28 Reducing Risks Through Adaptation Actions

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28 Reducing Risks Through Adaptation Actions

Seawall surrounding Kivalina, Alaska

Key Message 1

Adaptation Implementation Is Increasing

Adaptation planning and implementation activities are occurring across the United States in the public, private, and nonprofit sectors. Since the Third National Climate Assessment, implementation has increased but is not yet commonplace.

Key Message 2

Climate Change Outpaces Adaptation Planning

Successful adaptation has been hindered by the assumption that climate conditions are and will be similar to those in the past. Incorporating information on current and future climate conditions into design guidelines, standards, policies, and practices would reduce risk and adverse impacts.

Key Message 3

Adaptation Entails Iterative Risk Management

Adaptation entails a continuing risk management process; it does not have an end point. With this approach, individuals and organizations of all types assess risks and vulnerabilities from climate and other drivers of change (such as economic, environmental, and societal), take actions to reduce those risks, and learn over time.

Key Message 4

Benefits of Proactive Adaptation Exceed Costs

Proactive adaptation initiatives—including changes to policies, business operations, capital investments, and other steps—yield benefits in excess of their costs in the near term, as well as over the long term. Evaluating adaptation strategies involves consideration of equity, justice, cultural heritage, the environment, health, and national security.

Key Message 5

New Approaches Can Further Reduce Risk

Integrating climate considerations into existing organizational and sectoral policies and practices provides adaptation benefits. Further reduction of the risks from climate change can be achieved by new approaches that create conditions for altering regulatory and policy environments, cultural and community resources, economic and financial systems, technology applications, and ecosystems.

Executive Summary

Across the United States, many regions and sectors are already experiencing the direct effects of climate change. For these communities, climate impacts—from extreme storms made worse by sea level rise, to longer-lasting and more extreme heat waves, to increased numbers of wildfires and floods—are an immediate threat, not a far-off possibility. Because these impacts are expected to increase over time, communities throughout the United States face the challenge not only of reducing greenhouse gas emissions, but also of adapting to current and future climate change to help mitigate climate risks.

Adaptation takes place at many levels—national and regional but mainly local—as governments, businesses, communities, and individuals respond to today's altered climate conditions and prepare for future change based on the specific climate impacts relevant to their geography and vulnerability. Adaptation has five general stages: awareness, assessment, planning, implementation, and monitoring and evaluation. These phases naturally build on one another, though they are often not executed sequentially and the terminology may vary. The Third National Climate Assessment (released in 2014) found the first three phases underway throughout the United States but limited in terms of on-the-ground implementation. Since then, the scale and scope of adaptation implementation have increased, but in general, adaptation implementation is not yet commonplace.

One important aspect of adaptation is the ability to anticipate future climate impacts and plan accordingly. Public- and private-sector decision-makers have traditionally made plans assuming that the current and future climate in their location will resemble that of the recent past. This assumption is no longer reliably true. Increasingly, planners, builders, engineers, architects, contractors, developers, and other individuals are recognizing the need to take current and projected climate conditions into account in their decisions about the location and design of buildings and infrastructure, engineering standards, insurance rates, property values, land-use plans, disaster response preparations, supply chains, and cropland and forest management.

In anticipating and planning for climate change, decision-makers practice a form of risk assessment known as iterative risk management. Iterative risk management emphasizes that the process of anticipating and responding to climate change does not constitute a single set of judgments at any point in time; rather, it is an ongoing cycle of assessment, action, reassessment, learning, and response. In the adaptation context, public- and private-sector actors manage climate risk using three types of actions: reducing exposure, reducing sensitivity, and increasing adaptive capacity.

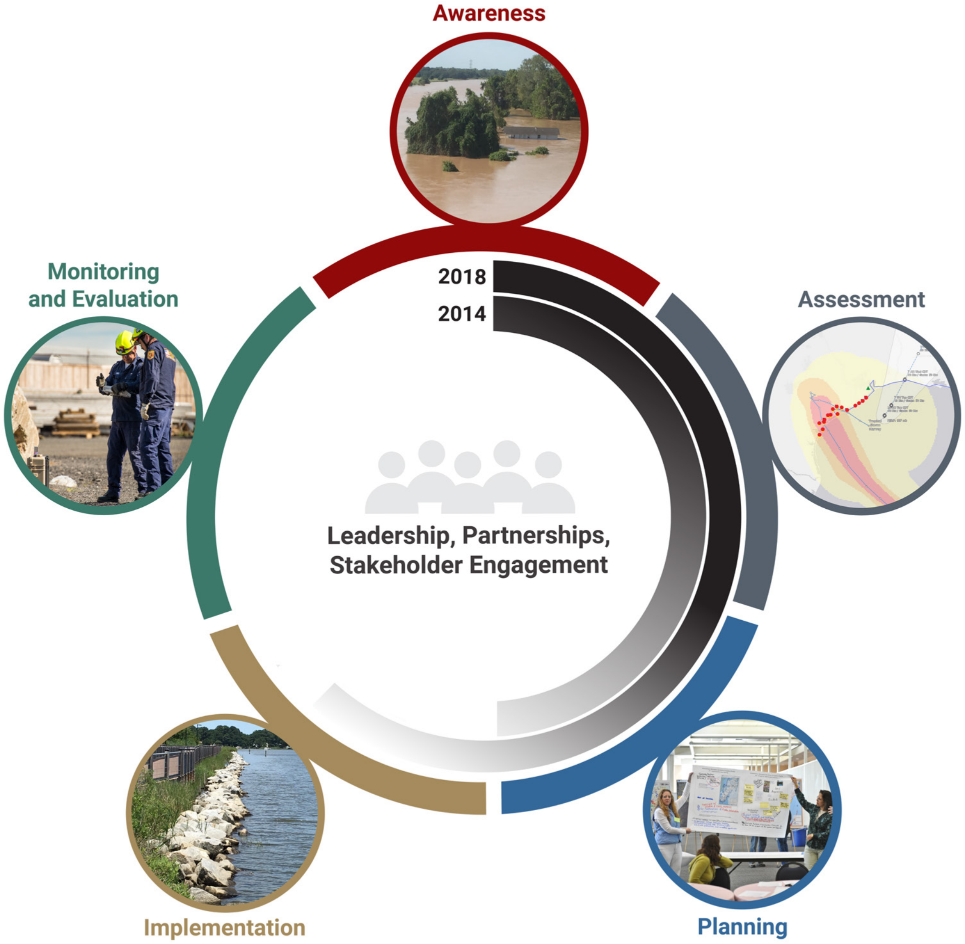
Climate risk management includes some attributes and tactics that are familiar to most businesses and local governments, since these organizations already commonly manage or design for a variety of weather-related risks, including coastal and inland storms, heat waves, water availability threats, droughts, and floods. However, successful adaptation also requires the often unfamiliar challenge of using information on current and future climate, rather than past climate, which can prove difficult for those lacking experience with climate change datasets and concepts. In addition, many professional practices and guidelines, as well as legal requirements, still call for the use of data based on past climate. Finally, factors such as access to resources, culture, governance, and available information can affect not only the risk faced by different populations but also the best ways to reduce their risks.

Achieving the benefits of adaptation can require up-front investments to achieve longer-term savings, engaging with differing stakeholder interests and values, and planning in the face of uncertainty. But adaptation also presents challenges, including difficulties in obtaining the necessary funds, insufficient information and relevant expertise, and jurisdictional mismatches.

