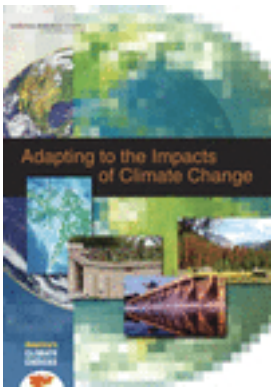
Free Summary

Adapting to the Impacts of Climate Change



America's Climate Choices: Panel on Adapting to the Impacts of Climate Change

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Summary

The global climate is changing, and impacts of climate change are being observed across the United States. Over the past 50 years, temperatures have risen nearly 2°F (1°C), some extreme weather events such as heavy precipitation and heat waves have increased in frequency and intensity, sea level has risen along most of the coast, and sea ice has been disappearing rapidly. These changes are all expected to continue, which means that in many respects the climate of the future will be different from the climate of the past.

In order to address the challenges associated with climate change, Congress directed the National Research Council to "investigate and study the serious and sweeping issues relating to global climate change and make recommendations regarding the steps that must be taken and what strategies must be adopted in response to global climate change." As part of the response to this request, the ACC Panel on Adapting to the Impacts of Climate Change was charged to "describe, analyze, and assess actions and strategies to reduce vulnerabilities, increase adaptive capacity, improve resilience, and promote successful adaptation to climate change in different regions, sectors, systems, and populations." (see Appendix B for the full Statement of Task).

America's climate change *adaptation* choices involve deciding how to cope with climate changes that we cannot, or do not, avoid so that possible disruptions and damages to society, economies, and the environment are minimized and—where possible—so that impacts are converted into opportunities for the country and its citizens. In some cases, such as in Alaska, the need to adapt has already become a reality. In most cases, however, adapting today is about reducing vulnerabilities to emerging or future impacts that could become seriously disruptive if we do not begin to identify response options now; in other words, adaptation today is essentially a risk management strategy.

Vulnerabilities to climate change impacts exist all across America and differ by region, sector, scale, and segment of our society. Consider, for example, the likelihood of reduced surface water supply in America's West because of reduced snowfall and snowpack in the western mountains and, at least in the Southwest, prospects for reduced total rainfall. These changes interact with the region's current vulnerabilities to drought conditions and the many competing demands for limited water resources. Options for adapting to the prospect of more severe water shortage in the West and Southwest include improving efficiencies in water use, reducing the need for water for competing purposes (e.g., power plant cooling), finding ways to reduce evaporation from reservoirs, learning more about potentials and limits of groundwater withdrawal, increasing mechanisms for inter-basin water transfers, revisiting approaches to water rights, and developing technology for affordable desalination of sea water. These are examples of options that can be considered by decision-makers responsible for water resources in the context of the local or regional socio-economics, combining relatively low-cost near term actions with preparations to evaluate more substantial actions in the longer term. While it is

difficult to know precisely the impacts that will occur in the future, adaptation offers a way to prepare and minimize the risks to social, economic, and natural systems associated with these impacts.

Adaptation to reduce vulnerabilities associated with likely impacts of climate change cannot be accomplished by the federal government or any other single decision-maker alone. The challenges are too diverse, the contexts are too different, and too many parties have knowledge and capacities to contribute. Given the diversity of climate impacts, vulnerabilities, and available adaptation options across the United States, the report concludes that adaptation planning and action will be required across all levels of government as well as within the private sector, non-governmental organizations (NGOs), and community organizations. Accordingly, this report outlines a framework which engages decision makers across all levels of governance and across public and private entities through the development of a national adaptation strategy. Within this national strategy, the federal government plays a unique and critical role in providing technical and scientific resources that are lacking at the local or regional scale, re-examining policies that may inhibit adaptation, and supporting scientific research to expand our knowledge of impacts and adaptation.

FUTURE IMPACTS OF CLIMATE CHANGE THAT CALL FOR ADAPTATION

Effective adaptation depends on an understanding of projected climatic changes at geographic and temporal scales appropriate for the needed response. Projected changes include average and extreme temperature; average and extreme precipitation; the intensity, frequency, duration, and/or location of extreme weather events; sea level; and atmospheric carbon dioxide (CO_2) concentrations. Because of the complex interactions between these climate changes and non-climate factors, such as demographics, economics, land use, and technology, the impacts of climate change will be highly diverse. For example, future climate changes will interact with underlying vulnerabilities in many coastal communities. In areas that have been highly developed, the ability to cope with flooding has been reduced as wetlands have been drained. With projected sea level rise and increases in storm surge, the impacts of flood damage and coastal erosion could be exacerbated. Thus, effective approaches to adaptation will be case and place-specific.

