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The Climate Crisis and the Adaptation Myth

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The Climate Crisis and the Adaptation Myth

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I. THE ISSUES

Influential studies have predicted that moderate climate change, up to 3 or 4 degrees Fahrenheit, will not be very damaging to the United States as a whole and will bring some benefits.[1] Underlying the argument that climate change will not be very damaging to the U.S. economy is the contention that vulnerable organizations, firms and households will take steps to adapt. This assumption is based partly on the fact that the United States is rich in technology, economic resources, competent organizations and educated people, all of which combine to create a high capacity to adapt. More fundamentally, the contention rests on the observation that the United States spans a wide variety of climatic conditions to which households and enterprises have adapted successfully in the past. According to a recent review, "The literature indicates that U.S. society can on the whole adapt with either net gains or some costs if warming occurs at the lower end of the projected range of magnitude, assuming no change in climate variability and generally making optimistic assumptions about adaptation."[2]

[1] William Nordhaus and Joseph Boyer, *Warming the World*, MIT Press, 2000; Robert Mendelsohn and James Neumann, *The Impact of Climate Change on the U.S. Economy*, Cambridge University Press, 1999.

[2] William Easterling III, Brian Hurd and Joel Smith, *Coping with Climate Change: The Role of Adaptation in the United States*, Pew Center on Global Climate Change, June, 2004.

These are key assumptions. The perception that damages will be limited has been a significant factor in the conclusion reached by the U.S. government that it was not in the national interest to join in the Kyoto Protocol agreement to reduce carbon emissions because the benefits in damages averted would be small relative to the costs incurred in mitigating GHG emissions in the U.S. to the extent called for in the Protocol. Furthermore, refusal by the United States, the world's richest country and largest cumulative emitter of greenhouse gases, to ratify the Kyoto Protocol discouraged other countries from joining or implementing an international agreement to limit emissions. Consequently, assumptions regarding adaptation in the U.S. have had broad policy repercussions.

Are these assumptions justified? Certainly the *potential* for adaptation exists. Studies have identified steps in key vulnerable sectors that can significantly reduce

damages. The National Assessment[3] identifies specific steps in all regions and sectors that could prevent or limit damages.

Such studies have indicated that damages to agriculture, forestry and other economic activities can be greatly reduced if economic agents adapt efficiently.[4] For example, damages to agriculture are estimated to be 50 percent less as a result of farmer adaptation.[5] Economists have criticized the "dumb farmer" assumption that farmers will just suffer damages and not do anything about it.[6] Other studies have estimated that damages from sea level rise could be reduced by over half, even including the costs of adaptation, if appropriate protective measures are taken.[7]

However, saying that the U.S. *can* adapt does not imply that it *will* adapt, at least not in the efficient and timely way needed if major damages are to be avoided. The question is whether it is likely that such steps will actually be taken and whether they will be taken in sufficient time to limit damages. If not, damages from climate change will be considerably higher than has been estimated. There is an important distinction between *anticipatory or preventive adaptation* that predicts and responds to vulnerabilities before damages are incurred and *reactive adaptation* that gears up to limit the recurrence of damage only after effects of climate change have been felt and damage done, in order to limit recurrence of the damage. If adaptation is mainly reactive, then damages will be much greater. Unfortunately, experience shows that, in the United States, responses to disaster are mainly reactive, often characterized by inattention beforehand and over-response afterwards. In the case of climate change, reactive adaptation will be especially costly because, decade by decade, the severity of climate change impacts is likely to increase as greenhouse gas concentrations in the atmosphere rise. Reactive adaptation would be likely to lag persistently behind the emerging risks. The more rapid the rise in atmospheric concentrations, the faster the rate of climate change and the less effective reactive adaptation is likely to be.

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Moreover, it is possible that whatever pro-active adaptive measures are put in place may be partially or wholly offset by "maladaptations," which serve to increase vulnerability and the likelihood of future damages. One example is continuing shoreline and floodplain real estate development. The International Hurricane Research Center has identified coastal regions in the United States that are most vulnerable to future hurricane damage. Among them are many – including eastern Long Island, Cape Hatteras in North Carolina, Palm Beach, Florida, and the region adjoining Lake Okeechobee in Florida – where the real estate boom has greatly increased the value of properties at risk. In many of these coastal communities, rather

[3] National Assessment Synthesis Team, 2000. *Climate Change Impacts in the United States*, Cambridge University Press.

[4] R. Mendelsohn and J.E. Neumann, 1999. *The Impact of Climate Change on the U.S. Economy*, Cambridge University Press.

[5] Mendelsohn, *op. cit.*, p.44.

[6] IPCC, Climate Change 2001: Working Group II, Impacts, Adaptation and Vulnerability.

[7] J. E. Neumann, G. Yohe and R. Nicholls, *Sea Level Rise and Global Climate Change: A Review of Impacts to U.S. Coasts*, Pew Center on Global Climate Change, 2000.

than restricting development in the vulnerable beach areas, local governments are protecting ongoing development by building sea walls and restoring beaches, a costly and flawed approach.[8]

[8] Cornelia Dean, Next Victim of Warming: The Beaches, *New York Times*, June 20, 2006.

II. THE APPROACH TAKEN IN THIS PAPER

The approach taken in this paper is to explore these issues by examining adaptations that have been made so far in the U.S. to the substantial climate changes that have *already* happened over the past half-century, as well as changes that are already inevitable because of greenhouse gas accumulations in the atmosphere up to this time. The extent and rapidity with which adaptations have been made to climate changes that have already happened or are inevitable should provide some guidance in assessing the likelihood of future adaptations and will help to identify those obstacles to adaptation that must be removed if future damages are to be limited.

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The U.S has already experienced considerable changes in temperature, precipitation, storm intensity and sea level due to climate change, and the effects of those changes have already been felt.[9]

[9] National Assessment Synthesis Team, 2000. *Climate Change Impacts in the United States*, Cambridge University Press.