In general, adaptation can generate significant benefits in excess of its costs. Benefit–cost analysis can help guide organizations toward actions that most efficiently reduce risks, in particular those that, if not addressed, could prove extremely costly in the future. Beyond those attributes explicitly measured by benefit–cost analysis, effective adaptation can also enhance social welfare in many ways that can be difficult to quantify and that people will value differently, including improving economic opportunity, health, equity, security, education, social connectivity, and sense of place, as well as safeguarding cultural resources and practices and environmental quality.

A significant portion of climate risk can be addressed by mainstreaming; that is, integrating climate adaptation into existing organizational and sectoral investments, policies, and practices, such as planning, budgeting, policy development, and operations and maintenance. Mainstreaming of climate adaptation into existing decision processes has already begun in many areas, such as financial risk reporting, capital investment planning, engineering standards, military planning, and disaster risk management. Further reduction of the risks from climate change, in particular those that arise from futures with high levels of greenhouse gas emissions, calls for new approaches that create conditions for altering regulatory and policy environments, cultural and community resources, economic and financial systems, technology applications, and ecosystems.

Five Adaptation Stages and Progress



The figure illustrates the adaptation iterative risk management process. The gray arced lines compare the current status of implementing this process with the status reported by the Third National Climate Assessment in 2014. Darker color indicates more activity. *From Figure 18.1* (*Source: adapted from National Research Council, 2010.*[1] *Used with permission from the National Academies Press, ©2010, National Academy of Sciences*).

Introduction

Many regions and sectors across the United States already experience significant impacts from climate change effects, and many of these effects are projected to increase. By the middle of this century, annual losses in the United States due to climate change could reach hundreds of billions of dollars (Ch. 29: Mitigation).[2]

Adaptation refers to actions taken at the individual, local, regional, and national levels to reduce risks from even today's changed climate conditions and to prepare for impacts from additional changes projected for the future.[3,4,5,6]

Adaptation is a form of risk management. Risk is sometimes defined as the likelihood of an event's occurrence multiplied by a measure of its consequences for human and natural systems. But because the probabilities and consequences of climate change threats are often not known with precision, and because different people often value the same consequences differently, it is useful to define risk more broadly as "the potential for adverse consequences when something of value is at stake, and the outcome is uncertain."[7] Risk arises from the combination of exposure to climate hazards, sensitivity to those hazards, and adaptive capacity. Adaptation can, however, provide significant societal benefits, reducing by more than half the cost of climate impacts in some sectors (Ch. 29: Mitigation).[8]

Adaptation involves managing both short- and long-term risks. Many important climate-influenced effects—storm intensity, sea level, frequency of heat waves—have already changed due to past greenhouse gas (GHG) emissions and will continue to change in the decades ahead.[3,4] Because several GHGs, in particular carbon dioxide, reside in the atmosphere for decades or longer, many climate-influenced effects are projected to continue changing through 2050, even if GHG emissions were to stop immediately. Thus, climate risk management requires adaptation for the next several decades, independent of the extent of GHG emission reductions. After 2050, the magnitude of changes, and thus the demands on adaptation, begins to depend strongly on the scale of GHG emissions reduction today and over the coming decades.[4,9]

Individuals, business entities, governments, and civil society as a whole can take adaptation actions at many different scales. Some of these are changes to business operations, adjustments to natural and cultural resource management strategies, targeted capital investments across diverse sectors, and changes to land use and other policies. Adaptation actions can yield beneficial short-term and/or longer-term outcomes in excess of their costs, based on economic returns, ecological benefits, and broader concepts of social welfare and security. Moreover, many strategies can provide multiple benefits, resulting in long-term cost savings. For example, restoring wetlands can provide valuable habitat for fish and wildlife as well as flood protection to nearby communities,[10] and conserving mangrove ecosystems can protect coastal communities from damaging storms[11] as well as help to store carbon.[12]

People are not uniformly vulnerable to climate change. Access to resources, culture, governance, and information affects the risks faced by different populations and partly determines the best ways to reduce their risks.[13] Achieving the benefits of adaptation can require up-front investments to achieve longer-term savings, engaging with differing stakeholder interests and values, and planning in the face of uncertainty.

Integrating climate risk management into existing design, planning, and operations workflows (or mainstreaming), in contrast to adding novel decision processes for climate adaptation alone, can provide many adaptation benefits.[14,15,16] Additional climate risk reduction, particularly under the most severe longer-term climate change projections, emphasizes the need for more and more significant changes to regulatory and policy environments at all scales, to cultural and community resource planning, to economic and financial systems, to technology applications, and to ecosystems.

Key Message 1

Adaptation Implementation Is Increasing

Adaptation planning and implementation activities are occurring across the United States in the public, private, and nonprofit sectors. Since the Third National Climate Assessment, implementation has increased but is not yet commonplace.

Adaptation has five general stages: 1) awareness, 2) assessment, 3) planning, 4) implementation, and 5) monitoring and evaluation, as shown in Figure 28.1,[17,18] although these are also known by other terms (see, for example, the U.S. Climate Resilience Toolkit at https://toolkit.climate.gov/ and the University of Notre Dame's Collaboratory for Adaptation to Climate Change at http://gain.nd.edu). Adaptation is an ongoing process in which organizations and individuals repeatedly cycle through the process shown in Figure 28.1, though specific adaptation efforts can follow different routes through these stages (e.g., California Emergency Planning Agency and California Natural Resources Agency 2012[19]).

The Third National Climate Assessment (NCA3) found that the first three stages were underway throughout the United States but with limited on-the-ground implementation.[18] Since then, the scale and scope of adaptation implementation have increased, including by federal, state, tribal, and local agencies (see Vogel et al. 2017, Halofsky et al. 2015, Leggett 2015, Ray and Grannis 2015, Wentz 2017, and the many examples of adaptation implementation in this chapter and elsewhere in this report[14,20,21,22,23]). For instance, Miami-Dade County's Capital Improvement Program is addressing hazards related to sea level rise, as is San Francisco's 2015 Seawall Resiliency Project. It remains difficult, however, to tally the extent of adaptation implementation in the United States because there are no common reporting systems, and many actions that reduce climate risk are not labeled as climate adaptation.[14] Enough is known, however, to conclude that adaptation implementation is not uniform nor yet common across the United States.[24]

Adaptation actions in the United States have increased in part due to 1) the growing awareness of climate-related threats and impacts and the risks these pose to business operations and supply chains (Ch. 16: International, KM 1), critical public infrastructure and communities, natural areas and public lands, and ecosystems; 2) the wider recognition that investing in adaptation provides economic and social benefits that exceed the costs; and 3) the increasing number and magnitude of extreme events that have occurred.[14]

