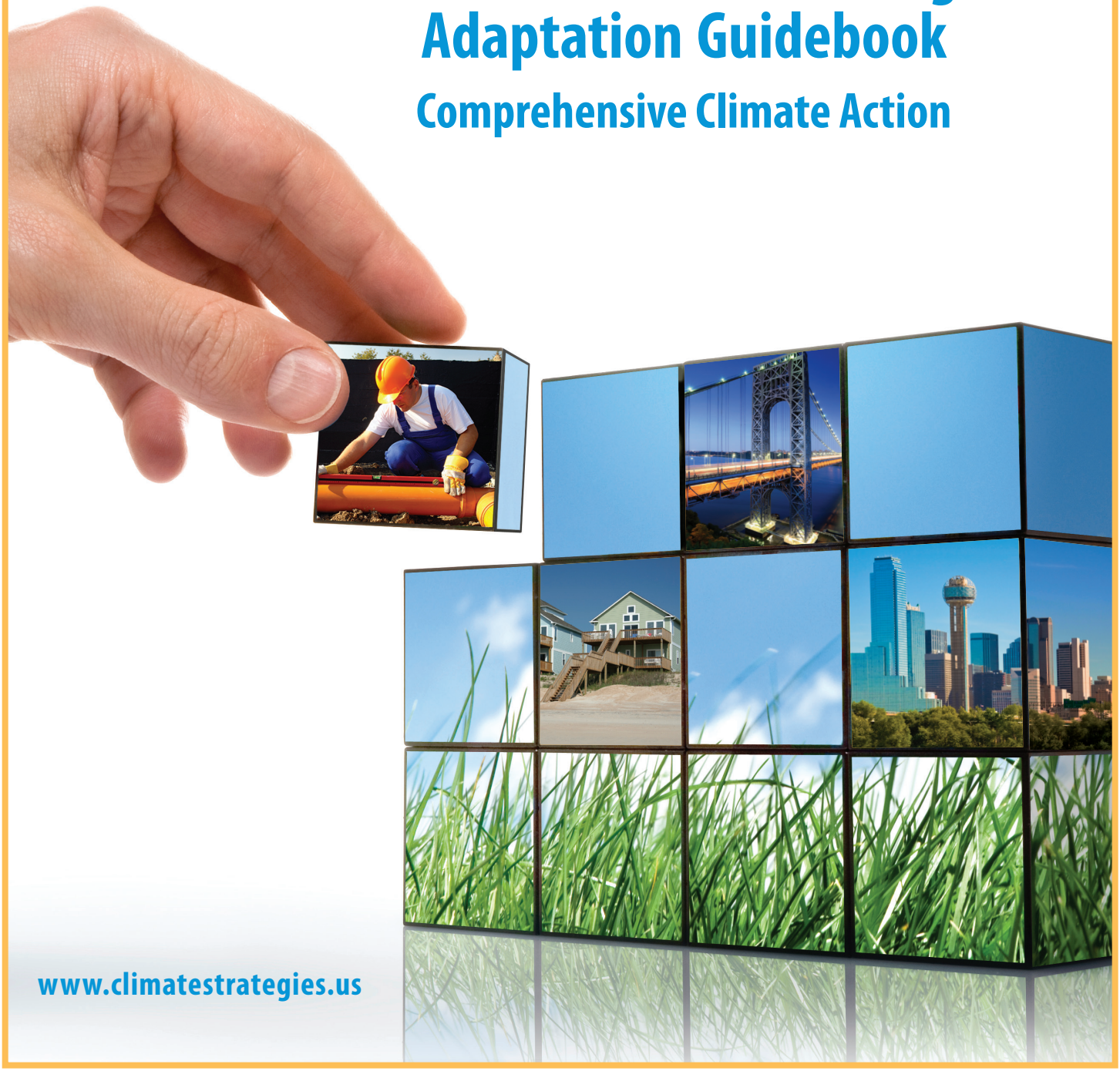
THE CENTER FOR
CLIMATE STRATEGIES

Center for Climate Strategies Adaptation Guidebook

Comprehensive Climate Action



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Glossary

Terms

Adaptation: actions that respond to actual or expected changes in the climate to prevent, moderate, cope with, and take advantage of the consequences of climate events

Resilience: actions that reduce the vulnerabilities to climate impacts

Climate Change: refers to the effects higher temperatures have on the earth's natural systems and the impacts that can result: stronger storms, longer droughts, sea level rise and seasonal shifts

Global Warming: man-made rise in temperatures caused by excessive amounts of carbon dioxide, methane, and other greenhouse gases in the atmosphere

Energy Efficiency: is the goal of efforts to reduce the amount of energy required to provide products and services

Benefit Cost Analysis (BCA): a form of economic analysis that assigns a monetary value to the measure of effect

Cost Effectiveness Analysis (CEA): a form of economic analysis that compares the relative costs and outcomes (effects) of two or more courses of action

Adaptation Metrics: a system of measurement for the selection and evaluation of adaptation actions.

Radiative Forcing: a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism

Stationarity: theory that the climate is stable and that future climate will be similar to current climate

Acronyms

CCS: Center for Climate Strategies

DALYs: Disability-Adjusted Life Years

IPCC: Intergovernmental Panel on Climate Change

LEDS: Low-emission Development Strategy

NAPAs: National Adaptation Programs of Actions

NAMAs: Nationally Appropriate Mitigation Actions

UNFCCC: United Nations Framework Convention on Climate Change

GOVT: Government

CE: Chief Executive

EO: Executive Office

FO: Facilitation Organization

SC: Stakeholder Committee

TWG: Technical Work Groups

Acknowledgements

The Center for Climate Strategies (CCS) developed the *Comprehensive Climate Action Planning: The Center for Climate Strategies Adaptation Guidebook* to inform and advance comprehensive climate action planning in order to demonstrate the technique and value of advanced planning and preparation for impacts that are prompted by frequent and more intense climatic events and a changing climate.

CCS is deeply grateful to the Rockefeller Foundation for its support of this project. The technical and funding support provided by the Rockefeller Foundation enabled CCS to develop and publish this Guidebook.

THE ROCKEFELLER FOUNDATION

THE CENTER FOR CLIMATE STRATEGIES

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CCS further appreciates peer review input from Brian Thomas, Jim Murley and Josh Foster.

Foreword

A living nation builds for its future.

Inscription on a Dutch barrier dam, the Afsluitdijk, built in 2005 in anticipation of future sea level rise.

Comprehensive climate actions that improve our ability to adapt to a changing climate can also improve economic, environmental, health and energy security if they are properly developed and implemented. This "win-win" opportunity is largely dependent on the quality of the policy development process by which actions are developed The most effective approaches for climate mitigation and adaptation have been implemented through collaborative, bottom up action planning processes that consider and evaluate comprehensive choices, key facts and competing values through the lens of stakeholders and experts.

Much experience on specific sector based actions exists in this area already by virtue of many programs and policies by states, regions, cities and counties. They have been the frontline not only of policy development, but are the most impacted by the consequences of shifts in nature, resources, markets and policies. Historically they rise to the challenges of local solutions to local problems with innovative and mainstream strategies that can be replicated, scaled and accelerated. This Guidebook provides a means by which such advancements can be implemented in jurisdictions of varying sizes in a manner that allows highly customized responses to climate changes using consistent systems for comprehensive planning.

Climate change refers to the effects of increasing temperatures on the earth's systems that result in numerous ground level impacts. These include intensified water cycles that lead to stronger storms, longer droughts, and shifts in the timing and level of watershed recharge and discharge, and water flows. It also includes sea level rise and increased risk of storm surges in coastal zones. Warming results in seasonal shifts, including changes in growing seasons at unprecedented rates. Disease vectors, such as insects, also can expand range and potency in a warming climate, along with certain tropical diseases. Warming results in the expansion of very high heat days in the summer, and in overnight winter temperatures, and raise human health and overwinter pest issues. Many other impacts of a warming world exist, but not all are fully understood.

Scientists are concerned that the warming of the world to temperature levels that are higher than previously experienced *at rates vastly in excess of any changes in known history* could bring a variety of uncertain and potentially uncontrollable impacts. Because one of the most important drivers of this change is human induced greenhouse gas emissions, and because these gases reside for very long periods in the atmosphere (persistent effects of more than a century), the mitigation of climate change through greenhouse gas emissions reduction is critical to risk management.

At the same time, the level of emissions increase from human activities in the earth's atmosphere has already significantly exceeded preindustrial levels and "built in" climate change effects for the next few decades. These "lock in" changes will require increasingly serious adaptive responses. This Guidebook focuses on systematic, practical means by which communities of varying sizes can plan for these changes as they also focus on long-term mitigation of risk.

The good news is that the ability of states, regions and local governments to pursue strong and effective policies and actions exists today. The better news is that many have been actively implementing solutions

and actions and using advanced technologies to reduce vulnerabilities and increase resilience in their communities.

Indeed, rather than being chased by fear of climate change impacts, states, regions and local governments are embracing the opportunities that change represents to address multiple important policy needs (see www.climatestrategies.us for detailed data and results on comprehensive climate action plans and projects sub nationally).

> In the Netherlands, we no longer see [climate change] as a threat. We see it as an opportunity. We can't avoid it, so let's think about investing in solutions. You can either adapt to climate change because you are forced to or you can plan for it. We choose to plan for it.
>
> *-Aalt Leusink, Scientist and Senior Advisor to the Dutch Government*

Readying our nation through sub national adaptation planning in anticipation of the impacts of climate change, while maintaining a parallel emphasis on mitigation, is the focus of the step-based *Comprehensive Climate Action Planning: Center for Climate Strategies Adaptation Guidebook.* The Guidebook is intended to build upon the work already in process in many states, regions and local governments across the US and the world. Every adaptation action identified has been tried and tested for its effectiveness; each step informed by the lessons of stakeholder-based, consensus driven planning.

In October 2010, the Interagency Climate Change Adaptation Task Force, co-chaired by the White House Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA), released a progress report that committed to a number of priorities including the priority to:

- **Build strong partnerships to support local, state, and tribal decision makers** in improving management of places and infrastructure most likely to be affected by climate change.