- During the 20th century, average temperatures in U.S. increased by 1 degree Fahrenheit, with northern areas rising as much as 4 degrees Fahrenheit;
- In the Northeast, temperatures in coastal regions have risen as much as 2 degrees Centigrade and precipitation has increased 20 percent in the last century;
- In the Southeast, temperature and rainfall have increased. Sea level intrusion has destroyed coastal forests and many square miles of coastal land have been lost to erosion;
- In Midwest, temperatures have risen 1 to 2 degrees Centigrade south to north and precipitation has increased, mostly in heavy storms resulting in more seasonal flooding;
- In the Great Plains, there have been similar increases, but in the lee of the Rocky Mountains on the western plains, rainfall has diminished;
- In the West, there have been rising temperatures, a larger fraction of winter precipitation falling as rain, a declining length of the snow season, reduced

snowpack, earlier snowmelt, and changed river flows. There has also been increasing drought in the Southwest.[10]

[10] Tim P. Barnett et al., Human-Induced Changes in the Hydrology of the Western United States, *Science*, 319: 1080-1082; February 22, 2008.

In addition to these regional effects, the amount of precipitation in intense weather events has risen, sea levels have risen, hurricane intensity has increased, coastal erosion has increased (especially in Alaska, where a decline in seasonal sea ice along the coasts has exposed shorelines to much more storm erosion), and throughout the country, growing seasons and the ranges of some biotic organisms have shifted. Such changes as these over past decades are well-documented.

Past increases in atmospheric concentrations of greenhouse gases have also *already* ensured as much climate change again in future decades, even if concentrations were miraculously stabilized overnight. Lags in the global climate system, due in part to the role of the oceans in absorbing and releasing heat, dictate that the effects of any rise in concentrations are not fully felt for decades. However, miracles will not occur. Realistically, few believe that concentrations can be stabilized at less than 550ppm, more than double pre-industrial levels. Many believe even that will be impossible. Any reasonable forecast would anticipate considerably more global warming and associated climate changes than have already been experienced.

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How have organizations in the United States responded to this reality? To sharpen the focus, I have looked primarily at organizations that are *most likely* to have undertaken adaptations because:

- their operations, investments or missions are vulnerable to climate change;
- they are making or planning long-term fixed investments or long-running programs which will inevitably feel the effects of climate change; and
- they have the organizational capacity to forecast and plan.

In the **public and quasi-private sector**, the organizations that fit these criteria include, among others:

- land and forest management agencies that will be exposed to ecological and hydrological changes;
- flood control and disaster insurance agencies;
- water-supply agencies in the West and Southwest that will feel the effects of drought and hydrological shifts;
- public health and disease prevention agencies that will have to contend with changes in disease vector ecology; and

- transportation infrastructure agencies exposed to risks of sea level rise, storm surges and flooding.

For agencies in all these vulnerable sectors that are making long-term investments and commitments, our study investigated whether plans, designs, investment decisions, operational policies, budgets or staffing have been changed to reflect past or inevitable future climate change. If not, one must ask what obstacles have led to a lack of adaptation responses so far.

III. OBSTACLES TO ADAPTATION

Climate uncertainty

There are many reasons to doubt whether adaptation steps will be timely and efficient, even in the U.S. where the capabilities exist. Some of these doubts arise from the characteristics of the climate problem. Others arise from the tendency, exposed by behavioral economists, for inefficiencies in human and organizational behaviors. One of the most significant obstacles arises from the fact that most damages are incurred as the result of extreme weather events: unusual heat waves, droughts, floods, hurricanes and storm surges. These damages occur because most human and natural systems can tolerate climatic fluctuations within ranges, but tend to fail when conditions move outside those ranges. If a roof is built to withstand wind speeds of one hundred miles per hour, speeds below that rate may blow off a few shingles, but if speeds exceed one hundred miles per hour, the roof might well blow off, causing catastrophic damage to the structure. If a flood levee is designed to stop the flood likely to occur once in a hundred years, a flood greater than that will probably overtop the levee, causing severe flooding behind it. For such reasons, studies such as the Stern Review and work by economist William Nordhaus have found that climate damages rise very non-linearly with changes in weather variables.

Extreme events are infrequent by definition. Therefore, it is difficult to estimate their probability or frequency of occurrence, since there are so few observations in the historical record. Weather records may go back a century or so. How do we know what a once-in-five-hundred year flood might look like? In estimating the probability of extreme events occurring infrequently at the "tails" of the probability distribution, the particular underlying probability distribution that is assumed to represent the data becomes very important, since it will determine the likelihood of such extreme events when extrapolated beyond the range of existing data. Moreover, since there will be very few observations or data points representing these extremes, sampling error in fitting the distribution to the historical record will be large.

More fundamentally, those distributions estimated from historical data will be increasingly unrepresentative of future conditions as climate changes. The mean or average event might shift; so might the variance of the frequency distribution and the probability of extreme events. However, it is very difficult to judge when the probability of extreme events has changed. The degree of flooding in Iowa in June 2008 had not been experienced since 1851, if then. Does its occurrence signal that severe flooding has become more likely or does it merely represent a recurrence of a

very unlikely event? It might take decades and several occurrences to conclude with statistical certainty that what had been regarded as a "once in a hundred year flood" has become a "once in a fifty-year flood."

Weather in most regions is notoriously variable. The noise to signal ratio in climate is large, making inferences about long-term changes difficult. Even trained scientists debated for decades whether climatic fluctuations exhibited any underlying trend, or whether observed changes merely reflected periodic fluctuations.[11] It is much more difficult for untrained observers to detect relatively small trends amidst much larger short-term fluctuations. For the average person, this is all the more true because people tend to place undue weight on recent events, extrapolating short term movements into the future. Although the long-term trend might be slowly upwards, one or two cold years are sometimes taken as evidence that there is no underlying warming, for example.

[11] Stephen E. Schneider, William E. Easterling, and Linda O. Means, 2000. Adaptation: Sensitivity to Natural Variability, Agent Assumptions, and Dynamic Climate Changes, *Climate Change* 45: 203-221.

Making matters worse, the variability of climate is typically much greater in specific locations than when averaged over a large area. Over a large area, many short-term fluctuations cancel out but it is the local weather record on which people base their judgments. People judge climate change on the basis of conditions where they are. For example, the variability of temperature is considerably greater in Reno than for all of Nevada, and greater for Nevada than for the West as a whole. This makes it all the more difficult for people to discern trends. Moreover, because Americans are highly mobile, many people have not lived in the same locations for long periods of time, complicating the problem even further.

Those are difficulties in interpreting the historical record. There are also difficulties in forecasting the future. Among climate scientists, there is still considerable uncertainty in projecting future climate change *in particular regions* because, although various global climate models might agree on global and broad continental-scale averages, they differ in their predictions for smaller regions.