Five Adaptation Stages and Progress

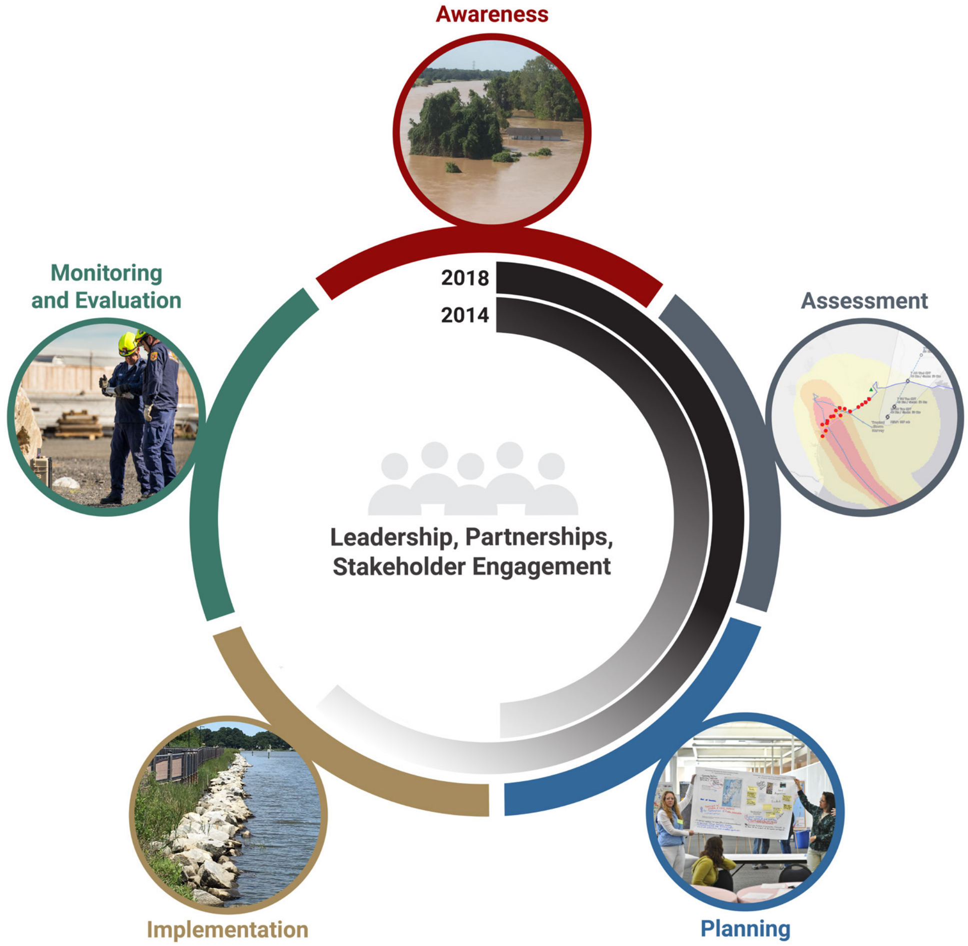


Figure 28.1: The figure illustrates the adaptation iterative risk management process. The gray arced lines compare the current status of implementing this process with the status reported by the Third National Climate Assessment in 2014. Darker color indicates more activity. Source: adapted from National Research Council, 2010.[1] Used with permission from the National Academies Press, ©2010, National Academy of Sciences.

Box 28.1: Department of Housing and Urban Development National Disaster Resilience Competition

Rebuild by Design is a design-driven approach to create innovative local resilience solutions conducted in the aftermath of Superstorm Sandy (http://www.rebuildbydesign.org/about#comp456). It was structured to connect local communities with some of the Nation's leading design firms to identify and solve problems collaboratively and to address vulnerabilities exposed by Superstorm Sandy. The design solutions for the winning proposals ranged in scope and scale from large-scale green infrastructure projects to small-scale residential resilience retrofits. The competition process strengthened the understanding of regional interdependencies, fostering coordination and resilience both at the local level and across the United States. Ultimately, nine projects were selected for implementation and received Community Development Block Grant-Disaster Recovery funding totaling $930 million.

While the level of implementation is now higher than at the time of NCA3, the scale of adaptation implementation for some effects and locations seems incommensurate with the projected scale of climate threats.[25] Communities have focused more on actions that address current variability and recent extreme events than on actions to prepare for future change and emergent threats.[14] Communities are currently focused more on capacity building and on making buildings and other assets less sensitive to climate impacts. Communities have been less focused on reducing exposure through actions such as land-use change (preventing building in high-risk locations) and retreat. Furthermore, many communities' adaptation actions arise and are funded in the context of recovery after an event, rather than taken proactively. Often, such adaptation is not as comprehensive as suggested by best practice guidance, as when adaptation plans address sea level rise but not other climate impacts. Few current adaptation plans seek to exploit synergies among various types of actions, and many plans pay little attention to the costs of actions or their co-benefits. Often explicit attention to evaluation and monitoring is scant or nonexistent.

Managing the Challenge

Public- and private-sector decision-makers have traditionally made plans assuming that the current and future climate will resemble the recent past, an assumption known as stationarity.[27] The assumption is often made explicitly. For instance, in order to design a new dam or to negotiate contracts on future deliveries of hydropower and irrigation water, a water agency might use probability distributions for precipitation and extreme flow events that are based on past or current streamflows in a watershed. In other cases, this assumption is made implicitly, as when a city issues building permits for coastal properties using current flood maps without updating them to reflect projected sea level rise.

Box 28.2: Adaptation Actions by Individuals

Many jurisdictions publish guidance to help individuals take actions to reduce the risks from natural hazards. For example, the city of Chicago suggests residents in flood-prone areas take the following actions **before a flood**:[26]

- Avoid building in a floodplain unless you elevate and reinforce your home.
- Elevate the furnace, water heater, and electric panel if susceptible to flooding.
- Install check valves in sewer traps to prevent floodwater from backing up into your home.
- Construct barriers (levees, beams, sandbags, and floodwalls) to stop floodwater from entering the building.
- Seal walls in basements with waterproofing compounds to avoid seepage.
- Keep an adequate supply of food, candles, and drinking water in case you are trapped inside your home.

Key Message 2

Climate Change Outpaces Adaptation Planning

Successful adaptation has been hindered by the assumption that climate conditions are and will be similar to those in the past. Incorporating information on current and future climate conditions into design guidelines, standards, policies, and practices would reduce risk and adverse impacts.

The assumption that current and future climate threats and impacts will resemble those of the past is no longer reliably true.[4,27,28] Human-caused carbon pollution in the atmosphere has already pushed many climate-influenced effects—such as the frequency, intensity, or duration of some types of storms and extreme heat, drought, and sea level rise—outside the range of recorded recent natural variability.[4,6,28,29] In addition, improved understanding of climate and Earth system science since the advent of systematic data collection in the 19th century has made it clear that the natural variability of the climate system at regional scales is much larger in places than previously understood. For instance, the southwestern United States was much wetter in the 20th century than in most of the preceding thousand years.

The deviation of climate patterns from the recent historical record is expected to grow even larger in the future because of continuing GHG emissions and because the full impact of previous emissions has not yet been felt due to long delays in the climate system's response to those emissions.[3,4,28] Failure to anticipate and adjust to these changes could be costly.

Adjusting to projected climate risk, rather than relying on interpretations of past impacts, has important implications for the location and design of built human infrastructure, engineering standards, insurance rates, property values, land-use plans and planning frameworks or processes, disaster response preparations, and cropland and forest management. In many respects, such climate risk management has attributes familiar to many decision-makers in businesses and communities that commonly manage or design now for a variety of weather-related risks, including storms, heat waves, water availability threats, and floods. Most organizations also manage other short- and longer-term risks and thus have direct experience with preparing for uncertain future conditions over multiple timescales.

However, climate adaptation is also less familiar to some individuals and organizations in that it requires a complete reversal from the near-universal current assumption of an unchanging climate. Many factors make the reversal of this assumption difficult, including unfamiliarity with climate change datasets and concepts; the need to differentiate among the timescales of weather and climate; the challenge of balancing slow-moving, chronic threats and faster, acute ones; the potential and unknown cascading effects of large-scale global changes on local and regional impacts;[30] and a lack of public awareness that some current and future changes in climate will be slow to accumulate but will take even longer in time to reverse, for the changes that are reversible.[31]

The timescales of climate threats also generally do not align with the scales of governance, impeding adaptation progress and often hindering problem identification and solving. Climate change introduces an unfamiliar new source of uncertainty. Where previously an organization may have created plans using a single, well-understood historical record to project a single set of future climate conditions, it now often faces large numbers of climate model projections produced with myriad uncertainties whose local implications may differ significantly across each projection.