Society's ability to cope with the impacts of climate change and avoid unacceptable levels of social and environmental costs decreases as the severity of climate change increases. At moderate rates and levels of climate change, adaptation can do a great deal. At severe rates and levels of climate change, however, limits of many adaptation options might be reached; resulting adaptations are likely to be much more disruptive and costly. In this very direct and profound sense, adaptation to the impacts of climate change and actions to reduce greenhouse emissions into the atmosphere are partners in America's response to concerns about climate change, not alternatives.

Many scientific challenges remain in assessing vulnerabilities and impacts associated with climate change. The level of scientific confidence in understanding and projecting climate change increases with increasing spatial scale while the relevance and value of the information to decision-makers declines. Therefore, a finer-scale

understanding of climate change risks and vulnerabilities is needed. In addition, multiple stresses will interact with climate change in determining its impacts and, because vulnerability varies greatly from place to place, the same climate condition in different locations may call for different adaptive responses.

OPTIONS FOR ADAPTING TO IMPACTS OF CLIMATE CHANGE

If the United States is to cope effectively with the impacts of climate change, it will need an array of adaptation options from which to choose. Until very recently, adapting to climate change has been a low national priority, and limited research has been completed to identify options for adaptation and evaluate their benefits, costs, potential, and limits. In the short term, the nation can draw lessons from: past experience with adaptations to climate *variability*; experience (albeit limited) with climate change adaptation that has been undertaken in some regions of the world; a limited number of careful analyses of adaptation possibilities; and from an onrush of creative thinking in connection with emerging efforts to do adaptation planning. But, in many cases, the options that we can identify for *adaptation to impacts of climate change* lack solid information about benefits, costs, potentials, and limits for three reasons: an inability to attribute explicitly many observed changes at local and regional scales to climate change (and therefore to document effects of adaptation in reducing those impacts), the diversity of impacts and vulnerabilities across the United States, and the relatively small body of research that focuses on climate change adaptation actions.

This report provides examples of the range of options currently available for adapting to climate variability and extremes in key climate-sensitive sectors, such as agriculture, energy, and transportation. Although these examples alone may not be sufficient for coping with future climate change, they offer a starting point for devising adaptation strategies. While the report provides a long list of options to be considered for various sectors, the table at the end of the summary illustrates the range and diversity of options for coastal regions (Table S.1). For example, options to cope with sea level rise near coastal areas include: hardening of coastal infrastructure so that it can handle higher water levels and storm impacts; sharing risks among vulnerable locations through insurance; and altering development and land use practices to relocate vulnerable infrastructure or activities away from the coasts. Some of the adaptation options can be implemented in the near term at relatively low cost or provide additional benefits. Early actions that can be deployed most easily in such an environment are likely to be low-cost strategies with win-win outcomes, actions that end or reverse maladapted policies and practices, and measures that avoid prematurely narrowing future adaptation options. In addition, the integration of efforts to reduce greenhouse gas (GHG) emissions and adapt to climate change impacts in a common sustainability agenda reduces risks of maladaptation.

In the long term, adaptation to climate change calls for a new paradigm that takes into account a range of possible future climate conditions and associated changes in human and natural systems, instead of managing our resources based on previous experience and the historical range and variability of climate. This does not mean waiting until uncertainties have been reduced to consider adaptation actions. Actions

taken now can reduce the risk of major disruptions to human and natural systems; inaction could serve to increase these risks, especially if the rate or magnitude of climate change is particularly large. Mobilizing now to increase the nation's adaptive capacity can be viewed as an insurance policy against an uncertain future. Because adaptation options are much more limited to cope with impacts of relatively severe climate change in the longer run, an important part of a national approach to adaptation is examining the prospects for these more severe impacts and considering possible limits to adaptation. Some projected impacts are likely to be beyond the scope of adaptation, unless adaptation involves major structural change to government and society.

DEVELOPING ADAPTATION STRATEGIES

Although many ideas are available about ways to adapt to climate variability and change, few of these options have been assessed for their effectiveness under projected future climate conditions and for their potential interactions across sectors and with other stressors. Little attention has been given to the processes that decision makers might use to make appropriate adaptation decisions. This report suggests some approaches to choosing among the many options to manage the risks associated with climate change, using examples from recent adaptation activities initiated primarily at the state and local levels.

