

## Adapting to the Impacts of Climate Change

Much of the nation's experience to date in managing and protecting its people, resources, and infrastructure is based on the historic record of climate variability during a period of relatively stable climate. Adaptation to climate change calls for a new paradigm—one that considers a range of

possible future climate conditions and associated impacts, some well outside the realm of past experience. Adaptation is a process that requires actions from many decision-makers in federal, state, tribal, and local governments, the private sector, non-governmental organizations, and community groups. However, current efforts are hampered by a lack of solid information about the benefits, costs, and effectiveness of various adaptation options, by uncertainty about future climate impacts at a scale necessary for decision-making, and by a lack of coordination. Therefore, a national adaptation strategy is needed to support and coordinate decentralized efforts. As part of this strategy, the federal government should provide technical and scientific resources that are currently lacking at the local or regional scale, incentives for local and state authorities to begin adaptation planning, guidance across jurisdictions, shared lessons learned, and support of scientific research to expand knowledge of impacts and adaptation.

**A**cross the United States, impacts of climate change are already in evidence. Some extreme weather events such as heat waves have become more frequent and intense, cold extremes have become less frequent, and patterns of rainfall are likely changing. For example, the proportion of precipitation that falls as rain rather than snow has increased across the western United States. Arctic sea ice has been reduced significantly over the past 30 years.

Even if emissions of greenhouse gases were substantially reduced now, climate would continue to change for some time to come and the potential consequences for humans and ecosystems are significant. It has been estimated, for instance, that a heat wave of the same magnitude as the 2003 European heat wave could cause more than five times the average number of expected heat-related deaths in a large American city; projected deaths in New York City alone, for one such event, could exceed the current national summer average. In ecosystems, changing climate could alter the distribution patterns of plant and animal species, reduce the productivity and abundance of species, and change habitats. Sea level has been rising, most likely at a faster rate than in



Image from U.S. Army Corps of Engineers

recent history, threatening the natural and built environments on the coasts and in fresh water systems, especially when combined with effects of more intense coastal storms.

This report, part of the *America's Climate Choices* suite of studies requested by Congress, discusses the impacts of climate change and how we as a nation can begin adapting to them in beneficial ways, exploring activities underway at state and local levels, adaptation options, and how the nation can become better prepared to make adaptation choices.

## Adaptation Choices

Society’s need to cope with climate variability and changing environmental conditions is not new; people have been adjusting to their environment since the dawn of civilization. Agriculture is one of the earliest examples, as farmers have had to continually adjust cultivation and breeding practices to varying climate conditions. Modern efforts to stabilize and protect our homes, livelihoods, and resources in the face of a variable climate include the development of floodplain regulations, insurance, wildlife reserves, drinking water reservoirs, and building codes.

However, these actions have been taken in response to a climate that has been relatively stable for the last 10,000 years. Planning for adaptation to climate *change* (rather than climate *variability*) is already under way in many sectors likely to be affected, from agriculture to tourism, with states and localities undertaking the most explicit planning to date. For example, Philadelphia has designed an early warning system for heat waves to reduce associated illnesses and deaths, particularly among the vulnerable populations of the elderly and poor (see Box 1).

In the short term, the adaptation actions that can most easily be deployed now are low-cost strategies with win-win outcomes, actions that offer near-term co-benefits, and actions that end or reverse maladapted policies and practices. Short term opportunities at the national level include opportunities to revise existing programs to take into account projected future climate changes; examples include the National Flood Insurance Program; federal, state, and professional engineering standards; and the Coastal Zone Management program.

### Box 1. Philadelphia: Adaptation to Heat Waves

Heat waves can cause significant loss of life, as observed in Europe in 2003 (which caused more than 70,000 deaths above average heat wave events) and in Chicago in 1995 (with nearly 700 excess deaths). Partly in response to heat waves in 1993 and 1994, Philadelphia developed its early warning system, the Hot Weather–Health Watch/Warning System to alert the city’s population when weather conditions pose risks to health. Whenever the National Weather Service issues a heat wave warning, television, radio stations, and newspapers are asked to publicize the heat wave warning, along with information on how to avoid heat-related illnesses. The system is estimated to have saved 117 lives during three years of operation, a benefit that can be compared with the costs of the system.

The report identifies a range of potential adaptation options—many of which are extensions of dealing with climate variability—for consideration at least in the short term in the key sectors of ecosystems, agriculture and forestry, water, health, transportation, energy, and coastal regions. Table 1 shows a few examples of those options. Unfortunately, many options lack solid information about benefits, costs, potentials, and limits for three reasons: (1) an inability to attribute many observed changes at local and regional scales explicitly to climate change (and therefore to document effects of adaptation in reducing those impacts), (2) the diversity of impacts and vulnerabilities across the United States, and (3) the relatively small body of research that focuses on climate change adaptation actions.