Regional climate models derived from the global circulation models also differ in their predictions. For example, planners in the West considering the construction of new dams to increase water storage capacity are struggling over predictions of future flows in the Colorado and other western rivers, which will depend on regional rainfall, snowpack, the timing of spring run-off, temperature and evaporation, and other factors, all of which are uncertain.[12]

[12] Matt Jenkins, Into Thin Air? *High Country News*, April 30, 2007.

As if these sources of uncertainty were not enough, climate change skeptics in and out of government have been deliberately sowing confusion and increasing public doubt about climate trends. For example, according to an inspector general's report at NASA, there was a sustained effort directed by political appointees to withhold information on climate change and to mute public statements by Dr. James Hansen, NASA's chief climate scientist. "Our investigation," the report said, "found that during the fall of 2004 through early 2006, the NASA Headquarters Office of Public Affairs managed the topic of climate change in a manner that reduced, marginalized or mischaracterized climate change science made available to the general public."[13]

[13] Andrew Revkin, New York Times, June 3, 2008

In another well-reported episode, an official at the White House Council on Environmental Quality who was a former lobbyist for the American Petroleum

Institute edited federal reports released in 2002 and 2003 on climate change to emphasize uncertainties and cast doubt on scientific findings. Also, major oil companies such as Exxon Mobil for years provided financial support to so-called "climate skeptics," a small group of scientists who have persistently argued against the findings of the Intergovernmental Panel on Climate Change.

Moral hazard

Adaptation in some instances is inhibited by moral hazard issues. For example, governmental crop insurance and disaster relief programs have *reduced* the incentives for farmers, households, and businesses to take action to avoid weather damages. Between 1989 and 2007 indemnified losses insured by the Federal Crop Insurance Program increased from $1.2 to $3.8 billion, an average annual rate of increase of 6 percent per year. This insurance against crop loss is subsidized from the federal budget. During that period, the premium subsidy rose from $0.2 billion to $3.8 billion, an average annual rate of 17.6 percent per year.[14] This subsidized insurance program provided strong incentives for farmers to take actions that increased their exposure to weather-related risks, which account for almost all losses. The incentives were further expanded by farm subsidies that raised farmers' returns from agricultural operations whether or not crop damages occurred.

Federal disaster relief program payments have also risen rapidly over past decades, both absolutely and as a percentage of assessed damages. In recent years these programs have covered roughly half of uninsured costs of weather-related disasters. Moreover, citizens, localities and state governments have come to expect federal disaster relief as an entitlement, accentuating the moral hazard problem.[15]

Organizational behavior

Organizations are inherently sluggish in responding to new conditions. In organizational decision-making, there is a strong status quo bias. The status quo is almost always the default option and deviations from it are almost always relatively small and incremental. More momentous changes occur only very infrequently, usually in response to major threats or pressures.[16]

Organizational actions and decisions are typically constrained by rules, routines, procedures, formulae, and precedents. These are often codified, but even if not, they are enshrined as "the way we do things" and are usually difficult and costly to overturn and therefore may become badly out-of-date. Such routines are usually changed incrementally and reactively when existing routines prove to be unsuccessful.[17] Interpretations of new experiences or evidence are made within frames of reference that are derived from past experience, and are also resistant to change. Moreover, adaptations to new conditions will usually be drawn from a repertoire of already known actions, competencies and strategies. Therefore, organizations change slowly and usually painfully.

Within these organizations, leaders and managers devote a very large fraction of their attention and the organization's resources to resolving immediate problems, leaving little with which to address longer-term problems like climate change. The

[14] Federal Crop Insurance Corporation, Summary of Business Reports, 1989-2008.

[15] David A. Moss, 1999. Courting Disaster? The Transformation of Federal Disaster Policy Since 1803, in *The Financing of Catastrophe Risk*, Kenneth A. Froot, ed., Chicago: University of Chicago Press.

[16] Frank E. Baumgartner and Bryan D. Jones, 2002. *Policy Dynamics*, University of Chicago Press.

[17] Frans Berkhout, Julia Hertin, and David M. Gann, *Learning to Adapt: Organizational Adaptation to Climate Change Impacts*, Tyndall Centre for Climate Change Research, February, 2004.

perception that climate change is an issue that can be put off and doesn't demand immediate attention makes it likely that it will be put off and not get attention.

Behavioral economics

Behavioral economics has illuminated other characteristics of human decision-making under uncertainty that are likely to inhibit adaptation. Humans are myopic decision-makers, sharply discounting events in the farther future or past. In particular, people assign a relatively low priority to climate change because its effects are perceived to occur in the future, not the present:

- People tend to underestimate cumulative probabilities when the probability of an event in a single period is low (i.e., the probability that the event will happen within x years is surprisingly high to most people). For example, people build or buy houses in fire-prone, flood and earthquake zones, even though the probability that an event will occur within their lifetimes is quite high;
- Humans exhibit strong "anchoring" to the status quo, tending to make only small adjustments away from it. Many people, for example, even refuse orders to evacuate when under immediate threat from natural disasters;
- People tend to resist and deny information that contradicts their value or ideological beliefs. An identifiable minority of "climate skeptics" continues to deny the scientific evidence and the conclusions of scientists regarding climate change.

In the following review of experience to date with adaptation to climate change, it will be seen that all these obstacles have played their roles.

IV. EXPERIENCE TO DATE

I have reviewed evidence regarding the adaptive steps that have already been taken by organizations that have adaptive capacity, must make long-term commitments and investments, and are particularly susceptible to damage from climate change. This review is by no means comprehensive but can be regarded as indicative of the stage that susceptible agencies have reached up to the recent past in adapting to the risks they face from climate change damages.

