MEMORANDUM TO THE PRESIDENT

FROM: "The National Security Adviser," "The Director of the National Economic Council," and "The Director of the Office of Science and Technology Policy"

SUBJECT: Policy Strategies to Address Global Climate Change

For fifteen years the U.S. government has struggled with developing appropriate policy responses to the hazards of global climate change. Industrial and agricultural activities, such as burning fossil fuels and clearing forests for crops, cause the emission of carbon dioxide (CO_2) and other "greenhouse gases." As these gases accumulate in the atmosphere, they will trap heat and alter the climate, which in turn will probably raise sea levels and may increase the number and severity of extreme weather events such as heat waves, droughts, and floods. Although often called "global warming," the expected changes in climate are likely to be more complex than a simple rise in global average temperature. For example, possible fluctuations in the Gulf Stream caused by a changing climate could actually cool parts of the North Atlantic region. Climate is naturally variable and humans are highly adaptive, but the effects of climate change could unfold more rapidly than the capacity of humanity and ecosystems to adjust.

Climate change has become a perennial issue on the foreign policy agenda. Because the emissions that cause climate change are global in scope, successive administrations have attempted to coordinate policy with other countries. The United States accounts for about one-quarter of world emissions of greenhouse gases, but our ability to act alone is limited. Industry is wary of potentially costly binding limits on its emissions unless other firms in the global marketplace are required to make comparable efforts.

It has proved particularly difficult to engage developing countries in controlling their emissions. Historically, these countries have accounted for only a small fraction of the greenhouse gases that have accumulated in the atmosphere, but their share is rising rapidly as they industrialize. About half of today's net emissions of greenhouse gases comes from these countries; on a per capita basis, however, emissions from developing countries remain at only one-tenth the level of those from the United States.

In 1992 the United States signed and ratified the United Nations Framework Convention on Climate Change, which established a broad framework for international cooperation on climate change. Today, 187 countries are members of the framework convention—essentially every nation on Earth except Iraq, Somalia, Turkey, and a few others. Widespread membership and compliance reflect the convention's exceedingly modest obligations. For the United States and other industrialized countries, compliance has required developing programs that "aim" to reduce emissions to 1990 levels, submitting reports on emissions of greenhouse gases, and contributing to a special fund that compensates developing countries for the "agreed full costs" of their efforts to comply with the convention's goals. The convention commits all members to work toward the "ultimate objective" of limiting atmospheric concentrations of greenhouse gases to levels that will avoid "dangerous anthropogenic interference with the climate system." This aspirational framework reflected the national interests of the key participants at the time the convention was finalized. Industrialized nations generally sought to control emissions but could not agree on the particular level of effort or on how to share the burden. Developing nations were wary of encumbering commitments and thus agreed only to actions that imposed no cost on their economies.

Most governments, including the Clinton administration, viewed the convention's commitments to control emissions as woefully inadequate. In 1995 numerous governments launched a diplomatic process to strengthen the convention, culminating in the 1997 Kyoto Protocol. Kyoto set targets for the total quantity of greenhouse gases that industrialized countries would be allowed to emit during a specific "budget period" of 2008–2012. (Kyoto is largely silent about obligations beyond 2012.) The protocol would allow countries flexibility in meeting their commitments through a worldwide system of tradable emission credits, modeled on the successful experience with trading air pollution credits in the United States. A utility in the United States, for example, could purchase part of its emission budget from Russia, where limiting emissions is much less costly. Since greenhouse gases mix globally in the atmosphere, this trading system would allow attainment of the environmental objective (less human stress on the climate system) at lower total economic cost.

Kyoto imposed no restrictions on the emissions from developing countries. However, a scheme known as the Clean Development Mechanism (CDM)—largely the brainchild of Brazil and the United States—was intended to encourage foreign investment in projects that yield lower emissions of greenhouse gases. Investors would calculate the level of emissions that would occur with and without their projects; the CDM would award valuable emission credits for the difference. For example, the World Bank has pooled funding from a coalition of twenty-three governments and firms to invest in projects such as a small dam in Chile that produces electricity while avoiding the need to burn fossil fuels and emit CO_2. The investors seek to jump-start the CDM and to get emission credits that they can use back at home; host countries such as Chile welcome the investment.

The Clinton administration never submitted the Kyoto Protocol to the Senate for its consent. When that administration left office, the rules for Kyoto's mechanisms—such as procedures for approving CDM projects and for enforcing compliance—were not yet settled, and thus no government could responsibly evaluate whether Kyoto served its interests. Moreover, Kyoto surely would have been defeated in the Senate. Critics of Kyoto pointed to its lack of binding obligations for China, India, and other developing countries to control their emissions. Imposing Kyoto's emission controls on the United States—a reduction in emissions of greenhouse gases to a level 7 percent below that of 1990—would have been politically and economically arduous. At the close of the 1990s U.S.

emissions were already 15 percent above 1990 levels and rising at 1.3 percent per year. Reversing that trend before 2008 would have been impossible without major economic disruption, and thus any plan for U.S. compliance would have required prodigious use of the international emission-trading system. That implied a large outflow of capital to developing countries (via the CDM) and especially to Russia (via emission trading). In Kyoto, Russian negotiators refused to accept a cap that was more strict than a simple freeze on their emissions at 1990 levels; by the late 1990s, however, the collapse of the Russian economy had closed factories and driven emissions down by nearly 40 percent, and emission projections for 2008–2012 suggested that Russia would have surplus emission credits of roughly one billion tons of CO_2. Selling those credits (mainly to U.S. firms) could have netted Russia perhaps $20 billion to $50 billion, although the surplus would not have been the result of any active Russian effort to control emissions. Critics branded these potential trades as "hot air."

Early in 2001 the Bush administration withdrew the United States from the Kyoto process. It argued that the United States could not meet its Kyoto targets at acceptable cost, and that it was unfair to force U.S. industry to compete in a world economy without meaningful emission controls on all nations.

In February 2002 the Bush administration announced an alternative approach that is based on voluntary actions by firms, investment in research and development on new technologies—such as hydrogen-powered fuel cells for vehicles and advanced low-emission coal plants—and partnerships with key developing countries to assist their application of advanced technologies. President George W. Bush emphasized the large remaining uncertainties in climate science and committed the United States to increasing its investment in scientific research. The technology and science programs committed to in that speech were allocated a total of $4.5 billion in FY03 federal resources, including nearly $1 billion for research on energy efficiency and renewable power. (A copy of that speech can be found in Appendix D.)

While most other nations have remained engaged with the Kyoto process, the Bush administration's dramatic withdrawal from Kyoto galvanized many governments to close ranks and profess their support for Kyoto. Even as public concern about this issue has waned in recent years here in the United States, our allies (especially in Europe) remain deeply concerned and are increasingly frustrated by what they view as an inadequate U.S. response to the problem at hand. Key European nations and Japan, however, are finding that they, too, face difficulty in meeting their Kyoto targets. Many developing countries, which had expected to benefit from new technologies and investments unleashed by the CDM, have grown dissatisfied as a robust market has not yet emerged. The CDM is floundering, in part because it is tied up in red tape and in part because the large potential surplus of emission credits from Russia and other nations that had hoped to sell to the United States has depressed prices and reduced the incentive to invest in projects in developing countries.

With climate change policy in the United States and abroad at a crossroads, you asked us to convene an interagency process to review your options. We find that the issue of climate change is one of the most complex topics on today's policy agenda. It involves most agencies of government, from the federal to the local levels. It requires working closely with Congress and with other nations; if a political deal with one key player unravels, then many others can come unstuck as well. Cutting emissions by more than half over the coming century—a goal that many experts think must be achieved to stabilize human stress on the climate system—implies the need for credible policies that impose costs on society today with uncertain benefits that accrue in the distant future. That intergenerational time scale is longer than most actions of government. Not only is this issue extraordinarily complex, it has also become highly polarizing. At one extreme, climate change is viewed as a hoax or conspiracy dreamed up by scheming scientists who want to usurp government control of the economy and lubricate a gravy train of government research funding. At the other extreme, climate change is seen as a threat so severe that it requires complete and immediate reorganization of the modern industrial economy. The public is deeply confused about the risks and options, offering both the danger that any policy will be easy to parody and the opportunity for you to shape public opinion along the lines most consistent with your favored policies.

Your policy options are not easy to summarize. We have prepared three broad policy strategies, which we present as speeches that you might give in the coming months. All three options recognize that climate change poses varying risks and costs to the U.S. economy and U.S. national security. The speeches differ in their assumptions about the magnitude of climate hazards and in their policy responses.

The first strategy—"adaptation and innovation"—assumes that the hazards from a changing climate are comparable with other environmental challenges that modern society has managed. This strategy advocates expanding current investments in scientific research, improving our capacity to adapt to a changing climate, and devoting resources to new technologies that could allow for lower emissions in the future. This strategy is based, in part, on the assumption that even an aggressive and costly effort by the United States and other industrialized nations would not have much impact on the rapidly rising emissions from developing countries. Climate change is inevitable and thus investments in adaptation are essential. Developing countries have been adamantly opposed to controlling their emissions unless they are fully compensated for the cost. Yet compensation would be extremely costly and adaptation is relatively inexpensive. This strategy also assumes that government resources are best spent catalyzing the development of radical new technologies that can eliminate carbon from the energy system. This speech suggests that special interests have inflated the danger of climate change to serve their needs and warns Americans not to become paralyzed by fear of this problem.

The second strategy—"reinvigorating Kyoto"—follows a radically different approach. It emphasizes that climate change could cause abrupt and potentially catastrophic shifts in weather patterns or sea level. For humans, adaptation could be expensive; for nature, adaptation may be impossible, leading to mass extinctions and the loss of unique ecosystems. With this perspective, the only sensible response is the adoption of aggressive controls on emissions to slow and stop climate change at its root. This speech embraces the process established in Kyoto as the only existing viable international framework. Even as it promises to reengage with that process, it demands reforms that would make Kyoto a much stronger multilateral framework. It advocates aggressive (but achievable) long-term goals for limiting the concentration of greenhouse gases in the atmosphere and mandatory participation of developing countries, with strict penalties for those who do not adhere. It suggests that the need to control carbon is so important that it must become an organizing principle for our foreign and domestic economic policy.

The third approach—"making a market"—also recognizes the need for concerted international action to control emissions. However, it rejects the Kyoto Protocol as an unrealistic, top-heavy scheme. This speech argues that the most effective international regimes, such as the World Trade Organization (WTO), have emerged over many decades from the "bottom up." They are the result of disparate practices that are loosely coordinated through international institutions but rely heavily on strong national institutions and practices. In the case of climate change, this speech emphasizes the need for a diversity of efforts—by key U.S. states, the federal government, other countries, and privately organized systems. It advocates creating emission trading systems in these jurisdictions and then allowing these new "currencies" to establish their value as governments and markets (not international bureaucrats, as in the Kyoto process) determine which systems best combine integrity and efficiency. This speech applauds unilateral action and acknowledges the efforts in some firms and states to begin experimental emission trading. It points to the nascent European emission-trading system as an important experiment, and it suggests that key U.S. jurisdictions explore ways to allow trading between U.S. trading systems and those in Europe. From such productive and experimental exchanges an international market can emerge over time. This speech warns against hasty action to involve all nations in creating this currency, since many—such as Russia and most developing countries—lack both the institutional capacity and desire to control emissions that, together, are essential to ensuring the strength of this new currency.

Each of these three strategies involves lumping together a multitude of detailed policy choices. A real policy could include elements from each. At this pivotal moment we want to ensure that your policy decisions are not constrained by the combinations of choices presented in these three speeches. Thus in this memorandum we unpack the major policy issues in each of six areas where you face choices:

- The scientific assessment of causes and consequences of climate change and policies for supporting additional scientific research;
- Adapting to a changing climate;
- Strategies for controlling emissions;
- Investing in new technology;
- Engaging with key developing countries; and
- Informing the public.

Science: The State of Knowledge and Policy Choices

In its simplest form, the physical cause of climate change is undisputed. The atmosphere naturally contains greenhouse gases such as water vapor, carbon dioxide, and methane. Absent these gases the planet would cool to a frozen ball, much as the desert chills rapidly on a cloudless night. When humans burn fossil fuels, clear forests, and engage in sundry other activities they pump carbon dioxide and other greenhouse gases into the atmosphere and alter the energy balance of the planet. (Fossil fuels are mainly composed of carbon; burning releases the carbon as carbon dioxide.

Similarly, plant matter and soils contain carbon that is emitted as carbon dioxide through burning or decay.)

The links between emissions of these gases, their buildup in the atmosphere, the ensuing changes in climate, and the ultimate consequences for humans and nature are highly contested. The uncertainties in this long chain—from emissions to consequences—put a premium on policy strategies that adjust easily to changing knowledge.

Climate is naturally variable. Small changes in the Earth's orbit around the sun cause the ice ages and other long-term cycles in climate. Since the depth of the last glaciation—about 20,000 years ago, when much of New England was buried under ice and mammoths roamed in California—the climate has warmed considerably (about 5°C to 7°C, on average). In addition to these orbital gyrations, natural changes in the intensity of the sun also affect climate. Some solar fluctuations occur regularly and are easy to predict, such as the eleven-year cycle during which the sun's output waxes and wanes (it last peaked around 2001). Other changes in the sun have appeared less frequently, yet may have significant consequences. Records of sunspots, for example, suggest that starting around 1645, the sun may have dimmed a total of about 1 percent for seven decades, which coincided with some of the lowest temperatures in the North Atlantic region (and perhaps also globally) during what was already a cold snap—the "Little Ice Age" that began around the thirteenth century and lasted until the nineteenth century. For the most part, such cold temperatures were unwelcome to populations that were already struggling to stay warm and grow crops. Until the very recent concern about global warming surfaced in the 1970s, most studies of climate change focused on natural causes and, interestingly, equated warming with an "improvement" in climate.

Within these natural variations, the fingerprint of human activities is coming into focus. Through burning fossil fuels and deforestation, humans have already caused atmospheric concentrations of CO_2 to rise about one-third, from 275 parts per million (ppm) on the eve of the Industrial Revolution in the late nineteenth century to about 380 ppm today. Global average temperatures have also risen about 0.5°C to 0.9°C during that period, although the warming has not been steady. From 1945 to 1970 the Earth experienced a period of cooling, possibly linked to a slight dimming in the sun and increased output of aerosols (which reflect sunlight back to space) from volcanoes and industrial activity. Since 1970 temperatures have risen; the 1990s were the warmest decade in the industrial era and probably warmer than any other period in the last two millennia.[1] Working with the best computer models of climate—which do a good job of reproducing the historical temperature record—there is a growing scientific consensus that most of the global warming observed in the last fifty years is the result of rising concentrations of greenhouse gases from human-caused emissions. In addition to that observed warming, another 0.5° C of warming is by now "built in" due to the greenhouse gases that have already accumulated in the atmosphere.