The Task Force is guided by a strategic vision of a resilient, healthy, and prosperous Nation in the face of a changing climate. The Task Force asserts that public and private decision-makers should consider the following in their efforts:

- **Adopt Integrated Approaches**: Adaptation should be incorporated into core policies, planning, practices, and programs whenever possible.
- **Prioritize the Most Vulnerable**: Adaptation strategies should help people, places, and infrastructure that are most vulnerable to climate impacts and be designed and implemented with meaningful involvement from all parts of society.
- **Use Best-Available Science**: Adaptation should be grounded in the best-available scientific understanding of climate change risks, impacts, and vulnerabilities.
- **Apply Risk-Management Methods and Tools**: Adaptation planning should incorporate risk-management methods and tools to help identify, assess, and prioritize options to reduce vulnerability to potential environmental, social, and economic implications of climate change.
- **Apply Ecosystem-based Approaches**: Adaptation should, where appropriate, take into account strategies to increase ecosystem resilience and protect critical ecosystem services on which humans depend, to reduce vulnerability of human and natural systems to climate change.

The processes and templates in the Guidebook directly respond to and complement the priorities called out by the Task Force as most essential. It is our hope that this Guidebook accelerates further uptake by state, regional and local governments which will lead us and our children into a future built upon the opportunities of knowledgeable bottom up comprehensive climate action that advances energy security and economic prosperity.

Thomas D. Peterson, President and CEO, the Center for Climate Strategies

Executive Summary

The Center for Climate Strategies (CCS) authored the *Comprehensive Climate Action: An Adaptation Guidebook*, to provide a complete stepwise, fact based, sector-specific methodology on climate adaptation action planning and policy development. This volume complements and translates the highly successful CCS mitigation policy development methodology to the adaptation policy arena. It is the result of extensive research, data gathering, and analysis conducted to establish a tested, effective, and efficient process for federal, state, regional, and local governments to apply when developing a climate change adaptation plan. The process is designed specifically with consideration of regional variations including demographics, natural systems, resource availability, and area politics.

The CCS Adaptation Guidebook details a methodology for developing and implementing an adaptation strategy at the multi-state, state/province, regional, or local levels. Several resource tools are included in the Guidebook. These tools grew from the experience and actions of CCS through comprehensive climate action planning performed by numerous states. We also learned from the approaches of municipalities and other countries to adaptation planning. The selected programs, actions, and locations are not intended to serve as an exhaustive review of all of the adaptation policies and initiatives in the United States and globally, but rather to offer a selection of references that are most applicable to and have greatly informed, the tools and templates included in the Guidebook and its contents.

The Guidebook is organized to provide a stepwise approach to adaptation. Each chapter can be used independently as a resource or the chapters can be used as a sequential guidance detailing the process of completing a comprehensive adaptation plan. The steps in the process are as follows and correspond with chapters in the Guidebook.

- The first step is getting organized and involves bringing in stakeholders and technical experts to identify and frame key climate change risks and adaptation needs, as well as identifying preliminary information, such as existing actions and studies related to adaptation planning.

- The second step in the CCS process is organizing vulnerabilities by major topic areas. Determining which vulnerabilities should be of highest priority should be done based on comparable risk analysis. The major topic areas should correspond to and inform technical working groups.

- Following that, specific potential adaptation options should be identified, including potential gaps and innovations. The Guidebook includes a catalogue of adaptation actions drawn from existing and planned adaptation efforts in US states and municipalities, as well as other countries.

- Next, from this range of potential options, priorities for analysis and further development must be identified through a screening process that focuses on key decision criteria to support goals and objectives of the adaptation plan.

- Following the idenfication of a set of initial priority actions, specfic design parameters should be defined for each option, including timing, level of effort, parties to be involved, program implementation mechanisms, and other specifications.

- Following, a systematic and quantitative process should be used to measure the cost-effectiveness of individual adaptation options. The Guidebook describes how such metrics can be developed and applied. These metrics can be used to evaluate adaptation options, and many can also be used to measure the success or failure of adaptations once they are implemented.

- Next, additional attributes of the adaptation options need to be evaluated, including externalities, distributional impacts, equity and other feasibility issues. Different approaches for making decisions about which adaptations to select are discussed in the Guidebook including methods for addressing uncertainty.

- It is important that adaptation to climate change consider other related consequences. The Guidebook addresses the effects of adaptation on mitigation (reduction) of greenhouse gas emissions. Consideration, particularly when evaluating adaptation options, should also be given to the implications adaptation in one sector or geographic area might have on other sectors, areas, or communities.

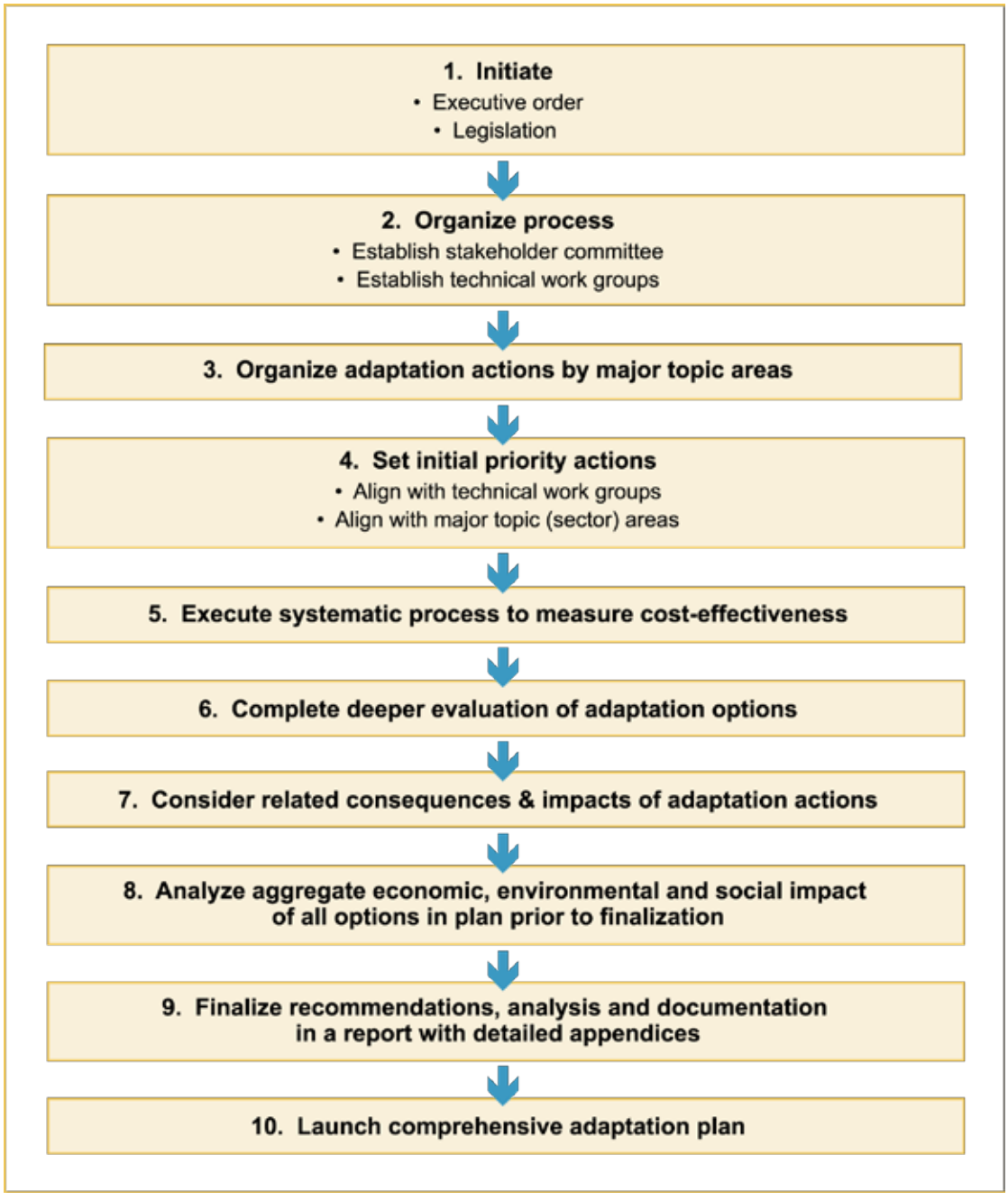
- It is also important that the aggregate economic, environmental, and social impact of all options in an adaptation plan be developed prior to finalization of the plan.

The process is outlined in Figure ES-1, on page 12, and the Guidebook chapters follow the sequence of the process.

The CCS process emphasizes working with agency officials, stakeholders, technical experts, and other members of the public to build consensus on the key vulnerabilities from climate change and the best suite of individual adaptation actions to reduce those vulnerabilities. The process can be used to select adaptation actions or set priorities within these actions. Analysis of the costs and effectiveness of adaptation options and program implementation needs is a key component of the CCS process. It is important to note that this approach does not get bogged down in detailed quantitative analysis, and that appropriate tools are used to manage risk and uncertainty in decision making. One virtue of the CCS process is that it can be used by a diverse group of stakeholders and techical experts, working with agency officials and the public, to build consensus on adaptation plans and programs that are fully implementable in less than a year.

When applied comprehensively and across sectors, the tools and templates set forth in this Guidebook offer a complete process for developing and implementing a climate change adaptation plan. The adaptation plan will include processes for measuring opportunities, risks, and impacts, as well as for informing decision-making, which is essential in times of strained economic resources for current and advanced planning. Through comprehensive climate action planning that includes adaptation, federal, state, regional, and local governments can anticipate, manage, and reduce the risks and impacts of climate change, as well as pursue opportunities for optimizing strong climate investments and policy making.