In brief, the report suggests that the adaptation process is fundamentally a risk management strategy. Managing risk in the context of adapting to climate change involves using the best available social and physical science to understand the likelihood of climate impacts and their associated consequences, then selecting and implementing the response options that seem most effective. Because knowledge about future impacts and the effectiveness of response options will evolve, policy decisions to manage the risk of climate change impacts can be improved if they are done in an iterative fashion by continually monitoring the progress and consequences of actions and modifying management practices based on learning and recognition of changing conditions.

The report proposes a sequence of steps for pursuing adaptation. To begin, decision-makers across a variety of agencies and institutions (e.g., federal, tribal, state, local governments; private sector firms; community organizations and NGOs) would identify their vulnerabilities and assess risks associated with the impacts of climate change. This information would need to be communicated among stakeholders and relevant decision-makers to raise their awareness of current and potential problems. Using a risk management approach, adaptation options for managing the risks associated with climate impacts can then be identified, evaluated, and implemented (Figure S.1).

The report also identifies some "lessons learned" about important elements to developing a strategy, including: establishment of clear objectives, opportunities to incorporate adaptation plans into existing management goals and procedures, the ability to identify co-benefits associated with adaptation measures, and the presence of strong leadership.

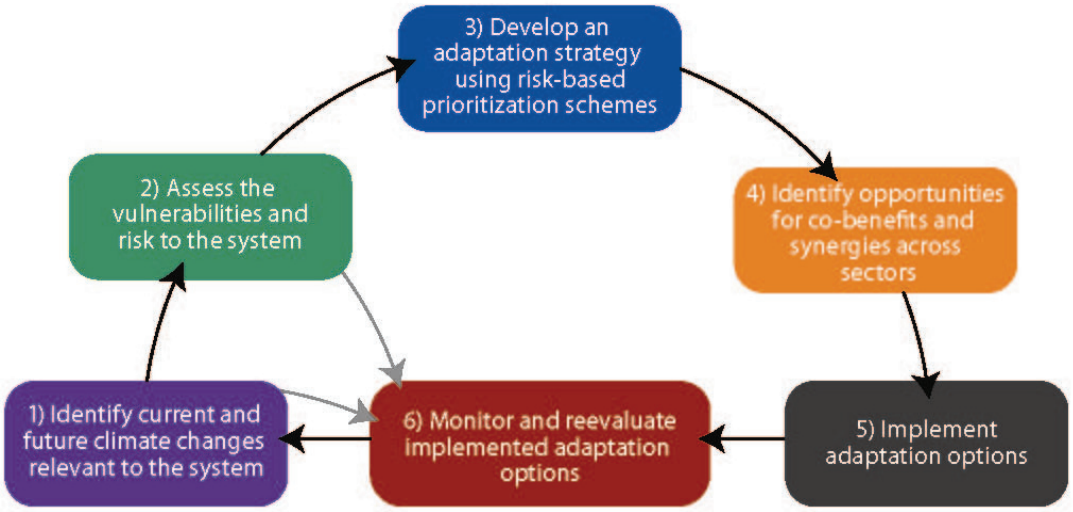

FIGURE S.1 The planning process is envisioned to incorporate the following steps: 1) Identify current and future climate changes relevant to the system; 2) Assess the vulnerabilities and risk to the system; 3) Develop an adaptation strategy using risk-based prioritization schemes; 4) Identify opportunities for co-benefits and synergies across sectors 5) Implement adaptation options 6) Monitor and reevaluate implemented adaptation options.

LINKING ADAPTATION EFFORTS ACROSS THE NATION

Adapting to climate change impacts is and will be an ongoing process. It cannot be thought of simply as a set of actions to be taken right now, although this report does identify some effective short term actions. Adapting calls for the development of a multi-party, public-private national framework for becoming more adaptable over time, including: improving information systems for telling us what is happening, both with climate change impacts and with adaptation experiences; working together across institutional and social boundaries to combine what each party does best; and making it a part of our national culture to continually review the effectiveness of current risk management strategies as we learn more about projected climate changes and impact vulnerabilities.

In this sense, adaptation poses enormous challenges across sectors, jurisdictions, and levels of governance. Successful adaptation to climate change involves a multitude of interested partners and decision-makers: federal, state, and local governments; the private sector, large and small; non-governmental organizations and community groups; and others. The issue is how to create a framework in which all of the parties work together effectively, taking advantage of the strengths of each and assuring that the activities reinforce each other rather than getting in each other's way.