Hurricane damage

In New York City, municipal authorities began just in the past two years to plan for an adaptation strategy, based on recognition of more severe vulnerabilities to flooding and hurricane damages as a result of sea level increase. Sea level rise and surges associated with severe storms would be likely to inundate Kennedy Airport and lower Manhattan, including the subway entrances and tunnels into Manhattan. "New York City has been working toward the establishment of a New York City Climate Change Adaptation Task Force, which will be convened this year. To advise this and

other efforts, the City will convene a group of scientists and insurance experts as a technical committee, which will develop scenarios on which Task Force members will base their adaptation strategies."[18]

New York City building codes are 40 years old. With respect to wind damages, they require only protection up to 110mph winds, though more intense hurricanes could result in wind speeds up to 135 mph. With respect to flooding, they rely on 1983 flood maps corresponding to a Category I hurricane and are based on historical data. Even the newer replacement maps adopted in late 2007, with enlarged flood zones, are still based only on historical data, and not on climate change modeling data.[19]

In the Gulf of Mexico, Hurricane Katrina resulted in an exceptional storm surge that overwhelmed the levees protecting New Orleans, resulting in catastrophic flooding. In reviewing the Katrina disaster, Berkeley engineer Robert Bea discovered that the Corps of Engineers had applied a safety factor of 1.3 to the benchmark hundred-year flood height, estimated from historical data, in designing the height of levees (contrasted with a factor of 4-6 used in offshore oil platforms, which withstood the hurricane). It emerged that this factor of 1.3 was carried over from the 1940s, when the Corps used it in protecting agricultural land and pasture in the South from flooding. The levees the Corps had built and rebuilt were designed to allow up to 2 feet of water to overtop the barrier in a hundred-year flood, as estimated with data decades old.[20] Bea also found that the Corps was rebuilding levees to the same standard – an earth mound without concrete sheathing – that had failed in the face of Katrina.[21]

Flood control

A. Federal Crop and Disaster Insurance

According to recent testimony from the Government Accountability Office, "The National Flood Insurance Program and Federal Crop Insurance Corporation have not developed information on the programs' longer term exposure to the potential risk of increased extreme weather events associated with climate change as part of their risk management practices. . . . Furthermore, according to NFIP and FCIC officials, both programs' estimates of weather-related risk rely heavily on historical weather patterns. As one NFIP official explained, the flood insurance program is designed to assess and insure against current – not future – risks."[22]

Moreover, real estate interests have lobbied against changes in the NFIP to update and expand flood zones within which flood insurance would be mandatory for homeowners with federally insured mortgages, since doing so would raise real estate costs. They have been joined in opposition by localities such as Michigan, where flooding is infrequent, since most of the program's payouts have so far gone to just three states bordering the Gulf of Mexico.

B. The Corps of Engineers Flood Protection Program

In the Upper Mississippi Basin, where a severe 1993 flood caused massive damage and scores of deaths, the Army Corp of Engineers partnered with other agencies to

[18] City of New York, PlaNYC 2030, Progress Report 2008, accessed online, May 1, 2008

[19] Teri Karush Rogers, How Safe is My Home?, *New York Times*, March 11, 2007.

[20] John Schwartz, The Dilemma of the Levies: New Data, Conflicting Requirements and Outdated Standards at the Corps, *New York Times*, April 1, 2006.

[21] Resurrection, *Fortune* magazine, August 21, 2006: 109. Statement of John Bea.

[22] Stephenson, Director of Natural Resources and Environment, Government Accountability Office, before the House Select Committee on Energy Independence and Global Warming, "Climate Change: Financial Risks to Federal and Private Insurers in Coming Decades are Potentially Significant," Washington, D.C., May 3, 2007.

produce a comprehensive plan to coordinate and improve the more than 100 flood control systems in the basin. That study was based on recently updated hydrologic frequency models, which still are based on historical records stretching back a century.[23] These hydrological parameters are used in the design of flood control structures and to estimate potential damages for insurance purposes. The underlying study discussed the problem of climate change in planning for the future: "Future climate change has the potential to change the frequency of flood events, manifesting itself as a shift in the discharge-frequency curve."[24] However, while acknowledging the fact of climate change, the study's draft final report did not factor its implications into its long-term comprehensive plan. Neither the available climate models nor the streamflow data were seen as providing compelling evidence to revise the assumption that the probabilities of flooding will remain unchanged or to revise the statistical model that had been codified in an inter-agency agreement to achieve consistency in flood risk estimation. According to the draft final report, "For the purposes of this study, it is assumed that whatever climate changes occur within the 50-year planning time frame will have little effect on the types of vegetation, cropping patterns or flood frequencies as currently determined."[25]

[23] U.S. Army Corps of Engineers, *Upper Mississippi Comprehensive Plan*, Draft Report, May 2006.

[24] U.S. Army Corps of Engineers, 2002. Uncertainty of Flood Frequency Estimates: Examining Effects of Land Use Changes, Climate Variability, and Climate Change: Synthesis Report, *Upper Mississippi River System Flow Frequency Study*, October 31:10.

[25] *Ibid.*, p.41.

Various explanations for maintaining this unrealistic assumption were put forward in interviews and study documents. General circulation models offer differing predictions of future precipitation and run-off at the regional scale. In recent decades, at some measuring points on the rivers, flood levels have increased but not at other points. Moreover, changing the estimated flood heights and frequencies would have major and potentially costly consequences for communities along the river in order to qualify for the National Flood Insurance Program. Therefore, forecasters chose to stick with hard historical data, even if poor predictors of the future, rather than venture into uncertain forecasts.[26]

[26] Telephone interview with Randy Kerr, Tennessee Valley Forecasting Center, April 7, 2006.

Another factor might stem from the fact that the Bush Administration and elements within the Congress, for ideological or more mundane reasons, have opposed efforts to promote or require adaptation to future climate change. For example, during 2007, the U.S. Senate defeated a draft bill requiring the Army Corps of Engineers to consider the impact of climate change in designing water resource projects.[27]

[27] Climate Change Capital, *Climate Change News Roundup*, May 17, 2007.

Water supply

Nowhere in the United States is water supply a bigger issue than in the semi-arid Southwest, where more than 30 million people depend on the over-appropriated Colorado River Basin and dwindling groundwater resources. More than a decade ago the American Water Works Association Public Interest Advisory Forum recommended that planners begin to assess the potential impacts of climate change on water supplies, and the Association has published a primer on climate change for water utility managers.[28] A decade later, the Western Governors' Association similarly called for attention to climate change in water management.

[28] American Water Works Association, *Climate Change and Water Resources: A Primer for Municipal Water Providers*, AWWA, 2006.

