28. Adaptation

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Key Messages

1. **Substantial adaptation planning is occurring in the public and private sectors and at all levels of government, however, few measures have been implemented and those that have appear to be incremental changes.**
2. **Barriers to implementation of adaptation action include lack of funding, policy and legal impediments, and difficulty in anticipating climate-related changes at local scales.**
3. **There is no "one-size fits all" adaptation, but there are similarities in approaches across regions and sectors. Sharing best practices, learning by doing, and iterative and collaborative processes including stakeholder involvement, can help support progress.**
4. **Climate change adaptation actions often fulfill other societal goals, such as sustainable development, disaster risk reduction, or improvements in quality of life, and can therefore be incorporated into existing decision-making processes.**
5. **Vulnerability to climate change is exacerbated by other stresses such as pollution and habitat fragmentation. Adaptation to multiple stresses requires assessment of the composite threats as well as tradeoffs amongst costs, benefits, and risks of available options.**
6. **The effectiveness of climate change adaptation has seldom been evaluated, because actions have only recently been initiated, and comprehensive evaluation metrics do not yet exist.**

Introduction

Over the past few years, the focus on climate change has transitioned from the question "Is it changing?" to the equally important question: "Can society manage the unavoidable changes and avoid the unmanageable?" (Bierbaum et al. 2007; SEGCC 2007) Research indicates that both mitigation and adaptation are needed in order to minimize the damages from climate change and to adapt to the pace and ultimate magnitude of the changes that occur (McMullen and Jabbour 2009; ORNL 2012a, 2012b; Skaggs et al. 2012).

The study and application of adaptation to climate change is nascent compared to the many analyses of policies and practices to reduce emissions. Uncertainties about future socioeconomic conditions as well as future changes in climate can make it difficult to make some adaptation decisions now. However, the pace and magnitude of projected change emphasize the need for being prepared for a wide range and intensity of climate impacts. Because of the influence of human activities, the past climate is no longer a sufficient indicator of future conditions. Planning and managing based on the climate of the last century means that tolerances of some infrastructure and species will be exceeded (Kareiva 2008; ORNL 2012b; USGS 2012b). For example, building codes and landscaping ordinances will likely need to be updated not only for energy efficiency, but also to conserve water supplies, protect against disease vectors, reduce susceptibility to heat stress, and improve protection against extreme events (ORNL 2012b; Solecki and Rosenzweig 2012). Although there is uncertainty about future conditions, research indicates that actions can still be taken (Kerr 2011; NRC 2010a). Given that some uncertainties about how climate will change cannot be eliminated, development, refinement, and deployment of tools and approaches that enable decision-making and increase flexibility and robustness to climate change are still needed (PCAST 2011; Wilby and Dessai 2010; Ch. 2 Our Changing Climate).

Climate change affects human health, natural ecosystems, built environments, and existing social, institutional, and legal arrangements. Adaptation considerations include local, state, regional, national, and international jurisdictional issues. For example, in managing water supplies to adapt to a changing climate, the implications of international arrangements need to be considered in the context of managing the Great Lakes, the Columbia River, and the Colorado River to deal with drought (Garfin et al. 2012; Winkler 2012). Both "bottom up" community planning and "top down" national strategies may help regions deal with impacts such as increases in electrical brownouts, heat stress, floods, and wildfires. Such a mix of approaches will require cross-boundary coordination at multiple levels as operational agencies integrate adaptation planning into their programs.

Adaptation actions can be implemented reactively, after changes in climate occur, or proactively, to prepare for projected changes (NRC 2010a). Proactively preparing for climate change can reduce the harm from climate change, such as more intense extreme events, shifting zones for agricultural crops, and rising sea levels, while also facilitating a more rapid and efficient response to changes as they happen. This chapter highlights efforts at the federal, regional, state, tribal, and local levels, as well as initiatives in the corporate and non-governmental sectors to build adaptive capacity and resilience towards climate change. A map of illustrative adaptation

activities and four-detailed case examples that highlight ongoing adaptation activity across the U.S. are provided in Sections II and IV of this chapter.

Adaptation Key Terms Definition Box*

Adapt, Adaptation: Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

Adaptive Capacity: The potential of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.

Mitigation: Technological change and substitutions that reduce resource inputs and emissions per unit of output. Although several social, economic, and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks

Multiple Stressors: Stress that originates from different sources that affect natural, managed, and socioeconomic systems and can cause impacts that are compounded and sometimes unexpected. For example, when economic or market stress combines with drought to negatively impact farmers.

Resilience: A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

Risk: A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

*Definitions adapted from (IPCC 2007; NRC 2007, 2010a).

Adaptation Activities in the United States

1. Federal Government

Federal leadership, guidance, information, and support are vital to planning for and implementing adaptation actions at all scales and in all affected sectors of society (C2ES 2012b; CEQ 2011; NRC 2010a). Several new federal climate adaptation initiatives and strategies have been developed in recent years, including:

- Executive Order (EO) 13514 requiring federal agencies to develop recommendations for strengthening policies and programs to adapt to the impacts of climate change;

- The creation of an Interagency Climate Change Adaptation Task Force (ICCATF) that led to the development of national principles for adaptation and is leading to crosscutting and government-wide adaptation policies;

- The development of three crosscutting national adaptation strategies focused on integrating federal, and often state, local and tribal, efforts on adaptation in key sectors: the National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate, the National Fish, Wildlife and Plants Climate Adaptation Strategy (forthcoming); and a priority objective on resilience and adaptation in the National Ocean Policy Implementation Plan (forthcoming);

- A new decadal National Global Change Research Plan (2012–2021) that identifies the goals of improving basic science, informing decisions, improving assessments, and communicating and educating (USGCRP 2012); and

- The development of several interagency and agency-specific groups focused on adaptation, including a "community of practice" for federal agencies that are developing and implementing adaptation plans, an Adaptation Science Workgroup inside the U.S. Global Change Research Program (USGCRP); and several agency specific climate change and adaptation task forces.

Federal agencies are all required to plan for adaptation. Actions include coordinated efforts at the White House, regional and cross-sector efforts, agency-specific adaptation plans, as well as support for local-level adaptation planning and action.

Table 28.1: Examples of Individual Federal Agency Actions to Promote, Implement, and Support Adaptation at Multiple Scales*

Agency	Component	Action	Description
All Federal Agencies		Developing Adaptation Plans as part of their annual Strategic Sustainability Performance Plans	The 2012 Strategic Sustainability Performance Plans for 50+ Federal agencies contain specific sections on adaptation. Agencies are required to evaluate climate risks and vulnerabilities to manage both short- and long-term effects on missions and operations.
Department of Health and Human Services (HHS)	Centers for Disease Control and Prevention (CDC)	Climate-Ready States and Cities Initiative	Through their first climate change cooperative agreements in 2010, CDC awarded $5.25 million to ten state and local health departments to assess risks and develop programs to address climate change related challenges.
Department of Agriculture (USDA)		Integrating climate change objectives into plans and networks.	USDA is using existing networks such as the Cooperative Extension Service, the Natural Resource Conservation Districts, and the Forest Service's Climate Change Resource Center to provide climate services to rural and agricultural stakeholders.
USDA	Forest Service	Developed a *National Roadmap for Responding to Climate Change* and a *Guidebook for Developing Adaptation Options*, among many resources	The *National Roadmap* was developed in 2010 to identify short- and long-term actions to reduce climate change risks to the nation's forests and grasslands. The *Guidebook* (developed in 2011) builds on this previous work and provides science-based strategic and tactical approaches to adaptation. Other resources are available on the Forest Service website.
Department of Commerce (DOC)	NOAA	Supports research teams and local communities on adaptation-related issues and develops tools and resources.	Supports research teams such as Regional Integrated Sciences and Assessments (RISAs), which are partnerships with universities working collaboratively to inform resource management, planning, and policy. Established six regional climate centers (RCCs) to better assess and deliver regionally-focused climate science and services. Developed the Digital Coast partnership.
Department of Defense (DOD)	U.S. Army Corps of Engineers (USACE)	Developed a USACE climate change adaptation plan, and continues to update guidance for incorporating sea level rise into projects.	The Civil Works Program of the USACE released its climate change adaptation plan in 2011. The goal of the plan is to reduce vulnerabilities and improve resilience of water resources infrastructure impacted by climate change. The plan includes guidance on "Incorporating Sea-Level Change Considerations in Civil Works Programs."
DOD	Department of the Navy	Developed road maps for adaptation in the Arctic and across the globe.	The Navy Arctic Roadmap (November 2009) promotes maritime security and naval readiness in a changing Arctic. The Climate Change Roadmap (May 2010) examines broader issues of climate change impacts on Navy missions and capabilities globally.
Department of Energy (DOE)		Develop higher spatial and temporal scales of climate projections, and is working to integrate adaptation and climate considerations into integrated assessments.	Develops community-based, high-resolution (temporal and spatial) models for climate projections and integrated assessment models that-increasingly reflect multi-sectoral processes and interactions, multiple stressors, coupled impacts, and adaptation potential.

Department of the Interior (DOI)	**Fish and Wildlife Services (FWS)**	**Developed a FWS climate change strategic plan. Established a network of Landscape Conservation Cooperatives.**	**The FWS climate change strategy plan (September, 2010) establishes a basic framework to help ensure the sustainability of fish, wildlife, plants, and habitats in the face of climate change. In 2009 DOI established a network of 22 Landscape Conservation Cooperatives (LCCs) designed to promote shared conservation goals, approaches, and resource management planning and implementation across the United States, including Alaska, Hawaii, and the Caribbean.**
DOI	U.S. Geological Survey (USGS)	Established a network of Climate Science Centers (CSCs).	DOI operates a National Climate Change and Wildlife Center and eight regional CSCs, which provide scientific information and tools that land, water, wildlife, and cultural resource managers and other stakeholders can apply to anticipate, monitor, and adapt to climate change.
Department of Transportation (DOT)	Federal Highway Administration (FHWA)	Developed Risk Assessment Model for transportation decisions.	DOT worked with five local and state-level transportation authorities to develop a conceptual Risk Assessment Model to help transportation decision makers identify which assets are: a) most exposed to the threats from climate change and/or b) associated with the most serious potential consequences of climate change threats. Completed in November 2011.
DOT		Comprehensive study of climate risks to transportation infrastructure in the Gulf Coast Region, followed by an in-depth study for Mobile, Alabama.	Phase 1 of the study (completed in 2008) assessed the vulnerability of transportation infrastructure to climate change impacts across the Gulf region. Phase 2, expected to be completed in 2013, is focused on Mobile, Alabama. The effort is designed to develop transferable tools that will help transportation planners across the country.
Environmental Protection Agency (EPA)		Developed Climate Ready Estuaries and Climate Ready Water Utilities Working Group. Developed a draft EPA water program adaptation strategy.	The Climate Ready Estuaries program works with coastal managers to: 1) assess vulnerabilities; 2) develop and implement adaptation strategies; 3) engage stakeholders; and 4) share lessons learned. The Climate Ready Water Utilities initiative provides resources and tools to assist the water sector in adapting to climate change. The Draft *National Water Program Strategy: Response to Climate Change* addresses climate change impacts on water resources and EPA's water programs.
National Aeronautics and Space Administration (NASA)		NASA's Climate Adaptation Science Investigator (CASI) Workgroup was initiated to engage NASA climate modelers, scientists, engineers, and NASA institutional stewards to explore climate impacts and adaptation strategies for NASA research centers and facilities.	The team leverages internal NASA technical capabilities and resources to build capacity to address climate change, and has engaged in a range of activities since CASI's launch in the summer of 2010, including: 1) downscaling NASA center and facility-specific climate hazard information and projections; 2) conducting climate research customized to the needs of each location; 3) building inventories of each facility and center's existing climate and impact data and research activities; and 4) coleading adaptation workshops

*This list contains selected examples of agency work on adaptation and should not be considered all-inclusive. Material provided in table is derived from Agency websites.