Key Message 3

Adaptation Entails Iterative Risk Management

Adaptation entails a continuing risk management process; it does not have an end point. With this approach, individuals and organizations of all types assess risks and vulnerabilities from climate and other drivers of change (such as economic, environmental, and societal), take actions to reduce those risks, and learn over time.

To grapple with these challenges, organizations have adopted a wide variety of approaches that, to varying degrees, address the five general stages of adaptation listed above. Iterative risk management provides a comprehensive framework and set of processes appropriate for addressing adaptation challenges.[32,33,34,35,36] The framework includes steps for anticipating, identifying, evaluating, and prioritizing current and future climate risks and vulnerabilities; for choosing an appropriate allocation of effort and resources toward reducing these risks; and for monitoring and adjusting actions over time while continuing to assess evolving risks and vulnerabilities. Risk communication accompanies each of these steps.[33,37,38,39] Iterative risk management helps address equity, economics, and other measures of social well-being and supports participatory stakeholder processes, which can enhance transparency and foster defensible decision-making, an important component of successful adaptation efforts.[40]

Iterative risk management emphasizes that the process of anticipating and responding to climate change does not constitute a single set of judgments at any point in time; rather, it is an ongoing cycle of assessment, action, reassessment, learning, and response.[41] The process helps manage risks that are well known, as well as those that are deeply uncertain due to data limitations or the irreducible unpredictability of some aspects of current and future climate.[33,42]

Iterative risk management is consistent with most of the elements in the many climate adaptation efforts and approaches currently in use,[42,43] including climate vulnerability assessment, iterative risk assessment, and adaptive management as often practiced by federal and other land and resource management agencies,[44] as well as disaster risk management.[45] Using a comprehensive framework helps highlight commonalities and differences across the approaches used by different jurisdictions and sectors, facilitating comparison and learning among their users. It also situates climate adaptation squarely within the broad range of other risk management activities, such as in the financial, engineering, environmental, health, and national security sectors.[2]

Adaptation Actions to Reduce Risk

Steps to implementing iterative risk management help decision-makers compare and allocate investments and identify incentives for managing and reducing risk. The planning and implementation steps of the generalized adaptation framework combine several types of actions[46,47,48,49] that

1. reduce exposure (for example, reduce the presence of people or assets in locations that could be adversely affected by climate impacts);

2. reduce sensitivity (that is, lower the degree to which a system is adversely affected by exposure to climate impacts); and

3. increase adaptive capacity (that is, raise the ability of human and natural systems to prepare for, adjust to, respond to, and recover from experienced or anticipated climate impacts).

For instance, in the time since Superstorm Sandy, New York City has reduced its potential future flood impacts by relocating a limited number of households out of the most flood-prone areas (reduced exposure), raising the height of some structures above the ground so they suffer less damage from any flooding (reduced sensitivity), and training the officials responsible for revising building codes and land-use policies to use the most up-to-date estimates of flood risk (increased adaptive capacity). Enhancing social cohesion—the degree to which those in a community identify with the community and with each other—is also known to increase adaptive capacity, such as the ability to rebound quickly from disasters.[50] More broadly, while adaptive capacity often refers only to the targets of adaptation action (such as communities, ecosystems, and infrastructure), "the ability of institutions themselves to adjust and evolve will be key to their ability to manage for change."[51]

Different populations also have different exposure, sensitivity, and adaptive capacity based on their access to resources and information, their culture, and the quality of governance. Such consideration can usefully inform decisions about the equitable and just allocation of resources in reducing climate risk.[52]

Adapting to Current Variability and Preparing for Future Change

Adaptation addresses two timescales: 1) adapting to current variability, which in any particular location may now be different than suggested by the historical record of climate observations, and 2) preparing for future change. This distinction is useful because some decision-makers may not appreciate the extent to which climate has already changed and because these timescales often call for different types of adaptation actions.

Miami Beach is currently raising the level of its roads and building seawalls to reduce current flooding due to higher sea levels, but it is also choosing the height of these new structures, anticipating that sea levels will be even higher in the future.[53] New York City and the Federal Emergency Management Agency (FEMA) agreed to develop two sets of flood maps, one showing current risk for the purpose of setting insurance rates and the other for the longer-term purposes of setting building codes and land-use planning.[54] The National Park Service, working with the U.S. Army Corps of Engineers, constructed a revetment, or retaining wall, and living shoreline in 2013 to protect the Cockspur Island Lighthouse in Georgia's Fort Pulaski National Monument against erosion and accelerated sea level rise. The new revetment incorporated a wider base than is currently required, enabling the addition of rock to extend its height as sea levels rise in the future.[55] The State of Louisiana's Coastal Protection and Restoration Authority's 2017 Coastal Master Plan has more than 100 structural and coastal restoration projects designed to provide benefits over the next decade and up to 50 years into the future.[56]

These timescale differences relate to the ubiquitous term resilience[57] that is frequently employed in adaptation planning under a spectrum of meanings.[58,59] These range from the ability to withstand and recover from current shocks and stressors while retaining basic functions under conditions of existing and near-term variability to the ability to transform in desirable ways over time as the magnitude of change increases.[60,61,62,63,64,65] Recognizing these timescales in planning, and communicating expectations for change along those timelines, can also help communities maximize benefits in the near term and identify the most important opportunities for longer-term well-being and resilience.

Organizations are increasingly exploring alternative approaches for replacing the assumption of an unchanging (or stationary) climate in their risk management activities. Vulnerability assessments, a common practice among managers of public lands and natural areas, often evaluate exposure, sensitivity, and adaptive capacity, and provide rankings of the seriousness of various climate risks. Multi-objective approaches, such as structured decision-making,[66] explicitly include multiple measures of well-being in risk assessment and management, often in difficult areas such as protecting cultural resources.[40] Scenarios are used to 1) assess risks over a range of plausible futures that include both changes in socioeconomic trends as well as climate and 2) choose adaptation actions robust over this wide range of futures.[18] California's 2018 Sea-Level Rise Guidance includes probabilistic sea level rise projections and a worst-case scenario, then integrates both with an adaptive pathways approach[67] that encourages robust and flexible plans that can adjust over time if seas rise faster than expected.

Climate risk management requires addressing socioeconomic (for example, future economic, technology, and regulatory conditions) as well as climate uncertainties. Risk management can address such uncertainties, even when they are difficult to characterize with confidence (Ch. 17: Complex Systems, KM 3).[42,68,69,70,71] The water sector is pioneering approaches for incorporating such information in water utility adaptation, including scenarios and other robust decision methods aimed at making successful decisions insensitive to a wide range of uncertainty.[72] Some agencies are beginning to combine both multi-objective and multi-scenario approaches in quantitative tools that identify vulnerabilities and evaluate tradeoffs among adaptive pathways, seeking risk management strategies that perform well across multiple scenarios and measures of well-being.[73,74,75,76] Implementing such methods can require a more complete set of system models than some agencies commonly use in their planning routines, though such tools are becoming increasingly available.[77]

Benefits of Adaptation Can Exceed the Costs

Adaptation can generate significant benefits in excess of its costs. Nationally, estimates of adaptation costs range from tens to hundreds of billions of dollars per year[78,79] but are expected to save several times that over the long run (Ch. 29: Mitigation).[80] The benefits and costs are larger in scenarios with high emissions. Formal benefit analysis is still in its early stages,[81,82] and more research is needed to assess comprehensively the benefits of specific strategies being considered by individuals and organizations.[83] Nonetheless, experience is growing. For instance, the U.S. Department of Housing and Urban Development's National Disaster Resilience Competition required applications to conduct benefit–cost analysis including qualitative and difficult-to-quantify co-benefits, such as economic revitalization and other social benefits.[84]

Key Message 4

Benefits of Proactive Adaptation Exceed Costs

Proactive adaptation initiatives—including changes to policies, business operations, capital investments, and other steps—yield benefits in excess of their costs in the near term, as well as over the long term. Evaluating adaptation strategies involves consideration of equity, justice, cultural heritage, the environment, health, and national security.