However, most of the necessary measures needed for adaptation remain in the future. Most Western states have just in the past few years created climate change

advisory committees to examine state-wide impacts, adaptations, and mitigation options. In 2006 the Western States Water Council (WSWC) recommended that water managers at the regional, state and local levels develop adaptation plans based on estimates of the changing probabilities of extreme climatic events. The WSWC pointed to a substantial research effort already underway, including the Climate Assessment for the Southwest (CLIMAS) program, housed at the University of Arizona, but also pointed to a continuing gap between researchers and water supply planners and managers

According to the WSWC report on research needs,

> "Long lead times are required to implement both structural (e.g. building new infrastructure) and non-structural (e.g. adopting new USACE flood control rule curves through an administrative or legislative process) options. It is necessary to begin laying the groundwork and making investments to support improved water management reliability – whether to respond to natural climate variability, forecasted climate change impacts, or population growth – well in advance of the time when the reliability is needed. Analytical uncertainties associated with assessing climate change impacts need to be addressed sooner rather than later, since results of those analyses are necessary early in the planning process. It thus makes sense to move expeditiously in developing the collaborative relationships with the climate research community that are important to procuring directed research outcomes."[29]

[29] Western States Water Council, *Proceedings of the Climate Change Research Needs Workshop*, Denver, May, 2007. p.17.

Much remains to be done, on the research front itself and to connect researchers with managers.

Many agencies in the Southwest are moving in that direction but are still not explicitly factoring in climate change. For example, the Arizona Governor's Drought Task Force developed the Arizona Drought Preparedness Plan in 2004. It does not take into account climate change, however, due to a lack of consensus on its impacts. In Colorado, the Colorado Water Conservation Board produced a Statewide Water Supply Investigation report in 2004 projecting demands, availabilities and options through 2030. The investigation noted that these projections may be affected by climate change, but did not use climate forecasts in projecting availabilities nor did it recommend the use of such forecasts in planning.

In New Mexico, which already faces declining groundwater levels and fully appropriated surface water resources, the State Water Plan published in December 2003 does not discuss the potential impacts of climate change. Water managers tend to work on five-year water budgets and deal primarily with existing scarcities. In Texas, where the western part of the state is largely dependent on groundwater, the Texas Water Development Board (TWDB) is constrained by law to use the historical "drought of record" in developing water supply availability forecasts and has not incorporated climate change forecasts. Regional Water Plans developed for the sixteen Texas water regions are based on Water Availability Models developed by the Texas Council on Environmental Quality as well as Groundwater Availability Models developed by TWDB, neither of which incorporate climate change impacts.

In summary, throughout the Southwest, where water availability is likely to be greatly affected by climate change within the planning horizon of infrastructure investments, adaptation up to this point has been slow and tentative.

In summary, throughout the Southwest, where water availability is likely to be greatly affected by climate change within the planning horizon of infrastructure investments, adaptation up to this point has been slow and tentative.

Major water supply agencies in the Southwest and elsewhere have just recently joined forces in the Water Utility Climate Alliance (WUCA) to study how climate change is affecting the provision of drinking water in major metropolitan areas.[30] The WUCA identified several key research needs that would improve the water supply sector's ability to develop strategies to cope with potential impacts of climate change and urged the U.S. Climate Change Science Program, as well as all researchers and scientists in the climate-change field, to:

[30] *Water and Wastewater News*, accessed online, March 6, 2008. www.wwn-online.com

- Reduce the uncertainty in climate change projections by improving and refining global climate models and applying them at the regional or local level;
- Enhance the collection, maintenance and accessibility of information, making the data more useful for decision-making purposes;
- Ensure that water providers worldwide have access to consistent climate data;
- Develop decision-support tools for planning, decision-making and policy-making that can accommodate deep uncertainty and the potential for abrupt climate changes; and
- Coordinate international research efforts, particularly with those countries that are already experiencing the effects of climate change, such as Australia.

In addition to improving research, WUCA members intend to develop strategies for adapting to climate change and implementing tactics to reduce their greenhouse gas emissions, but by mid-2008 have not yet done so.

Land and natural resource management

Federal agencies manage almost 30 percent of the land area of the United States, over 600 million acres of land, and more than 150,000 square miles of protected waters, including 13 national marine sanctuaries and one marine national monument. They are charged with responsible and sustainable stewardship. The principal agencies given this charge are the Bureau of Land Management, the U.S. Forest Service, the

National Park Service, and the National Oceanic and Atmospheric Agency, although other federal agencies, including the Department of Defense, control considerable federal land. Natural resources under their collective stewardship, and the people who make use of them in approximately 600 million annual visits, will be greatly affected by climate change.

In January 2001, the Department of Interior issued a directive to the Forest Service, the Fish and Wildlife Service, the Bureau of Land Management, the Park Service and other federal resource management agencies to "consider and analyze potential climate change effects in their management plans and activities." According to a 2007 GAO report, land and resource managers have simply ignored that directive.[31] Part of the reason is a conflict with the current strongly held ethos of managing by letting nature take its course with a minimum of intervention, despite the momentous changes that climate change will bring. Another part is uncertainty about the ecological changes that climate change will produce and what, if anything, can be done about it.

[31] M. M. Smith and F. Gow, Unnatural Preservation, *High Country News*, February 4, 2008.

In January 2001, the Department of Interior issued a directive to the Forest Service, the Fish and Wildlife Service, the Bureau of Land Management, the Park Service and other federal resource management agencies to "consider and analyze potential climate change effects in their management plans and activities." According to a 2007 GAO report, land and resource managers have simply ignored that directive.[32]

[32] M. M. Smith and F. Gow, Unnatural Preservation, *High Country News*, February 4, 2008.

The GAO report states that ". . . federal land and water resources are vulnerable to a wide range of effects from climate change, some of which are already occurring. These effects include, among others, (1) physical effects, such as droughts, floods, glacial melting, and sea level rise; (2) biological effects, such as increases in insect and disease infestations, shifts in species distribution including invasive species, and changes in the timing of natural events; and (3) economic and social effects, such as adverse impacts on tourism, infrastructure, fishing, and other resource uses."[33]

Experts contributing to the GAO report also identified several challenges that resource managers face in addressing the observed and potential effects of climate change in their management and planning efforts. In particular, BLM, FS, FWS, NOAA, and NPS have not made climate change a priority, and the agencies' strategic plans do not specifically address climate change. Resource managers focus first on near-term, required activities, leaving less time for addressing longer-term issues such as climate change.

[33] Government Accountability Office, *Climate Change: Agencies Should Develop Guidance for Addressing the Effects on Federal Land and Water Resources*, Washington, D.C., 2007:2.