Figure ES-1: CCS Climate Adaptation Planning Process



Introduction

As the national debate continues on how to most effectively curb and manage the progressive increase in greenhouse gas emissions, the need for federal, state, regional, and local governments and their stakeholders to reduce their vulnerability and fortify infrastructure and services to increase resilience against and adapt to the impacts of climate change is more urgent than ever. The changes in the frequency and intensity of climatic events have direct impact in accelerating the urgency and value of comprehensive climate policies and actions, which include mitigation and adaptation strategies. The Center for Climate Strategies (CCS) developed this Guidebook for state, regional and local governments as a reference manual for use when developing and implementing adaptation actions and policies across their services and infrastructure. It is important to note that while adaptation and planning for anticipated impacts from a changing climate is critically important for sub national governments particularly as a strong consideration for economic strategy, CCS strongly recommends comprehensive climate action planning that includes adaptation and mitigation actions. A combined approach on balance results in a net gain to state, regional and local governments including job creation and protection, monies saved and greenhouse gas emissions reduced.

CCS was formed in 2004 as a public purpose, nonpartisan, nonprofit 501(c)(3) partnership organization. Team members have extensive qualifications in environmental science, public policy, economics, management, business, investment, law, education, communications, and finance. Many have experience as elected and appointed public officials; high-level policy advisors; and academic, nonprofit, community, and business leaders. Currently CCS is involved in more than 40 project initiatives focused on the improvement of economies, environment and energy systems at the local, state, national, and international levels focused on climate mitigation, adaptation, capacity building, and communications in the United States, Mexico, Canada, and China. CCS is also working closely with multilateral institutions as an expert data source to help inform international frameworks and opportunities as well as challenges that nations face in the race to build strong economic futures by nations while planning for a significant shift in the energy sources in the global marketplace.

This Guidebook draws from sub national and national efforts in the United States and abroad to develop climate adaptation plans. It gives detailed guidance to the climate adaptation planning processes executed by sub national governments . CCS has drawn on collaborative projects it has worked on in the past, as well as other climate change adaptation plans, to synthesize a process that details a stepwise process for developing, implementing, and measuring areas, sectors and services anticipated to be most vulnerable to the impacts of climate change.

CCS has assisted with the development of climate adaptation plans in Alaska, Colorado, Florida, Maryland, New York, North Carolina, and Washington. Our stakeholder-based process brings together technical experts and decision-makers to look at the impacts of climate change and determine what steps can be taken to prepare for and adapt to those changes. CCS combines expertise in facilitation, communications, technical analysis, and policy design to provide cutting-edge, collaborative decision-making. Our work builds high levels of consensus for the implementation of specific policy actions that address multiple public policy objectives—including economic and energy security—and harnesses the creative power of stakeholders and policymakers to find the solutions that consistently yield the highest value and consensus for the lowest cost.

The CCS Adaptation Guidebook includes a stepwise process that complements its 10-step climate mitigation methodology. Ultimately, CCS recommends sub national climate strategies that apply an integrated approach to climate action and include equal focus on mitigation and adaptation. The approach is designed to leverage resources including political and financial capital, as well as existing legislative authorities, to achieve the greatest results.

The Guidebook offers inclusive detail of its process, including a catalogue of adaptation actions as a resource reference. It is based on the experience gained through CCS facilitated processes, but also

experiences of other governments that have addressed adaptation. The Guidebook draws on experiences from a number of municipalities and regional organizations that have developed adaptation plans or worked to incorporate adaptation into their planning processes.

The chapters in this Guidebook describe the process and procedures that sub national decision-makers can use to develop an adaptation strategy. The chapters are as follows:

- Chapter 1 presents a template for adaptation, what principles should be applied, and the process that can be used. It also provides a sample schedule.

- Chapter 2 offers a process for identifying priorities for adaptation planning. The chapter describes categories that can be used to organize vulnerabilities and adaptations into general categories of state-specific vulnerabilities (e.g., economic activities, health and society) and specific sectors (e.g., agriculture, water resources) within the general categories. It then presents a process that uses risk management to set priorities for which categories or sectors are most vulnerable.

- Chapter 3 and Appendix 3 identify possible adaptations for consideration. The adaptations are organized as follows: natural systems, infrastructure and the built environment, health and society, economic activities, and crosscutting issues. The catalogue of adaptations presented in the appendixes includes options identified by states, municipalities, and other countries that have already considered adaptation in their planning. To be sure, no such list can be comprehensive, as there are myriad of ways to adapt to climate change.

- Chapter 4 addresses metrics that can be used to evaluate the effectiveness of adaptations and monitor their performance. The chapter discusses the desirable characteristics of metrics for adaptation and the types of metrics that could be employed. It provides detailed information on metrics for water resources and health. The chapter concludes by examining how metrics can be used to evaluate and monitor adaptations across different sectors.

- Chapter 5 presents decision-making techniques that are helpful in evaluating and ranking adaptations. These techniques fall in two categories: approaches that seek to find optimal adaptations and those that help users evaluate adaptations in light of uncertainties about climate change and other factors.

- Chapter 6 puts adaptation to climate change in a broader context, in particular, whether adaptations will also help mitigate climate change. The chapter reviews recent literature on mitigation and adaptation and presents a process for identifying and evaluating adaptations with mitigation co-benefits.

- Chapter 7 summarizes insights gained from examining how 10 governments developed adaptation plans. The governments include U.S. states and municipalities and other countries. The insights include the role of stakeholders and analysis in the processes used to create the plans.

Taking action on climate should include strong analysis of benefits and costs of adaptation measures. Adaptation to climate change does not exist in a vacuum and demands comprehensive analysis of climate impacts. Decision-makers constantly review and change to the way in which climate sensitive sectors are managed. Such adjustments are typically made for many reasons in addition to climate change, including population growth, changes in the economy, impacts on the environment, new technologies, and changes in public opinion. In this light, those examining adaptation should also consider mitigation (reducing greenhouse gas emissions). For example, many adaptation measures can also reduce net greenhouse gas emissions, while others can increase emissions. It is also important to consider the benefit or harm an adaptation action in one sector can have on another. For example, cities can fortify their water supplies by building more reservoirs, but reservoirs can harm the environment. Thus, the identification, analysis, and selection of adaptation measures should consider the multiple

benefits and costs these options may bring specific to that state, region or local government. benefits of joint action are further discussed in the last chapter.

State, regional, and local governments are greatly exposed to the risks that climate change impacts present. In addition, state and local governments are, in many respects, among the first responders to climate change and may be held responsible for a lack of preparation. This Guidebook offers resources and measurable solutions to support sub national efforts to build resilience and a portfolio approach to adaptation as a comprehensive strategy to effectively anticipate and prepare for the impacts of climate change while maintaining a strong focus on mitigating the rate of growth and levels of greenhouse gas emissions.

Chapter 1

Adaptation Process Template

Objective

The objective of the adaptation process is to develop an adaptation plan. This is done by working with agency officials, stakeholders, technical experts and the broader public to identify and assess risk and vulnerability, and then recommend, design and analyze measurable adaptation actions that will most effectively reduce risk and vulnerability while considering other important opportunities and tradeoffs.

The template that is used in this process is not intended to provide a cookie-cutter approach for governments to use in analyzing vulnerability and setting priorities. Those developing adaptation plans should use an approach that offers the highest potential for effectiveness based on circumstances and vulnerabilities specific to the national, state, regional or local government. The objectives identified in the principles section of this chapter should serve as the primary objectives of the adaptation process.

Structure

The following identifies organizations and committees that have been used in previous mitigation and adaptation planning processes. Not all of the proposed structures need to be used. In particular, governments with limited funding or personnel may find it appropriate to employ a limited number of committees and technical workgroups or to engage with a limited number of expert stakeholders. At a minimum, a facilitating organization should be used and stakeholders should be engaged through a project stakeholder committee. Where feasible, we advise using the full approach as described below.

Government. The government convenes the process. This step is often initiated by a chief executive (e.g., governor or mayor) through an executive order (EO). In some cases, legislation by a state or local government is passed. The government also provides financial and technical support for the process.

Facilitating and Technical Assistance Organization. A facilitating organization (FO) manages the process; provides facilitation and coordinates the process; provides technical analysis and staff support; and prepares agendas, meeting summaries, and reports. It is important that the FO does not play an advocacy role and should remain objective in policy discussions. This organization provides stakeholder and technical work group facilitation and integrates technical evaluation capacity into the facilitative process (known as evaluative facilitation).

Stakeholder Committee. A key role of the government, in consultation with the FO, is to create a stakeholder committee (SC) to oversee and coordinate the adaptation process. This organization may be chartered in an executive order or law, for example, the Governor/Commissioner/Mayor's Task Force on Climate Change. The chair of the SC is typically a cabinet officer. However, the committee could be run out of the chief executive's (CE's) office. (Note: Other organizations can use this process.) The SC typically has an advisory function. It may oversee the process, consider recommendations from technical work groups (TWGs), decide on recommendations to the government, and oversee preparation of a final report.

The SC should include 24 to 36 individuals including but not limited to, government officials and representatives of different levels of government, the private sector, citizens' groups, the environmental community, and academics. Composition of the SC is critical and should provide a diversity of viewpoints. To a reasonable degree, a key consideration is to include representatives of those groups whose support may be needed to implement adaptations or whose opposition could stop or slow down implementation. Appendix 1 lists the types of organizations and interests that could have representation on the SC.

Technical Work Groups. TWGs support the SC by providing technical recommendation for consideration, such as identifying draft priorities for analysis, straw policy designs, or examining the impacts specific adaptation options, and typically include both SC members and additional resident experts to augment the SC. They can be organized by topic, such as adaptation as a whole, or by risk/impact category, as identified in Chapter 2 (e.g., Economic Activities, Health and Society, Infrastructure and Built Environment, Natural Systems, and Cross-Cutting Issues). TWG membership can consist of a member from the SC and others from government, the private sector, citizens' groups, non-governmental organizations (NGOs), and academia. Since the TWGs generally have a topic focus, specialists with expertise in the topic area could be added as members of the relevant TWG. TWGs examine options in depth, evaluate them, sort them, and, if asked to by the SC, make recommendations on which ones are most desirable. As noted above, if few options are being considered and if budget is limited, it may be sufficient to have the SG perform the work of TWGs.

Principles

The process includes the following key principles and guidelines:

- The process is fully transparent. All materials considered by the SC and TWGs are posted to the project website, and all meetings are open to the public. The transparency of technical analyses, the design of response actions, and participant viewpoints are critical to the identification and resolution of potential conflicts.