To date, there exists considerable guidance on actions in some sectors where benefits exceed costs, though guidance is lacking in many other sectors.[83] Benefit–cost information exists for adaptation responses to storms and rising seas in coastal zones, to riverine and extreme precipitation flooding, and for agriculture at the farm level.[85,86] Some of the actions in these sectors, at least in some locations, appear to have large benefit–cost ratios, both in addressing current variability and in preparing for future change. A benefit–cost ratio greater than 1 suggests a promising project to undertake, because the benefits it generates are greater than its costs. For instance, while sandbags protecting individual houses can, in general, have benefit–cost ratios less than 1, in South Florida sandbags can have a benefit–cost ratio of 20 to 1,[87] and along the Gulf of Mexico coastline, 3 to 1.[88] Along the Gulf of Mexico coastline, levees and seawalls can have benefit–cost ratios ranging from 2.3 to 1.5 to 1 for refineries and petrochemical plants, though the ratios are lower for other assets.[88]

Information on the cost of actions that can achieve common goals is increasing in the water management sector, such as for operational reliability and resilience and environmental protection (Ch. 3: Water) and for responding to extreme heat events (Ch. 14: Human Health). Loss of water services or power during a high heat event, for example, can produce considerable costs that can have cascading effects on other sectors, thereby further driving up costs.[89] The benefits of these adaptive actions against these threats have been studied less because they involve societal and environmental impacts that have been more difficult to quantify, study, and describe systematically.

Some studies quantify large benefits from adaptation actions involving natural systems,[90] such as the decommissioning and restoration of unused forest roads, which decreases erosion and improves fish habitat and water quality; the restoration of beavers to mountain areas, whereby beaver dams improve fish habitat and improve water supply during summer months; and treatment of hazardous fuel to reduce wildland fire risks (Ch. 6: Forests). Some types of storm water management also show large benefits from green infrastructure and other nature-based responses.[91,92] Coastal marsh restoration can sometimes provide benefits of protection against rising sea levels, along with added flood prevention and enhanced biodiversity. One effort involves restoring the river and surrounding lands of the Tidmarsh Wildlife Sanctuary in coastal Massachusetts, a former cranberry farm. The project includes cutting-edge environmental sensors that provide continuous data on marsh restoration, cranberry farm conversion, and climate change impacts and adaptation (see http://www.livingobservatory.org).

Extensive co-benefits may also be available from adaptation, in particular in the ecosystem services and health sectors (Ch. 7: Ecosystems; Ch. 14: Human Health). Coordinated adaptation and GHG mitigation planning may also provide defined co-benefits (Ch. 29: Mitigation, KM 4). For instance, tools are available to help decision-makers locate wind energy systems away from sensitive ecological sites, without incurring additional costs (for example, see the Nature Conservancy's Biodiversity and Wind Siting Mapping Tool at https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/newyork/climate-energy/working-with-wind.xml). Designs that provide green space and the use of cool and green roof technologies in cities can reduce heat-island effects, producing multiple benefits and cost reductions by helping to reduce emissions and air pollution, human health risks, and economic losses due to reduced labor productivity.[93,94]

Broader Measures of Well-Being

Benefit–cost analysis provides one important, but not the sole, means to evaluate alternative adaptation actions. Effective adaptation can provide a broad range of benefits that can be difficult to quantify, including improvements in economic opportunity, human health, equity, national security, education, social connectivity, and sense of place, while safeguarding cultural resources and practices and enhancing general environmental quality. Aggregating all these benefits into a single monetary value is not always the best approach,[8,95] since in many cases a lack of data and uncertainty over climate projections and benefit valuations may make it impossible to give a uniform treatment to different types of benefits, thereby implicitly favoring some over others. More fundamentally, different people may value benefits differently.[96] For instance, climate change can have significant impacts on equity and ecosystems, even though individuals can have strongly divergent views on distributional justice and the intrinsic value of nature and thus on how they value such impacts.

Considering various types of outcomes separately in risk management processes—termed multi-objective or multi-criteria analysis in the relevant literature[97]—can facilitate participatory planning processes. This also enhances the fairness of such processes by making more explicit the impacts of climate change on outcomes to different stakeholders, along with the policy tradeoffs among those outcomes. Pittsburgh's EcoInnovation District, in the city's Uptown and Oakland neighborhoods, employs bottom-up planning to improve the environment, support the needs of existing residents, and expand job growth. Louisiana's Comprehensive Master Plan for a Sustainable Coast has five broad objectives: reduce economic losses from flooding, promote sustainable coastal ecosystems, provide coastal habitats that support commerce and recreation, sustain the region's unique cultural heritage, and contribute to the regional and national economy by promoting a viable working coast.[56] The plan contains actions that advance all five objectives, reflecting a set of tradeoffs broadly acceptable to diverse communities in the face of hazards, including coastal subsidence (sinking land) and sea level rise.[98]

Risk management approaches that consider multiple objectives can include a specific focus on equity, with important implications on the content and process of adaptation planning and action.[99] Poor or marginalized populations often face a higher risk from climate change because they live in areas with higher exposure, are more sensitive to climate impacts, or lack adaptive capacity (Ch. 14: Human Health; Ch. 15: Tribes). Prioritizing adaptation actions for such populations may prove more equitable and lead, for instance, to improved infrastructure in their communities and increased focus on efforts to promote social cohesion and community resilience that can improve their capacity to prepare, respond, and recover from disasters. Equity considerations can also lead to the expanded participation of poor or marginalized populations in adaptation planning efforts. This can enhance the fairness of the process. Moreover, it can positively affect choices regarding the appropriate balance among the resources invested in reducing climate risk and those put toward other social goals, such as employment and education, and inform the most appropriate mix of adaptation actions in each community.[52] Also, at the state and national level, equity considerations for climate adaptation can help allocate an appropriate distribution of resources for adaptation among different local communities.

Key Message 5

New Approaches Can Further Reduce Risk

Integrating climate considerations into existing organizational and sectoral policies and practices provides adaptation benefits. Further reduction of the risks from climate change can be achieved by new approaches that create conditions for altering regulatory and policy environments, cultural and community resources, economic and financial systems, technology applications, and ecosystems.

A significant portion of climate risk can be addressed by mainstreaming; that is, integrating climate adaptation into existing organizational and sectoral investments, policies, and practices. Mainstreaming can make adaptation more likely to succeed because it augments already familiar processes with new information and tools, rather than requiring extensive new structures.[100,101,102] Mainstreaming can also encourage risk management actions that synergistically and coherently address adaptation along with other societal objectives. Mainstreaming can also prompt innovation in existing organizational structures[103,104] by improving their treatment of all types of uncertainty. However, mainstreaming can diminish the visibility of climate adaptation relative to dedicated, stand-alone adaptation approaches[105] and may prove insufficient to address the full range of climate risk, in particular the risks associated with higher GHG concentrations.