Federal agencies can be particularly helpful in facilitating climate adaptation by:

- Fostering the stewardship of public resources and maintenance of federal facilities, services, and operations such as defense, emergency management, transportation, and ecosystem conservation in the face of a changing climate (NPS 2010; NRC 2010a; Rosenzweig and Horton 2012; Smith et al. 2010);

- Providing usable information and financial support for adaptation (NRC 2010a; Smith et al. 2010);

- Facilitating the dissemination of best practices and supporting a clearinghouse to share data, resources, and lessons learned (National Climate Adaptation Summit Committee 2010; NRC 2010a);

- Dealing with and anticipating impacts that cross geopolitical boundaries and supporting flexible regulatory frameworks (NRC 2010a; Smith et al. 2010);

- Ensuring the establishment of federal policies that allow for "flexible" adaptation efforts and do not lead to unintended consequences (OTA 1993; Smith et al. 2010); and

- Building public awareness (CEQ 2010).

2. States

States have become important actors in national climate-related efforts, often through the creation of policies and programs that incentivize or inhibit adaptation at other governance scales (Goulder and Stavins 2011; Morsch and Bartlett 2011); through regulation; and by serving as laboratories for innovation (Feldman and Kahan 2007; Moser 2009). Although many of these actions are not specifically designed to address climate change, they often include climate adaptation components.

Many of the climate-specific adaptation actions at the state-level focus on planning. As of winter, 2012, at least 15 states have completed climate adaptation plans; four states are in the process of writing their plans; and seven states have made recommendations to create state-wide adaptation plans (C2ES (Center for Climate and Energy Solutions) 2012a).

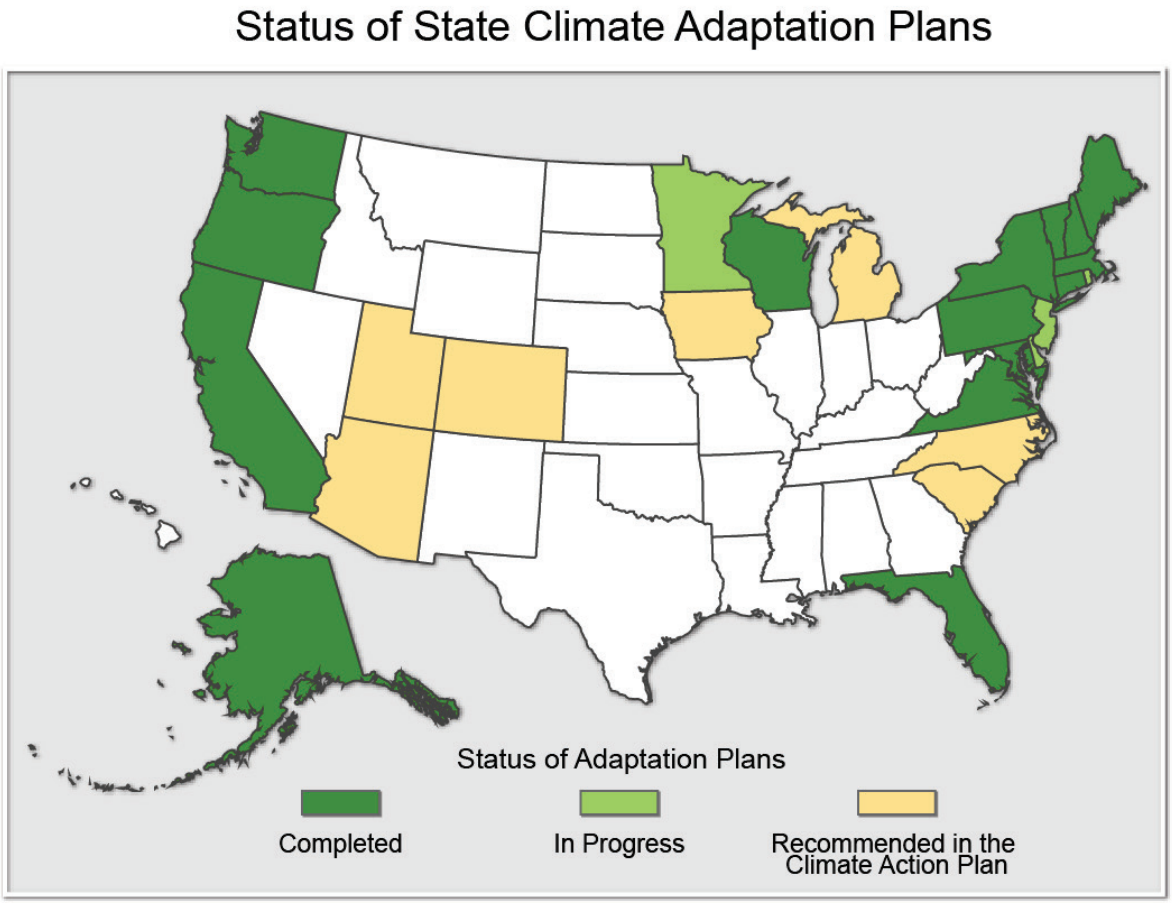

Figure 28.1 Status of State Climate Adaptation Plans. (Figure redrawn from C2ES (Center for Climate and Energy Solutions) 2012a)

In addition to formal adaptation plans, numerous states have created sector-specific plans that consider long-term climate change. For example, at least 16 states have biodiversity conservation plans that focus on preparing for long-term changes in climate (AFWA 2011). In addition to planning, some states have created legislation and/or programs that are either directly or indirectly targeted at reducing state-relevant climate vulnerabilities.

Table 28.2: Examples of State-Level Adaptation Activities

State	Adaptation Action
Alaska	Alaska Climate Change Impact Mitigation Program provides funds for hazard impact assessments to evaluate climate change related impacts, such as coastal erosion and thawing permafrost (Immediate Action Workgroup 2008).
California	Building standards mandating energy and water efficiency savings, advancing both adaptation and mitigation; State Adaptation Plan calls for 20% reduction in per capita water use (EPA 2012).
Florida	Law supporting low water use landscaping techniques (Salkin 2009).

Hawaii	Water code that calls for integrated management, preservation, and enhancement of natural systems (Marra 2012).
Kentucky	*Action Plan to Respond to Climate Change in Kentucky: A Strategy of Resilience,* which identifies six goals to protect ecosystems and species in a changing climate.
Louisiana	*Comprehensive Master Plan for a Sustainable Coast 2012* includes both protection and restoration activities addressing land loss from sea level rise, subsidence, and other factors over the next 50 years (State of Louisiana 2012).
Maine	The *Maine Sand Dune Rules* require that structures greater than 2,500 square feet be set back at a distance that is calculated based on the future shoreline position and considering two feet of sea level rise over the next 100 years (Grannis 2011).
Maryland	Passed *Living Shorelines Act* to reduce hardened shorelines throughout the state (Feifel 2010); passed "Building Resilience to Climate Change" policy which establishes practices and procedures related to facility siting and design, new land investments, habitat restoration, government operations, research and monitoring, resource planning, and advocacy.
Montana	Maintains a statewide climate change website to help stakeholders access relevant and timely climate information, tools, and resources.
New Mexico	The Active Water Resource Management program allows for temporary water rights changes in real time in case of drought (Propst 2012).
Pennsylvania	Enacted polices to encourage the use of green infrastructure and ecosystem based approaches for managing storm water and flooding (Solecki and Rosenzweig 2012).
Rhode Island	Requires public agencies considering land-use applications to accommodate a 3 to 5 foot rate of sea level rise.
Texas	Coordinated response to drought through National Integrated Drought Information System (NIDIS); RISAs (Southern Climate Impacts Planning Program [SCIPP], Climate Assessment for the Southwest [CLIMAS]); and state and private sector partners through anticipatory planning and preparedness (for example, implemented in 2011 drought) (SCIPP 2012).

3. Tribal Governments

Tribal governments have been particularly active in assessing and preparing for the impacts of climate change. For example:

- Adaptation planning in Point Hope, Alaska, emphasizes strategies for community health (Brubaker et al. 2010).

- In Newtok, Alaska, the village council is leading a land-acquisition and planning effort to relocate the community, because climate-induced coastal erosion has destroyed essential infrastructure, making the current village site unsafe (Bronen 2011).

- The Tulalip Tribes in Washington State are using traditional knowledge gleaned from elders, stories, and songs and combining this knowledge with downscaled climate data to inform decision-making (Simmonds 2011). Also in Washington State, the Swinomish Indian Tribal Community integrated climate change into decision-making in major

sectors of the Swinomish Community, such as education, fisheries, social services, and human health (Lamb 2011).

- The Haudenosaunee Confederacy in the northeastern U.S. is addressing climate impacts by preserving a native food base through seed-banking (Simmonds 2011; Ch. 12: Tribal Lands and Resources).

4. Local and Regional Governments

Most adaptation efforts to date have occurred at local and regional levels (Anguelovski and Carmin 2011; Gregg et al. 2011; Rabe 2009; Wallis 2011; Wheeler 2008). Primary mechanisms that local governments are using to prepare for climate change include: land-use planning; provisions to protect infrastructure and ecosystems; regulations related to the design and construction of buildings, roads, and bridges; and emergency preparation, response, and recovery (Dierwechter 2010; Grannis 2011; Kahn 2009; Selin and VanDeveer 2007; Solecki and Rosenzweig 2012).