There are three general kinds of alternative approaches for meeting this need:

(1) A strong federal government adaptation program, nested in a body of federal government laws, regulations, and institutions. With this approach, the federal government would take the lead in identifying adaptation actions in the national interest, would mandate appropriate responses while providing resources to support them, set goals for improvements in the nation's adaptive capacities, and assure coordination with other national programs and parties nationwide.
(2) A grassroots-based, bottom-up approach that is very largely self-driven. Adaptation planning and actions would be decentralized. Decisions would be made without significant federal encouragement or coordination, except for programs of the federal agencies themselves. Current adaptation efforts are largely occurring in this manner.
(3) An intermediate approach, where planning and actions are decentralized but the federal government plays a significant role as a catalyst and coordinator at the outset, providing information and technical resources, and continually evaluating needs for additional risk management at a national level.

The panel considered all three approaches, in consultation with social scientists, practitioners, and stakeholders, and found that the intermediate approach was the alternative with the strongest scientific support, because adaption requires place-based approaches in combination with technical and scientific capacity typically developed at the federal level. Based on its review of recent reports and in consultation with stakeholders – the panel also concludes that practitioners and stakeholders favor the intermediate approach. Elaborating on this approach, the panel found that emerging adaptation efforts in the United States are not well-coordinated, and as a result adaptation choices could result in unintended consequences and inconsistent, inefficient investments and outcomes. A national adaptation program is needed, guided by a strategy that focuses on cooperation and collaboration among different levels of government and between government and other key parties.

A national adaptation program itself will need to be adaptive, continually working to increase its own effectiveness. Solutions need to be developed that promote response to changing conditions, informed by ongoing information collection and dissemination, as opposed to a rigid response intended to be permanent. An ongoing assessment of progress (in terms of both outcomes and process) is an integral part to the success of this program. Other critical features of adaptive management involve learning from past and emerging experiences, recognizing the complexity and the inter-related nature of sectoral interests such as water, agriculture, and energy, and understanding the relationships between adaptation activities and the need to limit GHG emissions. Over time, there will be a need to adapt to our own adaptations (and mal-adaptations) as well as to our efforts to limit the magnitude of climate change.

THE INTERNATIONAL CONTEXT FOR AMERICA'S ADAPTATION EFFORTS

Engaging in international dialogues and actions about climate change adaptation could have several benefits for the United States. First, it would help address questions of

global equity as developing countries bear the consequences of climate change resulting from developed countries' emissions. Second, it would open an opportunity for the United States to provide assistance for international humanitarian concerns as part of existing development goals. Third, international engagement could help to address national security issues that will arise from climate change. Fourth, coordination among countries could improve the effectiveness of adaptation efforts by reducing redundant activities or those that act at cross-purposes. Fifth, international engagement offers the United States opportunities to exchange lessons learned from the adaptation experiences. And sixth, international engagement would open expanded global market opportunities for U.S. adaptation technologies, systems, and services.

For these reasons, it is important to integrate climate change adaptation objectives into a range of foreign policy, development assistance, and capacity-building efforts. Overall, devising solutions and making decisions about adaptation options should be placed within a broad international context.

SCIENCE AND TECHNOLOGY ADVANCES NEEDED TO SUPPORT ADAPTATION CHOICES

America's climate choices in adapting to impacts of climate change are limited by the nation's insufficient knowledge of adaptation, tools, and options related specifically to climate change. The report suggests a broad agenda of science and technology needs. Examples range from a better understanding of how adaptation measures may interact with one another and contribute to overall goals for sustainability to research and development related to water use efficiency improvement. Significant improvements in capacities for adaptation analysis and assessment, adaptation option identification and development, and adaptation management and implementation are needed to broaden and strengthen our adaptation choices. Lastly, to better manage and implement adaptation measures, it is important to improve risk analysis techniques and observing systems that measure the magnitude of climate change and the effectiveness of adaptation actions.

As a component of a cross-agency climate change research program, the report suggests that climate change adaptation research and development should be pursued as a shared partnership between the federal government, other levels of government, the private sector and other non-governmental organizations, and the academic research community. Ideally, the program's scope would include studies of autonomous adaptation as well as planned adaptation; it should explicitly include monitoring and learning from ongoing experiences with adaptation in practice to build the knowledge base that can guide future adaptation planning and implementation; and it should expedite advances in adaptation science and technology that have promise in reducing critical national and regional vulnerabilities to climate change impacts in the coming decades.