- The process is inclusive. A diverse group of SC and TWG members is chosen to represent a broad spectrum of interests and expertise in the state/region. A ground rule for participation is to be supportive of the process, but members are free to disagree on specific decisions within the process. The public is also invited to provide meaningful review of and input to decisions.

- The process seeks but does not mandate consensus. Votes will be taken at key milestones in the process in order to advance to next steps as indicated in meeting agendas. Alternatives that address barriers to consensus will be developed by the SC and TWGs, with the assistance of the FO as needed. Voting is conducted by simple request for objection at the point of decision (by hand), followed by resolution of conflicts, with the development of alternatives, as needed, to proceed. Final votes by the SC and the TWGs, where appropriate, include support at three levels: unanimous consent (no objection), super majority (less than 25% of members object), and majority (less than 50% of members object). The final report by the FO will document SC recommendations and views on each response action, including alternative views as needed.

- The process is implementation oriented. The goal of the process is ultimate adoption and program implementation of specific policies based on the recommendations of the SC and any subsequent, more-detailed analyses as needed.

- The process is stepwise. Each step of the process builds incrementally on the former toward a final solution. Sufficient time, information, and interaction are provided between steps to ensure comfort with decisions and quality of results.

Process

This process is the approach CCS uses to assist state, regional and local governments in developing mitigation and adaptation plans. Key aspects of the process are highly recommended.

Figure 1-1: Key Aspects of Adaptation Planning

- Clear communication and direction from senior elected officials
- Adherence to ground rules and process design parameters
- Inclusive and transparent process involving stakeholders
- Clear schedule, milestones, and deadlines
- Application of thorough and consistent analysis
- Continuous involvement of senior officials in the process
- Clear presentation of results through a final report

Below the steps in the process are described.

Step 1: Initiate Executive Order or Legislation

Typically, the process is started when the chief executive (CE) issues an order setting out the goals and objectives for the process and the deadlines (and schedule if appropriate); creates a task oriented organization and assigns a facilitation and technical support team; and provides the organization with a budget and staff to oversee and manage the process. Executive Orders (EO) often specify membership or at least inclusion of government members in addition to appointing the stakeholders and technical work group members.

However, the direction could also come through legislation. Although at the state level, legislation involves two branches of government and thus broader buy-in to the process, the process of getting legislation passed can take longer. The vast majority of state and municipal studies on mitigation alone or mitigation and adaptation were initiated with an order from the CE.

Step 2: Organize Process: Establish Stakeholder Committee and Technical Work Groups

One of the first sub steps is to select a Facilitation Organization (FO). The FO can provide staff support for the rest of the process.

A clear and achievable schedule should be developed. This includes identifying meetings, agenda, objectives, and dates for each meeting. Milestones, for example, when adaptations are to be identified or analyses to be completed, should be identified.

Budget, government and outside staffing needs should also be identified at the beginning of the process.

Members of the SC should be selected. The SC should meet and decide on the need for and organization of a TWG(s).

Create Technical Work Groups

As necessary, TWGs should be created to examine adaptation options in depth. The recommended approach is to create separate TWGs for each major category identified in Chapter 2 (such as was done in Maryland and Alaska):

- Economic activities
- Health and society
- Infrastructure and built environment
- Natural systems

Alternatively, a single TWG can be created for adaptation as a startup or initial planning development tool as a part of a mitigation process, as was done in Florida. The drawback of the latter option is that the TWG needs to be large enough to address many sectors, or it will need to reduce its scope. Florida had 15 adaptation categories, and focused on a short set of early actions as a bridge to a longer term, comprehensive plan.

Step 3: Organize Adaptation Actions by Major Sector Areas

This step involves organizing and preparing for confirmation of priorities for which categories of vulnerabilities will be the focus of adaptation response actions. Many sectors (e.g., coastal resources, water resources, biodiversity) may be at risk from climate change, as may many regions. Some governments may wish to take on all sectors and regions vulnerable to climate change. Others may wish to set priorities by selecting certain sectors or regions to focus on and target available resources for adaptation. For example, Maryland focused its initial adaptation work on coastal resources because sea level was considered to be the most important risk from climate change facing the state.

Step 4: Set Initial Priority Actions: Align with Technical Work Groups and Major Sector Areas

Chapter 2 describes a process that can be used to organize and set priorities. This step should be completed within two months of initiation of the adaptation effort in order to allow sufficient time for subsequent steps and the final report to be completed within a year of project initiation.

Priority actions and areas may be established based on specific geographic regions or communities. For example, efforts may be focused on coastal areas threatened by rising sea levels. Priority areas also may be specific sectors. For example, impacts of climate change on water supply may be of great importance in a state or region. Priority areas may be particular populations of affected people. For example, protecting low-income, elderly populations not living in air-conditioned residences from the effects of heat waves may be a top concern. Because no planning effort can give equal and adequate treatment to all possible consequences of climate change, identifying the priorities for consideration is an essential, fundamental, early step in the adaptation planning process.

Note that this process does not involve a detailed vulnerability assessment, that is, a study of potential impacts of climate change on the sectors and regions in the government's jurisdiction. Such an assessment often takes months to a year or more and can be expensive. Thus, available time and financial resources could be consumed in conducting a vulnerability assessment. Maryland, Alaska, and Florida did not engage in a vulnerability assessment, and relied upon a series of existing assessments. Nonetheless, some governments may find it helpful to examine the vulnerability of sectors and regions to climate change. The information from the assessments can be used to set priorities for adaptation. The vulnerability assessment need not involve new analyses, particularly new quantitative analyses. It can be

completed through input from a review of published literature and reports. It could be analogous to the baseline process in mitigation and thus should be done rapidly (e.g., within a few weeks) at the beginning of the project. Information sources on climate change impacts are listed in Appendix 1.

Policy Analysis

This step, which is the heart of the adaptation process, involves analyzing current policies regarding management of affected resources or regions to reduce risk, identifying alternatives, analyzing policy options, setting priorities, and making selections to recommend to the CE. Priority should be given to the sectors or regions that are established by the SC (or TWG) in Step 3 to be of highest priority.

Policy Baseline

This step involves identifying current or planned policies that are part of the adaptation analysis. For example, the review could discuss existing policies on coastal zone management, water resource allocation, water quality, wildlife management, and other topics. The report should be short and accessible. Thus, it need not be exhaustive, as current policies can be detailed and complex. It should provide a sufficient overview so that members of the SC and TWGs can use it to develop a basic understanding of the current legal, institutional, and regulatory environments.

Identify Adaptation Actions

The SC or TWG should review vulnerability analysis as appropriate and identify a full list of potential adaptations for consideration. The catalogue discussed in Chapter 3 should be consulted as it provides a comprehensive list of existing and potential new adaptation actions appropriate for state, regional or local implementation. TWG and SC members will expand this list by providing suggestions for additional adaptation options to fill gaps, localize the options, and provide innovation.

Step 5: Execute Systematic Process of Adaptation Options

We recommend examining no more than 50 adaptation options in depth in order to meet reasonable constraints and goals of time, resources and need. If more than 50 are identified, a voting or rapid screening process can be used to select the top 50 options (or smaller number that SC or TWG considers manageable and appropriate).

The screening should consider many factors including:

- importance of the climate impacts being addressed;
- urgency of adaptation priorities and vulnerabilities
- relative costs or savings for adaptation actions
- feasibility of implementation of the actions, including technical, social, institutional, economic, political, and other considerations
- important co-benefits or side issues, including climate mitigation

A screening should involve benchmarking as well as expert judgment in the identification of a top set of draft priorities for each TC. Depending on need, this may require a series of discussions to set up a review and balloting process, as well as follow up discussions to review results and revise if needed to ensure that the SC will receive actionable recommendations by the TWG. Chapter 4 contains discussion on metrics and tools for setting priorities across sectors that can be referenced to inform an expert and fact based screening process.

Step 6: Complete Deeper Evaluation of Adaptation Options

Adaptation actions are assigned by the SC to the appropriate TWG. TWGs will then analyze each option in depth for review by the SC and guidance on additional work as needed.

Options within sectors should be compared using common metric(s) if possible (see Chapter 4). This requires analysis of the effectiveness of the adaptation and costs or savings. Feasibility of the adaptations should also be examined. Feasibility can include considerations such as whether legislation can be passed, whether measures are likely to implemented without significant opposition, and whether technical skills and know-how exist to enable implementation.

TWGs should identify a priority set of options within sectors based on outcome of analysis and qualitative review, as appropriate. Options within a sector should be displayed in terms of decision criteria, such as cost-effectiveness. This requires estimating the effects of the adaptation using the metric(s) and costs. If it is not feasible to apply a metric(s) within a sector, indexes such as those described in Chapter 4 may be used to rank adaptations within sectors.

Typically TWG members will use a balloting process to identify a potential set of priority for analysis options for SC consideration. This approach has the advantage of being democratic, i.e., each member has a vote When a consensus or voting process is used, it is important that the SC and TWG membership be inclusive of divergent interests and viewpoints. An inclusive body is more likely to select options that have broad acceptance than a body that leaves out important interests or viewpoints.

If detailed analytical work is undertaken, additional experts might be needed to advise on the application of methods and to provide review. Although this can lengthen the process, it is important if technical issues are being addressed and time and resources can support the effort.

TWGs that address multiple sectors should apply an index (see Chapter 4) to rank options across sectors.

The SC (or TWGs working together) should rank all adaptations using results from TWG analysis and index scores. SC can review and revise index scores.

If requested, the SC may select a subset of adaptation options to recommend to the CE for implementation. Some adaptations may be implemented through executive order; others may require legislation.

Step 7: Consider Related Consequences and Impacts of Adaptation Actions

Some adaptation actions might have impact on related sectors, areas or services. In analyzing the value of a given adaptation action, it is important to consider related consequences and impacts. For example, if fortifying the wastewater infrastructure system is the adaptation action being considered, the overall water infrastructure system should be evaluated to ensure that fortifying one part would not overly stress other parts of the infrastructure.

Consequences and impacts are not predetermined to have potential negative impacts on other sectors, rather there are some instances when the benefits of adaptation actions are multiplied known as co-benefits.