According to a recent survey of 298 U.S. local governments, 59% indicated they are engaged in some form of adaptation planning (Carmin et al. 2012). Local adaptation planning and actions are unfolding in municipalities of varying sizes and in diverse geographical areas. Communities such as Keene, New Hampshire; New York City, New York; King County, Washington; and Chicago, Illinois are vanguards in the creation of climate adaptation strategies (Binder et al. 2010; NRC 2010a; Solecki and Rosenzweig 2012). In addition to local government action, regional agencies and regional aggregations of governments are becoming significant climate adaptation actors (USGS 2012b; Wallis 2011).

Table 28.3: Examples of Local and Regional Adaptation Activities

Local or Regional Government	Adaptation Action
Satellite Beach, FL	Collaboration with the Indian River Lagoon National Estuary Program led to the incorporation of sea level rise projections and policies into the city's comprehensive growth management plan (Gregg et al. 2011).
Portland, OR	Updated the city code to require on-site stormwater management for new development, and re-development and provides a downspout disconnection program to help promote onsite stormwater management (EPA 2010a) .
Lewes, DE	In partnership with Delaware Sea Grant, ICLEI-Local Governments for Sustainability, the University of Delaware, and state and regional partners, the City of Lewes undertook a stakeholder-driven process to understand how climate adaptation could be integrated into the hazard mitigation planning process. Recommendations for integration and operational changes were adopted by the City Council and are currently being implemented (City of Lewes 2011).
Groton, CT	Partnered with federal, state, regional, local, non-governmental, and academic partners through the EPA's Climate Ready Estuaries program to assess vulnerability to and devise solutions for sea level rise (Stults 2011).
San Diego Bay, CA	Five municipalities partnered with the port, the airport, and more than 30 organizations with direct interests in the future of the Bay to develop the San Diego Bay Sea Level Rise Adaptation Strategy. The strategy identified key vulnerabilities for the Bay and adaptation

	actions that can be taken by individual agencies, as well as through regional collaboration (Solecki and Rosenzweig 2012).
Chicago, IL	Through a number of development projects, the city has added 55 acres of permeable surfaces since 2008 and has more than four million square feet of green roofs planned or completed (City of Chicago 2008).
King County, WA	Created King County Flood Control District in 2007 to address increased impacts from flooding through activities such as maintaining and repairing levees and revetments, acquiring repetitive loss properties, and improving countywide flood warnings (Wolf 2009).
New York City, NY	Through a partnership with the Federal Emergency Management Agency (FEMA), the city is updating FEMA Flood Insurance Rate Maps based on more precise elevation data. The new maps will help stakeholders better understand their current and future flood risks and allow the city to more effectively plan for climate change (City of New York 2012).
Southeast Florida Climate Compact	Joint commitment among Broward, Miami-Dade, Palm Beach, and Monroe Counties to partner in reducing greenhouse gas emissions and adapting to climate impacts (Southeast Florida Compact Counties 2011).
Phoenix, AZ; Boston, MA; Philadelphia, PA; and New York, NY	Climate change impacts are being integrated into public health planning and implementation activities that include creating more community cooling centers, neighborhood watch programs, and reductions in the urban heat island effect (EPA 2011; Horton et al. 2012; White-Newsome et al. 2011).
Boulder, CO; New York, NY; and Seattle, WA	Water utilities in these communities are using climate information to assess vulnerability and inform decision-making (EPA 2010a).
City of Philadelphia	In 2006, the Philadelphia Water Department began a program to develop a green stormwater infrastructure, intended to convert more than one-third of the city's impervious land cover to "Greened Acres:" green facilities, green streets, green open spaces, green homes, etc., along with stream corridor restoration and preservation (ORNL 2012b).

There is no one-size-fits-all adaptation solution to the challenges of adapting to the impacts of climate change, as solutions will differ depending on context and scale as well as on local culture and internal capacity (National Climate Adaptation Summit Committee 2010; Solecki and Rosenzweig 2012).

5. Non-governmental and Private Sector

Many non-governmental entities have been significant actors in the national effort to prepare for climate change by providing assistance that includes planning guidance, implementation tools, contextualized climate information, best practice exchange, and help with bridging the science-policy divide to a wide-array of stakeholders (Agrawal 2008; Guston et al. 2000; Van Aalst et al. 2008). The Nature Conservancy, for example, established the Canyonlands Research Center in Monticello, Utah to facilitate research and develop conservation applications for resource issues under the multi-stresses of climate change and land-use demands in the Colorado Plateau region (Vose et al. 2012).

Table 28.4: Examples of Non-governmental Adaptation Efforts and Services

Types of Adaptation Efforts and Services	**Examples of Organizations Providing Services***
Adaptation planning assistance, including creation of guides, tools, and templates	Center for Climate Strategies, ICLEI-Local Governments for Sustainability, International Institute for Sustainable Development, The Nature Conservancy, World Resources Institute, World Wildlife Fund, Natural Resources Defense Council
Networking and best practice exchange	C40 Cities Climate Leadership Group, Adaptation Network, Center for Clean Air Policy, ICLEI-Local Governments for Sustainability, Institute for Sustainable Communities, Urban Sustainability Directors Network, World Business Council for Sustainable Development
Climate information providers	Union of Concerned Scientists, Urban Climate Change Research Network, Stockholm Environment Institute, U.S. Center
Policy, legal, and institutional support	Center for Climate and Energy Solutions (formerly Pew Center on Global Climate Change), Georgetown Climate Center
Aggregation of adaptation-pertinent information	Carbon Disclosure Project, Climate Adaptation Knowledge Exchange, Georgetown Climate Center

*This list contains examples of non-governmental organizations providing the identified services and should not be considered all-inclusive or a validation of actions claimed by the organizations.

With regard to the private sector, evidence from organizations such as the Carbon Disclosure Project (CDP) and the Securities and Exchange Commission's (SEC) Climate Change 10-K Disclosure indicate that a growing number of companies are beginning to actively address risks from climate change (CDP 2011). The World Business Council for Sustainable Development (WBCSD) and the Center for Climate and Energy Solutions (C2ES) have identified three types of risks driving private sector adaptation efforts, including risks to core operations, the value chain, and broader changes in the economy and infrastructure (PWC 2010; Sussman and Freed 2008; WBCSD 2009).

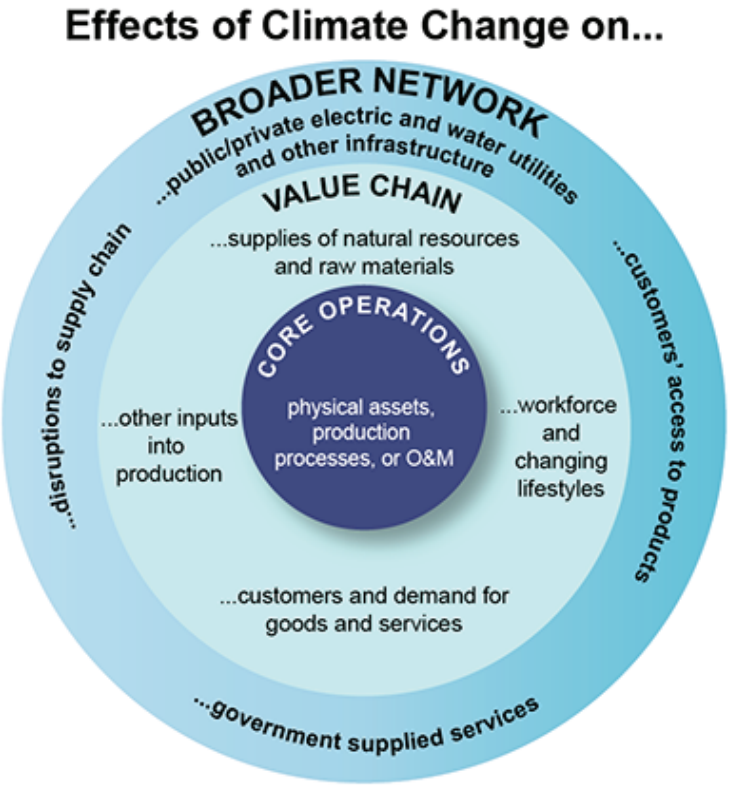

Figure 28.2. "Risk Disk" depicts three pathways by which risks posed by climate change can affect business, such as through core operations, value chain, and broader changes in the economy and infrastructure. (Sussman and Freed 2008).

This analysis is supported by responses to the 2011 CDP, and suggests that companies are concerned about how changes in the climate will impact issues such as feedstock, water supply and quality, infrastructure, core operations, supply chain, and customers' ability to use (and their need for) services (CDP 2011).

Table 28.5: Examples of Private Sector Actions to Adapt to Climate Risks Based on Responses to Carbon Disclosure Project

Company	Sector	Climate Risk	Examples of Actions Undertaken
Coca-Cola Company	Consumer Staples	Changes in physical climate parameters; Changes in other climate-related developments	Coca-Cola is working around the world to replenish the water used in finished beverages by participating in locally relevant water projects that support communities and nature. Since 2005, the Coca-Cola system has engaged in more than 320 projects in 86 countries. The range of community projects includes watershed protection; expanding community drinking water and sanitation access; water for productive use, such as agricultural water efficiency; and education and awareness programs. (http://www.thecoca-colacompany.com/citizenship/conservation_partnership.html)
ConAgra Foods, Inc.	Consumer Staples	Company experienced weather-related sourcing challenges, such as delayed tomato harvesting due to unseasonably cool weather, and difficulty sourcing other vegetables due to above normal precipitation.	As part of its business continuity planning, ConAgra Foods has analyzed its supply risk to develop strategic partnerships with suppliers, minimize sole-sourced ingredients, and identify alternate suppliers and contract manufacturers to minimize production disruptions in the instance of an unexpected disruption in supply. (http://company.conagrafoods.com/phoenix.zhtml?c=202310&p=Policies_Environment)
Constellation Brands	Consumer Staples	Changes in physical climate parameters; Changes in other climate-related developments	Constellation has already taken adaptation actions, particularly in California where water availability is an issue, to manage or adapt to these risks. Constellation is working with numerous organizations to help fund industry-based research to determine potential climate change impacts on vineyard production.
Munich Re	Reinsurance	Changes in regulation; Changes in physical climate parameters; Changes in other climate-related developments	Since 2007, a Group-wide climate change Strategy covering all aspects of climate change – e.g. weather-related impact, regulatory impact, litigation and health risks, etc. – has supported their core Corporate Strategy. The Strategy is based on five pillars: mitigation, adaptation, research, in-house carbon dioxide (CO_2) reduction, and advocacy. (http://www.munichre.com/en/group/focus/climate_change/default.aspx)
Pacific Gas and Electric Company (PG&E)	Utilities	Changes in regulation; changes in physical climate parameters; Changes in other climate-related developments	PG&E's adaptation strategies for potential increased electricity demand include expanded customer energy efficiency and demand response programs and improvements to its electric grid. PG&E is proactively tracking and evaluating the potential impacts of reductions to Sierra Nevada snowpack on its hydroelectric system, and has developed adaptation strategies to minimize them. Strategies include maintaining higher winter carryover reservoir storage levels, reducing conveyance flows in canals and flumes in response to an increased portion of precipitation falling as rain, and reducing discretionary reservoir water releases during the late spring and summer. PG&E is also working with both the US Geological Survey (USGS) and the California Department of Water Resources to begin using the USGS Precipitation-Runoff Modeling System (PRMS) watershed model, to help manage reservoirs on watersheds experiencing mountain snowpack loss. (http://www.pge.com/about/environment/commitment/)
SC Johnson & Son, Inc.	Household Products	Changes in physical climate parameters	SC Johnson is adjusting to the various physical risks that climate change imposes through a diversified supplier and global manufacturing base. In March 2009, SC Johnson announced a broad ingredient communication program. SC Johnson assesses risks along each ingredient's supply chain to ensure that the company is sourcing from a geographically diverse supplier base. In addition to evaluating product ingredients, SC Johnson has also diversified its operations around the world, allowing it to maintain business continuity in the face of a regional climate-related disruption.