CONCLUSIONS AND RECOMMENDATIONS

Because impacts of climate change are already being observed in the United States and elsewhere in the world, and because these impacts will increase in severity

even if GHG emissions are reduced substantially in the near term, the United States needs to improve its ability to adapt to impacts of climate change. Concerns about these impacts are generating increasing interest in adaptation and wide-ranging discussions about potential actions that might be taken by individuals, sectors, cities, and states—in some cases without sufficient information about the options that are available.

It is the judgment of this panel that anticipatory climate change adaptation is a highly desirable risk management strategy for the United States. Such a strategy offers potentials to reduce costs of current and future climate change impacts, not only by realizing and supporting adaptation capacities across different levels of government, different sectors of the economy, and different populations and environments, but also by providing resources, coordination, and assistance in assuring that a wide range of distributed actions are mutually supportive. Placed in a larger context of sustainable development, climate change adaptation can contribute to a coherent and efficient national response to climate change challenges that encourages linkages and partnerships across boundaries between different sectors and institutions in our society.

The report presents a number of findings and recommendations (see Box S.1) regarding the need for a national climate change adaptation effort. We emphasize the term "national," rather than "federal," because adaptation is an inherently diverse and disaggregated process. Adaptation options themselves are immensely diverse, and choosing "how" and "when" to adapt from a long list of possible options requires careful evaluation of the socio-economic context, the vulnerability of the sector or region, the resources available, and the scale at which the impact is likely to be felt. There is no one-size-fits-all adaptation option for a particular climate impact across the nation; instead, decision-makers within each level of government, within each economic sector, and within civil society need to weigh the many trade-offs between the available adaptation choices. Most decisions about how and when to implement adaptation options will require local input, and in many (if not most) cases, adaptation projects will occur at the local level. In addition, there is a very limited knowledge base evaluating adaptation measures. For all of these reasons, this report does not recommend specific adaptation measures to be implemented, aside from recommendations for several federal agencies. Rather, examples of adaptation measures that can be considered are discussed and a process for decision-makers to develop and evaluate options for adapting is detailed.

Box S.1
Recommendations

Recommendation 1: All decision-makers—within national, state, tribal, and local agencies and institutions, in the private sector, and nongovernmental organizations (NGOs)—should identify their vulnerabilities to climate change impacts and the short- and longer-term adaptation options that could increase their resilience to current and projected impacts.

Recommendation 2: The executive branch of the federal government should initiate development of a collaborative national adaptation strategy, which might take the form of a national adaptation plan. The strategy (or plan) should be developed in partnership with Congressional leaders, selected high-level representatives of relevant federal

agencies, states, tribes, business and environmental organizations, and local governments and community leaders.

Recommendation 3: Federal, state, and local governments, together with non-governmental partners, should work together to implement a national climate change adaptation program pursuant to the national climate adaptation strategy.

Recommendation 4: As part of an integrated climate change research initiative, the federal government should undertake a significant climate change adaptation research effort designed to provide a reliable foundation for adapting to the impacts of climate change in a larger context of sustainability.

Recommendation 5: Adaptation planning and implementation at the state and tribal level should be initiated regardless of whether the federal government provides the necessary leadership. States and tribes will need to take a significant leadership and coordination role, especially in areas where cities and other local interests have not yet established adaptation efforts. State and tribal governments should develop and implement climate change adaptation plans to guide policy and coordinate with federal, regional, local, and private sector efforts pursuant to the national climate adaptation strategy.

Recommendation 6: Local governments should develop and implement climate change adaptation plans pursuant to the national climate adaptation strategy, in consultation with the broad range of stakeholders in their communities.

Recommendation 7: The private sector, NGOs, and society at large should assess their own vulnerabilities and risks due to climate change and actively engage and partner with the respective governmental adaptation planning efforts to help build the nation's adaptive capacity.

Recommendation 8: The United States should engage as a major player in adaptation activities at the global scale. The United States should support the establishment of a collaborative, sufficiently funded international adaptation program that can be sustained over time.

Recommendation 9: Adaptation objectives should be incorporated into existing U.S. government programs and policies that have international components such as: 1) agriculture, trade policy, and food security; 2) energy policy; 3) transportation policy; 4) international aid and disaster relief; 5) national security; and 6) intellectual property agreements for technology transfer to other countries.

Recommendation 10: Federal, state, and local entities and the private sector should take actions now to address current, known climate change impacts and risks and/or to provide effective risk management at a relatively low cost.