Step 8: Report including Analysis of Aggregate Economic, Environmental and Social Impacts of Adaptation Actions Selected

The FO will draft a report on the process and results. This report is reviewed by TWG(s) and SC. A suggested outline for the report is as follows:

Executive Summary

Chapter 1: Introduction and Background of the Process

Chapter 2: Vulnerability Assessment and Policy Analysis

Chapter 3: Policies

a. Inventory of Existing Policies

b. Adaptation Options

Chapter 4: Economic Activities

Chapter 5: Health and Society

Chapter 6: Infrastructure and Built Environment

Chapter 7: Natural Systems

Chapter 8: Summary of Aggregate Economic, Environmental and Social Impacts

Chapter 9: Multi Sector Institutional and Integrative Issues Recommendations

Appendixes:

a. Meeting Schedule, Members, and Attendance

b. Quantification Methods, Guidance Memos for Metrics, Cost Effectiveness, and Other Analytic Approaches Used in the Assessment

c. Policy Option Templates, Analyses, and References for SC Recommendations by TWG

i. Economic Activities

ii. Health and Society

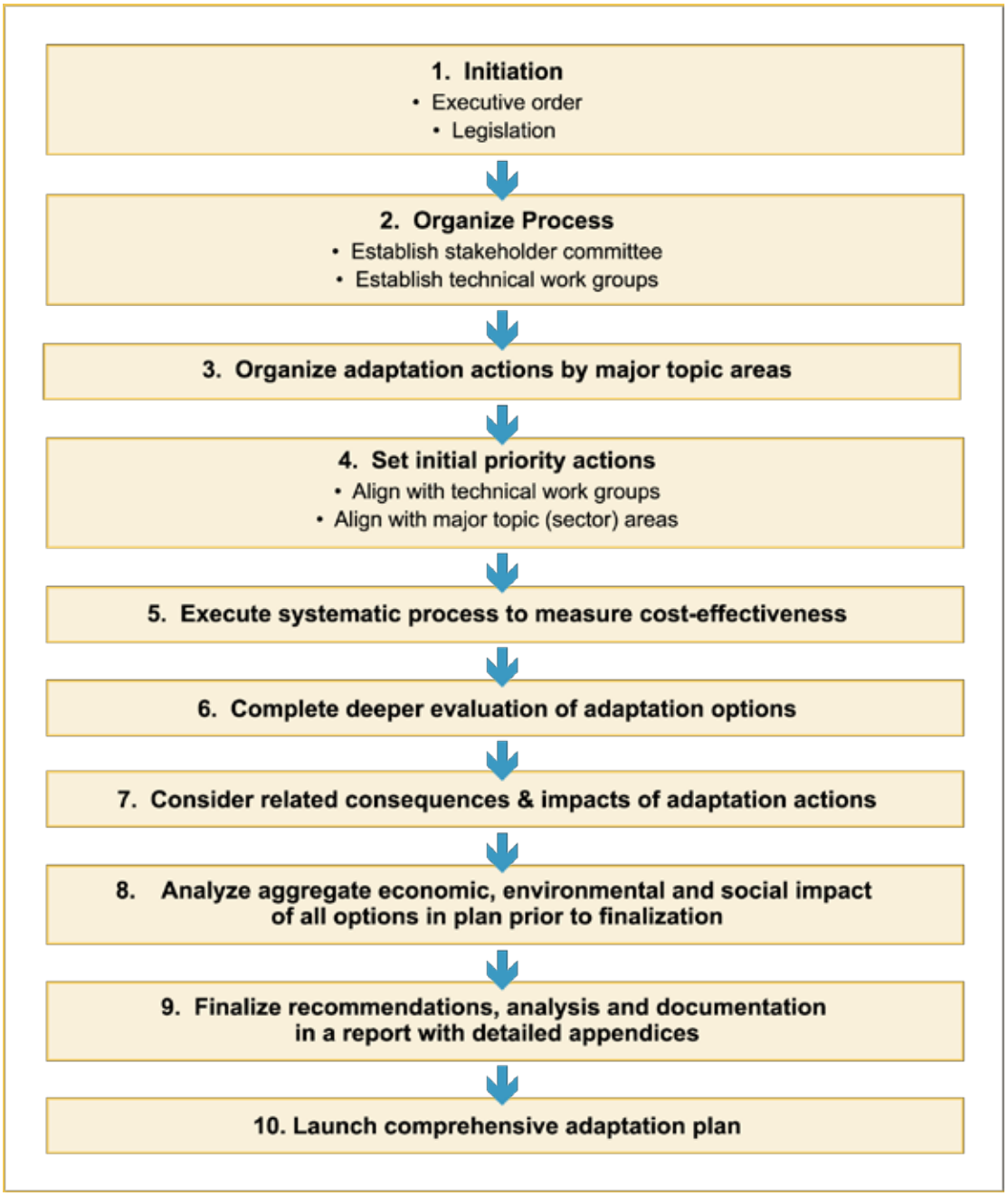
iii. Infrastructure and Built Environment

iv. Natural Systems

v. Multi Sector Institutional and Integrative Issues Recommendations

Figure 1-2, on page 24, displays the process.

Figure 1-2: CCS Climate Adaptation Planning Process



Schedule

The following draft schedule is suggested for planning purposes.
Note that the process takes less than one year to complete.

Date	Meeting
First Month	1st SC Meeting
Third Month	2nd SC Meeting
Fourth Month	3rd SC Meeting
Sixth Month	4th SC Meeting
Eighth Month	5th SC Meeting
Tenth Month	6th SC Meeting
Eleventh Month	Final Report

The TWGs work in parallel with the SC to ensure complement and to provide technical depth to the plan development process via the SC. TWGs meet regularly though frequency is determined by the focus and issue demand of the technical area a TWG if focused on.

Chapter 2

Identification of Priorities for Adaptation Planning

An essential step in climate change adaptation planning is to determine the areas that will receive priority focus when considering and developing adaptation policies. The impact areas that are targeted in order to determine priorities are established based on a number of factors specific to particular impacts including:

- Risk level and type
- Consequence
- Scope and range
- Frequency

Priority areas may be established based on specific geographic regions or communities. For example, efforts may be focused on coastal areas threatened by rising sea levels. Priority areas also may be specific sectors. For example, impacts of climate change on water supply may be of great importance in a state or region. Priority areas may be particular populations of affected people. For example, protecting low-income, elderly populations not living in air-conditioned residences from the effects of heat waves may be a top concern. Because no planning effort can give equal and adequate treatment to all possible consequences of climate change, identifying the priorities for consideration is an essential, fundamental, early part of the adaptation planning process.

Part one of this chapter provides guidance on a framework of categories of climate change risks and policies that can be used not only for structuring the identification of priorities for the adaptation planning process but also for every other step in the process. Part two provides guidance on a process for using existing baseline information to identify priority areas for adaptation planning.

Part I.
A Framework of Risks and Impact Categories

An initial task in climate change adaptation planning is to determine a framework of categories to be used throughout the planning process in order to group together climate change impacts and adaptation policies. Such groupings for both impacts and policies allow decision-makers, stakeholders, and those providing technical assistance to focus on related impacts and policies at the same time. The groupings also ensure that those with particular interests and expertise are effectively engaged in the part(s) of the planning process most important to them or to which they can best contribute.

The first step is to adopt a single framework applicable to impacts and policies. This establishes an effective stepwise planning process. When a stakeholder panel supported by different TWGs is doing the planning, a single, consistent framework makes it easy for the TWG that considers a particular group of impacts to also consider the adaptation policy options most related to those impacts. A single framework also helps ensure that information on and judgments about particular impacts are matched with information on and judgments about the policies intended to address those impacts. And the single framework of categories also is most effective for communicating with stakeholders, the media, and others about the planning process, its risks, and its policies.

A suggested single framework with categories of risks and policies is shown in Table 2-1, with illustrations on the following page, of where particular issues would fall within the suggested categories.

Table 2-1: Sample of CCS Single Framework of Categories including Risks and Policies

Risk/Policy Category	Examples of Included Issues
Economic Activities	Agriculture Tourism and recreation Forestry Fishing Industry Energy supply
Health and Society	Human health Vulnerable populations
Infrastructure and Built Environment	Infrastructure Transportation Energy supply and use Flooding
Natural Systems	Sea level rise Water supply Ecosystems and wildlife
Cross Cutting	Multiple issues and sectors affected by a specific risk or policy

These categories are used throughout this Guidebook to group risks and policies. For policies a crosscutting category is also used when considering policies that overlap two or more of these categories.

Several considerations support this suggested framework. The first is that the categories, in number and scope, should match and define the TWGs (see Chapter 1) being used in a particular planning process. Because there are often five TWGs, four categories are suggested in this framework, with one TWG devoted to each category and a fifth devoted to crosscutting issues. If there are more than five TWGs in a planning process, the number of categories in the framework for that process can and should be expanded accordingly. It usually is easier for decision-makers and/or stakeholders to reach agreement to add one more category than it is to reach agreement on eliminating a category; this confirms the value of a basic standard framework of four categories rather than five or more.

A second consideration is that the framework of categories should be designed to facilitate effective consideration of policies rather than be designed to match the organization of most baseline sources of information being used to identify priorities for the planning process (the subject of Part II of this chapter). This is due to the fact that most of the planning process is devoted to the consideration of policies, not to the consideration of risks. The categories suggested here work particularly well based on the experience of CCS in the development of state adaptation plans.

This framework can be tailored to the specific circumstances and needs of each planning process. As noted previously, if there will be more than five TWGs in a process, then the number of categories should

be expanded accordingly. There also may be important local differences in the risk and policy areas that are most important. For example, in regions threatened by rising sea levels, it may be such an important issue that it warrants consideration as its own major category. In certain states or regions, it may be better to assign an issue to a different category, depending on such factors as the interests and expertise of TWG members and the different issues being considered. For example, in one state, consideration of water resource risks and policies may be a matter of managing the water supply systems and it would make more sense to place this issue in the infrastructure and built environment (IBN) category. In another state, the water resource may relate more closely to the effects of changed hydrological patterns on natural ecosystems and it would be placed within the natural systems (NS) category.