Integrating climate adaptation into existing risk management processes requires including climate risks with the other risks an organization regularly assesses and manages; explicitly linking actions that address current climate variability with those needed to address larger, future changes; and linking policies across sectors (for example, energy and water) and jurisdictions. Much adaptation action occurs at the local level, so such linking can be horizontal (that is, among agencies within the same local jurisdiction) and vertical (that is, among different levels of local, state, tribal, and federal governments).[104]

Existing Mainstreaming

Mainstreaming climate adaptation into existing decision processes has begun in many areas, in particular those with well-developed risk management processes such as financial risk reporting, capital investment planning, engineering standards, military planning, and disaster risk management.

A growing number of jurisdictions address climate risk in their land-use, hazard mitigation, capital improvement, and transportation plans. In 2015, FEMA began requiring states to include the projected effects of climate change in their state hazard mitigation plans.[106] A small number of cities explicitly link their coastal plans and their hazard mitigation plans using a common, climate-informed vulnerability analysis to support both types of plans, thereby ensuring that the different city agencies are implementing risk reduction measures—such as land-use measures (reducing exposure), building codes (reducing sensitivity), and warning, evacuation, and recovery measures (increasing adaptive capacity)—that are synergistic and coordinated.[107] The City of Baltimore used climate-informed estimates of increased current and future storm intensity to design its storm water master plan, which includes green space and bio-swales that capture runoff, to improve water quality and reduce flood risk. California requires its water agencies to address climate change in their water management plans. Through the Department of Energy (DOE) Partnership for Energy Sector Climate Resilience, electric utilities across the country are collaborating with DOE to develop resilience planning guidance, conduct climate change vulnerability assessments, and develop and implement cost-effective resilience solutions (Ch. 4: Energy). The National Oceanic and Atmospheric Administration (NOAA), FEMA, and the U.S. Geological Survey are partnering with states to develop guidelines for integrated climate adaptation, land use, and hazard mitigation planning. Federal agencies have also begun implementing climate-smart management approaches for managing their natural resources (Ch. 7: Ecosystems, KM 2).

Private financial markets are increasingly paying attention to climate risk, for instance, by incorporating such risk accounting into their portfolios. In some cases, financial firms and companies perform climate risk accounting as part of a voluntary or mandatory disclosure system. In a recent report to the G20 (Group of Twenty), the Financial Stability Board's Task Force on Climate-Related Financial Disclosures provided a comprehensive framework for such disclosure and recommended that since "climate-related risks are material risks," they should be disclosed in mainstream (public) financial filings.[108,109] Ratings agencies have also begun to incorporate physical climate risk into credit ratings for corporations, infrastructure bonds, and other public-sector projects. Both Moody's and Standard and Poor's acknowledge emerging risks associated with climate change[110,111] and now embed these risks into their credit ratings.[112] In particularly vulnerable areas, such as South Florida, bond ratings are now beginning to reflect such risks.

The engineering community has begun incorporating climate resilience into its design standards by incorporating information about current and future climate threats and impacts[113] and updating existing engineering standards, codes, regulations, and practices—currently based on stationary climate assumptions.[114] The American Society of Civil Engineers (ASCE) recommends that engineers incorporate climate uncertainty, assess the costs of reducing risks, and follow an adaptive management process. Such a process would begin with low-regret strategies that perform well across a range of futures and periodically update as new information becomes available.[113] The ASCE and the States of California and New York have formed committees to develop such standards.[115]

Other sectors of government and industry are also starting to consider climate risk a major systemic risk. In its 2018 Global Risks Report, the World Economic Forum listed the top five environmental risks—including extreme weather events and temperatures and failures of climate change mitigation and adaptation—in terms of both likelihood and the impact on the global economy.[116] The U.S. military now routinely integrates climate risks into its analysis, plans, and programs,[117] with particular attention paid to climate effects on force readiness, military bases, and training ranges (Ch. 16: International, KM 3).[118,119] Naval Station Norfolk, for example, has replaced existing piers with double-decker piers that are elevated by several more feet and thus more resilient to rising sea levels and extreme weather events (Ch. 1: Overview, Figure 1.8).

Overcoming Up-Front Challenges

While yielding benefits, adaptation also presents challenges. These include difficulties obtaining the necessary funds; insufficient information and relevant expertise; jurisdictional mismatches among those responsible for taking adaptation actions and those who benefit from those actions; conflicting interests among relevant parties; and the pressures on agencies and professionals that serve the public to act cautiously, in particular by seeking to follow long-established procedures and experience.

Insufficient funding often hinders adaptation (Ch. 8: Coastal; Ch. 15: Tribes).[120,121,122] At the local level, adaptation planning and assessment have been supported by a mix of local government funds and federal, state, and foundation grants.[121] Full-scale implementation of the proposals resulting from these adaptation planning and assessment activities would require significantly more resources. In principle, the potential for longer-term savings can be used to generate near-term financing for adaptation efforts. But the mechanisms for doing so are not yet widely in place. Underwriters of municipal bonds, the most common means of financing water infrastructure in the United States, are just beginning to incorporate requirements for long-term sustainability under a changing climate as a condition for going to market.[112]

To the extent that climate resilience becomes an expected and required attribute of decisions concerning infrastructure and other long-term investments, as well as an expected part of asset management and life-cycle cost estimates, financing should become more available for cost-effective adaptation actions.[123] Changing social and economic norms could also affect the availability of financing. Once the implications become widely understood, public expectations, professional standards, and due diligence on the part of financers may similarly discourage investing in long-lived infrastructure designed for stationary conditions, as opposed to currently changing and future climate conditions.[124]

Adaptation often increases up-front costs, thus increasing the salience of steps to reduce those costs. Federal, state, and local governments in the United States spend over $400 billion annually on public infrastructure.[125] Estimates of annual adaptation costs range from tens to hundreds of billions of dollars annually.[78] Taking advantage of new infrastructure investments and capital stock turnover provides one particularly favorable opportunity for low-cost, proactive adaptation in both the public and private sectors.[2] Many jurisdictions and businesses possess significant stocks of deteriorating transportation, water, energy, housing, and other infrastructure, which often already lack resilience to current climate and weather events (Ch. 3: Water; Ch. 4: Energy; Ch. 12: Transportation).[3,126,127] The expected turnover of this capital stock creates opportunities for adaptation but also raises challenges, such as equity concerns, if, for example, upgrading the resilience of housing stock makes it unaffordable for lower-income residents.

Flexible design and adaptive planning can also reduce near-term adaptation costs while keeping options open for future resilience.[128] Such options begin with low-regret options, invest in capacity building, and adjust over time to new information. The Fort Pulaski example cited previously included a new coastal protection structure with an adaptive design that can be inexpensively adjusted as the future risk grows larger. The Metropolitan Water District of Southern California uses adaptive management to organize its 25-year Integrated Resource Plan; factored into its near-term investments in local supplies is the expectation that some investments will be expanded and others reduced as climate, demand, regulatory, and other conditions change in the future.[129] However, explicitly signaling that policies will change in the future may impede enforcement, make decision-makers seem indecisive, and make it easier for them to succumb to political pressure from special interests.[130]

Catalysts for Adaptation

Catalytic events, external incentives, community interest, leadership, and outside funding all help spur adaptation planning and implementation. Catalytic events, including disasters caused by extreme storms or droughts, often precipitate or accelerate adaptation action,[131,132] as happened with Superstorm Sandy in 2012, Hurricane Katrina in 2005, and the 2011–2016 drought in California (see, for example, Ch. 25: Southwest).

Internal drivers of adaptation include political leadership and policy entrepreneurs.[103] In addition, a recognition of the challenges posed by climate change and an ability to integrate the problem and potential solutions into existing belief and value structures also provide important catalysts for adaptation.