As the concentration of CO_2 and other greenhouse gases rises still further in the future, what might be the consequences? The crudest measure of impact is the change in average global temperature from a doubling in the concentration of atmospheric CO_2—a value known as "climate sensitivity." In 1979 the U.S. National Academy of Sciences (NAS) made the first-ever systematic assessment of climate sensitivity and suggested that doubling CO_2 concentration would yield an increase in global temperature of 1.5°C

[1]It is difficult to make simple declarative statements about temperature trends because a reliable continuous record of global climate does not exist prior to the late nineteenth century, when global shipping and colonialism allowed the establishment of a global network of somewhat accurate thermometers. To measure earlier climates, scientists must use proxies such as tree rings, ice cores, fossils, ancient Chinese records of sunspots, and other indirect measurements. There are many ways to assemble those proxies into a record of temperature and climate, and some methods yield diverging results. In addition to ground-based measurements since the late nineteenth century, continuous satellite records began in 1979, and there has been considerable controversy over how to square the relatively brief period of satellite measurement with the longer term records from ground-based thermometers, balloons, and rockets. The National Research Council evaluated these issues in 2000, outlined a research program to resolve the outstanding problems, and underscored that satellite and ground-based records alike show that the atmosphere is warming—although each method shows different rates.

to 4.5°C. In recent years more detailed assessments have uncovered many feedbacks that could amplify or dampen the effects of CO_2. Today's best assessments have dramatically increased the range to between 0.8°C and perhaps as much as 8°C, with most studies centered on a value for climate sensitivity of about 2°C.

The most recent full assessment of the science was completed in 2001 by the Intergovernmental Panel on Climate Change (IPCC)—an international assessment process involving thousands of scientists from around the world, including most of the best climate scientists from the United States. The IPCC examined uncertainties in the full chain from emissions of greenhouse gases to changes in climate and concluded that by 2100 the global climate will probably warm from between 1.4°C to 5.8°C. That range is actually wider than that predicted by the previous IPCC study just five years earlier, mainly because the most recent scenarios for emissions of greenhouse gases account for a much greater variety of possible futures and also because new climate models assume a wider range of possible climate sensitivities. In 2001 President Bush asked the NAS to convene a panel of distinguished scientists to review several key questions related to climate change, including the main findings of the IPCC report; the NAS panel reached essentially the same conclusions as the IPCC. (The Executive Summary of that NAS report, which offers a good brief synopsis of major scientific issues, is reproduced in Appendix C.)

We find it striking that more than two decades of intense research, reflecting a total investment of perhaps as much as $30 billion worldwide, has actually expanded the estimated change in temperature. That investment has not narrowed any key estimates of other changes in climate, such as the frequency and intensity of storms or the risks of drought. As scientists have learned more about the climate system, they have uncovered a vast field of unturned stones (see Box 1).

BOX 1

Uncertainties in Climate Science

The list of uncertainties in climate science is long. Five categories of unknowns presently dominate the scientific debate and are especially relevant for policy decisions:

- **Climate Feedbacks.** A wide range of processes affects the sensitivity of climate to changes in the concentration of greenhouse gases. For example, when glaciers and ice sheets melt, the reflectivity of the planet changes—bright ice becomes darker soil and ocean, which absorb more solar energy and thus cause additional warming. Today, clouds probably account for the greatest uncertainties in these feedback effects. Some types of clouds warm the planet; in the last century, for example, a measurable increase in overcast skies is consistent with an observed rise in average nighttime temperatures. Other clouds that are particularly bright and reflective cause cooling. The balance of forces is extremely complicated to unravel. Detailed satellite measurements show that the average worldwide effect of clouds today is a slight net cooling, but nobody knows how cloud effects may change in the future.
- **Carbon Cycle.** The concentration of CO_2 in the atmosphere—the main driving force for climate change—is the result of many natural processes that cycle carbon between different forms. The process is akin to a busy highway, where the number of cars on the road is the balance of those entering and exiting. Some leave for a brief moment to refuel their engines and passengers, only to return quickly—just as vast quantities of CO_2 from the atmosphere are stored temporarily in plants during the growing season, only to return when

the plants die. Most of the processes that shuttle carbon in and out of the atmosphere are sensitive to the amount of CO_2 already in the atmosphere. For example, some plants grow especially rapidly in elevated concentrations of carbon dioxide: as CO_2 rises, this "fertilization effect" could offset some of humanity's emissions, although field studies suggest that the availability of water and nutrients will dampen these effects. Nasty surprises also may be lurking within the carbon cycle. For example, if climate change causes less rainfall over the Amazon then massive fires in the drying forest could release still more carbon dioxide into the atmosphere and further dampen nature's ability to sop up excess CO_2 from the atmosphere. Although still speculative, this scenario is not implausible. The 1997–98 El Niño, for example, contributed to a widespread increase in forest fire activity in Southeast Asia and in South America.

- **Models of Global Climate.** What matters most in assessing the possible impacts of climate change on nature and human welfare are particular changes in rainfall, temperature, cloudiness, storms, and sundry other factors in particular locations, such as the wheat-growing region of Nebraska or the barrier islands at Cape Hatteras. A starting point for such assessments is models of the entire circulation of the atmosphere and the circulation of the oceans—called atmospheric general circulation models (GCMs) and oceanic GCMs. These models require vast amounts of data for calibration and presently occupy some of the world's largest supercomputers. Still, they are coarse in resolution: typical GCMs treat a roughly 100-by-100 kilometer area as a single unit, and thus they compute the same climate for Seattle as for Mount Rainier. (Experimental models, such as Japan's Earth Simulator, are yielding promising results running at a 10-by-10 km resolution.) To be tractable, GCMs must use simple mathematical parameters to approximate many complex processes, which is an additional source of predictive error. Some uncertainties and errors can propagate into large uncertainties when compounded over the multiple decades that are typical for GCM projections. GCMs have improved significantly in the last decade. Today's most complex models link atmosphere, oceans, biosphere, and human action; in the mid-1970s, by contrast, models usable for climate forecasting focused only on simple processes entirely within the atmosphere.

- **Abrupt Change.** Over the next few decades, the most likely impacts of climate change are within the realm of normal fluctuations in climate, such as changes in temperature, cloudiness, rainfall, and sea level. They are likely to unfold gradually and somewhat predictably, which will ease the task of adaptation. However, the forced change in Earth's heat balance caused by greenhouse gases might also yield abrupt and potentially catastrophic changes in climate, and there is ample evidence of such discontinuities in the past. Climate change could trigger alterations in the circulation of the oceans, which in turn might force a complete change in weather patterns, with unknown consequences. (Among the dramatic changes could be redirection in the Gulf Stream that, ironically, would make the North Atlantic region much colder.) There is strong evidence that the North Atlantic circulation has changed abruptly in the past when climate has cooled; the risk of such changes in a warming world are unknown. Already there is some evidence of potential changes in ocean circulation: parts of the Atlantic Ocean have become less salty since the 1950s, which is significant as it is changes in saltiness that, in part, determine the density of sea water and drive ocean circulation. Other nasty surprises may lurk in the warming of the Arctic tundra, which could release large amounts of methane (a strong greenhouse gas) presently locked away in ice crystals known as clathrates. Warmer temperatures might accelerate the normal movement and melting of the West Antarctic ice sheet; although presently thought to be well grounded, there is a small chance that the ice sheet could slide more rapidly into the ocean, which could raise sea levels by several meters over just a century. The likelihood of each of these events is difficult to assess but probably rises sharply with more rapid forcing of climate change; the full range of such catastrophic events is unknown.

- **Social Sciences and Humanities.** The fact that natural scientists have identified the problem of climate change as a physical phenomenon is not reason enough for policy response. Policy analysis also requires integrating insights from the social sciences, which has proved very difficult in practice. The greatest progress has been in integrating economics with physical assessments. These "integrated assessments" link a large number of different models and make it possible to assess the consequences of changing climate in the same units (dollars) as the cost of policies that could reduce climate change. However, this integration has left several major problems unsolved. Climate change involves costs and benefits that extend over long time periods—even generations. Standard techniques of discounting future costs and benefits into present values may be inappropriate when the consequences involve future generations whose preferences are unknown to today's generation of decision makers. Assessments also require integrating market costs and benefits—such as the impact of climate change on commodity crops—with effects that are difficult to measure in dollars. For example, how should we value unique species that go extinct when a changing climate erases their habitat? Surveys indicate that people are willing to pay large amounts to preserve some species (e.g., giant pandas) but not others; for many analysts, the existence of nature's biodiversity is reason enough to make every effort at protection. In addition, some types of assessments are politically charged. For example, poor nations that are less able to adapt are likely to suffer more greatly from climate change. However, wage levels are lower in these societies, which typically reduces the economic cost of lost life and health, thus lowering the estimated consequences of climate change. Similar results occur when the stress of heat is assessed—elderly populations suffer more than the young, but the elderly have fewer economically productive years left to lose. Studies built on such assumptions are typically assailed as unjust and politically untouchable. Which principles of justice should be applied if the average global consequences of changing climate are modest in the regions where societies are able to adapt easily, while highly adverse in areas already on the margin and unable to adjust? Quantitative assessments of the costs and benefits of climate policy rarely include any systematic treatment of politics, law, and institutions—despite the fact that these are organizing elements of society. These models may thus misstate societies' political choices and their ability to adapt to a changing climate, and they do a poor job of representing subtle processes such as the invention and application of new technologies.

All three of the policy options outlined in this memorandum envision substantial continued investment in the science of climate change so that future policy decisions will be better informed about the risks and costs of a changing climate. Regardless of the investment, however, it is likely that policy decisions today and in the future will have to be made in the context of extreme uncertainty. Moreover, the standard tools for making decisions under uncertainty are not easy to apply in this case. It may not be possible to hedge against some outcomes—such as extinctions or irreversible changes in climate—because species and climate are unique within our experience on Earth and we have no other planets with which to pool the risk. For some hazards, scientists have estimated the range of uncertainties; many other possible hazards are difficult to assess quantitatively or are simply unknown.

In 2002 President Bush established a new interagency, cabinet-level structure for managing U.S. investments in climate change science and technology. Within that structure, the Bush administration created the Climate Change Science Program (CCSP) and the Climate Change Technology Program (CCTP). We will discuss the CCTP later; the focus here is on the CCSP. Although government-wide efforts to ensure a rational and strategic investment in climate science date back to 1989, the CCSP's ten-year strategic research plan released in 2003 is the most comprehensive federal vision for climate science to date. It was based on unprecedented cooperation of federal agencies and adjusted through a detailed review process involving the NAS and other outside experts. The plan envisions support for better monitoring of the climate and seeks to study the causes of climate change; it includes a detailed strategy for investing in the support tools needed to aid policy decisions within the context of substantial uncertainty.

We think that this investment in science, which builds on earlier administrations' programs, is sound and requires no further attention from you at this point. However, we call your attention to three concerns.

First, you should know that the effectiveness of the government's investment in climate science will depend heavily on factors that are outside your direct control, such as the intellectual organization of the scientific effort. Over the last three decades the best climate models have become extremely complex and costly to maintain and run. Only a handful of models in the United States and a few others overseas operate at the most sophisticated frontier. With this small collection of highly complex tools, the scientific community must remain vigilant in ensuring that a diversity of approaches is supported and that efforts to compare model outputs do not yield "groupthink" that tends to overemphasize conventional wisdom while excluding fringe opinions and outliers that often spur substantial scientific insights.

Second, we find that the integration of social science and natural science modeling remains in its infancy. We are concerned that the social sciences are poorly organized to bring their insights to bear. Most assessments of climate change are based on quantitative models that make it difficult for most of the social sciences (except for economics) to participate in the debate. Policy analysis in this context is therefore framed in highly stylized "ideal" policies that do not account for how real policies are implemented by real political systems. That problem leaves you and your successors in the position of making policy choices with highly incomplete information about costs, benefits, and political consequences. For example, many of the models used to quantify the costs of controlling emissions assume that power plants fired with natural gas (which emits half the CO_2 per kilowatt of electricity from coal) or nuclear heat (which emits no CO_2) will be available when needed. Yet, in reality, the process of siting new power plants and their infrastructure such as reception facilities for imported liquefied natural gas (LNG) or disposal facilities for nuclear waste can be time consuming or impossible, which could raise the cost of efforts to control carbon. Political and legal experts have insights into these issues but, at present, are largely absent from the quantitative debate about environmental policy options.

Third, we note that the CCSP declares priorities but is strikingly silent on cost and value. The plan contains no estimates of cost, and the government's normal budgeting process focuses on an annual cycle that does not correspond with the CCSP's ten-year vision. The CCSP requires coordinating the actions of thirteen federal agencies and a complex multicommittee budget appropriation process in Congress that makes it difficult to move resources between agencies. Some aspects of climate science—such as building, launching, and operating satellites—are extremely expensive and dominate the total investment in climate science; NASA is the lead agency for most of those programs, and there is a danger that manned space flight and the new Moon/Mars initiative will crowd the budget for climate science. Overall, the grand vision of the CCSP is much larger than the budget available, which is a point underscored in the NAS's independent review of the CCSP.

We suggest that you direct your science adviser to convene a process to address these concerns. That process, which should include a prominent role for the NAS to help dispel any questions that "the science" is a handmaiden to politics, would ensure that the scientific community is organized to make optimal use of the increasingly costly climate monitoring and computer tools. It would also involve a more active effort to assess the value of different scientific research programs for policy decisions, which would ease the task of setting research priorities. In fourteen years of attempts to create an integrated federal budget and strategy for climate change, there has never been a serious effort to compare systematically the declared priorities of scientists and policymakers, a sober assessment of investment value, and actual budgetary spending. Yet the size of total spending on climate research is approaching $2 billion per year; future policymakers could benefit substantially from a more rational budgeting strategy.

Adapting to a Changing Climate

The impact of a changing climate on American interests depends on the consequences that are likely to occur and the ease with which we can adapt. Your assessment of these factors will influence your policy strategy. If you think we are largely immune and highly adaptive, then the case for controlling greenhouse gas emissions is weakened and your policy strategy might focus on boosting America's adaptive capacity. If you are skeptical of our ability to adapt then the need to address the root cause of climate change—emissions of greenhouse gases—becomes more urgent.

The most comprehensive assessment of climate impacts on the United States is the "National Assessment of the Potential Consequences of Climate Variability and Change," produced as part of the 1990 Global Change Research Act and completed in 2000. (Please see the Overview Conclusions reproduced in Appendix B.) The report assessed climate impacts during the course of this century in five climate-sensitive sectors, such as agriculture and coastal zones, across twenty different regions of the United States. The "National Assessment" complements a global assessment of climate impacts completed the same year by the IPCC.