In any framework of categories, there will be several issues that are relevant to more than one category. It is always important to promote information exchanges between TWGs.

Part II
The Process to Identify Priority Areas

Part II describes the process for determining priority action areas to be considered in the adaptation planning process.

Initial decisions about the nature, scope, and timing of the planning process and the resources available for this process will establish important parameters for the identification of priority areas. These decisions include whether the planning process is to be comprehensive or focused on one or more particular sectors; how many TWGs or other subgroups will be part of the process; how many issues each TWG will consider; and the length of time for the planning process. These decisions must be made before the process of determining priorities begins.

Following these initial decisions, priority action areas for adaptation planning should be identified and several steps that build upon one another are taken. The process begins with the preparation of an extensive initial list of climate change risks and vulnerabilities in the planning area. These are called "potential candidate risks."

The initial list is revised. Then a number of risks are chosen for analysis; these are confirmed as "candidate risks." After information is gathered on the candidate risks, a smaller group of risks is selected as the risks to consider in the planning process; these are called "priority risks." The remainder of the planning process involves considering and selecting policy actions to address those priority risks.

The steps leading to the selection of the priority risks follow.

A. Develop an initial list of potential candidate risks

First, those providing technical assistance to the process develop an initial list of potential candidate risks. Those providing technical assistance should consult with those convening the planning process to ensure that important risks are included in the initial list of potential candidate risks. The initial list should include more risks than will be selected for consideration (the actual candidate risks); the draft list is shortened in the next step.

B. Revise list of potential candidate risks

Those providing technical assistance to the process present the draft list of candidate risks to the decision-makers, stakeholders, or TWGs as appropriate. These individuals then revise the definition of risks and add and delete risks in order to produce a revised list of potential candidates from which they will select the candidate risks for analysis.

After an initial presentation of the draft list and a discussion of possible changes to it, the stakeholder panel or TWG selects items to be included in the final list of candidate risks for consideration based on

the number of votes received for each item. For example, if it has been determined that each TWG will consider 10 issues in its category, the 15 candidate risks in each category with the most votes will be included on the candidate list.

C. Select candidate risks

From the draft list of potential candidate risks, the actual candidate risks to be considered in the risk analysis phase are selected in consultation with the decision makers, SC stakeholders or TWGs based on application of multiple decision criteria. For a stakeholder panel or TWG, the candidate risks are voted on by the panel or group using their judgment on the best and most preferred options in light of the objectives and decision criteria of the process. There often will be a predetermined limit on the number of candidate risks to be analyzed, generally 15 for each risk and policy category. When this is the case, each panel or TWG member votes for that number of potential candidates (but no more) per category. The potential candidates getting the most votes, up to the predetermined limit, are the candidate risks to be analyzed.

D. Analyze candidate risks

After the candidate risks have been determined, those providing technical assistance to the process gather information from existing, baseline sources about the nature of those risks in the state or area being considered in the planning process. Information on the consequences and potential severity of the impacts, should they occur, and on the likelihood of those impacts actually occurring in the planning area should be included.

Some of the more important sources that can be used to gather information about the candidate risks are included in Appendix 2. These sources and others can be used to gather summary information for the selection of the final priority risks, which is the next step in this process.

When summarizing information on the candidate list, those providing technical assistance should assess each candidate risk using the matrix in Table 2-2.

Table 2-2. Risk assessment matrix for ranking risks.

	Likelihood of Impact Occurring		
Magnitude of Impact If It Occurs	Low (1 point)	Medium (2 points)	High (3 points)
Low (1 point)	2	3	4
Medium (2 points)	3	4	5
High (3 points)	4	5	6

A judgment is made on whether the magnitude of the possible impact, if it occurs, is low, medium, or high. If the magnitude is judged to be low, the risk is assigned 1 point; if medium, 2 points; if high, 3 points. Each risk area is also judged as to the likelihood of the impact of that magnitude actually occurring. If the likelihood is judged to be low, the risk is assigned 1 additional point; if medium, 2 additional points; if high,

3 additional points. The risk assessment matrix in Table 2-2 shows the resulting combined score for each of the nine possible combinations.

After all candidate risks are assessed using Table 2-2, those providing technical assistance prepare a list of all candidate risks, organized by category of risks and policies, in order of their risk assessment scores, with the score indicated for each risk. As becomes clear in the next step of the process, the risk assessment ranking is a tool for the decision-makers, stakeholders, and/or TWGs to use. It is not itself determinative of which risks become priority areas for the planning process.

It is possible that the same risk could be scored in two or more ways for different magnitudes of impacts. For example, the magnitude of an extreme water shortage could be high (3 points) and the likelihood of a shortage occurring could be low (1 point), for a total of 4 points. However, the magnitude of a moderate water shortage could be medium (2 points) and the likelihood could be high (3 points), for a total of 5 points. In a case like this, the risk should be assessed both ways, and the higher score should be used as the risk assessment score for that risk.

The risk assessment approach suggested here is similar, but not identical, to approaches suggested in two other resources on adaptation planning, both also recommend the use of a matrix to identify priorities among risks. The first resource guide is by the Climate Impacts Group of the University of Washington and King County, Washington, in association with ICLEI–Local Governments for Sustainability.[1] The King County resource guide suggests ranking risks as low or high risks and as low or high vulnerability, using a matrix with four cells. In that approach, risks that are ranked high on both points are likely to be priority planning areas; risks ranked high on one point may be priorities; and risks ranked low on both points are unlikely to be priorities.

The second reference is based on a planning effort undertaken by the New York City Panel on Climate Change as part of the community-wide comprehensive PlaNYC sustainability program.[2] This approach suggests ranking risks according to the magnitude of their impacts, as low, medium, or high, and according to the likelihood of occurrence, as low, medium, high, or very high, using a matrix with 12 cells. This approach suggests developing adaptation strategies for risks with 5 of the possible 12 combinations in the matrix: risks with high magnitudes of impact if their likelihood is medium, high, or very high and risks with medium impacts if their likelihood is high or very high. The next step is further evaluation and perhaps development of strategies for four other combinations: high magnitude/low likelihood, medium magnitude/medium likelihood, low magnitude/very high likelihood, and low magnitude/high likelihood risks. For the three others, this approach recommends waiting to see if strategies should be developed in the future.

The CCS approach has three advantages. First, a matrix with nine cells, as suggested in Table 2-2, is an appropriate balance between refinement and ease of use. Second, the numerical scoring used in the CCS risk assessment approach makes it possible to translate the matrix into a simple ranked list, which makes comparisons and consideration of candidate risks easier. Third, the CCS approach makes it clear that a risk assessment matrix is a tool for focusing discussion and is not a substitute for the judgment of decision-makers, stakeholders, or TWGs.

E. Determine priority areas

Next, those providing technical assistance to the process present the background information they gathered on all candidate risks to the decision-makers, stakeholders, or TWGs, as appropriate, in whatever form is needed for the planning process. The ranking of risks by their risk assessment scores, organized by category of risks and policies, is also presented. The decision-makers, stakeholders, or TWGs discuss the information and rankings, with input from those providing technical assistance. Because the risk assessment scores are merely a tool for focusing the discussion and are not determinative, there is no need to revise the ranking of risks.

After the discussion, the decision-makers, stakeholders, or TWGs, as appropriate, select the priority risk areas to be considered in the planning process. Typically, there are a predetermined number of priority areas to be considered in the process, perhaps 10 risks in each category. In this case, the decision-makers, stakeholders, or TWG cast 10 votes in each category, with the 10 candidate risks receiving the largest number of votes being selected as the priority risks.

If the discussion of and voting on the candidate risks suggests a more useful allocation of priority risks among categories than was predetermined, an appropriate adjustment should be made. At this point in the process, it may have become clear, for example, that 12 priority risks should be identified in one category and 8 in another, rather than 10 in each.

Once the priority risks for the planning process are determined, the planning effort moves to the next phases: the development, consideration, and selection of policy actions to address those risks.

Endnotes

[1] Center for Science in the Earth System (The Climate Impacts Group) and Joint Institute for the Study of the Atmosphere and Ocean, University of Washington; King County, Washington; in association with ICLEI–Local Governments for Sustainability. Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments. Available at http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf.

[2] Major, D.C. and O'Grady, M. May 2010. "Adaptation Assessment Guidebook, Appendix B to Climate Change Adaptation in New York City: Building a Risk Management Response," Annals of the New York Academy of Sciences 1196: 229–292.

Chapter 3

Catalogue of Climate Change Adaptation Actions

This chapter and Appendix 3 present a catalogue of adaptation actions that could be used as guidance for any jurisdiction undertaking an adaptation planning process, particularly at the state level. The catalogue was developed based on a survey of nations (i.e., Spain, Australia), states (Maryland, Florida, Alaska), counties (King County, Washington; Miami-Dade County, Florida), and cities (Boston, Chicago, Los Angeles) that have examined adaptation systematically. The chapter provides a description of the adaptation catalogue for five key areas that span the realm of potential actions that could be taken to plan for a certain level of impacts from climate change. These include economic activities, health and society, infrastructure and the built environment, natural systems, and crosscutting issues. Each is summarized in the following sections.

The list of adaptation options is not meant to be comprehensive and is intended to help users identify possible adaptations. Adaptations not listed in the appendix may be appropriate to consider in the adaptation process.

A. Economic Activities

There are eight key areas comprising 82 specific adaptation options, as summarized in Appendix 3. Three of these areas cover economic development; two cover agriculture, and the remaining three-address forestry, fisheries and tourism. The eight areas are mutually supportive, and there are common overarching themes. Action items in the economic development group focus on assessing the economic value of environmental services and encouraging activities that (a) engage the private sector; (b) use the emerging green market to stimulate job growth; and (c) encourage climate safe development. Agriculture items focus on assessing climate change impact on the agricultural industry, implementing more efficient farming practices, developing new policies and technologies that facilitate adaptation, and transferring knowledge. As with agriculture, fisheries and tourism items focus on impact assessments and development of better policies and management strategies. The forestry section focuses on evaluating existing research, conducting additional research, and improving modeling capacity.