The recommendations begin with a call for all decision-makers – within national, state, tribal and local agencies and institutions, in the private sector, and NGOs – to

identify their vulnerabilities to climate change impacts and the short- and longer-term adaptation options that could increase their resilience to current and projected impacts. They call for the development of a collaborative national adaptation strategy and program, including a significant climate change research effort as part of an integrated climate change research initiative. They suggest adaptation planning and implementation by U.S. states and tribes, local governments, and the private sector, non-governmental institutions, and society at large, in a spirit of national partnership; and they suggest U.S. support for international adaptation programs. Finally, they suggest incorporating adaptation objectives into a number of existing federal government programs.

In conclusion, the process of adapting to likely climate change impacts poses a daunting challenge and the stakes are high. Nevertheless, there are a large number of adaptation options that can be identified and initiated now. In many cases, these options would be relatively inexpensive, low-risk, consistent with sustainability principles, and have multiple ancillary benefits. The recommendations listed above provide a solid framework within which the nation can initiate a national effort to adapt to the impacts of a changing climate. Along with initiating near-term adaptation measures, it is important to consider adaptation to climate change impacts as a process that will require sustained commitment and a durable, yet, flexible strategy for several decades to come.

TABLE S.1 Possible options for adapting to climate change that have been identified in the ocean and coastal sector.

Climate change	**Impact**	**Possible adaptation action**	Federal	State	Local government	Private sector	NGO / Individuals
Accelerated sea level rise and lake level changes	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 into account projections for sea level rise	■	■	■		
		Eliminate public subsidies for future 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.)	■	■	■		
		Adapt infrastructure and dredging to cope with altered water levels	■	■			
		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 mitigate storm damage/erosion)	■	■	■		■
		Encourage alternatives to shoreline "armoring" through "living shorelines"	■	■	■		

		Develop strategic property acquisition programs to discourage development in hazardous areas, encourage relocation, and/or allow for inland migration of intertidal habitats	■	■			
Changes in sea ice	Changes in ecosystem structures	Plan and manage ecosystems to encourage adaptation (see ecosystem options)		■	■		
	Exacerbate coastal erosion; severe storms reach coast	Facilitate inland migration and relocation of coastal communities		■	■	■	■
Increased intensity/ frequency coastal storms	Increased storm surge and flooding; increased wind damage; sudden coastal/shoreline alterations	Strengthen and implement building codes that make existing buildings more resilient to storm damage along the coast		■	■		
		Increase building "free board" above Base Flood Elevation	■	■	■		
		Identify and improve evacuation routes in low-lying areas (e.g. causeways to coastal islands)	■	■	■		
		Improve storm readiness for harbors and marinas		■			■
		Establish marine debris reduction strategy	■	■	■		
		Establish and enforce shoreline setback requirements		■	■		
Ocean acidification	Potential changes in ocean productivity and food web linkages; degradation of corals, shellfish, and other shelled organisms; potential impacts on coastal infrastructure (i.e. construction materials)	Reduce CO_2 emissions	■	■	■		■
		Support ocean observation and long-term monitoring programs	■	■			
		Evaluate and manage for ecosystem and infrastructure impacts	■				

Changes in physical and chemical characteristics of marine systems	Changes in salinity; changes in circulation; changes in seawater temperature; changes in salinity and temperature stratification; changes in estuarine structure and processes (e.g. salt wedge migration); changes in ecosystem structure ("invasive", nonnative species), species distributions, population genetics, and life history strategies (including migratory routes for protected and commercially important species); increased frequency and extent of harmful algal blooms and coastal hypoxia events	Establish monitoring and mapping efforts to measure changes in physical, biological, and chemical conditions along the coast	■	■			■
		Utilize approaches that do not endanger species that are harvested or endangered	■	■			■
		Ensure flexibility in management plans to account for changes in species distributions and abundance	■	■			
		Implement early warning/notification systems for shellfish and beach closures, salinity intrusion in coastal rivers (for industry impacts and water resource management, i.e. freshwater intakes), and for unusual events such as hypoxia.	■	■		■	■
Changes in precipitation	Increased runoff and nonpoint source pollution / eutrophication; changes in coastal hydrology and related	Improve nonpoint source pollution prevention programs	■	■			
		Improve stormwater management systems and infrastructure		■	■		
		Improve early warning systems for beach and shellfish closures	■	■	■	■	■