The report concluded that it is highly likely that rising sea levels will cause erosion and some inundation of coastal wetlands. (Sea level rises because water expands when it warms; in addition, the runoff from melting glaciers raises the volume of water in the oceans.) Warmer winter temperatures are also likely to reduce snowpack, causing difficulties for watershed management in regions where water resources are already tapped heavily, such as in California and the Colorado River basin. Alaska is likely to face special difficulties since many roads and pipelines are built on permafrost, which is a poor foundation when it thaws. Across much of the United States higher heat indexes and more frequent heat waves are also likely, which will impose the need to build electric power systems that can meet the greater demand for air conditioning. Not all the news is bad, however. The study finds that agriculture and forestry are likely to benefit from higher concentrations of CO_2 (which causes plants to grow more rapidly if water and nutrients are ample). Growing stress from heat and drought could be harmful, especially to natural ecosystems that are less able to adapt than those that are actively managed by humans, such as crops. The impacts of changing climate are likely to vary considerably across regions.

For example, farmers already working at the edge of the climatic zone for their crops will likely face the need to switch crops or face losses. Soybean farming in the already warm southeastern United States is likely to suffer, but new areas for cultivation may open in the far north where temperatures are presently too low for soybeans. Under most scenarios, the National Assessment concludes that U.S. farmers and consumers would benefit from higher crop yields and lower prices. Other studies, however, suggest that some farmers—especially those without access to irrigation—could lose under many plausible scenarios of climate change.

In assessing the sources and impacts of climate change it is important to be mindful that much else is changing on the planet at the same time. Even as the "anthrosphere" in which the human economy operates is becoming more adaptive to climate, humanity is also imposing substantial changes on the energy, nutrient, and water cycles of nature's biosphere. Deforestation, planting crops, paving, building, and other changes in the land will affect nature's ability to adjust to the buildup of greenhouse gases. The fragmentation of natural forest ecosystems, for example, probably makes nature less adaptive because it impedes migration with the changing climate.

Over time, the United States and most other advanced industrialized countries have become more immune to variations in climate. In 1850 about two-thirds of the U.S. economy depended on the climate; farming, forestry, hunting and fishing, and other "outdoors" activities are vulnerable to climate change. Today, only about 5 percent of U.S. economic activity is affected directly by climate, although perhaps about one-third of total economic output has a significant indirect link to climate. A large and increasing fraction of the economy is largely decoupled from climate and weather. We live in office buildings with climate control, fly in aircraft that land and take off in nearly zero visibility, and buy food and other products on a world market that increasingly locates production where weather and other factors are most favorable. In contrast, less wealthy communities—both the poor here in the United

States and the very poor in the developing world—are generally more vulnerable and less able to adapt.

Despite better climate-proofing, we are not invulnerable. Estimates compiled by the National Oceanic and Atmospheric Administration (NOAA) suggest that on average severe weather events cause $11 billion in damages per year nationally. In outlier years, which may become more common with climate change, single storms have caused billions of dollars in damage. The assessed value of coastal real estate between Miami and Palm Beach alone is about $1 trillion; much of its value is tied to the proximate ocean and thus vulnerable as the water rises.

Some policy responses can boost our adaptive capacity in anticipation of a changing climate. For example, investment in better weather and climate forecasting has already reduced vulnerabilities to El Niño, a natural climatic cycle that typically occurs every two to five years and affects the whole planet. It is associated with extreme weather in the United States and causes crops to fail in Australia, Indonesia, and elsewhere in southern Asia. The 1982–83 El Niño, the strongest on record, caused abnormally high water levels on the Colorado River that threatened the integrity of the Glen Canyon dam, situated immediately above the Grand Canyon; failure of that dam, or others stressed by high water flows, could cause massive loss of life. The 1997–98 El Niño, also strong by historical standards, caused $4.5 billion in total losses of crops and property in the United States alone.

Over the last fifteen years governments and the private sector have developed sophisticated weather forecasting tools that can now assign a reasonable probability for the onset of El Niño a year in advance, making it possible to adjust water usage and crop choices, purchase grain for storage, and adopt changes in technology and behavior that can ameliorate El Niño's impact. Recently developed technologies for correcting errors in climate models hold the promise of two-year predictability for El Niño events. Equally important to the creation of early-warning systems is the promotion of flexibility, such as efficient markets that reliably price the scarcity of water. All of these measures to dampen the effect of El Niño on modern economies have occurred quite apart from the threat of climate change, and except in the poorest regions they are likely to spread widely in the coming decades. Other early-warning and adaptive responses have also limited the damage from other weather-related hazards, such as tornadoes, intense storms, drought, and flood.

As president you will be hard pressed to identify many ways that the federal government can effectively accelerate the "climate proofing" of our society. Most of the growing immunity to climate is the result of normal economic development rather than active policy. However, we highlight three areas where you might consider further action. First, you may want to make additional efforts to ensure that potential future climate impacts are known by those whose actions, today, could ease future adaptation. The need for information is especially great in the planning and construction of costly, long-lived infrastructure, such as bridges, power plants, and water-treatment plants located in coastal zones where sea level will rise. Already much is underway. River managers are examining the risk that saltwater from higher seas might reach the public water supply intakes in cities such as Philadelphia and Sacramento. When Boston city planners revamped that city's waterfront in the 1980s, they allowed for a rise in sea level in the design for new sea walls and protection against storm surges. Compared with just a decade ago, most new large weather-sensitive infrastructures in the United States are planned with an eye toward long-term climate change.

Second, and related, is the need to promote institutions that will aid adaptation. Many such institutions already exist, such as agricultural futures markets that aid in the hedging of risks and encourage actors in the private sector to gain the information they need about climate and weather impacts. Agricultural and water markets still fall far short of their efficient ideal, however. In the American West, especially, a plethora of distortions keep water from flowing to the places where it could yield the greatest economic value. In agriculture, the 2002 Farm Act probably set back the cause of creating an adaptive farm sector by reinvigorating a highly subsidized scheme that centrally determines crop choices and by exacerbating distortions in the value of farm land. The Bush administration has announced its intention to roll back that farm program if the European Union were to make similar cuts in subsidies; that deal is entangled in the foundering talks on the next trade round in the WTO. The long-term U.S. interest in making the agricultural sector even more adaptive is additional reason to pursue such a deal—quite apart from saving billions of dollars per year in price supports and removing distortions that propagate harm throughout world trade in agricultural products.

Third, many countries will press the United States to be accountable for the effects of climate change in other countries, notably in the developing world where exposure to climate is greater and the ability to adapt is already thin. In India, for example, despite a thriving industrial and service sector, roughly one-quarter of economic output and two-thirds of all employment are linked to agriculture. The United States could invest in programs to assist these countries in adapting, such as by helping them to build modern weather forecasting systems, with particular emphasis on improved forecasting of extreme weather hazards. But the track record with these programs is mixed, in part because it is very difficult to isolate "adaptation" projects from the broader development of the whole economy. An alternative approach is not to invest in adaptation-specific projects at all, but to assist these countries with their normal process of economic development. Wealthier and more democratic societies are generally better able to adapt on their own. Famine tends to arrive more readily when unaccountable tyrants govern the land.

It is probably not possible to achieve complete invulnerability to a changing climate. Three types of impacts on humanity, in particular, may be difficult to manage. If you assign importance to these hazards then it will be hard to justify a policy that relies mainly on adaptation to a changing climate rather than controlling emissions and mitigating the climate problem at its root.

First, some countries—mainly developing countries—will face enormous difficulty adapting. Low-lying nations, such as the archipelago of Vanuatu in the Pacific and Bangladesh, large swaths of which sit barely one meter above sea level, face the specter of disaster if sea levels rise. In Bangladesh alone, more than ten million people live within one meter of sea level. Economically, it may be much less costly to move these populations (or ignore their troubles), but as a matter of justice and politics that option may not be viable.

Second, some climate hazards may not readily confine themselves outside U.S. borders. For example, many scientists have suggested that a warmer and wetter climate will facilitate the spread of malaria, yellow fever, and other water-borne diseases. Industrialized countries have already brought these diseases under control, and developing countries will probably do the same as they become wealthier. It may prove difficult, however, to check the spread of climate-linked diseases as borders become more porous. When the United States brought malaria under control one hundred years ago, it was difficult for malarial patients to travel and reinfect a zone; today, every major malarial zone in the world is less than twenty-four hours from the United States by airplane, and forty million international air passengers arrive in the United States every year. Unlike property risks, for which insurance markets can respond rapidly to a change in danger, risks to human lives create liabilities that require a whole generation for adjustment. The 1999 outbreak in New York of the West Nile virus—a disease carried in birds that is transmitted by mosquito in a manner similar to malaria—illustrated the dangers and underscored that the public is easily panicked. The virus is known to have infected sixty-two people that year in New York State and killed seven; it has since spread across much of the United States. Combating health effects may require improvements in public health systems and disease monitoring, including outside the United States. Such investments are already rising in priority as we contemplate responding to possible bioterrorism attacks.

Third, and finally, it may be extremely difficult to adapt to the consequences of abrupt climate changes—such as a rapid shift in circulation in the North Atlantic or an accelerated century-long melting of the West Antarctic ice sheet. Better monitoring and analysis of these scenarios could improve our adaptive capacity, but the dislocations could be so large that adaptation is not an option.

Of these three points of vulnerability, the third could affect U.S. interests and security most dramatically. Yet the risks are difficult to quantify. We expect that such abrupt climate changes—perhaps low in probability but drastic in consequences for society—will become an ever larger part of the public debate about how to respond to climate change. If the public becomes worried about these scenarios it will be difficult to respond with a policy that relies mainly on adaptation.

Controlling Emissions

Whether and how you adopt policies to control emissions of greenhouse gases will be politically the most visible and controversial aspect of your climate change policy strategy. Since 1988, prominent senators and members of Congress have introduced bills to require mandatory limits on emissions, although not one of those bills has passed. In 2003, the Senate voted on a bill sponsored by Senators Joe Lieberman (D-CT) and John McCain (R-AZ), which would have imposed caps on U.S. emissions of greenhouse gases. The measure attracted forty-three positive votes—"free votes," say its detractors, who never expected the bill to pass, but for many others the near majority was a sign of growing legislative interest in adopting some sort of binding limits on emissions. Before the vote on the McCain-Lieberman bill, the only other time that the full Senate has voted on climate policy was in July 1997, four months before the final negotiations for the Kyoto Protocol, when the Senate passed the Byrd-Hagel resolution by a vote of 95-0, declaring that the Senate would not accept any treaty that did not hold developing countries to the same commitment schedules as the United States. (We address this nonbinding resolution in more detail later.)

Absent mandatory controls, since 1994 the federal government has had in place a program to encourage private firms to make voluntary reductions—also known as "1605(b)" after the section of the Energy Policy Act of 1992. In 2002, 228 American firms claimed that they achieved reductions totaling 265 million metric tons of CO_2 equivalents (about 4 percent of actual gross U.S. emissions that year). Many firms have participated in 1605(b) because they see it as a way to gain public credit for cost-effective reductions that they would have made anyway. Many participants also appear to believe that acknowledged reductions will also lead to future rewards, such as extra emission credits in some future emission trading program.

Critics complain that the voluntary 1605(b) program has loose accounting standards. (Some of that critique will be blunted by new accounting rules presently under development.) In recent years, several states have begun their own programs to register emission reductions and to encourage firms to measure their emission of greenhouse gases; those programs generally have much tighter accounting standards than 1605(b). Some observers nonetheless are critical of all these "voluntary" schemes because insofar as they offer an implicit promise to recognize emission reductions, they are, in effect, a back-door strategy for implementing a soft cap on emissions. These critics argue that government should not reward incumbent firms just because they file paperwork to register low-cost emission cuts that they would have made anyway. Alternative methods for allocating rewards such as a binding emission trading system could be much more efficient. For example, an auction of permits would deliver the value created in these permits to the public owners of the atmosphere rather than to private firms that are talented at filling out forms.

Designing Effective Emission Controls

Crafting a strategy for controlling emissions is a complicated and potentially risky task because it involves altering the metabolism of the industrial economy, which depends on fossil fuels. Over the last decade, successive administrations have examined four broad types of policies.

First, the government could make fuller use of voluntary programs. In addition to 1605(b), the government could make more aggressive use of labeling and informational programs. For example, the "Energy Star" program of the Department of Energy (DOE) and the Environmental Protection Agency (EPA) has had some success in convincing manufacturers to produce more efficient electrical equipment. For example, computer monitors, VCRs, and other devices used to consume large amounts of power in "standby" mode; "Energy Star" has helped to reduce this parasitic consumption of power without much altering the functionality of equipment. Manufacturers have been keen to participate as that allows them to show the "Energy Star" logo on their products, and this "voluntary" approach has probably forestalled less flexible binding regulations. Without such programs, few consumers would have been able to determine on their own why their electricity bills were so high and to identify viable technological alternatives.

Many voluntary programs have focused on household energy decisions. All told, about one-third of U.S. emissions of carbon dioxide come from households, and there is ample evidence that households are especially far from the frontier of best practice in their usage of energy. Homeowners often do not invest in even in the simplest and most cost-effective measures, such as adding insulation and buying efficient appliances. Many voluntary programs directed at homeowners already exist, but it will be difficult for the federal government to exert much additional direct leverage since many of the key decisions rest with state policymakers and regulators. For example, many states with regulated power utilities have allowed (or even mandated) utilities to work with customers to find cost-effective ways to provide energy services (such as lighting and heating) while also limiting demand for electricity and gas. These "demand-side management" programs have been inspired by the logic that it is often much less costly for society to invest in energy efficiency than to expand energy supply systems. Yet the actual record of these programs is mixed. Some have been highly successful—especially those involving large energy users (e.g., substituting ultra-efficient heat pumps for traditional air conditioners) and those that require only simple changes in end technologies (e.g., substituting efficient compact fluorescent lamps that provide the same light output while consuming one-quarter the electricity and lasting ten times longer than the incandescent bulbs that they replace). Although the logic of these programs is compelling and there is a history of notable achievements, in many cases these programs have been justified with accounting methods that regulators have allowed but that would not pass normal market tests.

An expanded voluntary effort should include not just attention to emissions from the energy system but also changes in the use of land, which could help reduce the roughly one-quarter of world greenhouse gas emissions that come from tropical deforestation. You could endorse efforts such as those of an international coalition of leading American and European nongovernmental organizations (NGOs)—the Climate, Community, and Biodiversity Alliance—which has developed voluntary standards for projects that limit carbon while also helping to preserve biological diversity and improve local livelihoods. To date, such voluntary programs have not played a central part in the U.S. government's efforts to promote emission controls. You could also redouble federal diplomatic and financial support for programs that build on existing U.S.-led diplomatic initiatives such as the Congo Basin Forest Partnership that links key governments and NGOs in West Africa with the goal of protecting forests and other natural resources in order to improve people's standard of living in that region.