B. Health and Society

There are nine sectors (including overarching issues) comprising 59 specific adaptation options, as summarized in Appendix 3. Three of these sectors address health issues exclusively. Recurring issues in the catalogue are:

- impact assessments on health, welfare, and safety;
- collaboration with the insurance industry to design programs that increase individual security, development of plans for greater social and economic equity; and
- Identification of the health-related vulnerability of people, regions, economies, and infrastructure.

The Health sections focus on improving human health by adapting the built environment to climate change; protecting communities against extreme weather events through various programs, such as community shelters; and preventing disease through vaccine campaigns and disease surveillance systems. Both the Cultural and Social and the Economic and Environmental Justice sectors stress impact assessments and institutional development. Education and Outreach to improve conservation is a recurring theme as is plan for forced migration, both to and from states in question. Establishment of methods and goals for water conservation and emergency preparedness is also clearly addressed.

C. Infrastructure and the Built Environment

There are 10 thematic issues with action items comprising 143 specific adaptation options, as summarized in Appendix 3. These thematic areas address a range of infrastructure concerns. Although many of the action items are unique to their issue, there are several overarching themes. These include incorporating climate change into overall infrastructure planning, strategy development, impact and vulnerability assessments,[1] upgrading, and building code adjustments.

The *Land Use Planning* theme focuses on reviewing existing information, improving planning through greater technical capacity, and integrating land use issues with budget issues, law, and zoning.

Transportation and infrastructure stresses emergency preparedness, ensuring that climate change becomes a part of transportation planning, and developing strategies to address removing infrastructure from threatened areas.

Infrastructure Planning calls for institutional development, updating building codes, changing investments based on climate change related risks, and implementing methods for reducing flooding, such as planting trees and using less pavement. Both *Managed Retreat/Relocation* and *Protection of Communities* have legal considerations and vulnerability assessments. Managed Retreat/Relocation encourages strategy development, retreat from high-risk areas, and emergency relocation plans, while *Protection of Communities* emphasizes strengthening building codes, installing structural protection, and encouraging the adoption of new design standards.

Adaptation proposes a broad range of activities that cannot be easily grouped. These activities encompass everything from promoting the purchase of hazard insurance to training for key adaptation sectors, such as infrastructure, building trades, and finance. Water Supply and Delivery is another theme whose action items stress vulnerability assessments, improvement management systems, and development of a strategy for long-term public water access. Storm Water Infrastructure addresses how potential increase in storm water can be accommodated. Accommodation includes methods to track risks and share them (e.g., insurance). Finally, Communications Infrastructure and Energy Infrastructure are very similar in that they both require impact assessment, increasing infrastructure resilience through routine maintenance and upgrades, and proper insurance to guarantee reconstruction in case of disaster.

D. Natural Systems

There are seven key *Natural Systems* issues comprising 90 specific adaptation options, as summarized in Appendix 3. *Overarching Natural Systems Concerns* center on improving monitoring capacity, assessing vulnerability, and developing climate change scenarios and sustainable practices for different natural systems. In addition to the above issues, the *Conservation of Natural Land and Marine Systems* action items focus on improving access to relevant information. Forest and fisheries items focus on evaluating existing strategies and information and improving technology or warning systems. *Wildlife and Fish* along with coastal zone items focus on developing guidelines, strategies and new policies, and *Hydraulic Systems* items develop monitoring and modeling capacity that most often require further research.

E. Cross-Cutting Issues

The CCS team has identified eight crosscutting issues comprising 85 specific adaptation options, as summarized in Appendix 3. Many of these crosscutting issues overlap and are mutually supportive. Prime examples are *Science and Research* action items such as “build decision support structure to guide state-specific research agenda” and “establish new Climate Change Scientific Advisory Council to advise state,” which are aimed at enabling planning and decision action items. Other key *Science and Research* outputs provide the foundation for action items in *Public Education and Outreach*, *Planning and Decision-Making*, and *Organizing State Government for Long-term Adaptation*. Many of the action items focus on intergovernmental affairs, coordination of state and inter-state responses, and enhancement of adaptive capacity.

Generally, all adaptations listed in Appendix 3 contribute to increasing resilience to climate change. Indeed, many of these measures will also increase resilience to risks from current climate impacts such as climate variability and extreme events.

Resilience can be defined as meeting the following criteria:

Robustness: the strength or ability of elements, systems, and other units of analysis to withstand a given level of stress or demand without suffering degradation or loss of function.

Redundancy: the extent to which elements, systems, or other units of analysis exist that are substitutable, i.e., capable of satisfying functional requirements in the event of disruption, degradation, or loss of functionality. This includes redundancy of processes, capacities, and response pathways within an institution, community, or system to allow for partial failure within a system or institution without complete collapse.

Planning and foresight: to prepare for identified impacts and risks. Although it is impossible to plan for every possible set of impacts and, in many cases, the cumulative effect of impacts is unknown; the process of planning brings learning, builds skills, and helps to create resilience.

Resourcefulness: the capacity to identify problems, establish priorities, and mobilize resources when conditions exist that threaten to disrupt some element, system, or other unit of analysis. It also consists of the ability to apply human and material resources in order to address priorities and achieve goals. This would include a *multi-faceted skill set,* including abilities that enable thorough preparation, such as comprehensiveness and detail-orientation; survival, such as quick decision-making and resourcefulness; and rapid recovery, such as innovation and diligence.

Diversity and decentralization: as it applies to planning, response, and recovery activities. A diversity of options has greater potential to match the particular scenario of impacts that occurs, while decentralization allows for parts of the system to continue operation even if other parts of the system are down.

Rapidity: the capacity to meet priorities and achieve goals in a timely manner in order to contain losses and avoid future disruption.

Flexibility: as it exists at an individual, organizational, and systemic level, with each level able to respond and contribute to each situation and to respond to shifting and unpredictable circumstances. This would include collaborative multi-sector approaches to planning, execution, and recovery, since no one sector has a monopoly on a particular impact, thus, an understanding of the overlaps and gaps between sectors is critical.

Plans for failure: so that breakdowns happen gracefully, not catastrophically. For example, when floodgates break, they do so in a way that channels floodwaters to uninhabited floods zones, perhaps damaging property but protecting human lives. The acceptance that the unpredictability and uncertainty of climate risks and responses will ultimately lead to failure of some element of the system allows for failure planning. In some cases, returning to a pre-existing state will not be possible or will not be appropriate. Incremental failures and planning for failures allow for real-time response and revision and limit social, environmental, and economic costs. Total system failure limits response options and results in greater suffering.[2]

Endnotes

[1]Vulnerability assessments are analyses of how systems, regions, or populations may be affected by climate change. They typically consider how climate may change, how that may initially affect systems (e.g., whether coastal areas could be inundated, whether water supplies could be reduced), and the ability (capacity) of the system to adapt to the impacts. A vulnerability assessment might consider whether a farmer experiences a decrease in crop growth, but would also consider what the farmer could do to adapt to the new conditions.

[2] Rockefeller Foundation. 2009. "Building Climate Change Resilience." New York: Rockefeller Foundation. http://www.rockefellerfoundation.org/uploads/files/c9725eb2-b76e-42eb-82db-c5672a43a097-climate.pdf. October 26, 2010.

Chapter 4

Establishing Metrics for Adaptation Planning and Performance in Key Adaptation Action Issue Areas

Introduction

Adaptation metrics are defined as a system of measurement for the selection and evaluation of adaptation strategies. The application of metrics is very important when measuring the need for and effectiveness of adaptation actions. Without metrics, there may only be a vague sense of the vulnerability or resilience of various systems and societies to climate change and even less sense of whether adaptations are reducing those vulnerabilities and increasing resilience. Metrics provide a way to compare the effectiveness of options including cost and can be used to help establish priorities among adaptation options.

To organize and prioritize adaptation actions and measure performance of a specific action, appropriate evaluation metrics are required to facilitate both analysis and communication functions. Moreover, metrics for use in adaptation planning processes must be relevant to decision-makers across a range of sectors, scales, and options and relevant to the specific region and governance level.

Readers who want the crux of our approach to metrics should keep the following thoughts in mind:

- Understand the limitations. Caution should be exercised in developing and using metrics in adaptation planning processes. They are not a panacea or "silver bullet" that will somehow deliver the right choice of option or the best measure of vulnerability reduction rather they will contribute to selection and decision-making of adaptation actions.

- Be aware of the potential for unintended side effects. Although metrics can help provide tangible quantitative measures to monitor progress and effectiveness, important characteristics of adaptation options may not necessarily be appropriately captured in a metric to measure adaptation. This can have unintended negative side effects.

- There is no single metric applicable in all settings, rather different sets of metrics depending on sector. Stakeholder-driven adaptation planning processes need flexibility in selecting and adjusting metrics that work best in their particular context. Forcing the use of a single set of metrics may actually increase the rigidity of the evaluation process and lead to maladaptive responses.

For policymakers, practitioners and stakeholders addressing climate change adaptation, discussions of metrics can often raise issues that seem more theoretical than practical. The rest of this chapter explores some of these theoretical areas with the intent to raise awareness and sensitivity by those on the ground that adaptation is a deeply complex aspect of comprehensive climate action planning that begs thorough analysis and design and strong consideration of regional context and considerations prior to plan execution.

What to Measure and How

In this chapter, we address these issues by posing the following key questions:

- What types of metrics can be used to report and monitor progress on adaptation?
- What has been the experience in the application of metrics in key vulnerable sectors?
- What are the key implications for decision-makers regarding the use of metrics in adaptation planning processes?

Finally, since there are few examples of applying metrics to climate change adaptation, so this chapter focuses on how metrics could be used including risks and benefits.

Purpose and Usefulness of Metrics in Adaptation Planning

The purpose of metrics is to provide meaningful measures of change. When applied during an adaptation planning process, decision makers can use the metrics to evaluate adaptation options based on risks and benefits for near- and long-term implementation outcomes. Metrics can also help decision-makers assess the extent to which implemented measures have been effective (or failed). Metrics can help to engage both stakeholders and policymakers in the assessment of the levels of risk and vulnerability for a variety of sectors (e.g., water, agriculture, public health, infrastructure) by helping to describe and, in some cases, quantify the effectiveness of changes in management practices and planned adaptation strategies.