	ecosystem impacts; increase coastal flooding						

Most current adaptation plans represent targeted efforts to address vulnerabilities in a single sector. They often build logically on past programs that have dealt with historically-observed variability and extremes. Table S.1 presents several options for adaptation for the ocean and coastal sector. The panel does not necessarily endorse pursuing these specific options, but presents them as illustrations of potential options to reduce vulnerabilities. Many of these options have not yet been tested and proven effective as adaptation options to climate change, and in most cases their benefits, costs, potentials, and possible limitations have not been carefully analyzed. The relevant entities involved in particular options are shown in the columns on the right. Although adaptation options are typically tailored and evaluated with respect to local conditions, there are roles for federal and state governments, as well as the private sector, non-governmental organizations (NGOs), and individuals.

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Board on Atmospheric Sciences and Climate

Division on Earth and Life Studies

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PANEL ON ADAPTING TO THE IMPACTS OF CLIMATE CHANGE

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

Foreword

America's Climate Choices

Convened by the National Research Council in response to a request from Congress (Public Law 110-161), *America's Climate Choices* is a suite of five coordinated activities designed to study the serious and sweeping issues associated with global climate change, including the science and technology challenges involved, and provide advice on the most effective steps and most promising strategies that can be taken to respond.

The *Committee on America's Climate Choices* is responsible for providing overall direction, coordination, and integration of the America's Climate Choices suite of activities and ensuring that these activities provide well-supported, action-oriented, and useful advice to the nation. The Committee convened a *Summit on America's Climate Choices* on March 30-31, 2009 to help frame the study, provide an opportunity for high-level participation and input on key issues, and hear about relevant work carried out by others. The Committee is also charged with writing a final report that builds on four panel reports and other sources to answer the following four overarching questions:

- What short-term actions can be taken to respond effectively to climate change?
- What promising long-term strategies, investments, and opportunities could be pursued to respond to climate change?
- What are the major scientific and technological advances needed to better understand and respond to climate change?
- What are the major impediments (e.g., practical, institutional, economic, ethical, intergenerational, etc.) to responding effectively to climate change, and what can be done to overcome these impediments?

The *Panel on Limiting the Magnitude of Future Climate Change* was charged to describe, analyze, and assess strategies for reducing the net future human influence on climate, including both technology and policy options. The panel's report focuses on actions to reduce domestic greenhouse gas emissions and other human drivers of climate change, such as changes in land use, but also considers the international dimensions of climate stabilization.

The *Panel on Adapting to the Impacts of Climate Change* was charged to describe, analyze, and assess actions and strategies to reduce vulnerability, increase adaptive capacity, improve resiliency, and promote successful adaptation to climate change in different regions, sectors, systems, and populations. The panel's report draws on a wide range of sources and case studies to identify lessons learned from past experiences, promising current approaches, and potential new directions.

The *Panel on Advancing the Science of Climate Change* was charged to provide a concise overview of past, present, and future climate change, including its causes and its impacts, then recommend steps to advance our current understanding, including new observations, research

programs, next-generation models, and the physical and human assets needed to support these and other activities. The panel's report focuses on the scientific advances needed both to improve our understanding of the intergrated human-climate system and to devise more effective responses to climate change.

The *Panel on Informing Effective Decisions and Actions Related to Climate Change* was charged to describe and assess different activities, products, strategies, and tools for informing decision makers about climate change and helping them plan and execute effective, integrated responses. The panel's report describes the different types of climate change-related decisions and actions being taken at various levels and in different sectors and regions; and it develops a framework, tools, and practical advice for ensuring that the best available technical knowledge about climate change is used to inform these decisions and actions.

America's Climate Choices builds on an extensive foundation of previous and ongoing work, including current and past National Research Council reports, assessments from other national and international organizations, the current scientific literature, climate action plans by various entities, and other sources. More than a dozen boards and standing committees of the National Research Council were involved in developing and organizing the study, and many additional groups and individuals provided additional input during the study process. Outside viewpoints and perspectives were also obtained via public events and workshops (including the *Summit*), invited presentations at committee and panel meetings, and comments and questions received through the study website http://americasclimatechoices.org.

Collectively, the *America's Climate Choices* suite of activities involve more than 90 volunteers from a range of communities including academia, various levels of government, business and industry, other nongovernmental organizations, and the international community. Study participants were charged to write consensus reports that provide broad, action-oriented, and authoritative analyses to inform and guide responses to climate change across the nation. Responsibility for the final content of each report rests solely with the authoring panel and the National Research Council. However, the development of each report included input from and interactions with members of all five study groups; the membership of each group is listed in Appendix A.