Second, you could develop a policy of controlling emissions through direct regulation, such as mandatory energy efficiency standards. Already government imposes many energy efficiency standards; their effectiveness and economic merits are hotly contested, but the potential to raise efficiency is substantial. For example, in 1972 the average U.S. refrigerator consumed 1,800 kilowatt hours (kWh) per year. Through a series of binding standards—

first in California and then nationwide—power consumption by the average refrigerator has declined to about 500 kWh per year, even as refrigerators have swelled in size and functionality has increased with the addition of such features as automatic defrost. It is difficult to disentangle the effect of higher electricity prices, awareness of energy issues, and autonomous innovation within the refrigerator business from the specific effect of tightening efficiency standards, but many experts argue that such standards are proof that government can and should force technological change through binding rules on equipment suppliers.

The single largest effect of government energy efficiency standards on total energy consumption and emissions of greenhouse gases is in personal vehicles. Ever since 1975 the United States has set standards that require each major vehicle manufacturer to achieve a minimum average level of efficiency for the fleet of cars and light trucks it sells—the so-called Corporate Average Fuel Economy (CAFE) standards. These standards, along with higher gasoline prices, explain why during the 1980s total fuel consumed (and carbon emitted) from personal vehicles actually declined even as the total distance traveled by passenger cars and trucks rose steadily every year. Only in the 1990s did emissions resume their rise—partly because the efficiency standards for new cars have been largely stagnant since 1985 and notably because new consumer tastes favor less efficient "light trucks" over "passenger cars." The CAFE rules treat these categories as distinct and allow much lower mileage averages for trucks (20.7 miles per gallon, or mpg) than for cars (27.5 mpg). (The National Highway Traffic Safety Administration, which administers the CAFE program, has raised light truck standards to 22.2 mpg for the model year 2007.) The category of "light trucks" includes nearly all minivans, crossover vehicles such as DaimlerChrysler's PT Cruiser, and all SUVs; today, 36 percent of registered vehicles are "light trucks." Roughly 5 percent of personal vehicle sales are trucks that weigh more than 8,500 pounds and therefore are not even subject to the relatively lax fuel economy standards for light trucks; favorable treatment under federal tax laws creates additional incentives for people to use such ultra-heavy personal machines.

In 2002 the National Research Council issued a report showing that it was possible to increase fuel economy for new passenger cars and trucks by about 50 percent over the next decade, with little impact on vehicle safety. It also recommended eliminating the bureaucratic distinction between "cars" and "light trucks," which is a vestige of much earlier policies that aimed to protect U.S. light truck manufacturers from foreign competition and to exempt short-haul industrial and farm vehicles from the strict fuel economy standards for passenger cars. The logic of that earlier era is difficult to justify today.

We find, however, that most firms and economists are united in their belief that product- and facility-specific regulation—often called "command and control" regulation—is excessively costly. For example, strict energy efficiency standards force consumers to spend capital on efficiency features that they otherwise would not select; more costly vehicles cause consumers to delay purchases, which in turn probably makes the vehicle fleet older and perhaps less efficient than it would be otherwise. However, such regulation may be your only option if citizens abhor policies that raise the price of carbon-rich fuels.

Third, you could pursue a market-based policy that relies on taxing emissions—often called a "carbon tax" since carbon dioxide is the main greenhouse gas. The tax sends a price signal to firms and households, encouraging them to reduce emissions where that would be cost effective. As economic policy it is attractive because with a tax you will know the cost that your policy imposes on the economy; unlike a cap on emissions (which we discuss below), there is little risk that your policy could accidentally impose a cost on the economy that is higher than Americans are willing to pay. Revenues from a carbon tax could be used to lighten taxes on capital or labor, which could help to accelerate economic growth; tax revenues could also be earmarked for special purposes such as research and development (R&D) into climate-friendly technology and other politically useful activities.

The central problem with this approach is its political difficulty. The last presidential effort to create a broad-based tax on fossil fuels was the Clinton administration's ill-fated "BTU tax" that was part of its 1993 economic recovery package. Although the proposed tax was very small (about four cents per gallon of gasoline, which is much less than the typical variation in fuel prices during the summer driving season), many voters disliked the measure and Congress declined to pass it. The conventional wisdom that has arisen from that debacle is that direct regulation and alternative policy instruments that impose costs with stealth while visibly demonstrating action are politically more likely to succeed than higher taxes. The failure of the BTU tax, however, also stemmed from the failure of the Clinton administration to articulate a compelling special purpose that would require the energy tax.

Given the public's assumed reluctance to pay higher taxes, it will be difficult to muster the political coalition needed to adopt a carbon energy tax. Moreover, nearly all environmental groups actively reject the tax approach because its effect on emissions is uncertain. Instead, they prefer emission caps, which make it clear what the economy must deliver for the environment.

In addition to the political arithmetic that has deterred U.S. policymakers from seriously considering carbon taxes, such measures also present special problems for international coordination. If you impose a meaningful tax on the United States you will want to ensure that other countries impose similar measures on their firms as well. In practice, though, countries that have adopted carbon taxes typically riddle them with loopholes and special exceptions to reward politically powerful groups and to reduce the real costs of compliance. A coordinated international approach based on taxation would require complementary rules to limit these loopholes, and such rules would be difficult to enforce. Indeed, similar types of disciplines on tax policy exist in the WTO, where despite sophisticated enforcement institutions it has been very difficult to assure compliance.

The problems with the preceding policy options have led most analysts and politicians to focus on a fourth option: a market-based "cap-and-trade" system. In this scheme, each nation would adopt a binding cap on its total emissions. The nation would then allocate emission credits within its borders—probably far "upstream," at power plants, refineries, and other primary users of fossil fuels that cause emissions of greenhouse gases. (A "downstream" system could be costly to administer since millions of firms and households, each causing relatively low emissions, would be required to engage in the trading system.) Firms would then be free to trade these credits, which would ensure that actual emission controls are applied where it is cheapest. The United States has successfully used such "cap-and-trade" systems in phasing out lead in gasoline and in controlling emissions of sulfur dioxide, the leading cause of acid rain. This vision for a cap-and-trade system is already built into the Kyoto Protocol, mainly because of the insistence of the Clinton administration. It is also a central part of domestic policy proposals such as the McCain-Lieberman bill.

An emission trading system offers opportunity for political arbitrage. The permits that would be allocated under this system could be extremely valuable, and special handouts could be used to blunt opposition and reward politically powerful constituencies while not actually appearing as a cost on the government's books. When Congress crafted the 1990 Clean Air Act, it awarded most of the sulfur emission credits to existing emitters, the interest group that would have been most adamant in opposing emission controls. Studies show that awarding just 10 percent of carbon emission permits to the hardest-hit stakeholders—coal mining firms in particular—could blunt their opposition by offsetting their immediate losses as the economy shifts away from carbon-intensive fuels. We question the economic efficiency of a scheme that diverts large resources to an ailing industry—rather than allowing the market itself to determine coal's fate—but as a matter of political expediency such allocations are probably unavoidable. Your economic advisers will urge you to auction the permits, as is done in many other areas in which the government leases a public good for private purposes (e.g., the radio spectrum for cell phones). Using standard methods for calculating the value of property rights, the stock of U.S. emission credits could be worth about $1 trillion, making this the largest allocation of public property since the opening of the American West.

Several entities have already created pilot programs to trade credits and prove the merit of the concept. For example, the Chicago Climate Exchange (CCX) opened in December 2003 for trading among nineteen North American entities that have agreed to reduce their emissions 1 percent per year for four years to demonstrate the functionality of the market. At present, carbon dioxide permits are trading in CCX on a spot basis for less than $1 per ton—an extremely low level that reflects the lack of any meaningful incentive to control emissions in the U.S. economy. Similar pilot efforts are taking shape in the northeastern United States. The European Union has created a binding trading system for large industrial sources that will begin operation in 2005.

In principle, the greatest gains from emission trading will arise in an international system. Indeed, the architects of the Kyoto Protocol envisioned that the thirty-eight industrialized countries with binding emission caps would be allowed to trade portions of their emission quotas on an international exchange. As you evaluate whether such a system is in the U.S. interest we urge you to develop a careful strategy for assessing which nations should be allowed inside an international trading system that includes the United States.

On the one hand, it is useful to involve as many countries as possible in the trading system because that offers the greatest potential gains from trade. Economic modeling and pilot projects have already proved that flexibility in the geography of emission control can cut costs dramatically. For example, American Electric Power—the largest coal-burning U.S. electric utility—has demonstrated that it is less costly to limit net emissions to the atmosphere by protecting a rainforest in Bolivia than to control emissions from its existing power plants located in the United States. Gas companies in western Europe and pipeline companies in Japan are exploring ways to get credit for investing in less-leaky pipelines and more efficient compressors on the gas transmission system in Russia. Gazprom, Russia's natural gas monopoly, welcomes this approach because it would attract badly needed investment in its crumbling gas-transmission system, and the Western firms see it as an opportunity to enter the Russian gas market and control emissions at much lower cost than in the already tight and relatively efficient systems they operate at home.

On the other hand, the countries that have the greatest opportunity for low-cost emission controls—developing countries, as well as Russia and Ukraine—are those that have the weakest internal institutions and thus are least likely to be able to monitor and enforce the system. Since emission credits are analogous to a new form of currency, countries with weak institutions could print excessive quantities of this new currency, degrading the value of the scrip held by all others and causing higher emissions that undermine the scheme's environmental objectives. An international treaty probably does not offer strong enough institutions to deter such actions; violators could be ejected, but by the time their transgressions were known for certain it might be too late for others to adjust their behavior before the currency scheme unravels. No durable currency has ever sprung forth by starting with large numbers of highly diverse agents in the absence of strong institutions that are essential to assuring the integrity of the currency. It is useful to keep in mind the experience in Europe of creating the euro. In that case, twelve countries created a common currency within an existing context of strong collective institutions, independent courts, a robust administrative bureaucracy, and a new central bank. Even then, the transition has been far from seamless. In 2003, when France and Germany failed to comply with limits on their budget deficits, the European Monetary Union declined to penalize them, even though this failure in essence siphoned value from compliant members. It would be a daunting task to attempt to create a currency of emission credits in the context of much weaker international law with the participation of countries such as Russia and most of the developing nations that question the need for any emission controls.

The analogy with creating a currency suggests that it may be better to build a market from the "bottom up" rather than attempt to create an international trading system with centralized Kyoto-style rules that work "top down." Countries that care most about the environmental problem at hand would establish their own trading systems (currencies) and enforcement rules. Then portals (exchanges) between the systems would be established according to bilateral consent. Thus countries could control their exposures to poor enforcement and excessive allocation by deciding where they open portals. Inspired by the early years of the General Agreement on Tariffs and Trade (GATT), members in this bottom-up regime might also create international rules of mutual recognition, reciprocity, and most-favored-nation arrangements to ensure that those who accept the strictures of core trading arrangements gain the benefit of access to all markets that are part of the regime. Enforcement would rest principally with member states and the market, which would value each country's scrip individually, just as currency markets assign varying values to dollars, yen, euros, and rupees.

This bottom-up approach cannot be sustained forever. As the screws are tightened you must have a credible plan for eventually involving all emitters so that none can "free ride" on the benefits of protecting the climate while paying none of the cost. As the number of parties grows there will be a need for better central coordination and multilateral enforcement systems. But that topic might be deferred until some future moment when the foundations for a broader system have been laid and tested. Indeed, the architects of GATT did not create any provisions for multilateral enforcement; a system of "dispute panels" arose later within the GATT system. Only today, more than fifty years after the modest creation of GATT, has an effective enforcement system arisen through experience, learning, and the creation of institutional arrangements such as the WTO.

Your view of the urgency of the climate problem will shape how you strike this balance between including many nations versus starting with a small number of like-minded countries that already have strong institutions in place. If you think that substantial controls on emissions are necessary and urgent, then a global approach involving most or all nations is important since you must rapidly gain leverage over the majority of world emissions. If you think that we have several decades (or longer) to develop an effective global emission control system, then you can afford to pursue a policy strategy that starts with modest coverage and limits on emissions and then evolves from the bottom up.

The credibility of efforts to create a trading system probably matters much more than the exact stringency and timing of cuts. There are long lead times in shifting energy systems; delay today creates the possibility to gather more information and wait until new technologies are available, but delay also carries costs of lost opportunity if investors ignore the possibility of strict future limits. In the developing world, where energy systems are expanding rapidly and equipment purchased today will condition technology opportunities for decades, there may be a special need for credible decisions now that send a long-term signal for change.

The Cost of Controlling Emissions

Even if you employ a well-designed market-based system of emission trading there are many potential economic risks in the magnitude and timing of the cut. Modest cuts in emissions, such as a 5 percent to 10 percent cut below the trajectory of emissions over a decade or longer, probably pose few risks for the economy. Firms and households will respond with low-cost, minor changes in technology and practice; an emission trading system will allow flexibility in exactly where the economy makes the reduction.

The timing of deeper cuts, however, requires greater care. Roughly half of U.S. emissions come from capital stock, such as power plants and steel mills, that has a lifetime of approximately twenty-five years or longer. This stock turns over slowly. Tight limits imposed with little warning over a short period could require the owners to implement costly retrofits or abandon these facilities. Yet such premature retirement of capital equipment would offer few environmental benefits, since the climate change problem itself is caused by the slow accumulation of greenhouse gases in the atmosphere. The amount of warming is more sensitive to the trajectory of emissions over time than to the exact timing of emission controls.

There are no precise maps to guide your decisions on the timing and cost of emission controls. The Clinton administration commissioned two studies through the Department of Energy on this issue and received diametrically opposed answers. One, a survey of national laboratories, found that many emission control technologies were already available for substantial emission cuts; a vigorous national commitment to energy efficiency, it argued, could keep emissions at approximately 1990 levels for little cost. The other relied on macroeconomic models and suggested that complying with the Kyoto commitments could cost hundreds of billions of dollars. Other studies using similar methods also concluded that this high cost yielded little benefit of averted climate change. This discrepancy reflects, in part, a conflict between the intellectual paradigms that guide the experts. Engineers who look at energy systems piece by piece find waste aplenty; optimally designed projects and technologies, they claim, will allow firms and households to save money while also cutting emissions. Economists tend to see the economy as an equilibrium that is costly to disturb; even if money-saving potentials exist, they claim, it may be costly to gather the information needed to identify and implement the best measures within the real organizations that populate the economy. Efforts to combine these two perspectives have proved difficult but generally suggest that considerable carbon savings are available at low cost. In 2000 the Clinton administration's DOE published a comprehensive scenario analysis of the U.S. economy. It concluded that the expected level of emissions in 2010 could be cut by 5 percent with fuller implementation of money-saving energy efficiency projects. Nonetheless, the study showed that emissions would rise overall in the absence of policies that, in effect, raised the price of carbon emissions.