In addition, resource managers have limited guidance about whether or how to address climate change and, therefore, are uncertain about what specific actions, if any, they should take. The orientation to "let nature take its course" has taken strong root within resource management agencies, creating a presumption among many

managers that *taking no action is the appropriate response to climate change*. In general, resource managers lack specific guidance for incorporating climate change into their management actions and planning efforts. Without such guidance, their ability to address climate change and effectively manage resources is constrained. While a broad order developed in January 2001 directed BLM, FWS, and NPS to consider and analyze potential climate change effects in their management plans and activities, the agencies have not yet provided specific direction to managers on how they are to implement the order.[34] For example, resource managers explained that current planning is based on current and historical conditions, and the modeling and forecasting capabilities with which to anticipate the impacts of climate change at local and regional scales are still lacking. Nor has redressing these priorities been assigned a high priority.

[34] *ibid*.

Transportation infrastructure

The U.S. Climate Change Science Program recently initiated an assessment study of potential impacts, vulnerabilities and adaptation responses of the nation's transportation infrastructure to climate change, using the central Gulf Coast as a case study. It found substantial vulnerabilities. For example, storm surges associated with hurricanes could easily reach 7 meters in height. With storm surge at 7 m (23 ft), more than half of the area's major highways (64 percent of interstates; 57 percent of arterials), almost half of the rail miles, 29 airports, and virtually all of the ports are subject to flooding.

Transportation investments are guided by state and municipal plans, which must conform to codified federal planning guidelines if the investment projects are to be eligible for federal funding. Those guidelines do not yet require consideration of climate change. The assessment found, through interviews with transportation planners and officials in the region and examination of medium and long term transportation plans, that "most agencies do not consider climate change projections per se in their long-range plans, infrastructure design, or siting decisions. This appears to be changing, spurred in part by the devastating effects of Hurricanes Katrina and Rita."[35] Nonetheless, it was found that "None of the existing State and Metropolitan Planning Organization documents examined here, all of which date from 2000 to 2006, directly addresses or acknowledges issues of climate change and variability."[36]

[35] US Climate Change Science Program, Executive Summary, *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study*, Phase I; March, 2008: 8.

[36] *Ibid:* chapter 5:8.

A similar study by the Transportation Research Board of the National Academy of Sciences pointed out that since most transportation infrastructure investments have a very long lifetime, future climate conditions must be taken into account. Their report made many recommendations for changes in current practices, which they characterized as follows:

> "Faced with a new problem such as this predicted break in trend, transportation professionals typically adopt incremental rather than radical solutions. This tendency to proven methods and practices is understandable, particularly for engineers, who are designing infrastructure expected to

provide reliable service for decades, and in view of the uncertainties about the rate of climate change and the magnitude of its effects. Nevertheless, reinforced by conservative institutions, regulatory requirements, and limited funding, this way of thinking can hamper timely responses to issues such as climate change that involve risk and uncertainty.

Interviews with transportation planning officials conducted for the U.S. Department of Transportation's (U.S. DOT) Gulf Coast study by Cambridge Systematics, Inc. (2006) are illustrative of prevailing attitudes. The interviews were conducted in spring 2006 when the impacts of Hurricanes Katrina and Rita were very much on the minds of local planners. Understandably, local officials were concerned with the immediate problems of rebuilding and recovery from the hurricanes. When questioned about the possibility that climate change could bring about more storms of the intensity of Katrina or Rita in the future, however, many local officials expressed skepticism or pleaded ignorance. Others opted for a literal interpretation of SAFETEA-LU's planning guidance, which does not require consideration of climate change, or pointed to federal policies that allow replacement of facilities only as they are currently designed, preventing consideration of design modifications that could provide for adaptation to potential climate change impacts (e.g., elevated bridges to accommodate sea level rise, storm surge, and wave action). Some officials interviewed believed that FHWA regulations prevented them from considering any changes that would extend beyond the time horizon of their long-range plans. Still others identified limited current funding that, in combination with uncertainties about the rate and timing of projected climate changes, disinclines planners to give more attention to the issue."[37]

[37] Transportation Research Board, Special Research Report 290, *Potential Impacts of Climate Change on U.S. Transportation*, National Research Council, Washington, D.C., 2008:102.

Public health

Assessments have found that climate change will create or intensify many public health problems in the United States, especially from extreme weather events, including heat waves and flooding disasters. In addition, climate change will intensify smog and other air pollution risks, including increased outbreaks of asthma and allergies. Water-borne diseases will be increased by inland flooding, while outbreaks of "red tide" will be likely to increase in coastal waters. Moreover, climate change is expected to exacerbate vector-borne diseases such as Hantavirus, West Nile virus, Lyme disease and dengue fever. Nonetheless, according to the National Assessment of the Potential Consequences of Climate Variability and Change, "Vigilance in the maintenance and improvement of public health systems and their responsiveness to changing climate conditions and to identified vulnerable sub-populations should help to protect the U.S. population from any adverse outcomes of projected climate change."[38]

[38] Jonathan A. Patz et al., The Potential Health Impacts of Climate Variability and Change: Executive Summary of the Report of the Health Sector of the National Assessment, *Environmental Health Perspectives*, 108: 367-376, 2000.

Interviews were conducted in 2006 and 2008 by graduate students in the Yale School of Forestry & Environmental Studies to ascertain the extent to which local and

national public health agencies had responded to ongoing climate change by altering forecasts, plans, strategies, operations, budgets or staffing. Municipal public health officials in Los Angeles, Chicago and Philadelphia responded that, although they are aware of the relevance of climate change to these public health risks, it has not as yet affected their plans or operations, largely because those are based on more immediate priorities. Moreover, climate change risks are perceived to be relevant in the more distant future. Indicative is the response of Dr. David Dassey of the Los Angeles Department of Public Health: "It is not the nature of a local health department to anticipate the distant future. . . . I believe that any such [climate-related] environmental changes will be incremental and probably not noticeable for some time to come."[39]

At the national level, the Centers for Disease Control and Prevention (CDC) is the lead agency dealing with the public health risks of climate change, providing not only research and guidance but also considerable funding for local public health agencies. As of 2006, CDC was just coming to grips with climate change, and had not made any concrete responses in operations, plans, budgets or staffing.[40] However, by 2008, an Associate Director for Climate Change was in place at CDC. Research had been initiated on such topics as the impact of climate change on the range and ecology of disease vectors and communicable disease epidemiology, but CDC scientists recognize that they lack the knowledge of disease ecology, population dynamics and other variables to make useful forecasts.[41] However, a recent report has indicated that CDC now spends less than one million dollars per year on climate-related programs and several important studies have been shelved because of insufficient funds.[42]