Preface

This report presents the findings of the Committee on Adapting to the Impacts of Climate Change, one of four concurrent panel efforts within the America's Climate Choices Committee study. It was our assignment to identify the opportunities and challenges associated with adaptation, to identify and evaluate the available options and lessons learned within the United States and elsewhere, and to make recommendations regarding U.S. adaptation efforts.

Adapting to climate change is a relatively new topic for U.S. citizens, who have only recently become fully aware of the implications of changes in the Earth system that will result from having more heat trapped in the oceans and the atmosphere. In recent years, some states, cities, and sectors have begun to make plans to adapt to current and anticipated changes in the climate system. Some "early adopters" have focused primarily on limiting greenhouse gases (GHGs). Others, however, are also addressing ways to limit impacts of the anticipated changes, recognizing that regardless of efforts to limit emissions, adaptation is required now and will become even more important in the coming decades. Although planning for adaptation is still in its infancy, there is a groundswell of interest in moving forward quickly to avoid future impacts of climate change.

Advising the nation on how to prepare for the impacts of climate change is especially daunting in a country with so much geographic and economic diversity and so many private and public sector decision-makers. The challenges associated with multiple regions, sectors, scales and timeframes have made this a difficult assignment, and in the end, our panel has concluded that is not possible to provide a list of actions to be taken now to adapt in each region and sector. As has been noted by many researchers and practitioners, adaptation is fundamentally implemented at local and regional levels and needs to consider the socio-economic and political factors. Priorities regarding "what to do" need to be set in decision contexts relative to other important priorities faced by society and resource managers. Vulnerability associated with climate change is based on underlying social and ecological stresses, and these stresses tend to vary dramatically from place to place. Degrees of vulnerability are not directly connected to wealth, but certainly a lack of financial capacity is highly correlated with a reduced number of options for adaptation. In this report, our panel emphasizes that adaptation decisions need to be made in the context of promoting long-term sustainability objectives, including social, economic and ecological welfare rather than focusing only on the short-term outcomes that may be more politically and economically expedient.

Despite this place-based framework, our panel shares the perspective that adaptation needs to be addressed in a coordinated way and that there is a need to involve the federal government in this coordination. Further, there is a need to acknowledge the implications of our adaptation and GHG-reduction decisions on national security, and to be prepared for the potential impacts of decisions taken by other countries.

This assignment has been both challenging and exhilarating for other reasons as well. Although dozens of new publications on adaptation have emerged during the year that we have worked on this effort, on balance there is very little published literature about the effectiveness of alternative approaches to adaptation to impacts of climate change, and in particular very few

estimates of cost that are useful in the context of the wide variety of U.S. decision processes. The exhilarating part of this effort has been the opportunity to meld a variety of kinds of knowledge into a truly integrated document that benefits from a balance between social and physical science and practical experience.

We were aided in our efforts by the support of truly exceptional National Research Council staff. Our project director, Claudia Mengelt, did a heroic job at maintaining forward momentum and managing this intensive effort. She was unceasingly energetic, professional, and optimistic, in spite of relatively severe time limitations and a large committee of talented but very independent-minded members. Claudia was ably assisted in her work by Amanda Purcell, who impeccably handled the logistics; Michael Craghan, who developed the matrix format and did much of the citation development; and Kara Laney, who assisted with our research in multiple ways. We also want to acknowledge the highly professional stewardship provided by the study director, Ian Kraucunas, and the BASC board director, Chris Elfring, who engaged often with our committee to provide sound advice, particularly about coordination with the other committee and panel findings. We depended heavily on the U.S. Global Change Research Program report, *The Impacts of Climate Change on the United States,* and are grateful to those who helped to produce it and shared their findings with us first-hand. The *Impacts* report informed our conclusions about what climate impacts we need to be prepared for. Many international and national climate and adaptation experts shared their expertise with us in person, by phone, and through documents they provided. Their input was invaluable and used liberally in the case studies and findings of this report.

Our committee is grateful for the opportunity to work together at this important moment in history, when climate change science and policy are intersecting for the first time as part of a major national agenda. We are humbled by the size of this task and the magnitude of the known and unknown challenges that lie ahead, especially on the ambitious time schedule for the America's Climate Choices reports.

Katharine Jacobs, Chair through January 3, 2010, and *Tom Wilbanks*, Chair
Panel on Adapting to the Impacts of Climate Change

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

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