We note that long-lived capital assets are typically much more responsive to policy incentives than suggested by their old nameplates. The White House, for example, is two centuries old; yet throughout the building you find modern conveniences and energy-efficient equipment, from computers to refrigerators, that were unavailable when John and Abigail Adams took up residence in 1800. The nation's oldest fossil fuel power plants that are connected to the grid date to the 1920s, but inside their brick walls the facilities have little in common with flapper-era technology. We also note that those who have argued that rapid and deep emission cuts are feasible often fail to recognize that technologies do not automatically appear where they are needed. Rather, technological change is often encumbered by the organizations and networks that must evolve alongside any transformation of the whole energy system.

The pace at which policy can encourage lower emissions is revealed in passenger and freight transportation, which accounts for about one-quarter of all U.S. emissions of greenhouse gases. Beyond the ten- to fifteen-year lifetime of new cars, another five years is typically needed to develop a new line of products, and still longer is required for testing and acceptance of truly radical new technologies. Ultra-efficient hybrid-engine vehicles, for example, first appeared on the U.S. market in 1999, yet four years later they accounted for only 0.3 percent of new vehicles sold and a much smaller fraction of the total passenger miles driven in the United States.

As a rule, complete transformation of the energy system takes about five decades. The shift to automobiles as the dominant mode of transportation in the United States required building new infrastructure (roads), head-to-head competition with the incumbents (rail cars and horses), and a complete shift in fueling systems from solid coal and hay to liquid oil-based products. Few pondered in the 1880s—when personal cars entered the U.S. market as leisure toys for the super-rich—the slow pace of diffusion of automobile technology or how pervasive automobiles would eventually become. The New York vehicle census found that cars outnumbered horses for the first time only in 1912—and New York's rich population was at the forefront of this transportation revolution. (Today, ironically, the super-rich have reverted to horses for leisure.) We are also mindful that analysts often overstate the potential of new technologies, forgetting that for every transformation traced to an original technological seed there have been dozens of false starts, such as Ford's amphibious car that promised to allow seamless interconnection between road and waterway mobility.

If you impose an excessively tight cap on U.S. emissions, you could repeat the experience with Kyoto in which an unrealistic cap forced the United States to consider either a politically unrealistic shell game of purchasing credits from Russia or simply exiting the regime. One solution to this problem is to create a "safety valve" in the trading system—a mechanism that allows the government to issue additional emission credits at an agreed price. In effect, this "valve" would limit the price of the emission credits and would make a cap-and-trade system behave like a tax if the cost of compliance rose higher than expected—if, for example, firms did not have enough time to meet a stringent cap on emissions with the normal turnover of the capital stock. Critics of the "safety valve," however, argue that only the terror of potentially high prices will force firms to focus on low-carbon innovations.

In developing your climate strategy you should be aware that many gases trap heat and cause changes in climate. Carbon dioxide is a relatively weak gas, but it is emitted in such prodigious quantities that it accounts for most of the current and expected future change in climate. Methane, by contrast, is a much stronger greenhouse gas, but the volume emitted is tiny compared with CO_2. Whereas CO_2 lingers a century or so in the atmosphere, methane survives in the atmosphere for just a decade. Thus efforts to control methane will have a rapid effect on climate but little impact on the long term. Avoiding carbon dioxide emissions is essential to long-term climate protection, but decades are required for the atmosphere to "feel" effects of changing the trajectory of carbon emissions. Scientists have developed indexes that account for these different properties of gases, allowing for crude conversion of different gases into common units—typically measured in "CO_2 equivalents."

In 2002, the gross U.S. emission of greenhouse gases totaled 6.9 billion metric tons of CO_2 equivalents. Of that total, 83 percent was emitted as CO_2 itself; the rest was as methane (9 percent), nitrous oxide (6 percent), and other gases (2 percent). Offsetting those gross emissions was the absorption of CO_2 by U.S. forests and croplands, with estimates ranging as high as one billion tons of CO_2. (Nobody is quite sure how much carbon is absorbed on U.S. territory. Some studies suggest that the quantity is extremely large because U.S. forests are still rebounding from massive deforestation in the nineteenth century, which implies that current high absorption is merely a transient effect.)

In principle, any effort to control emissions should set broad goals and then leave firms and households to find the emissions that are least costly to control. For example, firms such as the sanitation giant Waste Management have discovered that it is inexpensive to control methane from landfills by adopting new technologies to contain and manage landfill gas. The gas is so rich in methane—which is also the main ingredient in natural gas—that the landfill managers have been able to sell it for a profit. By encouraging the search for such innovative low-cost solutions, a multi-gas strategy can be less costly than policies that focus on just one gas (e.g., CO_2) or even on just one activity (e.g., emissions from large electric power plants). In practice, however, many of these gases and activities are difficult to monitor, and thus you must balance the hypothetical benefits of a multi-gas comprehensive approach against the cost and difficulty of its administration. Faced with exactly this challenge, the European Union, which is developing the world's first international system for trading emission credits, has opted initially to restrict the system just to easily measured CO_2 from burning fossil fuels at industrial sources. The EU system regulates other sources and gases separately and establishes a plan to include them in the trading system at a later date, when monitoring of emissions has improved and the trading system has proved its mettle.[2]

Finally, the metrics that are used to measure progress could have a large impact on the cost of compliance and the success of attempts to engage other countries in a collective effort to limit emissions. In most countries, and in the Kyoto process, goals have been set in terms of the volume of emissions—tons of CO_2 equivalents per year. Those terms often make the United States look like a poor performer, as we account for about one-quarter of the world's total emissions, which is hardly surprising since the United States also accounts for about one-quarter of the world's economic activity. The second-largest emitter (China) is quite far behind, at only 13 percent. After that follow Russia (7 percent), Japan (5 percent), and India (4 percent), and then many others spaced close together. Individual European nations account for small shares; the twenty-five nations of the EU collectively, however, account for less than one-sixth of the world's emissions.

Volumetric measures are also problematic as instruments for policy because they leave the United States and other countries exposed to unintended consequences. Over the short term, the single greatest factor in determining emissions in the United States has been the size of the economy; when the U.S. economy grew

[2]Regarding multi-gas strategies, you should be aware that a controversy is brewing within the scientific community about the role of soot in climate change. Emitted from diesel engines, biomass burning, power generation (mainly by coal), and other activities, soot can absorb heat and cause climate warming. Soot particles also accelerate the formation of clouds, but as mentioned earlier the exact effects of clouds on climate remains an area of ongoing scientific dispute. The soot debate is unlikely to alter the fundamental theory of climate change, but if soot proves to be a major cause of climate change then the allocation of responsibility by nation and activity may change a bit. Developing countries may account for a disproportionate share of the soot flux because they generally make less use of the technologies (e.g., flue gas scrubbers for power plants) and the fuels (e.g., natural gas) that yield lower soot. Soot is also implicated as a major cause of lung disease and other environmental harms, so most societies are likely to regulate soot more tightly over time and to welcome the opportunity to combine efforts to protect the climate with policies that deliver immediate local benefits that will make it easier to build a political coalition in favor of action. The atmospheric lifetime of soot is very short compared to the century-long lifetime of CO_2, and thus efforts to cut soot are not simple substitutes for mitigation of CO_2.

rapidly in the late 1990s, so did our emissions, making the Kyoto targets increasingly beyond the American grasp. By setting obligations in terms of the total volume of emissions, Kyoto unwittingly appeared to put environmental protection into direct conflict with economic growth. Indeed, when measured in terms of emission volumes the advanced industrialized countries that have performed best have done so through economic weakness. Germany shut down factories in the former East Germany; Luxembourg, which achieved the deepest percentage cut in emission volumes of any industrialized nation in the 1990s, owes its success to closing a major steel plant and relying more heavily on imported (rather than domestically generated) electricity.

When President Bush announced his climate change policy in February 2002, therefore, he adopted the measure of "greenhouse gas intensity"—the ratio of emissions to the size of the economy. He set a goal of cutting intensity by 18 percent over a decade. Figure 1 shows this measure for some key countries and reveals that the United States is in the pack. Our carbon intensity is about 210 grams of carbon emitted per dollar of economic output (gC/$). Japan and France rest at about two-thirds that value, reflecting aggressive energy-efficiency policies and high energy prices as well as large sources of carbon-free nuclear power in both countries' energy systems. By this measure, many developing countries actually appear worse than the United States. China's official statistics suggest a carbon intensity of around 300 gC/$. South Africa has among the highest carbon intensities (400 gC/$), as its heavy mining and industrial economy is based on the least costly electricity in the world, nearly all of it generated with carbon-intensive coal. India's carbon intensity is about the same as that of the United States, but the level is rising due to industrialization of the Indian economy.

So far, the United States is the only major country to focus on intensity as the measure of responsibility and progress. Two factors explain why others have not followed suit. First, President Bush's 18 percent target is widely seen as lacking ambition. The U.S. intensity peaked in 1922 and has been declining at about 18 percent per decade ever since (see Figure 1). Second, intensity is a

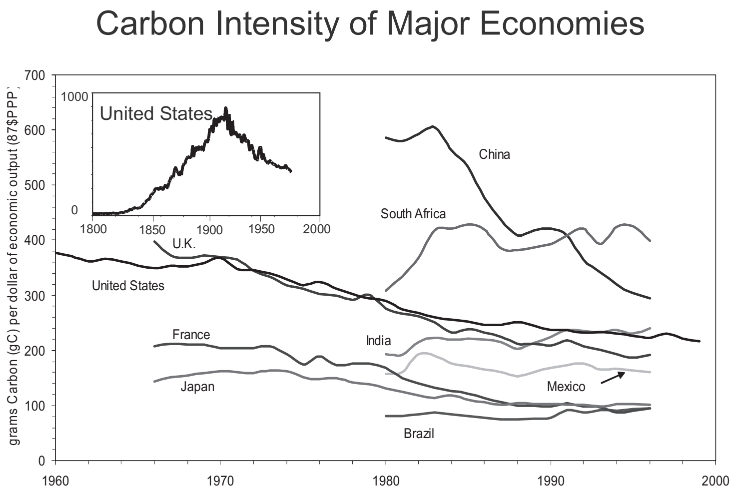

Figure 1: The Carbon Intensity of Major Industrialized and Developing Economies (in grams of carbon emitted as CO_2 per dollar of economic output). Inset shows carbon intensity for the United States from 1800.

Source: Oak Ridge National Laboratory (emissions statistics); U.S. Department of Commerce and the World Bank (economic output).

Notes: Economic output figures are converted into common dollar units using the World Bank's "purchasing power parities," which account for the higher local purchasing power of money in most developing countries. Use of market exchange rates would give developing countries much higher carbon intensities than the United States and other industrial economies. These data show only CO_2 emissions from burning fossil fuels and thus do not account for potentially important but less well-documented sources of greenhouse gases, such as CO_2 and methane released from the decaying biomass submerged in lakes behind hydroelectric dams. The data here also exclude deforestation (a major factor in the United States and other industrializing countries in the decades surrounding 1900 and a major factor today in Brazil and many forest-rich tropical nations) and emissions of methane from animal husbandry, the growing of certain crops (e.g., rice), drilling for oil and gas, and other sources.

convenient measure only in countries where the energy system is changing slowly and in favorable ways. In some countries, intensity measures are actually more volatile than total emissions, especially when the economy (the denominator in the intensity measure) changes abruptly. When the Soviet Union collapsed, for example, intensity rose sharply because the officially measured economy shrank more than total consumption of energy. Nor will all countries accept the premise that carbon intensity should decline over time. Brazil, for example, has traditionally relied on hydroelectric power and has therefore had an extremely low and stable carbon intensity (about 80 gC/$); now that most hydroelectric sites are already being used and Brazil has experienced costly blackouts during dry years, the government is encouraging construction of new fossil fuel–powered plants. Although a new pipeline from Bolivia, as well as recent gas finds in the ocean off of Rio de Janiero, has made it possible to use ultra-clean gas in these new plants, Brazil's carbon intensity is nonetheless set to rise. After long reliance on home-brewed liquid fuels made from sugar, oil-based products are also figuring more prominently in Brazil's energy system, and that too will raise carbon intensity.

Many developing countries favor per capita measures of accountability, which make them look responsible, as their populations are large relative to their emissions. China's per capita emissions are only one-tenth those of the United States. Some academics and a few diplomats from developing countries also favor an approach that would hold each nation accountable not only for its current emissions but also for the accumulated concentrations still lingering in the atmosphere from their past emissions. That historical approach would assign responsibility for about one-third of today's climate change to the United States, while developing countries (whose emissions have risen only recently) would account for only a small share. Such proposals appear harmful to U.S. interests because they imply that we have already spent a larger share of our part of the atmospheric budget. As you explore ways to engage other countries, however, you should be aware that they may measure responsibilities in ways that differ sharply from the metrics that the U.S. government finds most attractive.

Investing in New Technologies

To the extent that you think climate change is a problem that merits limiting future emissions, you will need to consider the special role of technology policy. Adopting a credible limit on total emissions will send a strong signal to innovators. However, the technologies that will be needed probably will not arrive autonomously. Some will be prohibitively risky or expensive for private firms to develop solely on their own. It will be difficult for investors to appropriate all the benefits of their innovations, which is an additional reason why public programs will be needed to offset under-investment by the private sector.

To give you a sense of the magnitude of the technological task, consider that the entire world's economy today is powered with about 14 trillion watts (terawatts, or TW) of primary energy. Of that, about one-quarter emits essentially no greenhouse gases—mainly nuclear power and hydroelectricity, but also much smaller quantities of wind power and tiny amounts of solar power. Over the next fifty years, total world energy consumption may rise to about 35 TW. If the world decides to stabilize atmospheric concentrations of CO_2 over the next century at 550 ppm (about twice the pre-industrial level), then during the next fifty years the amount of carbon-free power must rise nearly fivefold. In other words, by 2050 the total amount of zero-carbon power supply must exceed the total power supply of all forms on Earth today. Historically, the supply of carbon-free energy has grown at only about 0.3 percent per year faster than the total energy supply. At that historical rate of "decarbonization," perhaps only 10 TW of carbon-free power will be available in 2050—an amount that is short by half of what would be needed to put the world economy on a path to stabilize the atmosphere. This calculation is merely an illustration, as nobody knows the true safe level for stabilizing concentrations. The value of 550 ppm is the one adopted by the European Union for planning purposes since 1996, and some firms (such as BP) have also loosely adopted such goals.[3]

There are many options available, from advanced nuclear plants to new wind turbines and perhaps exotic energy forms such as satel-

[3]If the arbitrary 550 ppm goal reflects the allowable climate forcing from all greenhouse gases (not just CO_2), then the allowable limit for CO_2 may be about one-fifth lower—roughly 450–500 ppm, depending on the assumptions for the emissions and concentrations of methane and other important greenhouse gases.

lites tethered in space that beam power collected from the sun back to Earth. None of these technologies, however, is ready to deploy in the large quantities needed. As you consider whether and how the federal government could play a role, you should be aware that there is a long and checkered history of U.S. policy intervention in the invention and deployment of new technologies. That history suggests four lessons that can guide your thinking.