External incentives include the legal requirements, engineering standards, climate-related financial risk disclosure requirements, and changes in insurance coverage. For instance, some existing laws and regulations provide catalysts for adaptation,[133] typically through procedural planning requirements rather than substantive mandates. At the state and local levels, some laws specifically require the consideration of climate change impacts and adaptation options in planning processes, but these cover only a small subset of jurisdictions and geographic areas in the United States.[134,135,136] At the federal level, few laws explicitly promote adaptation, but many can be interpreted as requiring the consideration of climate change impacts on the ability of a federal agency to comply with various statutory and regulatory mandates.[23,137]

Once begun, successful adaptation often entails sustained networks, financing, the sharing of best practices, and champions, as shown in Box 28.3.

Box 28.3: Common Attributes of Effective Adaptation

Factors that shape or contribute to the successful adoption and implementation of adaptation by public-sector organizations include

- plans written by a professional staff and approved by elected officials;
- community engagement, including the participatory development of plans; the formation of action teams or regional collaborations[138] across jurisdictions, sectors, and scales; and public- and private-sector leaders who champion and support the process;
- adaptation actions that address multiple community goals, not just climate change;
- well-structured implementation, including the identification of parties responsible for each step, explicit timelines, explicit and measurable goals, and explicit provisions and timelines for monitoring and updating the plan; and
- adequate funding for the adaptation actions and for sustained community outreach and deliberation.

(Adapted from Brody and Highfield 2005, Berke et al. 2012, Horney et al. 2012, IPCC 2012, NRC 2009, Cutter et. al. 2012, GAO 2016, Wilhite and Pulwarty 2017, Bassett and Shandas 2010, Berke and Lyles 2013, Lyle and Stevens 2014, Hughes 2015, Highfield and Brody 2012, Mimura et al. 2014[47,60,70,139,140,141,142,143,144,145,146,147,148,149].)

Formal and informal networks of government, nongovernmental organizations, and academic, faith-based, and private-sector parties engaged in developing and implementing adaptation are expanding. These networks support individuals, communities, and organizations as they strive to understand and reduce current and future climate risks. Federal, state, and local agencies; nongovernmental organizations; utilities and industry associations; and private-sector consultants have in recent years developed a wide range of written guidance and online platforms intended to support climate adaptation planning and mainstreaming efforts. While not exhaustive, the list includes the 100 Resilient Cities, the C40 Cities Climate Leadership Group, the Urban Sustainability Directors Network (USDN), and the Water Utility Climate Alliance.

Over the past several years, examples of sustained collaborative partnerships between research and management in support of climate risk management have included NOAA's Regional Integrated Sciences and Assessments (RISA), the U.S. Department of Agriculture's (USDA) Climate Hubs, and the Department of the Interior's (DOI) Climate Adaptation Science Centers (CASCs). These regional climate information networks provide data, tools, forecasts, interpretation, and extension services for agencies and communities to build into integrated services and work together to coordinate stakeholder engagement across multiple sectors as new knowledge emerges.[150,151] Some examples include knowledge platforms, such as the Climate Adaptation Knowledge Exchange (www.cakex.org), the Georgetown Climate Center's Adaptation Clearinghouse (http://www.adaptationclearinghouse.org/), and the U.S. Climate Resilience Toolkit website (toolkit.climate.gov); these platforms include directories of practitioners and inventories of data tools for managing natural and built systems in the face of climate change.

More local, targeted resources, such as Louisiana's Coastal Protection Restoration Authority Master Plan Data Viewer (http://cims.coastal.la.gov/masterplan/), offer detailed information about climate risks and probabilities in specific geographic locations to help planners and communities better anticipate and prepare for climate impacts. Such initiatives and networks enable practitioners to share best practices and evaluate and inform adaptation implementation while empowering communities to advance preparedness and resilience efforts across the United States.

Beyond Incremental Change

Integrating climate risk into existing practices can lead to change that is more than incremental. For instance, it often proves profitable in the near term to build in low-lying areas subject to future extreme flooding[152] rather than in areas with lower future risk. Updated flood maps and risk-adjusted insurance rates would likely lead to different patterns of development.[153] In many cases, however, addressing the full range of future climate change requires substantial changes in organizational practices and procedures, in public- and private-sector institutions, in individual and societal expectations and norms, in capital investment planning, and in laws.[154,155] Decision-makers may wish to take active steps to anticipate and steer change in desired directions and to avoid the unanticipated consequences of ad hoc or crisis-based responses. In some cases, this involves seeking, legitimizing, and accelerating large changes, rather than attempting to retain today's conditions as long as possible.[10,156,157]

Reducing climate risk often requires managing interdependent systems in ways that transcend current jurisdictional and sectoral boundaries (Ch. 4: Energy; Ch. 17: Complex Systems, KM 3). Water, electric power supply, and agriculture often depend critically on one another (see Ch. 17: Complex Systems, KM 1) but are not treated similarly for potential adaptation actions. Effective climate risk management often requires closer coordination among regulatory agencies and, in some cases, may necessitate some restructuring. For instance, the City of Los Angeles's One Water LA program requires multiple city agencies to coordinate on integrated management of the city's water, land-use, and flood control actions.[158] Major reforms can prove difficult and often occur only in response to major system shocks, such as reforms to the Stafford Act after Hurricane Katrina[159,160,161] or the consolidation of many local water agencies in Australia into a small number of large, regional organizations during a decade of severe drought.[162]

Some sectors are already taking actions that go beyond integrating climate risk into current practices. Faced with substantial climate-induced future changes, including new invasive species and shifting ranges, ecosystem managers have already begun to adopt novel approaches, such as assisted migration and wildlife corridors (Ch. 7: Ecosystems, KM 2), and to rethink the goals of conservation management.[163] Many millions of Americans live in coastal areas threatened by sea level rise; in all but the very lowest sea level rise projections, retreat will become an unavoidable option in some areas of the U.S. coastline (Ch. 8: Coastal, KM 1). The Federal Government has already provided resources for the relocation of some communities, such as the Biloxi-Chitimacha-Choctaw tribe from Isle de Jean Charles in Louisiana. But the potential need for millions of people and billions of dollars of coastal infrastructure to be relocated in the future creates challenging legal, financial, and equity issues that have not yet been addressed.

The ability of adaptation to reduce severe climate impacts like these will ultimately depend less on scientific uncertainties and the ability to implement engineering solutions than on perceived loss of culture and identity, in particular identities associated with unique cultural heritage sites and a sense of place (Ch. 8: Coastal; Ch. 15: Tribes, KM 2).[68] Because different regions and groups face different levels of risk and have differing abilities to respond, considerations of equity and justice influence judgments about any limits to adaptation.[52,68]

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Traceable Accounts

Process Description

The scope for this chapter was determined by the Fourth National Climate Assessment (NCA4) Federal Steering Committee, which is made up of representatives from the U.S. Global Change Research Program member agencies. The scope was also informed by research needs identified in the Third National Climate Assessment (NCA3). Authors for this NCA4 chapter were selected to represent a range of public- and private-sector perspectives and experiences relevant to adaptation planning and implementation.

This chapter was developed through technical discussions of relevant evidence and expert deliberation by chapter authors during teleconferences, e-mail exchanges, and a day-long in-person meeting. These discussions were informed by a comprehensive literature review of the evidence base for the current state of adaptation in the United States. The author team obtained input from outside experts in several important areas to supplement its expertise.