			(http://www.scjohnson.com/en/commitment/overview.aspx)
Spectra Energy, Inc.	Energy	Changes in regulation; Changes in physical climate parameters; Changes in other climate-related developments	Spectra Energy uses a corporate-wide risk analysis framework to ensure the oversight and management of its four major risk categories: financial, strategic, operational, and legal risks. Physical risks posed by climate change fall within these categories and the company uses risk management committees to ensure that all material risks are identified, evaluated and managed prior to financial approvals of major projects. (http://www.spectraenergy.com/Sustainability/)

Some companies are taking action to not only avoid risk, but to explore potential opportunities embodied in a changing climate, such as developing new products and services; developing or expanding existing consulting services; expanding into new operational territories; extending growing seasons and hours of operation; and responding to increased demand for existing products and services (Agrawala et al. 2011; CDP 2011; Dell and Pasteris 2010; Oxfam America 2009; PWC 2010).

I. Adaptation Process

General patterns in adaptation processes are only beginning to emerge, with similarities discernible across sectors, systems, and scales (Anguelovski and Carmin 2011; Dell and Pasteris 2010; Means et al. 2010).

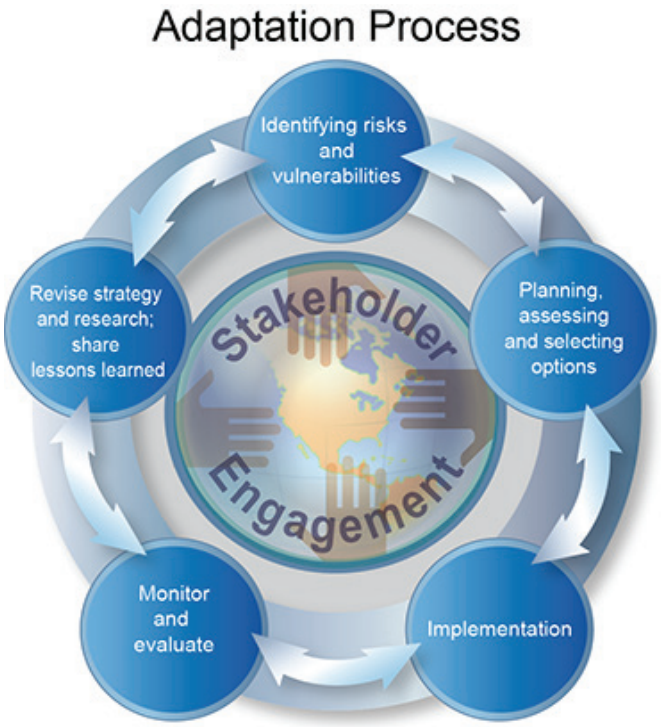

Figure 28.3: Generalized Adaptation Process adapted from America's Climate Choices

This is not a step-wise or linear process; various stages can be occurring simultaneously, in a different order, or be omitted completely.

Identifying and Understanding Risk, Vulnerabilities, and Opportunities

Most adaptation action is currently in the initial phase, with many actors focusing on identifying the relevant climate risks and conducting current and future risk and vulnerability assessments of their assets and resources (Carmin et al. 2012; Glick et al. 2011; Ingram et al. 2012; Lackstrom et al. 2012; NRC 2010a; Rowland et al. 2011; USGS 2012b; West et al. 2009). In 2011, only 13% of 298 U.S. municipalities surveyed, had completed vulnerability or risk assessments – but 42% expected to complete an assessment in the future (Carmin et al. 2012). At least 21 state fish and wildlife agencies have undertaken climate vulnerability assessments or recently completed an assessment of a particular species, habitat, or both (AFWA 2011). Multiple qualitative and quantitative methods are used to understand climate vulnerability and risk, including case studies and analogue analyses, scenario analyses, sensitivity analyses, monitoring of key species, and peer information sharing (Barrett et al. 2011; EPA 2011; Ford et al. 2010; Füssel 2007a; Heller and Zavaleta 2009; Hulme and Dessai 2008; NPS 2010; Pahl-Wostl et al. 2011; USGS 2012b).

Planning, Assessing, and Selecting Options

Once risks and vulnerabilities are understood, the next stage typically involves identifying, evaluating, and selecting options for response to existing and future changes in the climate (NPS 2010). Decision-support planning methods and associated tools help to identify flexible and context-relevant adaptation activities for implementation (Means et al. 2010; NRC 2010a). Participatory approaches support the integration of stakeholder perspectives and context-specific information into decision-making (Fazey et al. 2009; Few et al. 2007; Preston et al. 2011; Smit and Wandel 2006), often by having community members and governing institutions work collectively to define the problem and design adaptation strategies that are robust while being sensitive to stakeholder values (Brunner 2005; Preston et al. 2011; Stern et al. 1996; World Bank 2008). Moreover, regional collaboration has emerged as an effective strategy for defining common approaches to reducing potential threats, selecting metrics for tracking purposes, and creating governance structures to help navigate political challenges (ICLEI 2012; Moser and Ekstrom 2010b; Pyke 2011; Southeast Florida Compact Counties 2011).

Common approaches to adaptation planning include "mainstreaming" or integrating climate adaptation into existing management plans (for example, hazard mitigation, ecosystem conservation, water management, public health, risk contingency, and energy) or developing stand-alone adaptation plans (ASTHO 2012; Culver et al. 2012; Horton et al. 2012; Lackstrom et al. 2012).

Many frameworks, tools, and approaches have emerged to help decision makers make decisions in light of uncertainty (Kareiva 2008; Means et al. 2010). Many of these, however, are specific to particular localities or resources, are not easy to use, and require sophisticated knowledge of climate change (Federspiel 2012; Hammill and Tanner 2011). In general, these approaches promote options that allow reversibility, preserve future options, can tolerate a variety of impacts, and are flexible, such that mid-course adjustments are possible (OTA 1993; Wilby and Vaughan 2011). Among these approaches are Robust Decision Making (RDM), Iterative Risk Management (IRM), Adaptive Management or Co-Management, Portfolio Management, and Scenario Planning (Gregg et al. 2011; Groves and Lempert 2007; Kareiva 2008; Lempert et al. 2006; Moore et al. 2012; Moser 2012; NPS 2010; NRC 2004, 2010a; Williams 2012) (see Ch. 26: Decision Support for more on decision frameworks, processes, and tools).

Implementation

Because climate change adaptation action in the United States is relatively new, there is little peer-reviewed literature on adaptation actions, or evaluations of their successes and failures (Ford et al. 2011; Ingram et al. 2012; Moser 2009; NRC 2010a). Many of the documents submitted as part of the 2013 National Climate Assessment (NCA) process indicate that adaptation actions are being implemented for a variety of reasons – often with an aim toward reducing current vulnerabilities to hazards or extreme weather events, such as forest thinning and fuel treatments that reduce fire hazards in national forests or through the diversification of supply chain sourcing in the private sector (CDP 2011; Vose et al. 2012). Additionally, an increasing movement toward mainstreaming climate adaptation concerns into existing processes means that discerning unique climate adaptation activities will be a challenge (Dovers and Hezri 2010; Lackstrom et al. 2012).

Monitoring and Evaluation

There is little literature evaluating the effectiveness of adaptation actions (Means et al. 2010; Preston et al. 2011; Solecki and Rosenzweig 2012; Vose et al. 2012). Evaluation and monitoring efforts, to date, have focused on the creation of process-based rather than outcome-based indicators (Culver et al. 2012; Preston et al. 2011). A number of efforts are underway to create indicators related to climate adaptation (USGCRP 2012), including work by the National Climate Assessment Development Advisory Committee Indicators Working Group (Janetos et al. 2012) and the U.S. Environmental Protection Agency (EPA 2010b).

Revise Strategies/Processes and Information Sharing

Uncertainty about the future climate as well as about population growth, economic development, response strategies, and other social and demographic issues, can stymie climate adaptation activity (McCollum et al. 2011; Moore et al. 2012; USGS 2012b). Through iterative processes, however, stakeholders can regularly evaluate the appropriateness of planned and implemented activities and revise them as new information becomes available (EPA 2011; NPS 2010; NRC 2010a). Additionally, the sharing of best practices and lessons learned can be pivotal means to advancing understanding and uptake of climate adaptation activity (Lackstrom et al. 2012; Preston et al. 2011). The use of established information-sharing networks such as regional climate initiatives are illustrations of the types of networks that have supported stakeholder adaptation activity to-date (Means et al. 2010; Preston et al. 2011; Solecki and Rosenzweig 2012; WBCSD 2009).

II. Climate Adaptation Map

This map highlights some climate adaptation activities taking place in different geographical regions and scales in the United States. It is not intended to be a comprehensive compilation of national adaptation activity.