First, there are many examples of technological spin-offs from government programs. Fuel cells, which convert hydrogen fuel into emission-free electricity and could become the backbone of a zero-carbon "hydrogen economy," are the by-product of academic tinkering in the nineteenth century applied in the space program. Transistors, the Internet, and many other technologies embedded in today's economy and society are also accidental offshoots of government programs and private tinkering that originally were directed at other goals. Who would have thought in the 1960s, when the Defense Department supported packet switching partly with the goal of creating a communications system that could withstand the disruption of nuclear war, that the Internet would result? These spin-offs are often used to justify open-ended technology programs in the belief that something useful will appear from the investment. That faith-based approach to technology policy could be wasteful because it is hard to predict which programs will be most effective.

Second, the desire for grand solutions to grand problems will yield political pressures for grand projects—a new "Manhattan Project" or "Apollo Program" to eliminate carbon. Such analogies are probably misplaced. Neither the construction of the first nuclear weapon nor putting a man on the moon required much attention to cost, and both were implemented within hierarchical military-style organizations. In contrast, completely transforming the economy will require enormous sensitivity to the cost and ease of transition—especially if many developing countries are to be enticed down low-carbon pathways. And the transition will occur within a market that operates most efficiently without hierarchical regulatory instructions.

The record of grand energy technology programs is generally not encouraging. Even programs that have succeeded in creating new technologies have often failed the test of markets. The U.S. Navy's nuclear submarine program provided most of the seed funding for light-water reactors; that support and the regulated utilities that bought most reactors explain why nuclear power rapidly diffused into widespread use in the U.S. electric power system. But those same protections also sheltered nuclear technology for too long from commercial considerations. Even more than the 1979 accident at Three Mile Island, the exorbitant and growing cost of reactors killed the industry. The potential for commercial improvement is evident in today's more competitive electric power market, in which new owners of reactors have found many innovative ways to squeeze about one-fifth more electricity from their plants than was typical in the old, highly regulated electricity system. Perhaps the worst failures in energy technology programs were the multi-billion-dollar efforts inspired by the oil crises of 1973 and 1979. A massive clean coal technology program, designed to make greater use of U.S. coal resources, was laden with special interests; politics, rather than market potential, drove the choice of technologies. In most large technology programs, such political distortions tend to arise as the programs become more visible and costly. It is hard to square the economic imperative for widgets in every congressional district with the need for nimble, efficient, and ruthless technology choices. In this thicket of troubles some success stories have nonetheless emerged. For example, a small program supported by the Department of Energy to develop high-efficiency electronic ballasts for fluorescent lights has accelerated the diffusion of this technology and saved hundreds of millions of dollars' worth of electricity.

The standard lesson from these programs is to avoid prematurely selecting "winners." It is difficult to put that advice into practice, however, and you should be wary of policy proposals that claim they will not anoint the early sprinters or political ponies. Managers of these programs find it relatively easy to avoid picking winners at the earliest basic research stages because supporting a diverse portfolio of fledgling ideas is relatively inexpensive. The real problem arises when technologies become sufficiently mature that a demonstration project is necessary. Almost always, industrial-scale demonstration of energy systems is very costly, and thus it is impossible to afford a large portfolio of projects. Today's conventional solution to this problem is to require reviews by outside experts, which can help avoid squandering resources on certain failures but often are unable to exert the subtle scrutiny that is needed throughout the management of successful projects.

Another standard remedy to this problem is to require private-sector co-financing. The private sector, it is thought, is unlikely to risk its money on poor commercial prospects; thus partnership with the private sector, in principle, can help select the most promising technologies. The Partnership for a New Generation of Vehicles (PNGV), a program adopted in the 1990s with the goal of enticing each U.S.-based auto manufacturer into producing an eighty-mpg prototype car, took this approach to sharing costs and following industry leadership (with outside expert review) in selecting technology pathways. The result was that PNGV followed paths that industrial partners probably would have followed on their own anyway—with PNGV, however, the research was, in effect, subsidized. And the attempt to distinguish between pre-commercial (public) research and commercial (private) research meant that useful findings were immediately appropriated by the private firms. As in pharmaceuticals, the rapid private appropriation of federally supported innovations has sped their appearance in the marketplace. Yet it may prove difficult to sustain public support for private appropriation especially if the commercial benefits of new products are highly visible.

In some respects, the PNGV program is deeply troubling. The eighty-mpg target bore little relation to realistic efficiency goals. While U.S. manufacturers toiled within PNGV, the Japanese manufacturers Honda and Toyota created hybrid cars that use ultra-efficient gasoline and electric motors in tandem. These cars achieve around fifty mpg today—nearly twice the level of conventional sedans—with the useful attribute that real people can afford to purchase them, and real people can actually drive them on real roads. In other respects, PNGV appears to have played a constructive role. It helped accelerate the diffusion from the national laboratories into application of new technologies and materials, such as a fuel cell designed at Los Alamos that required lower quantities of costly platinum.

Some technology partnership programs appear to have functioned well. The U.S. government created Sematech, a partnership with U.S. (and eventually international) semiconductor manufacturers that has proved profitable, has promoted common industry standards, and probably slowed the decline of U.S.-based semiconductor fabrication. (At the time, halting that loss was seen as a strategic goal for the economy and national security, which made Congress willing to appropriate the necessary funds.) The enterprise with the strongest record is the Defense Department's Advanced Research Projects Agency (DARPA), which deploys a large fund across a portfolio of innovative but risky projects. Like a venture capitalist, DARPA expects that only a few of its seeds will actually deliver blockbuster benefits, but the ones that do work pay for the entire portfolio. DARPA has thrived because of its connection to the defense agenda and the fact that most of its innovations have not required tests of commercial viability. If you adopt a technology policy that implies large amounts of spending on particular technologies—"winners"—you should consider the DARPA model rather than the moonshot or the Manhattan Project.

Third, it is very difficult to draw boundaries around the field of "energy" or "climate" technology. No field of scientific and technological research dominates the supply of plausible ideas for climate-neutral energy systems; new concepts can be found in high-energy physics, most fields of engineering, and chemistry. Biology is even a contender, as genetically engineered microbes could be jiggered to produce hydrogen. The hot field of nanotechnology also holds promise: microscopic carbon tubes, for example, could prove to be effective hydrogen storage devices. As it is impossible to identify the best frontier at the outset, it might be best to pursue a broad sprinkling of resources earmarked only loosely for topics such as "carbon-free energy" and "ultra-efficient energy systems" through existing basic science institutions—at the National Science Foundation, the Department of Energy, and (to a lesser degree) the National Institutes of Health. There is no good record of what the United States and other countries spend on such basic energy research, but the large probable return from a well-designed portfolio suggests that society (whether the United States or the world) probably dramatically underinvests in this area.

Fourth, radical and novel technologies are, to some extent, global public goods. International coordination of R&D may be needed. Whereas international coordination on controlling emissions of greenhouse gases is difficult because a large number of countries with highly disparate interests must be engaged, coordination on an international technology agenda is probably much easier. The United States, Japan, and the core group of large European nations together account for about 85 percent of world spending on R&D. All these nations already share a common (though not identical) interest in addressing the problem of climate change, and all have well-developed public institutions for administering sophisticated and costly research programs. There is a long history of collaboration among these nations on basic research programs, from joint experiments in the atmosphere to multi-billion-dollar scientific facilities, such as the European Organization for Nuclear Research (CERN), a high-energy physics facility on the French/Swiss border, and ITER, one of the next-generation facilities that will aim to demonstrate scientifically and economically viable nuclear fusion.

The more aggressive your technology policy on climate change, the greater will be the need for international collaboration. At present, there is almost no international collaboration on energy R&D, except in a few special areas marked by extremely expensive facilities (such as ITER) or a long history of international coordination (such as advanced fission nuclear reactors). The main international program in this area is managed by the International Energy Agency and consists of little more than governments declaring their own greenhouse gas R&D programs and exchanging broad reports with an international secretariat. Rarely do international collaborations lead to collective funding, but even efforts to achieve a coordinated research strategy could be beneficial.

The need for international coordination may be especially great for reasons that will be difficult for you to acknowledge publicly. Some technologies are so risky or stigmatized that they cannot be developed in the advanced industrialized world. In crop engineering, for example, Europe has slipped far behind the world's top innovators because of public concern about the technology. China appears to have reached the number two spot (just behind the United States) in crop genetic engineering due to a combination of generous government support for R&D, some pilfering of Western intellectual property, and, notably, lack of public opposition. Leadership in genetic engineering may determine the countries that lead the future of biological engineering for energy systems. In nuclear power, even the industrialized countries that have historically embraced that technology—Japan and France—find it ever harder to deploy new reactors. These difficulties have created niches for others. One of the promising new reactor designs is currently on the drawing boards at the South African electric power utility Eskom. Russia could also become a leader in the design and testing of new reactors.

The United States has already developed a technology strategy that incorporates some of these four lessons. The Climate Change Technology Program gives particular attention to two major projects. One involves co-funding (with industry) the FutureGen power plant—a potentially innovative project that would gasify coal and produce electricity while sequestering the resultant CO_2 underground. This plan builds on a long history of experiences with integrated gasification combined cycle (IGCC) power plants. Not only is this a promising way to decouple electricity production from the emission of CO_2 while allowing us to continue burning America's enormous coal reserves, but IGCC could also create a U.S.-based export market. IGCC plants are much more efficient than standard pulverized coal plants, and other nations will seek this technology as they face constraints on carbon while also wanting to make efficient use of their locally available coal resources. The other major element of U.S. technology investment is in hydrogen—notably the FreedomCAR initiative, a joint venture with U.S. automobile manufacturers to produce hydrogen-powered fuel cell cars as part of a shift to a hydrogen energy system. For these and other initiatives, including tax incentives for adoption of new technologies, the fiscal year 2005 budget request includes nearly $4 billion.

Although both these initiatives are admirable, earlier technology programs offer some warning lessons. In particular, we highlight the danger of pushing advanced technologies without any credible signal in the marketplace to favor investment in low-carbon systems. We also note that the FreedomCAR initiative is strikingly similar to some of the most flawed aspects of the PNGV venture, both in its parochial attention to U.S.-based auto manufacturers and in its embrace of the possibly irrelevant distant goal of a fuel cell–based hydrogen economy. The National Academy of Sciences recently reviewed the prospects for a hydrogen economy and concluded that the barriers such as onboard fuel storage in passenger cars remain formidable and the vision of a hydrogen economy—especially one centered on fuel cell–powered passenger vehicles—is probably more distant than is widely believed.

Finally, we note that your choices about technology policy for climate change are not isolated from other energy-related policies. These include subsidies, such as the many large subsidies that have been given to fossil fuels over the years, as well as the significant 1.8 cents per kilowatt hour (adjusted for inflation) production tax credit for wind power, which partly explains the rapid rise in this source of electric energy. (That subsidy expired at the end of 2003 but is likely to be renewed. For now, the lack of that subsidy cut the 2004 forecast for installation of new wind turbines from 2,000 megawatts to just 500 megawatts.) Wind power emits no CO_2, and wind power costs have declined markedly with greater experience building and operating wind turbines. Several states are experimenting with new power dispatch systems that can accommodate more easily the intermittent nature of wind power supplies. Many states have also adopted mandates to require certain fractions of the power supply from zero-carbon renewable fuels such as wind. Some have also created vibrant markets for tradable renewable power credits. Insofar as such policies encourage widespread application of low- and zero-carbon technologies, the need for additional active CO_2 limitations will diminish.

Another subsidy that has altered the landscape of the energy system is the Price-Anderson Act, which limits liability for nuclear power plant operators in case of accident and is widely seen in the industry as a prerequisite for construction of any new reactors. A new generation of more market-savvy nuclear reactors is on the drawing boards, and a comprehensive study by the Massachusetts Institute of Technology has shown that constraints on CO_2 could make these reactors competitive in U.S. electricity markets.

Perhaps the most important interaction between the carbon challenge and broader energy policy is the crisis in U.S. natural gas markets. Throughout the 1990s U.S. gas prices hovered around $2 per million British thermal units (BTU), but since 2000 they have climbed much higher (with peaks in spot markets above $20) as efforts to find new gas supplies in the continental United States are faltering and the main fields in Canada that supplied most of the incremental U.S. demand in the 1990s are being depleted. Most analysts expect that this shortfall will increasingly be filled by liquefied natural gas (LNG) from countries such as Trinidad, Nigeria, Qatar, Algeria, Australia, Indonesia, Russia, and Venezuela. Today, LNG accounts for just 1.5 percent of total U.S. gas supply, but that fraction may rise to perhaps to 10 percent over the next one to two decades. As LNG shares rise, U.S. gas prices will probably fall from their current high levels, but U.S. gas markets may become increasingly sensitive to events overseas as prices in U.S. markets are buffeted by competition in a world gas market that in many ways will be similar to the world market for oil.

The shift to gas, when it displaces coal, is good news for carbon intensity, since gas-fired power plants emit less than half the carbon per kilowatt-hour of electricity produced by standard coal plants. In the last decade there has been a strong preference for gas because those plants are less costly to build and have lower emissions of other environmental pollutants. Of all the new electric power capacity commissioned in 2003, 98.7 percent was fired by gas. High gas prices are forcing many of those plants to operate well below capacity. Builders of new plants are reconsidering their choice of fuels, and in the last year regulators have noted a sharp rise in the number of coal-fired plants that they have been asked to consider for approval. High gas prices have also encouraged electricity companies to form two new consortia to explore possible construction of new nuclear reactors.

Finally, the failure to adopt a comprehensive energy bill in 2004 left unsettled other issues that will affect the industry's ability to respond to the carbon challenge. Spending by the electricity industry on R&D appears to have been in a long slide; at present, electric utilities and generators invest barely 0.3 percent of their turnover in research. (Of major industries, only building materials and the railroads spend less of their turnover on research.) It is hard to reconcile the magnitude of the technological tasks facing the electricity industry with this very low level of R&D spending.