Local public authorities are primarily responsible for actions on the ground, such as mosquito spraying in the wake of floods, but the CDC *has* provided guidance documents, such as an "Excessive Heat Events Guidebook," available online, suggesting both warning systems and emergency responses. The CDC has organized workshops for local public health officials and others to focus on climate change health impacts and responses. The CDC has also issued a Policy Statement on Climate Change, which summarizes some of the main public health risks and identifies eleven priority health responses. Most of these priorities point toward actions to be taken in the future, such as "Develop and implement preparedness and response plans for health threats such as heat waves, severe weather events and infectious diseases."[43]

So, it appears that between 2006 and the present, the Centers for Disease Control and Prevention, the national public health agency, has initiated steps to adapt to climate change, but funding has been insufficient and most local agencies remain focused on their current priorities. Though indications of a recent institutional response are evident, the lags in adaptation responses have been considerable, since warnings of the public health risks of climate change go back decades.[44]

State and local level adaptation responses

A recent review by the Pew Center on Global Climate Change has reported that only a half-dozen states have prepared or are currently preparing climate adaptation plans.

[39] Amanda Cowan, U.S. Adaptation to the Health Risks of Climate Change, unpublished paper, Yale School of Forestry & Environmental Studies, May, 2006. Interview conducted April 28, 2006.

[40] *Ibid.*, Interview with Dr. Michael McGeehin, Director of the Division of Environmental Health Effects, CDC, conducted April 21, 2006.

[41] Maria Terekhov, U.S. Adaptation to the Health Risks of Climate Change, unpublished paper, Yale School of Forestry & Environmental Studies, May, 2008.

[42] EPA Calls for More Studies on Health Risks of Climate Change, *Science*, 321: 477, July 25, 2008.

[43] Centers for Disease Control and Prevention, *CDC Policy on Climate Change* at http://www.cdc.gov/ClimateChange/policy.htm

[44] WHO, Potential Health Effects of Climate Change, Geneva, 1990; Eric Chivian et al., *Critical Condition: Human Health and the Environment*, MIT Press, Cambridge, MA, 1993.

These are Alaska, California, Florida, Maryland, Oregon, and Washington. In 27 other states, climate change action plans are under preparation. Less than half of these plans include any substantial mention of adaptation planning. For the most part, these plans seek to identify actions to be taken in the future, indicating a general lack of prior action on adaptation.

In addition, a number of county and municipal governments are planning or taking action to reduce their vulnerabilities to climate change damages. ICLEI - Local Governments for Sustainability, is an organization that has been playing a leading role in stimulating and sharing information about these activities through its Climate Resilient Communities Initiative. However, as at the state level, most community climate change action plans focus on mitigation options, not adaptation, or seek to identify adaptation measures that could be taken in the future. An exception to this future orientation is found in Boston, Massachusetts, where the Deer Island Sewage Treatment Plant in the middle of Boston harbor was built at a higher elevation than originally planned to prevent flooding.[45]

Probably no state has had a more urgent need to initiate adaptation measures than Alaska. Because of its northern latitude, temperature has risen twice as much as in the contiguous United States, by 3.5 degrees F on average and by 6 degrees during winter. Alaska is already experiencing significant current damages from climate change, including damage to infrastructure from melting of permafrost, dislocation of more than one hundred coastal communities from shoreline erosion as sea ice barriers disappear, increasingly severe and widespread forest fires and forest pest outbreaks as temperatures rise, changes in fish and marine mammal populations and other impacts. Infrastructure damages alone are expected to add between $3.5 and $6 billion to normal maintenance and replacement costs over the next two decades. In the view of the Alaska Climate Impact Assessment Commission, these damages will partially be offset by increasing tourism business as temperatures rise, and a potentially large expansion of the shipping industry when and if an ice-free Arctic shipping route emerges.

Scientists at the University of Alaska have down-scaled global circulation models to create climate forecasts for Alaska, which show dramatic future warming – as much as 20 degrees Fahrenheit in winter temperatures. Nonetheless, the Commission's final report in 2008 finds that data on which to plan for adaptation is out of date and deficient. Shoreline and maritime maps, precipitation frequency distributions, census data on more than 16,000 items of infrastructure and hundreds of communities at risk need to be updated for planning purposes. The Department of Transportation, for example, reported to the Commission that it "has not systematically studied the need for, or implemented specific changes to policy or regulations relative to climate change, nor does it have pertinent data upon which to base such changes." With respect to adaptation responses, "generally, the Commission feels that we are early in the period of climate change understanding when it comes to determining precise budget impacts and service delivery changes by state government."[46]

[45] Pew Center on Global Climate Change, *Adaptation Planning – What U.S. States and Localities are Doing*, Washington DC, April, 2008.

[46] Alaska State Legislature, *Alaska Climate Impact Assessment: Final Commission Report*, Juneau, March 17, 2008: 30.

The Commission recommended that the Alaska state government:

- Support monitoring systems integrated with state and federal agencies and the University of Alaska, to collect or update pertinent baseline data on physical, biological, and cultural factors;
- Support the state Division of Geological and Geophysical Surveys (DGGS), or other appropriate entities, for the identification and mapping of permafrost, landslides, riverine/coastal erosion, and soil type for engineering studies and community planning;
- Provide support to ensure that decisions are based on science and engineering analysis and are well documented with recent data and future monitoring programs;
- Support education and public awareness of the fact that Alaskans live in a dynamic natural environment, and that adaptation is nothing new, despite what is sometimes said;
- Plan for infrastructure development along the Northwest Arctic and Arctic coasts for maritime industries and offshore resource development.

Despite its exposed position and the importance of natural resources to the state economy, the responses of the Alaska state government have clearly lagged behind the pace of climate change already experienced, in large part because of a lack of timely data for monitoring and planning.