**Table 1. Sea Level Rise and Lake Level Changes: Examples of some adaptation options for one expected outcome\***

Impact	Possible adaptation action	Federal	State	Local govt.	Private sector	NGO / Indiv.
Gradual inundation of low-lying land; loss of coastal habitats, especially coastal wetlands; saltwater intrusion into coastal aquifers and rivers; increased shoreline erosion and loss of barrier islands; changes in navigational conditions	Site and design all future public works projects to take sea level rise into account	■	■	■		
	Eliminate public subsidies for development in high hazard areas along the coast	■	■			
	Develop strong, well-planned, shoreline retreat or relocation plans/programs (public infrastructure and private properties), and post-storm redevelopment plans		■	■		
	Retrofit/protect public infrastructure (stormwater/wastewater systems, energy facilities, roads, causeways, ports, bridges, etc.)	■	■	■		
	Use natural shorelines, setbacks, and buffer zones to allow inland migration of shore habitats and barrier islands over time (e.g., dunes and forested buffers)	■	■	■		■
	Encourage alternatives to shoreline “armoring” through “living shorelines”	■	■	■	■	

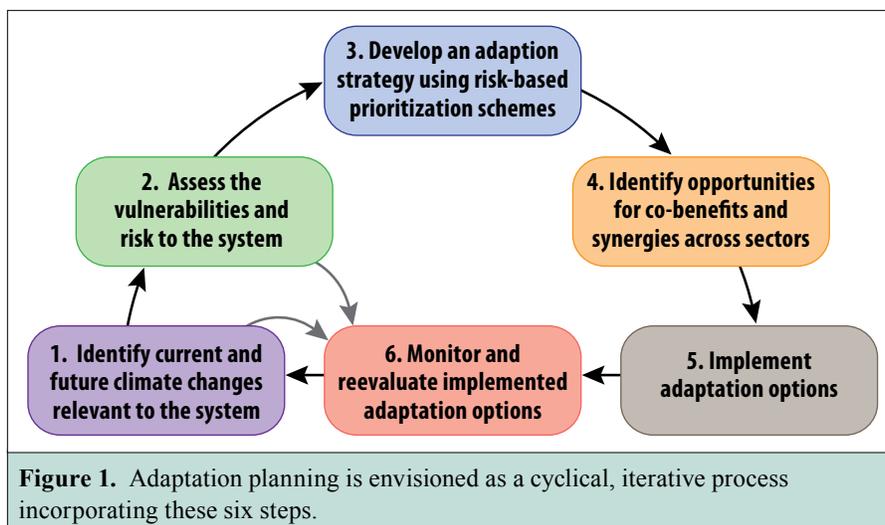
\* Excerpted from Table 3.8 in the full report

Actions taken so far to cope with climate variability are likely to have limited value in coping with impacts of the large or rapid changes in climate that are projected if efforts to limit emissions are not successful. Abrupt changes that push the climate system across thresholds are possible, creating novel and potentially irreversible conditions such as ice-free arctic summers or extreme rises in sea level. Adapting to those impacts could require major structural changes in government and society and consideration of currently unacceptable, or at least very difficult, adaptation measures such as large-scale retreat of populations from at-risk areas.

Alaskans already face such decisions and the related problem of funding adaptation efforts (see Box 2). If impacts are great enough that returning to pre-disturbance conditions becomes impossible, some current regulations and guidelines, such as ecosystem and land management policies, might have to be rethought and revised. Prudent risk management suggests the need to consider contingency plans for high impact-low probability events, supported by new research on implementing “worst-case” plans.

## Managing for the Risks of Climate Change

Adaptation to climate change calls for a new paradigm that manages risks related to climate change by recognizing the prospects for departures from historical conditions, trends, and variation. This means not waiting until uncertainties have been reduced to consider adaptation actions. Mobilizing now to increase the nation’s adaptive capacity can be viewed as an insurance policy against an uncertain future.



Vulnerability to climate change—the capacity to be harmed—is a function of 1) the nature and magnitude of the changes experienced; 2) underlying social, cultural, economic, geographic, and ecological factors that determine sensitivity to climate change; and 3) the nation’s ability to avoid, prepare for, and respond to impacts on ecological, economic, and human systems.

For decision-makers, a first step is to identify the important vulnerabilities for a region or sector. The next step is to identify a set of adaptation options. The set of adaptation options that are ultimately deemed worth pursuing will vary greatly from region to region and sector to sector. Decision-makers will have to weigh relative costs of adaptation options against the risks of impacts, as well as to determine which options will contribute to other management goals, such as developing in a sustainable manner, improving public health, or enhancing economic competitiveness. In all cases, decision-makers will need to monitor the effects of their adaptation decisions and update the planning process as new information about climate change, vulnerabilities, and effectiveness of adaptation options emerges (Figure 1).