Potentially very important is the repeal of the Depression-era Public Utilities Holding Company Act (PUHCA), which has prevented most electricity companies from owning other utilities outside their home market. Absent PUHCA, the electricity industry probably would become financially much stronger, which should make it easier to encourage firms to take technological risks, especially if they see credible mandatory limits on their greenhouse gas emissions on the horizon. But the transition to a post-PUHCA era will be highly disruptive, with most firms focused on immediate survival and consumption of their rivals—an eat-or-be-eaten corporate ecology.

Engaging Developing Countries

If you are persuaded that efforts are needed to control emissions of greenhouse gases, then you must also decide whether and how to engage with developing countries. Politically and economically it will be difficult to avoid crafting a credible policy toward developing countries. For the last decade, developing country participation has been a litmus test for U.S. foreign policy on climate change. When large energy firms and their customers wanted to fan opposition to the Kyoto Protocol they ran advertisements in which the camera focused on a pair of scissors that cut around all the developing countries: exempting most of the world while regulating the United States and other industrialized nations, the voiceover proclaimed, was unfair and ineffective.

The demand for meaningful participation of developing countries was the centerpiece of the resolution sponsored in July 1997 by Senator Robert Byrd (D-WV) and Senator Chuck Hagel (R-NE). Intended to demonstrate U.S. resolve in advance of the final negotiations on the Kyoto Protocol that December, the resolution passed 95-0 and proclaimed that the Senate would not accept any treaty that did not also require that developing countries adopt "specific scheduled commitments … within the same compliance period." That resolution cast a shadow over Kyoto, which did not impose any obligation on developing countries, and it has become a Rorschach test. Those who oppose limits on emissions point to the tersely worded resolution itself, which demands of developing countries what they adamantly refuse to accept. Those who advocate taking at least modest steps to limit U.S. emissions—including Senator Byrd himself—point to the floor debate that expressed the "sense of the Senate." Some senators in that debate interpreted the resolution as requiring identical and strict commitments for developing countries, while the interpretations of other senators were more liberal and elastic. As this resolution has attracted considerable public attention in the United States and overseas, we reproduce the resolution and excerpts from the floor debate in Appendix A.

Our deliberations have focused on four broad options for engaging developing countries. First, you could do nothing. This approach makes sense if you do not think that the climate problem merits much attention, or if you think that efforts to engage developing countries will end in failure. The "do-nothing" policy implies that the bulk of your climate policy will involve adaptation to the likely effects of climate change as well as low-cost and "no regrets" emission controls here in the United States.

Developing countries favor lack of engagement. They have expressed concern about climate change, and mounting evidence shows that they are more vulnerable than industrialized nations to storm surges, heat waves, drought, and other effects of a changing climate. Compared with advanced industrialized nations, their economies depend more on weather-related activities such as agriculture; they are less able to devote the capital to invest in climate-proofing for infrastructures; and they are less likely to build institutions such as systems for forecasting extreme weather events that can help reduce climate vulnerabilities. Their preference for inaction reflects not lack of concern and exposure but, rather, the higher priority they place on the immediate task of development. These countries know that the United States and other advanced industrialized countries developed without limitations on the use of fossil fuels. They also insist that advanced industrialized nations take the first steps in implementing meaningful policies before they themselves act; a grand compromise to that effect was codified in the United Nations Framework Convention on Climate Change. Many diplomats from developing countries argue that the industrialized nations—in particular, the United States—have broken that pledge, and thus efforts to engage developing countries have been additionally hampered by erosion of trust and credibility. It may prove relatively easy to reverse that erosion in the future by proffering substantial and concrete new proposals and incentives. For now, however, opposition to binding commitments is the one issue on which nearly all developing countries agree.

In the future it may be additionally difficult to gain these countries' participation since the Kyoto experience may be viewed increasingly as a false promise. The Clean Development Mechanism had been touted as a device for attracting foreign investment for projects that reduce emissions, but so far only three minor projects have gained approval. The World Bank has helped to jump-start the CDM by organizing the Prototype Carbon Fund (PCF)—a $180 million consortium of six governments (excluding the United States) and seventeen firms (none based in the United States) to fund a portfolio of CDM-like projects. Because the PCF's mandate is to promote only the highest quality projects, most of the PCF projects are sited in countries with strong domestic institutions. None is in the largest developing countries—such as China, India, Indonesia, and Malaysia. Just one project is in Brazil and one in South Africa. More than one-third of the PCF projects are in eastern Europe and do not involve developing countries at all. From the perspective of most of the key developing countries, the promised investments for climate protection are still elusive.

A second option is to demand that developing countries accept caps on their emissions. This approach requires sailing into strong diplomatic headwinds, and failure is likely. You could construct targets based on emission intensities or other metrics that developing countries find acceptable. As noted in Figure 1, Chinese emission intensity has declined sharply from about 600 gC/$ in the mid-1980s to around 300 gC/$ today. China is proud of that accomplishment, although perhaps half of the reduction reflects reported declines in the consumption of coal in China that many analysts believe are fictitious. It might be possible to design emission caps that reflect the interests of key developing countries and set with enough "headroom" to allow them to grow. You should be aware, however, that developing countries will refuse caps unless they are generous, but generous caps could undermine the integrity of emission trading systems in the United States and other industrialized countries. Generous caps could be akin to the vast windfall of surplus emission credits awarded to Russia in Kyoto; failure to enforce trading rules within developing countries could lead to a flood of bogus emission permits from those nations into permit trading systems elsewhere in the world.

It might be possible to force developing countries to accept strict caps by linking this issue to other matters, perhaps within the World Trade Organization. Such linkages will be difficult to craft and will probably backfire. The WTO agenda is already overcrowded, and developing countries (as well as most trade experts) are already opposed to integrating an ever-expanding list of environmental standards into trade rules. The effects of loading environmental, labor, human rights, and other standards on the world trading system may include the loss of well-being for all nations by raising barriers to trade as well as increasing the risk that new trade rounds will fail to make progress due to conflicts over these new rules and standards. By undermining economic development, such countries could make developing countries more vulnerable to climate change than otherwise would be the case.

You might try to reduce opposition in the developing world to accepting limits on emissions by raising awareness in these nations of the dangers of climate change. In the past, the U.S. government has provided some support to research programs and civic groups in developing countries with this aim. Such campaigns are difficult to organize, however, and unlikely to have any substantial near-term effects. The standard response from developing country diplomats—demanding that the United States, especially, take the lead in controlling emissions—will be difficult to counter. Insofar as there is any awareness of climate dangers in developing countries, it is usually organized by NGOs that are nearly uniform in their view that the industrialized countries (in particular the United States) are the root cause of this problem. Calling attention to climate change may raise the visibility of that argument, which could actually make it harder to achieve meaningful action in developing countries.

A third approach involves reinvigorating the Kyoto system, in particular the CDM. In our review of the efforts to elaborate the Kyoto system we found the CDM system to be encumbered with complicated rules and highly politicized procedures. However, these problems may have remedies. Procedures for approving CDM projects could be streamlined; true experts rather than politically instructed diplomats could be empowered to make more of the key decisions about the level of credit that would be awarded for projects. Additionally, you could put pressure on the members of the Kyoto Protocol to abandon the practice of shunning certain types of projects, such as nuclear plants and large hydroelectric dams, from receiving CDM credit. Another critical piece of reform for the CDM would be to insist that a new and improved CDM allow credits for tropical forest conservation and management projects. The U.S. government has consistently supported projects to preserve nature, and at the same time such projects can help avoid emissions of carbon that would come from deforestation and other changes in natural landscapes. However, many types of these projects have been excluded from receiving due credit under the CDM before 2012 (and perhaps thereafter as well). You could build a coalition for forestry reform in the CDM by allying with Brazil, Indonesia, and several other forest-rich nations that are themselves trying to attract more resources for forest protection. If the United States were to reengage with the Kyoto process it could make such reforms of the CDM a condition of its return. If the United States were to stay outside the Kyoto process but establish its own national emission trading system, it could create a scheme that operates in parallel with the CDM but with more efficient and sensible rules. Credits would then flow through the U.S. system instead of the CDM. Since the United States would be such a large market, the United States could, in effect, impose a superior alternative.

Many other countries would welcome a strategy that reinvigorates the CDM. A more effective CDM would be useful not only for developing countries that host investments but also for the main industrialized nations. A recent report from the European Environment Agency suggests that the European Union will miss its Kyoto target by a few percent, mainly because emissions from transportation are rising more rapidly than expected. European firms and governments may need to purchase emission credits overseas to make up the difference. Japan and Canada are also likely to fall short on their targets; they, too, will need outside credits. So long as the CDM remains hobbled and inefficient, the paper credits in Russia and Ukraine remain the only large quantities of credits available on international markets, giving these countries excessive influence and reducing the tangible benefits that developing countries obtain from sustaining their engagement with the Kyoto process.

There are substantial risks stemming from a strategy focused on reforming the CDM, however. Leveraging changes in the CDM by reengaging with the Kyoto Protocol will require making promises that might be hard to fulfill. It proved impossible even for the Clinton administration, which professed deep concern about the climate change problem, to ready the Kyoto Protocol for Senate consent. Many of the CDM's deficiencies are already written into the Kyoto system—either into the Kyoto treaty itself (e.g., the discouragement of nuclear power projects) or into the procedures that govern the CDM, which were painstakingly negotiated over a four-year process that largely finished in 2001. With so much time and effort invested, many countries may be unwilling to revisit closed deals. Perhaps only a spectacular failure of the Kyoto Protocol will force the necessary rethinking. Moreover, many observers claim that it will be impossible to make the CDM system work efficiently even under the best conditions. These observers claim that it is impossible to make the hypothetical "baseline" calculation—the level of emissions that would result in the absence of a particular project. The experience to date suggests that these observers are probably correct, and that partly explains why the CDM has attracted much less investment than enthusiasts had originally hoped. A major push by the United States could yield sustainable reforms to the CDM, but even after such reinvigoration the patient may still be mortally wounded.

Fourth, you could craft a new strategy for engaging with developing countries. The three options presented so far—disengagement, emission caps, and an offset scheme such as the CDM—have dominated most policy discussion for the last decade. None has had much impact on the behavior of developing countries. The fourth strategy could involve working with developing countries to craft "climate-friendly" development strategies. Unlike the CDM, which aims to animate investment by awarding credits, this approach could attempt to put climate issues into the mainstream of development policy. It could focus on broad policy initiatives, such as investment in natural gas infrastructures that make it easier for countries to operate natural gas–fired electricity generators where they otherwise would build less efficient and more carbon-heavy coal-fired ones. Many countries are already making such investments. China and India, for example, are in the midst of installing large gas infrastructures. In China these include a pipeline from gas reserves in the western part of the nation to Beijing and Shanghai, as well as LNG terminals in southern coastal cities. In India these infrastructure projects include new gas pipelines, incentives to develop newly discovered offshore gas reserves, and India's first-ever operational LNG terminal, which took its first delivery in January 2004. At the same time, a program to develop advanced coal power plants that allow for sequestration of CO_2 could help developing countries that are rich in coal reserves (such as China, India, Indonesia, and South Africa) gain confidence that taking the climate problem seriously will not undermine their efforts to supply electricity and other modern energy services. (In crafting the FutureGen project the Bush administration sought to engage developing country partners. However, the outcome of those partnership discussions remains uncertain; if FutureGen is funded fully and yields successful innovations, minds will focus on protection and ownership of FutureGen's intellectual property, which could undermine efforts to engage foreign partners.) Within the CDM system such broad programs to create the physical and intellectual infrastructure for low-carbon futures would never gain any credit because it would be too difficult to quantify the long-term and highly leveraged effects of these investments across the entire economy.

For the United States, this strategy of mainstreaming climate into development would require working principally with the major policy organs in developing countries that are responsible for development—for example, finance, industry, and planning ministries. The U.S. role could involve supporting activities that would help countries realize their own development goals in ways that also incidentally reduced carbon emissions. The advantage of this approach is that it would involve swimming with the tide—identifying activities that the host government would favor (and fund) already and activities that already align with the interests of private profit-making ventures. For example, the United States already has extensive development assistance programs in major developing countries, mainly through the U.S. Agency for International Development (USAID). These programs include attention to the improvement of energy efficiency and to reorganization of energy systems in ways that encourage investment in modern technologies. A slight refocus of these programs could make carbon a central organizing principle; by helping these countries reorganize their energy systems to make them more profitable and to serve better the needs of the local population, such programs could also lower the intensity of greenhouse gas emissions. Among the successes, USAID programs have already helped countries identify ways to make fuller use of low-carbon renewable power. For example, in India a USAID project has helped a sugar cane refinery recycle crop wastes to generate heat and electricity, which has reduced the need for fossil fuel energy.

This development-linked approach could leverage large amounts of emission reductions. However, it also carries many dangers. Developing countries may simply choose to embrace those programs that they would pursue anyway. By design, the exact reduction in emissions will be difficult to quantify, which will lead many environmental groups to claim that the "mainstreaming" approach is simply a rhetorical device that only pretends to deliver real solutions to the climate problem. The program could create expectations that it will become a large source of funds that, inevitably, will yield disappointment. The West-East pipeline in China, for example, involves $20 billion in mainly Chinese investment. In such huge projects it may be difficult for relatively tiny amounts of climate change–related programmatic funding to have much effect. If the World Bank had participated in China's Three Gorges hydroelectric dam, for example, it would have leveraged its funding by demanding the application of Western environmental and human rights standards. Wary, the Chinese government raised the needed capital on its own—outside the bank's purview.

Informing the Public

The sixth major dimension in which you face policy choices is communication with the public. Public opinion about climate change is highly malleable. Awareness of climate change is high, but willingness to act has varied considerably, and understanding of the underlying processes and options is poor.

A survey of polls by the Program on International Policy Attitudes (PIPA) at the University of Maryland found that a small minority of the U.S. population dismisses the theory of climate change altogether. A Gallup poll in March 2001 revealed that slightly more than half of Americans thought that the majority of scientists believe that global warming is occurring. Americans generally know very little about Kyoto. A Pew poll in April 2001—in the middle of the firestorm about the Bush administration's withdrawal from Kyoto—found that only 26 percent of those polled were willing to venture an opinion as to whether we had withdrawn from the treaty. Interestingly, some evidence suggests that public support for Kyoto has risen since 2001 even as it has become increasingly implausible that the United States could ever meet its Kyoto commitments.