Table 28.6 --- which will be turned into Figure 28.4: Global Adaptation Map

	Adaptation Activity
1.	The State of Hawaii Office of Planning, in cooperation with university, private, state, and federal scientists and others, has drafted a framework for climate change adaptation that identifies sectors affected by climate change, and outlines a process for coordinated statewide adaptation planning. (Adapting to Climate Change: A Planning Guide for State Coastal Managers, (NOAA 2010)
2.	One of the priorities of the Hawaii State Plan is preserving water sources through conservation of the forests, as indicated in their "Rain Follows The Forest" report. (http://hawaii.gov/dlnr/chair/pio/nr/2011/The-Rain-Follows-the-Forest.pdf)
3.	New England Federal Partners is a multi-agency group formed to support the needs of the states, tribes, and communities of the New England Region and to facilitate and enable informed decision-making on issues pertaining to coastal and marine spatial planning, climate mitigation, and climate adaptation throughout the region. (http://www.epa.gov/region1/eco/energy/adaptation-efforts-epane.html)
4.	The City of Philadelphia is greening their combined sewer infrastructure to protect rivers, reduce greenhouse gas emissions, improve air quality, and enhance adaptation to a changing climate (http://www.phillywatersheds.org/ltcpu/)
5.	The City of Keene, NH, replaced culverts with larger ones that were designed to withstand projected increases in precipitation and population demand. (City of Keene 2010)
6.	New York City has created a Green Infrastructure Plan and is committed to goals that include the construction of enough green infrastructure throughout the city to manage 10% of the runoff from impervious surfaces by 2030. (http://www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_plan.shtml)
7.	The City of Lewes, DE, undertook an intensive stakeholder process to integrate climate change into the city's updated hazard mitigation plan. (http://www.ci.lewes.de.us/Hazard-Mitigation-Climate-Adaptation-Action-Plan/)
8.	Local governments and tribes throughout Alaska, such as those in Homer, are planting native vegetation and changing the coastal surface, moving inland or away from rivers, and building riprap walls, groins, or seawalls. (http://www.cakex.org/virtual-library/2555)
9.	Villages are physically being relocated because of climate impacts such as sea level rise and erosion; these include Newtok, Shishmaref, Kivalina, and dozens of other villages. (http://www.commerce.state.ak.us/dca/planning/npg/Newtok_Planning_Group.htm)

10. The City of Cedar Falls recently passed legislation that includes a new floodplain ordinance that expands zoning restrictions from the 100-year floodplain to the 500-year floodplain, because this expanded floodplain zone better reflects the flood risks experienced by the city during the 2008 floods. (http://www.epa.gov/dced/pdf/iowa_climate_adaptation_report.pdf)

11. In January 2011, the Michigan Department of Community Health (MDCH) released the *Michigan Climate and Health Adaptation Plan*, which has a goal of "preparing the Public Health System in Michigan to address the public health consequences of climate change in a coordinated manner." In September 2010, MDCH received three years' funding to implement this plan as part of the Climate-Ready States and Cities Initiative of CDC. (http://www.michigan.gov/documents/mdch/MDCH_climate_change_strategicPlan_final_1-24-2011__343856_7.pdf)

12. The City of Chicago was one of the first cities to officially integrate climate adaptation into a citywide Climate Adaptation Plan. Since its release, a number of strategies have been implemented to help the city manage heat, protect forests, and enhance green design, such as their work on green roofs. (http://www.chicagoclimateaction.org/pages/adaptation/11.php)

13. The City of Grand Rapids, MI, recently released a Sustainability Plan that integrates future climate projections to ensure that the economic, environmental, and social strategies embraced are appropriate for today as well as the future. (http://grcity.us/enterprise-services/officeofenergyandsustainability/Pages/default.aspx/)

14. Tulsa, OK, has a three-pronged approach to reducing flooding and managing stormwater: 1) prevent new problems by looking ahead and avoiding future downstream problems from new development (for example, requiring on-site stormwater detention); 2) correct existing problems and learn from disasters to reduce future disasters (for example, through watershed management and the acquisition and relocation of buildings in flood-prone areas); and 3) act to enhance the safety, environment, and quality of life of the community through public awareness, an increase in stormwater quality, and emergency management. (http://www.smartcommunities.ncat.org/articles/rooftop/program.shtml)

15. Firewise Communities USA is a nationwide program of the National Fire Protection Association and is co-sponsored by USDA Forest Service, DOI, and the National Association of State Foresters. According to the Texas Forest Service, there are more than 20 recognized Texas Firewise Communities. The Texas Forest Service works closely with communities to help them to reach Firewise Community status and offers a variety of awareness, educational, informational, and capacity-building efforts, such as *Texas Wildscapes*, a program that assists in choosing less fire-friendly plants. (http://texasforestservice.tamu.edu/main/article.aspx?id=1602)

16. After the heavy rainfall events of 2004 that resulted in significant erosion on his farms, Dan Gillespie, a farmer with NRCS in Norfolk, NE, began experimenting with adding cover crops to the no-till process. It worked so well in reducing erosion and increasing crop yields that he is now sharing his experience with other farmers (http://www.lenrd.org/projects-programs/; http://www.notill.org/; personal communication, L Carter, June 1, 2012)

17. Point Reyes National Seashore is preparing for climate change by removing two dams that are barriers to water flow and fish migration. This change restores ecological continuity for anadromous fish (those that migrate from the sea to fresh water to spawn), creating a more resilient ecosystem. (http://www.cakex.org/case-studies/1083)

18. Western Adaptation Alliance is a group of 10 cities in four states in the Intermountain West that share lessons learned in adaptation planning, develop strategic thinking that can be applied to specific community plans, and join together to generate funds to support capacity building, adaptation planning, and vulnerability assessment. (http://sustainablecommunitiesleadershipacademy.org/workshops/regional-western-adaptation-alliance)

19. Navajo Nation used information on likely changes in future climate to help inform their drought contingency plan. (Navajo Nation Department of Water Resources 2003)

20. California Department of Health and the Natural Resources Defense Council collaborated to create the *Public Health Impacts of Climate Change in California: Community Vulnerability Assessment and Adaptation Strategies* report, which is being used to inform public health preparedness activities in the State. (http://www.ehib.org/papers/Heat_Vulnerability_2007.pdf) (English 2007)

21. State of Idaho successfully integrated climate adaptation into the State's Wildlife Management Plan. (USGS 2012b) (**http://fishandgame.idaho.gov/public/wildlife/cwcs/**)

22. The Rising Tides Competition was held in 2009 by the San Francisco Bay Conservation and Development Commission to elicit ideas for how the Bay could respond to sea level rise. (http://www.risingtidescompetition.com/risingtides/Home.html)

23. The City of Flagstaff, Arizona, created a resilience strategy and passed a resilience policy, as opposed to a formal adaptation plan, as a means to institutionalize adaptation efforts in city government operations (City of Flagstaff, 2012).

24. The Olympic National Forest and Olympic National Park were sites of case studies looking at how to adapt management of federal lands to climate change. Sensitivity assessments, review of management activities and constraints, and adaptation workshops in the areas of hydrology and roads, fish, vegetation, and wildlife were all components of the case study process. (http://www.fs.fed.us/pnw/pubs/pnw_gtr844.pdf)

25. King County Flood Control District was reformed to merge multiple flood management zones into a single county entity for funding and policy oversight for projects and programs – partly in anticipation of increased stormwater flows due to climate change. (http://www.nerrs.noaa.gov/doc/pdf/training/strategies_king_county.pdf)

26. The Water Utilities Climate Alliance has been working with member water utilities to ensure that future weather and climate considerations are integrated into short- and long-term water management planning. (Culver et al. 2012) (http://www.wucaonline.org/html/)

27. Seattle's RainWatch program uses an early warning precipitation forecasting tool to help inform decisions about issues such as drainage operations. (CEQ, 2011a) (http://www.atmos.washington.edu/SPU/)

28. City of Portland and Multnomah County created a Climate Action Plan that includes indicators to help them gauge progress in planning and implementing adaptation actions. (City of Portland 2009) ((http://www.portlandoregon.gov/bps/article/268612)

29. In 2010, the State of Louisiana launched a $10 million program to assist communities that had been impacted by Hurricanes Gustav and Ike in becoming more resilient to future environmental problems. Twenty-nine communities from around the State were awarded resiliency development funds. The Coastal Sustainability Studio at Louisiana State University started working in 2012 with all 29 funded communities, as well as many that did not receive funds, to develop peer-learning networks, develop best practices, build capacity to implement plans, and develop planning tools and a user-inspired and useful website to increase community resiliency in the State. (http://lra.louisiana.gov/index.cfm?md=newsroom&tmp=detail&articleID=608 and http://resiliency.lsu.edu/)

30. FWS and The Nature Conservancy are cooperating in a pilot adaptation project to address erosion and salt water intrusion, among other issues, in the Alligator River Refuge. This project incorporates multiple agencies, native knowledge, community involvement, local economics, and technical precision. (http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/northcarolina/afield-spring-2011.pdf)

31. North and South Carolina are actively working to revise their state wildlife strategies to include climate adaptation (Lackstrom et al. 2012).

32. The Southeast Florida Climate Compact is a collaboration of the four southernmost counties in Florida (Monroe, Broward, Palm Springs, and Miami-Dade) focusing on enhancing regional resilience to climate change and reducing regional greenhouse gas emissions (Southeast Florida Compact Counties 2011). (http://www.southeastfloridaclimatecompact.org/documents/DraftRCAP.pdf)

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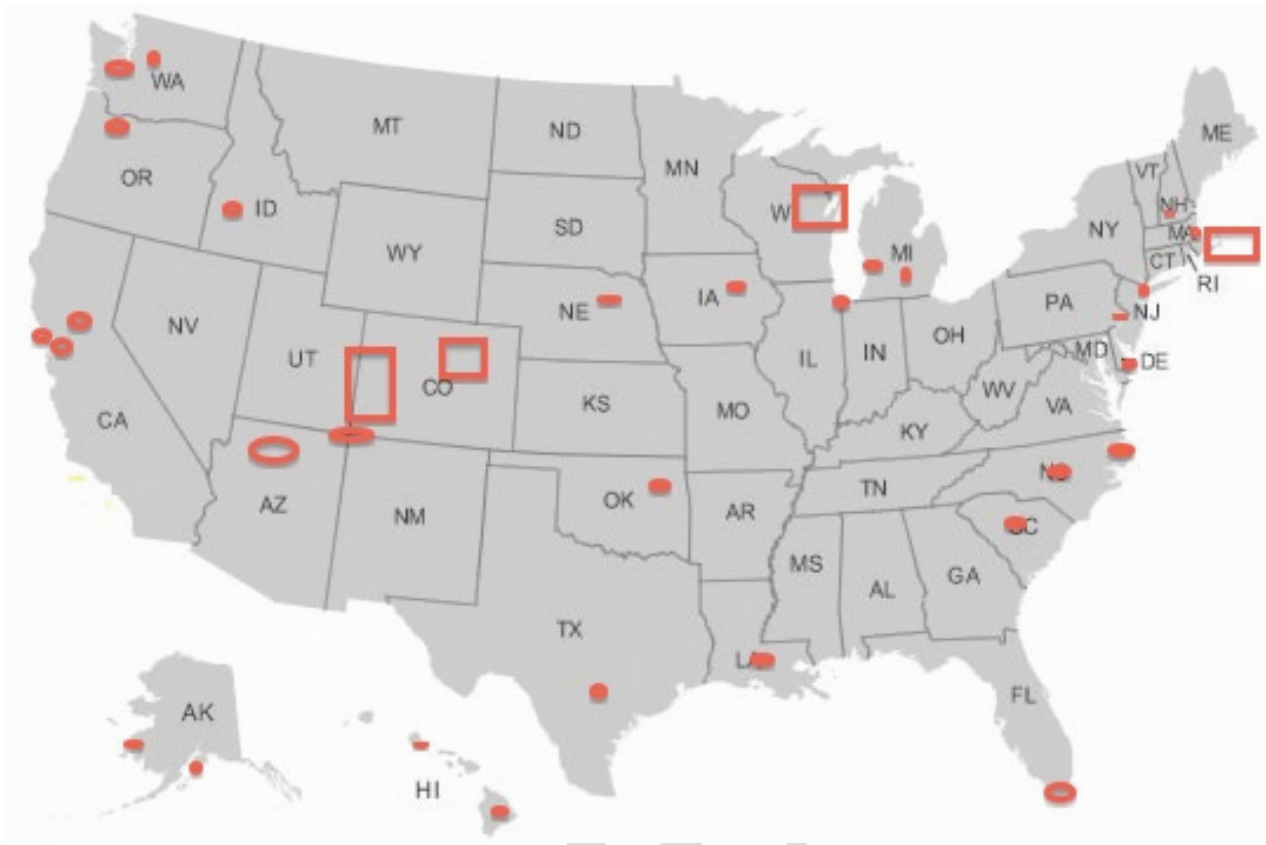