### Box 2. Alaska: Retreat from the Coast

Alaskan coastal and river communities are experiencing greater erosion and flooding because of increased storm activity and windiness; reduced sea-ice extent, which increases the intensity of storm surges; and thawing of permafrost, which increases susceptibility to erosion. Traditionally, many of these communities were semi-nomadic, moving inland during periods of severe storms, and had little permanent infrastructure. During the past 100 years, however, their mobility has been reduced by the

building of houses, schools, airports, and other permanent facilities—changes that have increased vulnerability to climate change.

Six Alaskan communities are now planning some type of relocation. However, no funds have been appropriated to begin the relocation process. The U.S. Army Corps of Engineers has identified 160 additional villages in rural Alaska that are threatened by climate-related erosion, with relocation costs are estimated at \$30-50 million per village.

Some civil and resource managers are already engaged in adaptation planning. New York City embraced such a process as a way to integrate ongoing plans focused on growth management, infrastructure, and environmental sustainability. Climate change was chosen as the integrating element because adaptation to changes in climate-related risks could serve as a focal point. This “mainstreaming” of climate change planning into other ongoing initiatives moved adaptation to an advanced stage very quickly.

Building adaptive capacity includes developing not only infrastructure and policies, but also more flexible institutions and investments in research on adaptation processes and outcomes. The report recommends that the federal government undertake a significant climate change adaptation research effort designed to investigate new options for action and substantially improve knowledge of the benefits, costs, potentials, and possible limits of these options.

## Need for a National Adaptation Strategy

Because vulnerabilities to climate change and options for adaptation are diverse and often specific to local contexts, adaptation decisions will need to be made and implemented by a wide variety of parties in all levels of government, business, and society at

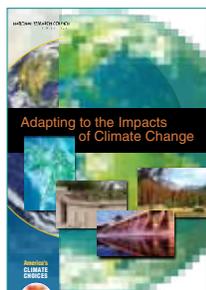
large. Though the contexts may vary, decision-makers can often learn from the experiences of their peers and adjust best practices to their own circumstances. However, there is currently neither a clear federal policy directive to encourage proactive adaptation to climate change nor a venue for managers to share innovative ideas and collaborate on adaptive activities.

To fill this void, the federal government should play a significant role as a catalyst and coordinator: providing information, technical resources, and incentives for adaptation decision-making and implementation; helping to avoid unintended consequences and inconsistent or inefficient investments and outcomes; continually evaluating needs for additional risk management at a national level; and serving as a role model by considering adaptations in federal programs. Thus the report recommends that the executive branch, in consultation with Congress, develop a national adaptation strategy. This strategy would be implemented through programs that would guide adaptation across jurisdictions, serve as a central point for sharing lessons learned, and provide guidance and support of the scientific research needed to expand knowledge of impacts and adaptation.

**America’s Climate Choices** is a congressionally requested suite of studies from the National Research Council designed to inform and guide the nation’s response to climate change. Experts representing various levels of government, the private sector, nongovernmental organizations, and research and academic institutions were selected to provide advice in peer-reviewed reports on limiting the magnitude of climate change, adapting to the impacts of climate change, advancing the science of climate change, and informing effective decisions related to climate change.

**Panel on Adapting to the Impacts of Climate Change:** **Katharine L. Jacobs\*** (*Chair – through January 3, 2010*), University of Arizona; **Thomas J. Wilbanks** (*Chair*), Oak Ridge National Laboratory; **Bruce P. Baughman**, IEM, Inc.; **Roger N. Beachy\***, Donald Danforth Plant Science Center; **Georges C. Benjamin**, American Public Health Association; **James L. Buizer**, Arizona State University; **F. Stuart Chapin III**, University of Alaska, Fairbanks; **W. Peter Cherry**, Science Applications International Corporation; **Braxton Davis**, South Carolina Department of Health and Environmental Control; **Kristie L. Ebi**, IPCC Technical Support Unit WGII; **Jeremy Harris**, Sustainable Cities Institute; **Robert W. Kates**, Independent Scholar, Bangor, Maine; **Howard C. Kunreuther**, University of Pennsylvania Wharton School of Business; **Linda O. Mearns**, National Center for Atmospheric Research; **Philip Mote**, Oregon State University; **Andrew A. Rosenberg**, Conservation International; **Henry G. Schwartz, Jr.**, Jacobs Civil (ret.); **Joel B. Smith**, Stratus Consulting, Inc.; **Gary W. Yohe**, Wesleyan University; **Claudia Mengelt** (*Study Director*), **National Research Council**.

\* Asterisks denote members who resigned during the study process to take policy-making positions in government.



The National Academies appointed the above panel of experts to address the specific task requested by the National Oceanic and Atmospheric Administration. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee’s report.

For more information, contact the Board on Atmospheric Sciences and Climate at (202) 334-3426 or visit <http://nationalacademies.org/basc> or America’s Climate Choices at [americasclimatechoices.org](http://americasclimatechoices.org). Copies of *Adapting to the Impacts of Future Climate Change* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; [www.nap.edu](http://www.nap.edu).