Private sector responses

Many private business sectors are exposed to significant risks from climate change, along with opportunities. Government policies to mitigate greenhouse gas emissions will create financial and regulatory risks for many industries, along with new opportunities for companies to expand in providing solutions to climate problems. However, the private sector is also exposed to the same physical risks that public agencies must contend with, not only risks to their own facilities, infrastructure and staff, but also to those of their suppliers and customers. The presumption has been that the private sector will adapt efficiently and briskly to those risks, even if government agencies lag. According to Mendelsohn and Neuman (1999:5), "Efficient private adaptation is likely to occur, even if there is no official (government) response to global warming."

There is evidence that at least some private sector organizations are adapting to changing climate conditions, albeit mostly reactively. In the Gulf Coast in the aftermath of Katrina, a few dozen builders are constructing well-fortified houses designed beyond code requirements to withstand winds from Category 5 hurricanes and finding buyers for them, even at extra cost in excess of $30,000. Property insurers are offering discounts on policy premiums of up to 25 percent on these homes.[47]

[47] Joseph Treater, Let a Hurricane Huff and Puff, *Wall Street Journal*, June 22, 2006.

Oil companies with offshore and onshore facilities in the Gulf have responded to studies indicating that climate change may produce more intense hurricanes in the

region by revisiting their design standards for offshore oil rigs and pipelines, especially after their experience with Katrina. Companies have seen what were expected to be one-in-a-hundred-year storms happening every few years.[48]

Insurance companies are concerned about increasing storm losses, especially from hurricane damages. The empirical record over the past 30-35 years indicates an increase in hurricane intensity.[49] Some companies have reduced coverage in vulnerable areas. Many are re-examining their actuarial estimates and/or have markedly increased premium rates. Yet, according to one observer, "Although insurers first expressed concern about climate change more than three decades ago, fewer than one in a hundred appear to have seriously examined the business implications."[50] Efforts by the insurance companies to project future hurricane losses through quantitative risk modeling have been obstructed in some states, including Texas and Florida, by insurance regulatory commissions that have recommended against the use of such models in rate-making.

The financial sector has begun incorporating climate risks into investment decisions. For example, major financial institutions, including Citigroup, JP Morgan Chase, Morgan Stanley, and Bank of America have begun including a range of carbon prices and policy scenarios into project evaluation. However, this group (of 6) represents only a small fraction of banks and financial institutions.[51] Investment banks and brokerages have been issuing an increasing number of research reports on climate-related risks and opportunities, however, and more investments and investment vehicles have been created that are geared to climate-related opportunities in renewable energy, etc.

A more comprehensive review by the consulting firm KPMG identified industries at greater risk from climate change and also characterized industries in terms of their current level of preparedness. Their report identified sectors perceived to be at greatest physical risk (health care, agriculture and forestry, transportation, insurance, tourism), as well as others at considerable risk from physical impacts (real estate, finance, construction and materials, retail, manufacturing). These perceptions are those now prevalent in the private sector and reflected in company reports, but do not necessarily fully reflect risks to particular companies or businesses.

Nonetheless, the KPMG review still finds considerable discrepancy between the level of self-assessed exposure to the physical risks of climate change and the level of preparedness to deal with them. The review finds that in the health care, tourism, and transportation industries there is generally a low degree of preparedness or adaptation to the physical risks of climate change, despite a high level of exposure. In the retail, financial and real estate sectors, there is only a moderate degree of preparedness, according to the review.[52]

A complementary study by the Pew Center on Global Climate Change also undercuts the idea that the private sector will adapt efficiently and promptly, suggesting that private sector managers face many of the same obstacles as their public sector colleagues. The Pew study finds that ". . . the physical risks of climate change are often overlooked by business. The reasons for this are several: the uncertainty of future projections and the long-term nature of the change make it easy

[48] Jad Mouawad, At Time of Epic Storms, the Oil Industry Thinks Anew, *New York Times*, September 15, 2005.

[49] K. Emmanuel, 2005, Increasing Destructiveness of Tropical Cyclones over the past Thirty Years, *Nature*: 436: 686-688; K. Emmanuel, 2006, "Climate and Tropical Cyclone Activity: A New Model Downscaling Approach". *Journal of Climate*: 19: 479-480.

[50] Edwin Mills, 2005, Insurance in a Climate of Change, *Science*: 309: 1040-1044.

[51] Jillian Mincer, Banks Shift to Greener Policies, *Wall Street Journal*, January 11, 2008.

[52] KPMG International, *Climate Changes Your Business*, 2008

for businesses to set aside current climate risk, and concerns about greenhouse gas emissions and mitigation are more pressing to corporate leaders and shareholders. Moreover, many decision-makers have yet to recognize that the past is not the best predictor of the future – whether for climate averages or climate variability."[53]

[53] Frances G. Sussman and J. Randall Freeed, *Adapting to Climate Change: A Business Approach*, Pew Center on Global Climate Change, Washington DC, April 2008: 29.

V. CONCLUSIONS

Despite a half century of climate change that has significantly affected temperature and precipitation patterns and has already had widespread ecological and hydrological impacts, and despite a near certainty that the United States will experience at least as much climate change in the coming decades, just as a result of the *current* atmospheric concentrations of greenhouse gases, those organizations in the public and private sectors that are most at risk, that are making long-term investments and commitments, and that have the planning, forecasting and institutional capacity to adapt, have not yet done so.

With few exceptions, even at this time, such organizations are at early stages of developing strategies by which to adapt to climate change risks. There have been very few changes in forecasts, plans, design criteria, investment decisions, budgets or staffing patterns in response to climate risks.

Private and public sector organizations face significant obstacles to adaptation: uncertainty regarding future climate change at regional and local scales; uncertainty regarding the future frequency of extreme weather events; and uncertainty regarding the ecological, economic and other impacts of climate change. Organizations lack relevant data for planning and forecasting, and such data as are available are typically outdated and unrepresentative of future conditions.

Organizations also face institutional and human barriers to adaptation: the need to overcome or revise codes, rules, and regulations that impede change; the lack of clear directions and mandates to take action; political or ideological resistance to the need for responsiveness to climate change; the preoccupation with near-term challenges and priorities and the lingering perception that climate change is a concern only for sometime in the future; and the inertia created by a business-as-usual assumption that future conditions will be more or less like those of the past.

Without national leadership and concerted efforts to remove these barriers and obstacles, adaptation to climate change is likely to continue to lag. It will be largely reactive rather than anticipatory and preventive, responding to damaging impacts once they have occurred.

To say that the United States *can* adapt to climate change does not imply that the United States *will* adapt.

About the Author

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