III. Barriers to Adaptation

Despite emerging recognition of the necessity of climate change adaptation, many barriers still impede efforts to build local, regional, and national-level resilience. Barriers are obstacles that can delay, divert, or temporarily block the adaptation process (Ekstrom et al. 2011) and include: difficulties in using climate change projections for decision-making; lack of resources to begin and sustain adaptation efforts; fragmentation of decision-making; institutional constraints; lack of leadership; and divergent risk perceptions/cultures and values (Bierbaum et al. 2013 ; NRC 2010a). Barriers are distinguished from physical or ecological limits to adaptation, such as physiological tolerance of species to changing climatic conditions that cannot be overcome (except with technology or some other physical intervention) (Adger et al. 2007; Gregg et al. 2011; McIlgorm et al. 2010; USGS 2012b).

Table 28.7: Summary of Adaptation Barriers

Barrier	Specific Examples	References
Climate Change Information and Decision-Making	• Uncertainty about future climate impacts • Disconnect between information providers and information users • Fragmented, complex, and often confusing information • Lack of climate education for professionals and the public • Lack of usability and accessibility of existing information	(Barsugli et al. 2012; Brunner 2012; Carmin et al. 2012; Culver et al. 2012; Dilling and Lemos 2011; Fowler and Wilby 2007; Groves and Lempert 2007; Hauser and Jadin 2012; Horton et al. 2012; Kareiva 2008; Kerr 2011; Lackstrom et al. 2012; Larsen 2011; Lebow 2012; Marra 2012; McCollum et al. 2011; McNie 2007; Mitchell 2010; National Climate Adaptation Summit Committee 2010; Needham et al. 2012; NRC 2007, 2010a; OTA 1993; Schramm 2012; USGS 2012b; Vose et al. 2012; White-Newsome et al. 2011; Winkler 2012)
Lack of Resources to Begin and Sustain Adaptation Efforts	• Lack of financial resources / no dedicated funding • Limited staffing capacity • Underinvestment in human dimensions research	(Brugger and Crimmins 2011; Brunner 2012; Carmin et al. 2012; Garfin et al. 2012; Gregg et al. 2011; Ingram et al. 2012; Lackstrom et al. 2012; Marra 2012; Mittal 2009; Needham et al. 2012; Schramm 2012; Simmonds 2011; USGS 2012b)
Fragmentation of Decision-Making	• Lack of coordination within and across agencies, private companies, and non-governmental organizations • Uncoordinated and fragmented research efforts • Disjointed climate related information • Fragmented ecosystem and jurisdictional boundaries	(Clark and Levin 2010; Horton et al. 2012; Lebow 2012; National Climate Adaptation Summit Committee 2010; NRC 2009; OTA 1993; Simmonds 2011; USGS 2012b; Winkler 2012)
Institutional Constraints	• Lack of institutional flexibility • Rigid laws and regulations • No legal mandate to act • Use of historical data to inform future decisions • Restrictive management procedures • Lack of operational control or influence	(Adger et al. 2009; Brugger and Crimmins 2011; Carpenter and Brock 2008; Craig 2008; Folke 2006; Garfin et al. 2012; Gregg et al. 2011; Lee 1994; Marra 2012; McNeeley 2012; Moser and Ekstrom 2012; Nelson et al. 2007; NRC 2004; Simmonds 2011; USGS 2012b)
Lack of Leadership	• Lack of political leadership • Rigid and entrenched political structures • Polarization	(Brugger and Crimmins 2011; Ding et al. 2011; Leiserowitz et al. 2011a; Moser 2012; Moser and Ekstrom 2012; Schramm 2012; Smith et al. 2009; Smith et al. 2010)
Divergent Risk Perceptions, Cultures, and Values	• Conflicting values/risk perceptions • Little integration of local knowledge, context, and needs with traditional scientific information • Cultural taboos and conflict with cultural beliefs • Resistance to change due to issues such as risk perception	(Adger et al. 2009; Ding et al. 2011; Doria et al. 2009; Gifford 2011; Kahan et al. 2007; Kahan et al. 2011; Lackstrom et al. 2012; Leiserowitz 2006; McNeeley 2012; NRC 2009; Renn 2011; Renn et al. 2011; Simmonds 2011; Van Aalst et al. 2008; Verweij et al. 2006; Weber and Stern 2011)

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IV. Overcoming Barriers to Success

Individuals within and across sectors and regions are organizing to collectively overcome barriers and adapt to climate change. Colorado River Basin water resource managers, government leaders, federal agencies, universities, non-governmental organizations (NGOs), and the private sector are collaborating on strategies for managing water under a changing climate through partnerships like the Western Governors Association (WGA) and WestFAST (Western Federal Agency Support Team).

In Wisconsin, the Northern Institute of Applied Climate Science and the U.S. Forest Service, working with multiple partners, initiated a "Climate Change Response Framework" integrating climate-impacts science with forest management. In Cape Cod, Massachusetts, the U.S. Department of Transportation's Volpe Center worked with federal, regional, state, and local stakeholders to integrate climate change mitigation and adaptation considerations into existing and future transportation, land-use, coastal, and hazard-mitigation processes.

Through the creation of the National Integrated Drought Information System (NIDIS), the federal government, in partnership with the National Drought Mitigation Center (NDMC), states, tribes, universities, and others, has improved capacity to proactively manage and respond to drought-related risks and impacts through: 1) the provision of drought early warning information systems with local/regional input on extent, onset, and severity; 2) a web-based drought portal featuring the U.S. Drought Monitor and other visualization tools; 3) coordination of research in support and use of these systems; and 4) leveraging of existing partnerships, forecasting, and assessment programs.

V. Next Steps

Adaptation to climate change is in a nascent stage. The federal government is beginning to develop the institutions and practices necessary to address adaptation, including through efforts such as regional climate centers within the U.S. Department of Agriculture, the National Oceanic and Atmospheric Administration (a division of the Department of Commerce), and the Department of the Interior. A number of states and local governments are engaging in adaptation planning, but most have not taken action to implement the plans (Bierbaum et al. 2013). Despite some early successes, the pace and extent of adaptation activities are not proportional to the risks to people, property, infrastructure, and ecosystems from climate change; important opportunities are also being overlooked.

One of the key areas of focus for global change research is enabling research and development to advance adaptation across scales, sectors, and disciplines. This includes research for overcoming the barriers identified in Section III, such as strategies that foster coordination, better communication, and knowledge sharing amongst fragmented governing structures and stakeholders. Research on the kinds of information users desire and how to deliver that information in contextually appropriate ways, as well as research on decision-making in light of uncertainty about climate change and other considerations, will be equally important.

In addition to these areas, emerging areas of needed research include:

- *Costs and Benefits of Adaptation.* Methodologies to evaluate the relevant costs of adaptation options, as well as the costs of inaction, need to be developed.

- *A Compendium of Adaptation Practices*. A central and streamlined database of adaptation options implemented at different spatial and temporal scales is needed. Information on the adaptation actions, how effective they were, what they cost, and how monitoring and evaluation were conducted should be part of the aggregated information. (National Climate Adaptation Summit Committee 2010; NRC 2010a).

- *Adaptation and Mitigation Interactions*. Research and analysis on the growing and competing demands for land, water, and energy and how mitigation actions could affect adaptation options, and vice versa (Bloetscher et al. 2011; Ingram et al. 2012; ORNL 2012a; Skaggs et al. 2012).

- *Critical Adaptation Thresholds*. Research to identify critical thresholds beyond which social and/or ecological systems are unable to adapt to climate change. This should include analyzing historical and geological records to develop models of "breakpoints" (NAST 2000; National Climate Adaptation Summit Committee 2010).

- *Adaptation to Extreme Events*: Research on preparedness and response to extreme events such as droughts, floods, intense storms, and heatwaves in order to protect people, ecosystems, and infrastructure. Increased attention must be paid to how extreme events and variability may change as climate change proceeds and how that affects adaptation actions (IPCC 2012; Kates et al. 2012).

A key federal role in adaptation, as indicated in the literature, has been the role of enabling and facilitating adaptation within states, regions, local communities, and the public and private sectors (NRC 2010a). The approaches include working to limit current institutional constraints to effective adaptation, funding pilot projects, providing useful and usable adaptation information – including disseminating best practices, and helping develop tools and techniques to evaluate successful adaptation. Some companies in the private sector and numerous non-governmental organizations have also taken action, particularly in capitalizing on the opportunities associated with facilitating adaptive actions and building tools and technologies that are useful in enhancing resilience. Actions and collaborations have occurred across all scales. At the same time, barriers to effective implementation continue to exist.

Effective adaptation will require ongoing, flexible, transparent, inclusive, and iterative decision-making processes, collaboration across scales of government and sectors, and the continual exchange of best practices and lessons learned. All stakeholders have a critical role to play in ensuring the preparedness of our society to extreme events and long-term changes in climate.

VI. Case Studies

Illustrative Case One: National Integrated Drought Information System

NIDIS (National Integrated Drought Information System), originally proposed by the WGA and established by Congress in 2006 (Hayes and Pulwarty 2012), is a federally-created entity that improves the nation's capacity to proactively manage drought-related risks across sectors, regions, and jurisdictions. It was created by Congress to "enable the Nation to move from a reactive to a more proactive approach to managing drought risks and impacts." NIDIS has successfully brought together government partners and research organizations to advance a warning system for drought-sensitive areas.

