examined in the discussion on weapons of mass destruction, what's causing some of the roots of terrorism, of the gaps between first and third world countries. Have you been to India lately? Why did the Congress Party come back into power? What are we being told about that? The poor are being left out of this kind of development. The poverty around the world and the spread of AIDS in Africa have got to haunt us.

I sound like I'm preaching up here, but I just feel you people in the audience have enormous potential on these issues. If science and policymaking don't embrace these questions, we aren't going to make it. The conversation needs to be broadened.

So we are not going to get that full separation between religion and politics immediately, but we have got to see why fundamentalisms are part of it. And we have also got to get beyond the notion that all the religious are just fundamentalists and politicos. We have got to get to a ground of religiosity and ethics that can enter the conversation in a very different tone.

DR. REJESKI: I would like to bring up the speakers from the first panel and have them join us for a last round of questions. I think it's worth having all four people who have presented their views address this question, which asks, How do we get the ideas and conclusions that you have been talking about beyond the intelligentsia? A lot of people, I think, have talked to the need to educate a much larger group of society, and I hope that all of you might be able to just share your thoughts on that one, because I think it is a pervasive problem.

DR. GORDON: Well, one starts thinking about the media. The television sitcoms are abominable, but could we imagine some attractive programs that focus on the issues that we have talked about here? It probably wouldn't last more than a season, but nevertheless the question is, How could these ideas attract a larger audience? I have nothing more to suggest, other than let's get some good writers to do it. We are doing a study on Middle East issues now, and one of the suggestions there has to do with broadening the cultural views of both sides as a basis for later accommodation. One of the participants in that study has written a script in which two teenage girls, one Jewish and one Muslim, share experiences in their languages, and the script looks like it could be a big hit.

DR. EL-ASHRY: I recall back in the mid 1970s, during the early days of the environmental movement, if it hadn't been for the media, I don't think we would have been able to reach the public to such a great extent. At the time, schools such as Stanford would convene workshops to bridge the science on the environment with the public information on the environment. Furthermore, there was a whole generation of environmental correspondents who wrote newspaper articles that helped translate difficult issues like biodiversity. If not for that kind of reporting, by the time of the 1992 Earth Summit, who would have understood what biodiversity is? You very seldom see that kind of reporting now.

I have a feeling we have a long way to go with the young generation that is coming up, and things are not going to happen overnight. We need to train the next generation of leaders, and these are the young people who are in school right now. Of course, some of them on the science and policy side may be here at this symposium. I think we really need to concentrate also on teaching the young people in school about the important issues that have been raised in these proceedings.

DR. BOESCH: I certainly agree with my colleagues. My own experience—and I do a lot of lecturing, talking to public groups of all sorts—is that the biggest impact is through the media, and I think we need to seize on learning moments as opportunities that attract the editorial attention of the media. One of the problems that we have to face is that the corporate pressures and bottom-line competition that affect the media have diminished environmental journalism. The Society of Environmental Journalists, for example, still holds very interesting, vibrant meetings, but a very small minority of the journalists who go are truly environmental journalists. They are usually multitasking on other issues, and the newspapers that I deal with, for example, in this area, the *Baltimore Sun* and the *Washington Post,* don't have any continuity in expertise in environmental reporting. It is a very difficult challenge.

Compounding that challenge is the editorial imperative to keep the story simple and interesting. These complex issues that integrate energy, environment, and food or, heaven forbid, science and religion are just too complicated to explain with a short, simple graph and a story that our average readership can understand. So it's a real challenge, and I spend a lot of time trying to build capacity in environmental journalism as one of the most important ways to get the help needed to inform the public.

DR. TUCKER: Certainly, the efforts to get information out through the media are laudable, but information is not going to be enough. The PBS series, "The Race to Save the Planet," really disempowered people, frightened people, as Bill Moyers acknowledges. So, one of the questions to get out to a larger public is also, Why do people do science? Many scientists have a sense that is rarely shared with the larger public of the beauty and wonder about the world in which we live. I'm not trying to be too simplistic. I know science museums do this rather effectively. But scientists themselves, when they speak from the heart about these kinds of issues, have enormous power, enormous effectiveness. So I would invite you to share your sensibilities from your research into this universe in which we live.

MR. GORDON: To think about the media and meeting the public as the mechanisms for evoking change and consciousness about the issues that we have been discussing is to use our existing tools. I would like to ask a question partly as a challenge: What new tools might be brought to bear? As I ask myself that question, one possible answer is gaming. Could we design games that engage players in these issues in a fun-filled environment, a Disneyland, or wherever? The second new medium might be experiential, for example, to go on the safari in Safariland or somewhere else, but the notion of living in a world that is devoid of species can be demonstrated by constructing that environment and having people observe it. Move yourself into the future and see what it looks like. And third, I would observe that crises demand public attention. Look at the opportunity for teaching morality that comes out of the prison scandal in Iraq. If I were teaching in high school now, that would be a focus of mine. So let's watch for the opportunities and the crises as they emerge and use them as teaching moments to illustrate what the moral implications are and what the solutions might be.

DR. REJESKI: I would like everyone to help me thank the panel.