Key Message 1

Adaptation Implementation Is Increasing

Adaptation planning and implementation activities are occurring across the United States in the public, private, and nonprofit sectors. Since the Third National Climate Assessment, implementation has increased but is not yet commonplace. (*High Confidence*)

Description of evidence base

There exists extensive documentation in the gray literature of specific adaptation planning and implementation activities underway by local, state, regional, and federal agencies and jurisdictions. The literature also contains reports that attempt to provide an overview of these activities, such as the recent set of case studies in Vogel et. al. (2017).[14] Websites, such as those of the Georgetown Climate Center (http://www.georgetownclimate.org), provide summaries and examples of adaptation activities in the United States. The sectoral and regional chapters in this National Climate Assessment also provide numerous examples of adaptation planning and implementation activities. The literature also offers work that aims to provide surveys of large numbers of adaptation activity, such as Moser et. al. (2018)[121] and Stults and Woodruff (2016).[164]

Major uncertainties

While the amount of adaptation-related activity is clearly increasing, the lack of clear standards and the diverse lexicon used in different sectors make it difficult to systematically compare different adaptation activities at the level of outcomes across sectors and regions of the country. In addition, publicly available adaptation plans may never actually result in implementation. It is thus difficult to provide a quantitative assessment of the increase in adaptation activity other than just counting plans and initiatives. Given the reliance on small-sample surveys, judgments about the distribution of adaptation actions across categories have potentially large errors that are difficult to estimate. In addition, it is difficult to assess the contribution of these activities to concrete outcomes such as risk reduction or current and future improvements to well-being, security, and environmental protection.[130] There also exists little gap analysis that compares any given set of adaptation activities with what might be appropriate according to some normative standard or what might be reasonably achieved. Thus, while adaptation activities are clearly increasing in the United States, scant evidence exists for judging their consequences.

Description of confidence and likelihood

There is *high confidence* that the amount of adaptation activity, in particular implementation activity, is increasing. There is less agreement and evidence regarding the consequences of this activity.

Key Message 2

Climate Change Outpaces Adaptation Planning

Successful adaptation has been hindered by the assumption that climate conditions are and will be similar to those in the past. Incorporating information on current and future climate conditions into design guidelines, standards, policies, and practices would reduce risk and adverse impacts. (*High Confidence*)

Description of evidence base

The assumption that the historical record of events and variability will be the same in the future is called the stationarity assumption[27] and has guided planning for climate and weather events in most places for most of recorded history. The evidence is strong that the stationarity assumption is no longer valid for all impacts and variability in all locations, because climate change is altering both the events and their variability.[3,4,28,165] Regional chapters in this assessment establish the climate variables for which, and the extent to which, non-stationarity has been confirmed around the United States. These chapters also provide extensive documentation of cases in which failure to adapt to current and future climate conditions can cause significant adverse impacts.

Major uncertainties

While significant uncertainties can exist in estimating the extent to which current variability differs from historic observations in any particular location, there is robust evidence that such differences do occur in many locations (see Ch. 18: Northeast; Ch. 19: Southeast; Ch. 20: U.S. Caribbean; Ch. 21: Midwest; Ch. 22: N. Great Plains; Ch. 23: S. Great Plains; Ch. 24: Northwest; Ch. 25: Southwest; Ch. 26: Alaska; and Ch. 27: Hawai‘i & Pacific Islands).[5,6,28,166] However, the development and use of analytic tools, decision-making processes, and application mechanisms built on the assumption of non-stationarity lag significantly behind the growing realization that stationarity is no longer a sound basis for long-range planning.[167] Nonetheless, new techniques are being applied.[10,72,168] For example, scenario planning can provide alternative actions that can be carried out if different impacts occur.[70,71]

Description of confidence and likelihood

There is *high confidence* that most organizations’ planning is currently based on extensions from the record of local climate conditions.[169]

Key Message 3

Adaptation Entails Iterative Risk Management

Adaptation entails a continuing risk management process; it does not have an end point. With this approach, individuals and organizations of all types assess risks and vulnerabilities from climate and other drivers of change (such as economic, environmental, and societal), take actions to reduce those risks, and learn over time. (*High Confidence*)

Description of evidence base

Evidence from a large body of literature and observations of experience support the judgment that iterative risk management is a useful framework (e.g., National Research Council 2009, America's Climate Choices 2010, Kunreuther et al. 2012[142,170,171]). The literature also suggests its conceptual similarity with other methods that use different names.

Major uncertainties

The literature and practice of climate change are undergoing a process of maturation and convergence. The process began with many organizations and sectors developing their own approaches and terminology in response to climate risks, meaning that a wide variety of approaches still exist in the field. We believe that the field will progress and converge on the most effective approaches, including iterative risk management. But this convergence is still in process, and the outcome remains uncertain.

Description of confidence and likelihood

Significant agreement and strong evidence provide *high confidence* that adaptation is a form of iterative risk management and that this is an appropriate framework for understanding, addressing, and communicating climate-related risks.[33]

Key Message 4

Benefits of Proactive Adaptation Exceed Costs

Proactive adaptation initiatives—including changes to policies, business operations, capital investments, and other steps—yield benefits in excess of their costs in the near term, as well as over the long term (*medium confidence*). Evaluating adaptation strategies involves consideration of equity, justice, cultural heritage, the environment, health, and national security (*high confidence*).

Description of evidence base

Both limited field applications and literature reviews highlight adaptation co-benefits, including those associated with equity considerations.[83] Near-term benefits are assessed from observations of adaptation results, as well as from comparisons to similar situations without such responses; longer-term benefits are generally assessed from projections.

Major uncertainties

Benefits are based on understanding the relevant systems so that one can compare similar cases and construct counterfactuals. Such understanding is excellent for many engineered systems (for example, how a storm drain performs under various rainfall scenarios) but is less robust for many biological systems. Benefit–cost ratios can have large uncertainties associated with estimates of costs, the projection of benefits, and the economic valuation of benefits. In addition, because expected differences in benefit–cost ratios are sufficiently large and the number of current examples is sufficiently low, there are large uncertainties in applying results from one case to another.

Description of confidence and likelihood

There is suggestive evidence that provides *medium confidence* that many proactive adaptation actions offer significant benefits that exceed their costs. However, because of a small sample size and insufficient evaluation, it is in general hard to know the extent to which this is true in any particular case. There is strong agreement that evaluating adaptation involves consideration of a wide range of measures of social well-being.

Key Message 5

New Approaches Can Further Reduce Risk

Integrating climate considerations into existing organizational and sectoral policies and practices provides adaptation benefits. Further reduction of the risks from climate change can be achieved by new approaches that create conditions for altering regulatory and policy environments, cultural and community resources, economic and financial systems, technology applications, and ecosystems. (*High Confidence*)

Description of evidence base

There is significant agreement, but only case study evidence, that effective adaptation can be realized by mainstreaming.[100,101,102] Significant evidence exists regarding the scale of longer-term adaptation required in some climate futures based on modeling studies. Significant agreement, but less direct evidence, exists on the scale of organizational and other changes needed to implement these adaptation actions.

Major uncertainties

It is not well understood how community acceptance of needed adaptations develops. This presents both a barrier to the implementation of adaptation measures and an opportunity for additional research into ways to close this gap in understanding. Additionally, a need exists to clarify the co-benefits of addressing multiple threats and opportunities. Effective adaptation also depends on networks of collaboration among researchers and practitioners and the long-term support of monitoring networks. The sustainability of both types of networks is a major uncertainty. Their effectiveness is both an uncertainty and major research need.

Description of confidence and likelihood

There is significant agreement that provides *high confidence*, in at least some cases, that both 1) mainstreaming climate information into existing risk management and 2) creating enabling environments and institutions to improve adaptation capacity, implementation, and evaluation reduce risk, produce co-benefits across communities and sectors, and help secure economic investments into the future.

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