The creation of NIDIS involved many years of development and coordination among federal, state, local, regional, and tribal partners with the help of Governors' associations and Senate and congressional leaders. NIDIS provides: 1) drought early warning information systems with regional detail concerning onset and severity; 2) a web-based portal (www.drought.gov); 3) coordination of federal research in support of and use of these systems; and 4) leveraging of existing partnerships and of forecasting and assessment programs. NIDIS currently supports work on water supply and demand, wildfire risk assessment and management, and agriculture. Regional drought early warning system pilot projects have been established to illustrate the benefits of improved knowledge management, improved use of existing and new information products, and coordination and capacity development for early warning systems. These prototype systems are in the Upper Colorado Basin, the Apalachicola-Chattahoochee-Flint River Basin in the Southeast, the Four Corners region in the Southwest, and the State of California. The NIDIS Outlook in the Upper Colorado Basin provides early warning information every week, for example, that is utilized by a variety of users from Federal agencies, water resource management, and the recreation industry.

The Western Governors Association, the U.S. Congress, and others have formally acknowledged that NIDIS provides a successful example of achieving effective federal-state partnerships by engaging both leadership and the public, and establishing an authoritative basis for integrating monitoring and research to support risk management. Some of NIDIS' keys to success include:

- **Useable Technology and Information for Decision Support:** The production of the U.S. Drought Monitor map which integrates multiple indicators and indices from many data sources, was developed before NIDIS was established and has become a useful visual decision support tool for monitoring and characterizing drought onset, severity, and persistence. NIDIS has engaged regional and local experts in refining the regional details of this national product and in "ground truthing" maps via email discussions and webinars.

- **Financial Assistance:** Federal funding was allocated to NOAA specifically for NIDIS, but leveraged in kind by other agencies and partners.

- **Institutional/Partnerships:** Effective collaborations, partnerships, and coordination with NOAA, WGA, USDA, DOI, and USGS as well as local, regional, state, and tribal partners and with the National Drought Mitigation Center at the University of Nebraska, Lincoln, have led to multi-institutional "buy-in".

- **Institutional/Policy:** The NIDIS Act was oriented toward the improvement of coordination across federal agencies and with regional organizations, universities, and states. It focused on the application of technology, including the Internet, and on impact assessments for decision support. A key aspect of NIDIS is the development of ongoing regional outlook forum based on the above information to build awareness of the drought hazard and to embed information in planning and practice (in partnership with the National Drought Mitigation Center, the Regional Integrated Sciences and Assessments (RISA), and other research-based boundary organizations) to reduce risks and impacts associated with drought**.**

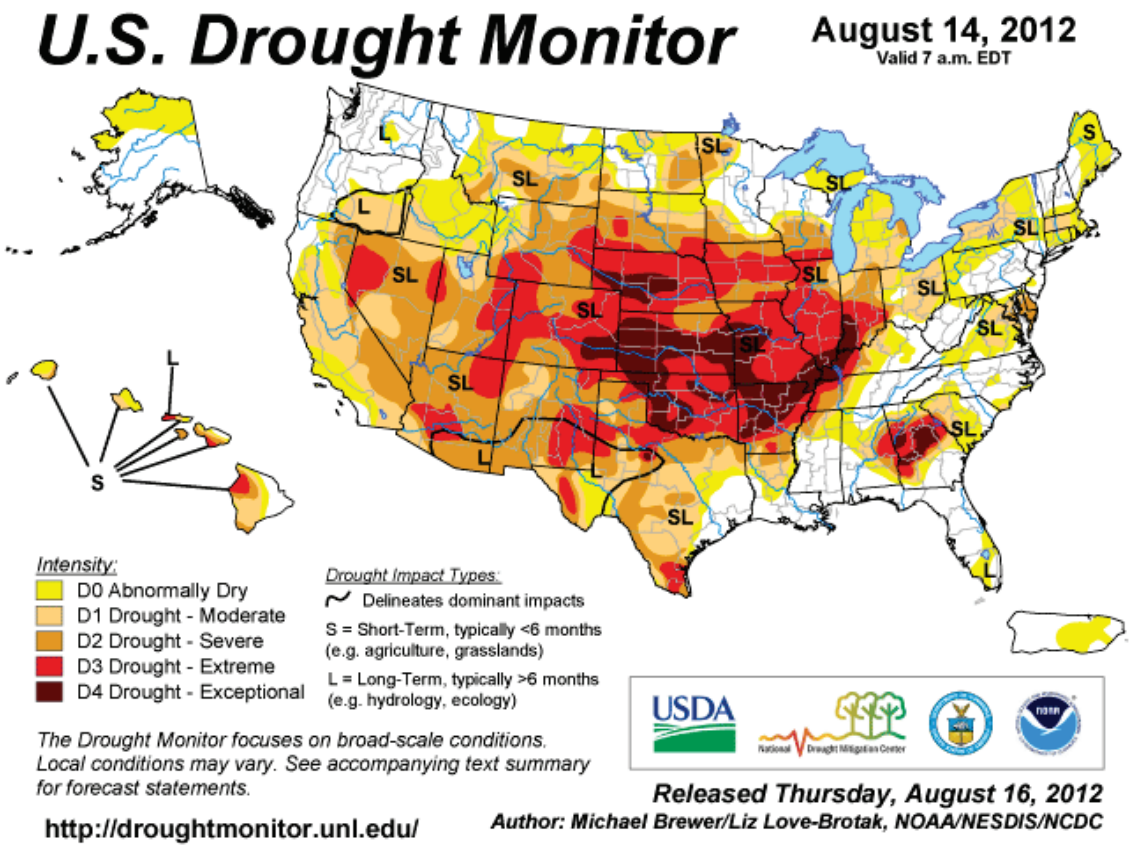

Figure 28.5: U.S. Drought Monitor Map accessed on August 20, 2012. The U.S. Drought Monitor is produced in partnership between the national Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC-UNL.

- **Leadership and Champions:** NIDIS supporters worked at all levels over more than two decades (1990s and 2000s) to establish the NIDIS Act, including political (WGA, Southern Governors Association, National Governors Association, U.S. Senators, and congressmen); scientific (Wilhite, Pulwarty, Verdin); and federal agencies (NOAA, USDA, DOI).

- **Risk Perceptions:** Whereas drought had been considered primarily a western issue in previous decades, drought is now regularly impacting the south, southeast, and northeast parts of the country and response strategies are needed. Because of the 2012 drought, more than 63% of the contiguous U.S. by the end of July was classified as experiencing moderate to exceptional drought and more than 3,200 heat records were broken in June 2012 alone (NOAA 2012; Schwalm et al. 2012)

Illustrative Case Two: Adaptive Governance in the Colorado River Basin

The Colorado River supplies water and valuable ecosystem services to 33 million people and is vulnerable to climate change because of decreases in mountain snowpack and water availability, increased competition among water users, fires, drought, invasive species, and extended extreme heat events, among other threats (Cayan et al. 2010; Christensen and Lettenmaier 2007; Garfin et al. 2012; Hidalgo et al. 2009; Pierce et al. 2008; Seager and Vecchi 2010). The 1922 Colorado River Compact, which allocates water among seven U.S. states and Mexico, was agreed upon in a particularly wet time period (Gray et al. 2011; Woodhouse et al. 2006); thus the river water is already over-allocated for current conditions. Given the likelihood of having less water because of climate change, resource managers and government leaders are increasingly recognizing that water must be managed with flexibility to respond to the projected impacts and the range of possible future climates (Brown 2010; Garfin et al. 2012). Multiple actors across all scales of governance (including tribal, local, state, and federal), non-governmental organizations, and the private sector are organizing and working together to address these concerns and the relationship between climate and other stresses in the basin.

The Western Governors' Association (WGA) spearheaded adaptation efforts to enable federal, state, tribal, local, and private sector partners to address a range of issues, including climate change (Brown 2010; Garfin et al. 2012; Western Governors' Association 2006, 2008, 2010). For example, the Western Federal Agency Support Team (WestFAST), which was established in 2008, created a partnership between the Western States Water Council (WSWC) and 11 federal agencies with water management responsibilities in the western United States. The agencies created a work plan in 2011 to address three key areas: 1) climate change; 2) water availability, water use, and water reuse; and 3) water quality. To date they have produced the WestFAST Water-Climate Change Program Inventory, the Federal Agency Summary, and a Water Availability Studies Inventory (http://www.westgov.org/wswc/WestFAST.htm).

The WSWC and the USACE produced the Western States Watershed Study (WSWS), which demonstrated how Federal agencies could work collaboratively with western states on planning activities (USACE 2009). In 2009, the WGA also adopted a policy resolution titled "Supporting the Integration of Climate Change Adaptation Science in the West" that created a Climate Adaptation Work Group composed of western state experts in air quality, forest management, water resources, and wildlife management. Other important adaptation actions were the SECURE Water Act in 2009, the Reclamation Colorado River Basin water supply and demand study, and the creation of NIDIS to support stakeholders in coping with drought (Hayes and Pulwarty 2012 ; U.S. Bureau of Reclamation 2011a, 2011b).

Illustrative Case Three: Climate Change Adaptation in Forests

Figure 28.6: Northwoods Climate Change Response Framework Region (Figure Source: USDA Forest Service 2012)

Northern Wisconsin's climate has warmed over the past 50 years, and windstorms, wildfires, insect outbreaks, and floods are projected to become more frequent in this century (Swanston et al. 2011). The resulting impacts on forests, combined with fragmented and complex forest ownership, create management challenges that extend across ownership boundaries, creating the need for a multi-stakeholder planning process (Joyce et al. 2009; Miles 2010; WDNR 2009, 2010).

To address these concerns, the Northern Institute of Applied Climate Science, the USDA's Forest Service, and many other partners initiated the Climate Change Response Framework to incorporate scientific research on climate change impacts into on-the-ground management. Originally developed as a pilot project for all-lands conservation in northern Wisconsin, it has expanded to cover three ecological regions (Northwoods, Central Hardwoods, and Central Appalachians) across eight states in the Midwest and Northeast. The Framework uses a collaborative and iterative approach to provide information and resources to forest owners and managers across a variety of private and public organizations. Several products were developed through the Framework in northern Wisconsin:

1. Vulnerability and mitigation assessments summarized the observed and projected changes in the northern Wisconsin climate; projected changes in forest composition and carbon stocks across a range of potential climates; and assessed related vulnerabilities of forest ecosystems in northern Wisconsin (Swanston et al. 2011).

2. *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers* (Swanston and Janowiak 2012) was developed to help managers identify management tactics that facilitate adaptation. A "menu" of adaptation strategies and approaches for planning, implementing, and monitoring adaptation activities was synthesized into an adaptation workbook from a broad set of literature and refined based on feedback from regional scientists and managers (Butler et al. 2011; Janowiak et al. 2012).

3. A series of adaptation demonstrations was initiated to showcase ground-level implementation. The Framework and adaptation workbook provide a common process shared by diverse landowners and a formal network that supports cross-boundary discussion about different management objectives, ecosystems, and associated adaptation tactics.