Willingness to pay for emission controls varies especially with the state of the economy. In 2000, when the public perceived the economy as strong, a Gallup poll showed a majority willing to support environmental goals even at the expense of the economy. Two years later, as the economy faltered, that public commitment had dropped considerably. A January 2002 poll by ABC News and the *Washington Post* ranked environmental issues far down the list of priorities—below the campaign against terrorism, economic growth, education, Social Security, health care, national defense, prescription drugs for the elderly, and balancing the federal budget. A PIPA poll in October 1998 suggested that two-thirds of Americans were willing to spend $50 per household (or less) to comply with the Kyoto Protocol; that number is comparable to the estimated cost per household from a study done by President Bill Clinton's Council of Economic Advisers (CEA) on the cost of meeting Kyoto. The CEA study implied that about 85 percent of the effort at reducing emissions would take the form of overseas investments through Kyoto's international emission trading and CDM systems. Yet the PIPA poll showed that most Americans opposed emission trading until the concept was explained. Then, 65 percent favored trading with less developed countries. Yet the CEA's own analysis implied that most trading would probably occur with Russia—a scenario that the main pollsters have not explored.

Politically, the renewed attention to security in the wake of September 11, 2001, could affect the ease of building public support for action on climate change and the technological options available. Greater public attention to energy security could improve the prospects for policies that boost energy efficiency and renewable energy, which would lower the trajectory for U.S. emissions of CO_2. At the same time, however, concerns about terrorism could make it harder to site LNG facilities and nuclear power plants, which could push the U.S. electric power system back to greater reliance on coal and locally available renewable sources. If coal is the main winner then the U.S. emissions trajectory would rise—indeed, with natural gas pries at historically high levels investors in new power generation equipment are examining the option of building new coal plants. Concerns about energy security could be used to build a coalition for developing advanced coal gasification facilities that also sequester carbon—as in the FutureGen project that is already advancing. Security could become the glue that binds broad public support to a wide array of yet undetermined elements of energy policy. Similarly, concern about gasoline prices—which rose sharply in 2004 due to shortages in refining capacity and high crude oil prices—could also fan public concern in a variety of malleable directions, including toward mandates for higher fuel efficiency.

Regardless of your policy we recommend that you devote considerable effort to explaining it to the public. If you choose a minimal course of action focused primarily on adaptation and developing innovative technologies—which we represent in the first speech—we think you should explain why the climate change problem does not require an urgent effort. In February 2002, when President Bush announced his administration's policy, he did not articulate a fundamental view of the climate issue; rather, President Bush raised concerns about the costs of action, which is a line of argument that his opponents may blunt easily by arguing that technologies are available to control emissions and that the threat of changing climate is so severe that it requires radical action. The case for minimal action would be easier for the public to understand if you demonstrate that the climate problem does not pose challenges that are substantially different from other environmental challenges. No American president has ever articulated these views, yet the public is inclined to believe that environmental quality is deteriorating—implying that environmental problems require drastic responses—even though many key measures of our environmental health have improved dramatically in recent decades.

If you choose to support reinvigorating the Kyoto system—the course represented in our second speech—then you will need to explain why the United States withdrew from Kyoto in the first place and why it makes sense to reengage. At present, the small fraction of the American public that pays attention to Kyoto-related matters probably also views the U.S. exit as evidence of arrogant American unilateralism. This second speech argues that the Bush administration had no choice because the United States never could have complied with the Kyoto targets—a point President Bush made in March 2001 when he withdrew from Kyoto, but the point was lost in the furor of the moment. You can acknowledge that the public has deep concerns about this issue but point out the inconsistency between public expectations of what it would cost to meet Kyoto's requirements and the likely reality. You can articulate how reengagement with Kyoto will yield enormous diplomatic leverage that the United States can use to make Kyoto more effective and less discriminatory—thus shaping the mental model of "Kyoto" away from a particular set of (unachievable) obligations into a process that needs American guidance.

Finally, if you choose to articulate a different pathway—as we outline in the third speech—then the public will need your vision as a guide. The third speech suggests that the problem of climate change requires a reduction in long-term emissions, but it argues that the best approach does not correspond with today's conventional wisdom. It argues for a decentralized bottom-up approach rather than a top-down treaty-based system as in Kyoto.

In almost every aspect of this issue—the natural science, the economics, the role of firms, public administration, etc.—the public is exposed to a wide range of conflicting opinions. The public needs help to frame the issues, to establish models and analogs, and to comprehend what is at stake, because all the major elements of the climate problem—its causes, effects, and remedies—are beyond the grasp of normal human experience.

Summary of the Three Options

We have organized the wide array of policy choices into three broad options. Each is a coherent package of choices drawn from the six dimensions articulated above. We underscore, however, that these three options are hardly the only possible combinations.

Adaptation and Innovation

This option rests on the notion that uncertainties in the science of climate change make spending substantial resources on the control of emissions premature. The speech underscores that some amount of climate change is inevitable as emissions continue to rise from the industrialized and especially the developing nations; the effects of a changing climate, however, are unlikely to be different from variations in weather and climate that we already experience, and thus adaptation will be relatively easy. The speech also underscores that although analysts have identified many ways to control emissions at low cost, in practice these measures are likely to be much more difficult to implement; there is great risk, therefore, that the cost of controlling emissions will be high, possibly very high. This option thus presents the minimal effort that probably could be justified. It envisions voluntary programs to control emissions from the energy system and also through better protection of tropical forests. It advocates modest investment in new technologies that might yield breakthroughs as well as continued investment in science so that we can improve understanding of the problem and gain early warning of approaching dangers.

Advantages

- Minimal budgetary cost. While the economy is recovering and federal budgets are tight, this option carries the minimal cost to industry and to the federal government.
- Emphasizes the normal adaptive capacity of the economy. Articulates a reason—adaptation—for why the United States should not impose draconian controls on emissions. This reason is probably more durable than simply arguing that the science is uncertain; the American public has proved that it is willing to spend large resources combating uncertain hazards, such as food contamination, asbestos, air pollution, nuclear war, and terrorism. The arguments about uncertain science have had credibility with a small (and probably shrinking) minority. Adaptation, if articulated clearly, has the potential to be more convincing.
- Domestic interests. This option focuses narrowly on U.S. interests; it does not attempt to appeal to wooly notions of international justice by speculating about the dangers of climate change in developing countries.

- Gives priority to industrial growth. This policy is unlikely to disrupt incumbent industries in the production and use of oil, gas, and coal. The investment in new technology might yield technologies that could aid U.S. business and create jobs in the future.

Disadvantages

- Adaptation is seen as non-action. The argument for minimal action is subtle and rests on our ability to adjust to changes in the environment. Opponents might characterize this response as "let them eat pollution." Americans have generally not tolerated policies that acknowledge the existence of an environmental problem while simultaneously claiming that the problem poses little danger. If adaptation is your policy it might be more effective not to give a high-profile speech calling attention to the issue.
- Public backlash. If the climate change problem becomes a major issue then public support for more aggressive action—controls on emissions—will grow stronger. The lack of any binding controls may make it hard for you to retain credibility in that context.
- Offensive to some allies. Other nations will view this as inadequate, especially as it is hostile to the Kyoto system. Good or not, Kyoto remains the dominant international institution by far on the subject of climate change.
- Potentially disadvantageous to U.S. business. Insofar as you believe that limits on carbon may be imposed eventually, a rousing speech against binding limits may actually harm U.S. industry by protecting it (temporarily) from the need to plan for a carbon-constrained future. U.S. firms may be less able to compete against firms that have already found ways to cut carbon, and U.S. exporters will not have developed the technologies needed to compete in the global market.

Reinvigorating Kyoto

This speech defines climate change as the most serious international environmental issue of our era. It argues that the effort to cut carbon should become an organizing principle for U.S. foreign policy, and it suggests that most of the solutions to the climate problem will improve America's energy security while also protecting the planet's ecosystems, on which all life depends. It envisions reengagement with the Kyoto process because creating an alternative to Kyoto would require a huge effort for little benefit. Serious solutions to the climate problem will require global engagement, and this speech argues that most other nations are already engaged productively in the Kyoto regime. This speech explains that the United States had no choice but to abandon Kyoto's unrealistic short-term targets; it demands renegotiation of the Kyoto targets and the setting of fair targets for developing countries. It argues that short-term targets should be set in the context of a long-term goal for stabilizing the atmosphere. Although nobody knows what concentration of greenhouse gases in the atmosphere is truly safe, this speech suggests starting with the goal of 550 ppm—twice the pre-industrial level. It demands reform of the CDM to make it more efficient and to allow credit for the protection of the world's diminishing tropical forests. The speech underscores that adaptation to the most worrisome effects of climate change is not possible, and it argues that it is unjust to impose a changing climate on developing countries that are already struggling to make ends meet.

Advantages

- Requires emission reductions. A large centrist group of voters probably favors some binding action to control emissions, though their exact willingness to pay for control is unknown.
- Appealing to core constituency for climate policy. It recognizes and supports the Kyoto system as the only existing international framework; it emphasizes the need to start now with the implementation of policies to bend emission trajectories.

- Olive branch to nations devoted to Kyoto. Other industrialized nations, especially Canada, Japan, and the members of the European Union, will see this as a reengagement with an institution (Kyoto) that is very important to them.
- Tough but fair with developing countries. This speech outlines a plan for engaging developing countries that is consistent with at least some interpretations of the Byrd-Hagel resolution.
- Concrete strategy. Offers a vision for addressing a problem that, at least periodically, commands public concern.

Disadvantages

- Presently not credible. You do not have the votes in either the House or the Senate to adopt the national policies that would be needed to make such a strategy credible. Getting the votes will require considerable presidential effort to shape public priorities and understanding of the issue. Other policy priorities will probably suffer. So long as the public is focused on the economy and the war on terrorism, concern about environmental issues (especially distant global issues) has remained low, and thus the electoral benefits from investing in this strategy may be small.
- Unknown cost. A well-designed policy can minimize cost, but opponents will portray this as a scheme to tax energy that could bankrupt the economy; those same opponents were effective in organizing opposition to the Kyoto commitments on similar grounds.
- Risk of diplomatic failure. Developing countries and other nations that are reluctant to control their emissions (e.g., Russia) will be furious, as they have adamantly opposed meaningful limits on their emissions. Reaching agreement with them could be extremely difficult unless you allow liberal "headroom" in their targets (which will recreate the problem of surplus credits with Russia under Kyoto). If you set strict targets for the United States, however, industry will demand strict targets for the rest of the world as well—the more headroom you supply to others the harder it will be to gain consent here in Amer-

ica. To brandish a stick at these reluctant nations you might need to link this issue to other matters of importance to developing countries such as trade talks, but that could complicate and undermine U.S. objectives in those other areas.

Making a Market

This speech also argues that the climate problem is a serious long-term threat to America's prosperity. However, it articulates a dramatically different approach. It sees the Kyoto framework as unworkable because it tries to create a global emission trading system from the "top down," whereas the most successful international regulatory regimes are built from the "bottom up." This speech gives little attention to the science and effects of climate change, except to declare that the evidence is strong enough to warrant prudent action. It focuses instead on changing the public understanding of the problem at hand, comparing the task of building a global trading system to the creation of a new form of money. It argues that we must focus on establishing integrity in that monetary system by working first with a small group of other countries—first and foremost the European Union—that have a common interest in creating a strong currency. The speech argues that we must move slowly and cautiously in that effort, as failure will undermine the value of the currency and erase the political will and public trust needed to sustain action.

The speech focuses on the need for action by the United States to establish its own emission trading system and, having designed the best procedures for the United States, to negotiate links to other trading systems. Such American unilateralism, it argues, is necessary to avoid mistakes of the past, such as the failure of the Kyoto rules to create incentives to encourage the protection of tropical forests. It argues that unilateralism is essential and that a global framework will be the by-product—not the cause—of meaningful action in key leading nations. In this system there will be multiple currencies that reflect different experimental efforts to establish the best rules and institutions; over time, those diverse national efforts will converge into a global scheme as the best rules and procedures supplant the worst.

At the same time, the U.S. government must work with leading innovative firms to make a market for new energy technologies, so that investments in advanced renewable power technologies, hydrogen energy systems, nuclear power, and other options can enter the niche markets where experience and competition will lead to improvement. Such markets do not arise spontaneously; over time, the best new technologies will make it possible to achieve the deep cuts in carbon that are needed to stabilize the climate.

Advantages

- Bold and direct. As with the second speech, you will probably gain political benefits by visibly addressing the seriousness of the climate change problem and by reengaging with an international process by offering a credible vision for a global strategy.
- Market based. This vision takes the market—and the history of market-making—as its centerpiece. It will resonate with business and it will allow you to build on the increasing use of market-based measures for protecting the environment, which have demonstrated a clear record of success. This will be attractive to centrist voters, including many Republicans.
- Unique and innovative. The speech can be memorable because it does not map easily on any of the options that are debated in the mainstream today. A sharp break with the failing past, rooted in a strong commitment to an effective solution, will force the pundits to think and debate. A by-product of all that would be continued free attention for your way of solving the problem.
- Possibility for international cooperation. Pursuing a different track within a multilateral vision offers a chance of diplomatic success. Frustration with Kyoto is leading some governments to search for alternative international arrangements, but so far the United States has not offered an attractive rival vision. At the same time, offering an explicit link to the Euro-

pean trading system will be attractive to key allies (notably the United Kingdom). The EU system is new and fragile; outside recognition will help to establish its legitimacy.

- Flexibility of unilateral action. By reserving a large role for unilateral choice you can tune the stringency and timing of the U.S. effort to the levels that you think will gain approval in Congress. You can build on the existing McCain-Lieberman proposal as a foundation for constructing a politically sustainable coalition in favor of a U.S. national trading system. The registries of emissions that several states, such as California, have developed can provide a foundation for setting baselines and determining the level of emission controls that is politically achievable. These leading states already have laid some of the groundwork needed to develop a political coalition for a carbon market.

Disadvantages

- Confirms rejection of Kyoto. The attack on Kyoto will produce negative reactions in many quarters, and that could complicate the task of building domestic support.
- Irritates developing countries. By arguing that the current approach to engagement with developing countries is not working you will force developing countries to confront the eventual need to undertake binding obligations. You may be able to blunt their opposition by using examples of current bilateral U.S. programs in developing countries as examples of investment and technology transfer that would expand with the creation of stronger market signals to invest in low-carbon energy systems. However, the credibility of such promises is low, and thus bringing the developing countries on board may require an explicit grand bargain with identifiable tangible outcomes. Crafting that could be very difficult and possibly expensive.
- Complex. Outlining a new vision on a complicated subject inevitably leads to a complicated speech. Communication may be easier if you adopt simple slogans and messages that correspond

with what the public already thinks about the climate issue and its solution.

- Uncertain success. A grand alternative vision, announced with fanfare, is a liability if you do not see it through to realization.

Recommendation

We recommend that you convene a meeting of your key economic, science, and national security advisers, employing this memo and the three alternative speeches as a starting point for the discussions. We suggest that you develop a policy by giving feedback on the options addressed here, leading to one central choice that can serve as a platform for constructing your policy. With that platform we can then elaborate a fuller policy and speech that you would present to the nation and to our allies.