From the beginning, the Framework has taken an adaptive management approach in its adaptation planning and projects. Lessons learned include:

- Define the purpose and scope of the Framework and its components early, but allow for refinement to take advantage of new opportunities;
- Begin projects with a synthesis of existing information to avoid duplicating efforts;
- Plan for the extra time necessary to implement true collaboration;
- Carefully match the skills, commitment, and capacity of people and organizations to project tasks;
- Maintain an atmosphere of trust, positivity, and sense of adventure, rather than dwelling on failures;
- Acknowledge and work with uncertainty, rather than submit to "uncertainty paralysis";
- Recognize the necessity of effective communication among people with different goals, disciplinary backgrounds, vocabulary, and perspectives on uncertainty;
- Integrate the ecological and socioeconomic dimensions early by emphasizing the many ways that communities value and depend on forests; and
- Use technology to increase efficiency of internal communication and collaboration, as well as outreach.

The Framework brings scientists and land managers together to assess the vulnerability of ecosystems based on scientific information and experience in order to plan adaptation actions that meet management goals. On-the-ground implementation has just begun, and an increased focus on demonstrations, monitoring, and evaluation will inform future adaptation efforts.

Illustrative Case Four: Transportation, Land Use, and Climate Change: Integrating Climate Adaptation and Mitigation in Cape Cod, Massachusetts

Cape Cod, Massachusetts, a region of scenic beauty and environmental significance, is currently affected by sea level rise, coastal erosion, and localized flooding – impacts that are likely to be exacerbated by climate change (Volpe National Transportation Systems Center 2011a, 2011b). To address these concerns and help meet the state's greenhouse gas (GHG) reduction target (25% reduction based on 1990 levels by 2020), the DOT's Volpe Center worked with federal, regional, state, and local stakeholders to integrate climate change into existing and future transportation, land-use, coastal zone, and hazard mitigation planning through an initiative called the Transportation, Land Use, and Climate Change Pilot Project (Pilot Project) (Commonwealth of Massachusetts 2004; Volpe National Transportation Systems Center 2011a).

The process was initiated through an expert elicitation held in mid-2010 to identify areas on Cape Cod that are or could potentially be vulnerable to sea level rise, flooding, and erosion. The Volpe Center then used a geographic information system (GIS) software tool to develop and evaluate a series of transportation and land-use scenarios for the Cape under future development projections (ESRI 2011; Volpe National Transportation Systems Center 2011b). All scenarios were evaluated against a series of criteria that included: 1) reduction in vehicle miles traveled (VMT); 2) reduced greenhouse gas (GHG) emissions; 3) reduction in transportation energy use; 4) preservation of natural/existing ecosystems; 5) reduction in percentage of new population in areas identified as vulnerable to climate change impacts; and 6) increased regional accessibility to transportation (Volpe National Transportation Systems Center 2011a).

Once the preliminary scenarios were developed, a workshop was convened in which community and transportation planners, environmental managers, and Cape Cod National Seashore stakeholders selected areas for development and transit improvements to accommodate new growth while meeting the goals of reduced GHG emissions, increased resilience to climate change, and the conservation of natural systems (Volpe National Transportation Systems Center 2011b). Through interactive, visualization tools, participants were able to see in real-time the impacts of their siting decisions, allowing them to evaluate synergies and potential tradeoffs of their choices and to highlight areas where conflict could or already does exist, such as density enhancement in areas already or likely to be vulnerable to climate change (APA 2011). As a result, the stakeholders developed a refined transportation and land-use scenario that will support the region's long-range transportation planning as well as other local, regional, and state plans. This updated scenario identifies strategies that have climate adaptation and mitigation value, helping to ensure that the region simultaneously reduces its GHG footprint while building resilience to existing and future changes in climate (Volpe National Transportation Systems Center 2011a, 2011b). The overall success of the pilot project stemmed from the intensive stakeholder interaction at each phase of the project (design, implementation, and evaluation).

Traceable Accounts

Chapter 28: Adaptation

Key Message Process: A central component of the process were bi-weekly technical discussions held from October 2011 to June 2012 via teleconference that focused on collaborative review and summary of all technical inputs relevant to adaptation (130+) as well as additional published literature, the iterative development of key messages, and the final drafting of the Chapter. An in-person meeting was held in Washington, DC in June 2012. Meeting discussions were followed by expert deliberation of draft key messages by the authors, and targeted consultation with additional experts by the lead author of each key message. Consensus was reached on all key messages and supporting text.

Key message #1/6	**Adaptation planning is occurring in the public and private sectors and at all levels of government, however, few measures have been implemented and those that have appear to be incremental changes.**
Description of evidence base	The key message and supporting text summarizes extensive evidence documented in the peer reviewed literature as well as the more than 130 Technical Inputs received and reviewed as part of the Federal Register Notice solicitation for public input. Numerous peer-reviewed publications describe that a growing number of sectors, governments at all scales, and private and non-governmental actors are starting to undertake adaptation activity (Garfin et al. 2012; Solecki and Rosenzweig 2012). Much of this activity is focused on planning with little literature documenting implementation of activities (Lackstrom et al. 2012; NRC 2010a; USGS 2012b). Supporting this statement is also plentiful literature that profiles barriers or constraints that are impeding the advancement of adaptation activity across sectors, scales, and regions (Horton et al. 2012; Marra 2012). Additional citations are used in the text of the adaptation chapter to substantiate this key message.
New information and remaining uncertainties	n/a
Assessment of confidence based on evidence	n/a

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Key Message Process: See key message #1.

Key message #2/6	**Barriers to implementation of adaptation action include lack of funding, policy and legal impediments, and difficulty in anticipating climate-related changes at local scales.**
Description of evidence base	The key message and supporting text summarizes extensive evidence documented in the peer reviewed literature as well as the more than 130 Technical Inputs received and reviewed as part of the Federal Register Notice solicitation for public input. A significant quantity of reviewed literature profiles barriers or constraints that are impeding the advancement of adaptation activity across sectors, scales, and regions (Horton et al. 2012; Marra 2012; NRC 2010a). Numerous peer-reviewed documents describe adaptation barriers (LINK TO CHAPTER TABLE 28.7). Moreover, additional citations are used in the text of the adaptation chapter to substantiate this key message.
New information and remaining uncertainties	n/a
Assessment of confidence based on evidence	n/a

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Key Message Process: See key message #1.

Key message #3/6	**There is no "one-size fits all" adaptation, but there are similarities in approaches across regions and sectors. Sharing best practices, learning by doing, and iterative and collaborative processes including stakeholder involvement, can help support progress.**
Description of evidence base	Literature submitted for the Assessment as well as additional literature reviewed by the author team fully supports the concept that adaptations will ultimately need to be selected for their local applicability based on impacts, timing, political structure, finances, and other criteria (Culver et al. 2012; NRC 2010a). Similarities do exist in the types of adaptation being implemented, although nuanced differences do make most adaptation uniquely appropriate for the specific implementer. The selection of locally and context-appropriate adaptations is enhanced by iterative and collaborative processes where stakeholders directly engage with decision makers and information providers (NPS 2010; NRC 2010a, 2010a). While there are no 'one-size fits all' adaptation strategies, evidence to-date supports the message that the sharing of best practices and lessons learned are greatly aiding in adaptation progress across sectors, systems, and governance systems (Lackstrom et al. 2012; Preston et al. 2011). Additional citations are used in the text of the adaptation chapter to substantiate this key message.
New information and remaining uncertainties	n/a
Assessment of confidence based on evidence	n/a

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Key Message Process: See key message #1.

Key message #4/6	**Climate change adaptation actions often fulfill other societal goals, such as sustainable development, disaster risk reduction, or improvements in quality of life, and can therefore be readily incorporated into existing decision-making processes.**
Description of evidence base	The key message and supporting text summarizes extensive evidence documented in the peer reviewed literature as well as the more than 130 Technical Inputs received and reviewed as part of the Federal Register Notice solicitation for public input. Literature submitted for the Assessment as well as additional literature reviewed by the author team support the message that a significant amount of activity that has climate adaptation value, is initiated for reasons other than for climate preparedness and/or has other co-benefits in addition to increasing preparedness to climate and weather impacts (Lackstrom et al. 2012; NRC 2009, 2010a; Preston et al. 2011). In recognition of this and other factors, a movement has emerged encouraging the integration of climate change considerations into existing decision-making and planning processes (i.e., mainstreaming) (EPA 2012; NRC 2010a; ORNL 2012b). Additional citations are used in the text of the adaptation chapter to substantiate this key message.
New information and remaining uncertainties	n/a
Assessment of confidence based on evidence	n/a

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Key Message Process: See key message #1.

Key message #5/6	**Vulnerability to climate change is exacerbated by other stresses such as pollution and habitat fragmentation. Adaptation to multiple stresses requires assessment of the composite threats as well as tradeoffs amongst costs, benefits, and risks of available options.**
Description of evidence base	The key message and supporting text summarizes extensive evidence documented in the peer reviewed literature as well as the more than 130 Technical Inputs received and reviewed as part of the Federal Register Notice solicitation for public input. Climate change is only one of a multitude of stresses affecting social, environmental, and economic systems. Activity to-date and literature profiling those activities support the need for climate adaptation activity to integrate the concerns of multiple stresses in decision-making and planning (IPCC 2007; NRC 2007; OTA 1993). As evidence by activities to-date, integrating multiple stresses into climate adaptation decision-making and vice versa will require the assessment of tradeoffs amongst costs, benefits, the risks of available options, and the potential value of outcomes (Culver et al. 2012; Needham et al. 2012) (ORNL 2012b). Additional citations are used in the text of the adaptation chapter to substantiate this key message.
New information and remaining uncertainties	n/a
Assessment of confidence based on evidence	n/a

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Key Message Process: See key message #1.

Key message #6/6	**The effectiveness of climate change adaptation has seldom been evaluated, because actions have only recently been initiated, and comprehensive evaluation metrics do not yet exist.**
Description of evidence base	The key message and supporting text summarizes extensive evidence documented in the peer reviewed literature as well as the more than 130 Technical Inputs received and reviewed as part of the Federal Register Notice solicitation for public input Numerous peer-reviewed publications indicate that no comprehensive adaptation evaluation metrics exist meaning that no substantial body of literature or guidance materials exist on how to thoroughly evaluate the success of adaptation activities (Hauser and Jadin 2012; Ingram et al. 2012; Lebow 2012; NRC 2010a). This is an emerging area of research. A challenge of creating adaptation evaluation metrics is the growing interest in mainstreaming; meaning that separating out adaptation activities from other activities could prove difficult. Additional citations are used in the text of the adaptation chapter to substantiate this key message.
New information and remaining uncertainties	n/a
Assessment of confidence based on evidence	n/a

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