Thus, it is important that decision-makers and stakeholders understand the role of metrics so that their application can motivate appropriate actions. Prior to the implementation of adaptation actions, the use of metrics can aid policymakers in the process of identifying, prioritizing, and selecting appropriate adaptation actions within and across sectors and regions. In many cases, however, metrics are devised that are not consistent with the objectives of a program and can induce behavior that is inconsistent with program-wide objectives. For example, “teaching to the test” may teach children how to be good test-takers rather than broad thinkers. On the other hand, tons of carbon dioxide equivalent is meaningful because the goal of greenhouse gas emissions control is to reduce or slow the growth of radiative forcing. Getting the largest reduction in radiative forcing will do the most to reduce climate change in the long term.

Desirable Characteristics of Metrics in Adaptation Planning

The use of a common metric to assess climate change policy options is illustrated by the use of metrics to evaluate greenhouse gas mitigation options. Emissions of different greenhouse gases such as carbon dioxide, nitrous oxide, and methane can be compared based on carbon dioxide equivalents. This measures the relative contribution of different greenhouse gases to radiative forcing over a given time period. The cost-effectiveness of greenhouse gas reduction options can be directly compared by estimating the cost of the measures relative to the amount of reductions in emissions that they achieve. One common and widely accepted metric to measure cost effectiveness is dollars per reduction in ton of carbon dioxide equivalent. Even here, other factors such as the feasibility of adopting and implementing different measures should be considered along with cost effectiveness before selecting options to be implemented.

To date, there is nothing comparable to mitigation metrics when applying metrics to adaptation actions. The need to develop suitable metrics for adaptation has been increasingly recognized as a critical element of adaptation planning processes. To enable more informed comprehensive climate action planning that includes adaptation in parallel with mitigation, the following principles should be remembered:

- ❖ Customize: metrics should be based on state, regional or local sectors of specific vulnerabilities

- Prioritize: metrics for adaptation actions can inform prioritization of actions based on impact and vulnerability.

- Plan: metrics can inform the development of a comprehensive climate action plan and provide clarity on benefits and risks based on timeframe of implementation of those actions.

- Monitor & Measure: metrics inform process to maintain oversight and measure quantitative and qualitative impacts of adaptation actions.

Measuring of metrics should not consume inordinate staff time or financial resources. The use of metrics for adaptation measures is significantly more involved and complicated than metrics typically used to quantify mitigation measures. In adaptation, there are different sets of metrics than in mitigation and it is not likely that a single metric can be effectively relied upon to capture full impacts of an adaptation action, however the systems for measurement adaptation and mitigation are the same.

The literature on the measurement of adaptation benefits is limited in scale and scope, spanning a handful of studies over a few sectors, namely, agriculture, energy demand, and coastal resources. The only common metric that has been applied to measure all climate change impacts is monetary. The difficulty of using a monetary metric such as dollars to measure all vulnerabilities and adaptation is that for non-market vulnerabilities, such as human health or biodiversity, the application of dollars is not transparent. Economists can estimate the dollar value of a statistical human life or of existence of a species, but the estimates tend to be highly controversial and subject to dispute.

An additional important consideration in developing adaptation metrics is time. Climate change will happen over decades and the full effect of adaptation measures cannot be measured immediately. It will not be possible to know soon after an adaptation action is implemented whether the investment yields the benefits that were projected. But, there are intermediate metrics that can be applied. These include process metrics such as whether the immediate costs were as projected, how well the implementation went (e.g., were steps taken in a timely manner). There also may be intermediate outcomes that could be measured.

Our approach to metrics is highly linked with actions that can be taken at the sub national (i.e., state, regional and local) levels and is focused on the prioritization and evaluation of adaptation response measures directly. In stakeholder-driven adaptation planning processes, the primary focus is on micro-level issues, e.g., how costly is the measure when compared to alternatives; how effective is the measure for reducing vulnerability to climatic risks; and how can long-term performance be measured? As a result, we consider sectoral metrics to be the most useful and relevant. Moreover, instead of trying to devise a common metric to measure all vulnerability and adaptation, we established a process to determine whether it makes most sense to apply a common metric or a limited number of metrics. Identification of sector-specific metrics will enable cost-effectiveness analyses of adaptation options within a sector.

The following sections address metrics in two sectors: water resources and human health. The discussion identifies metrics that could be used to analyze and measure effectiveness of adaptation options within these sectors, but not across them.

Water Resources

Although the literature is limited, benefits have been assessed for adaptation measures that affect water resources. The metrics cover water availability, reliability and water quality. Using past work on adaptation evaluation, literature from the water sector, and consultations with experts, following is a list of metrics for water resources grouped in two categories.

Water Supply

There are several aspects of water supply to consider, such as how much water is available, where the water is located, and when the water is available.[1] Most simply, water supply per capita is a measure of

the total water supply within the boundaries of a jurisdiction (e.g. a country, state, or city) divided by the population residing within those boundaries. It is a broad measure for how much water is available per person.

So the simplest metric for comparing the effect of water supply adaptation action is to divide the total water supply by the in-boundary population, which establishes the amount of water available per person based on the population served. Water supply can be measured using any metric as long as there is consistency (e.g., gallons per day, cubic liters per day, etc.).

To take the exercise a step further and calculate the cost effectiveness of adaptation actions in the water supply sector, divide the total cost associated with the adaptation measure by the gallons per day based on population served to determine the cost effectiveness of water supply adaptation actions.

Water supplies and demand are usually expressed on an annual basis. So, the metric has the virtue of being relatively straightforward to measure. The metric also has the virtue of being easy to understand and results across different locations (i.e., different water basins) and technologies can be directly compared.

As with just about any metric, there are limitations or difficulties in applying the metric. Some of these limitations are briefly summarized in the bullets below.

- ***Value:*** One key limitation is the implicit assumption that a gallon has the same value anywhere it is measured. The adaptation option with the lowest cost per gallon is the most cost-effective everywhere. But that assumes that gallons are of equal value. Yet a marginal gallon of water in a water-stressed community is likely to be of much greater value than such a gallon in a community with plentiful water supplies.
- ***Functionality:*** The metric also does not consider how water is used. In an urban environment, particularly in a humid location, water use per capita is likely to be much lower (per capita) than in an agricultural area in the arid and hot southwest.
- ***Spatial/Temporal Variation:*** Another limitation is that water is a mobile resource and is often unevenly concentrated in space and time.

There are alternatives to overcome some of the limitations noted above. Consider the case of California: climate change is expected to change the timing of snowmelt runoff from the Sierra Nevada Mountain Range. An earlier runoff from the mountains without increased reservoir storage capacity would lead to shortages of water during hot and dry summer months when precipitation is scarce (ignoring changes in quantity of precipitation due to climate change). A variant metric of supply that is relevant for such a region would be the percentage of land area or population under high water stress annually. Another alternative is a metric for water supply that is disaggregated into smaller units of space and time (e.g. average water supply per day or month by county) so that the uneven distribution of water supply over these dimensions is made apparent for decision-makers. A third alternative is a metric for water reliability when droughts are a concern where the probability of shortfall or water-use restrictions is measured.

Moreover, instead of a focus on the *outputs* of water supply one could focus on measuring the *inputs* of water supply. That is, there are two key inputs to water supply that are human-influenced: water use/demand and water supply capacity.[2] Adaptation in the water sector will be a mixture of both supply- and demand-side measures. With water demands placing an increasingly heavy burden on limited freshwater resources, as is happening in the American Southwest, for example, water conservation strategies and other demand-side management actions have been implemented to help ensure future supplies. These actions can be monitored by water use per capita or a variant of this metric — water consumption as a percentage of supply.

On the supply side, several potential actions can be taken to enhance supply including desalination, reuse, increased storage capacity, and leak detection programs. The impact of any of these supply-side management actions can be measured using a metric of additional supply per capita, where additional supply can be measured as the difference between supply under the proposed action and supply under the status quo.

Water Quality

While the quantity of water available is important, the quality of water is critical for many uses including human consumption, domestic uses, industrial uses, and agricultural production. Water quality for these purposes can be measured as treated water supply per capita, though the level of treatment necessary depends on the intended use of the water. Water quality also affects aquatic species that are used directly by humans for consumption or for recreation (e.g. fishing) and also by species that may not be used directly by humans, but are valuable nonetheless (e.g. for biodiversity). Metrics can be developed for water quality that cover a variety of water characteristics including dissolved oxygen, temperature, turbidity, acidity, and nutrient loading (e.g. nitrogen and phosphorous). Water quality metrics are dependent on the end-use of the water and may be set based on the regional goals for water quality.

In theory, a single index of water quality could be developed that could be used to estimate relative cost-effectiveness of different water quality adaptation options (e.g., $ per unit increase in the index) in different locations. In practice, however, the issues with water quality can differ substantially by region, so it may not be feasible to develop a single metric. For example, nutrient loadings from farm runoff may be an issue in Mid-western agricultural areas, whereas salinity may be a critical water quality issue in the arid Southwest. Nonetheless, it may be entirely feasible for a single state, country or municipality to develop a water quality index that would be useful for comparing adaptation options. Water quality conditions would in all likelihood be uniform within a municipality or country and probably across most states (or not so varied) as to make it feasible to develop an index.

Water quality indexes could be developed for states, counties or municipalities by assembling experts to (a) identify key water quality criteria; (b) identify thresholds (e.g., water quality standards such as maximum contaminant level; but these could include other water quality levels as maximum contaminant level goals or secondary contaminant levels); (c) assign scores (e.g., on a 1 to 5 scale with 5 being highest water quality) to ranges of pollutant concentrations. The experts could also propose weights to reflect relative importance of different measures of water quality (e.g., dissolved oxygen vs. turbidity).

As with water supply, options can be evaluated by examining relative cost-effectiveness. The calculation would be:

$$\text{Water Quality Cost Effectiveness} = \$\$ \text{ Adaptation Cost} / \Delta \text{ Water Quality Index}$$

Water quality adaptation options could be ranked by estimating how much the options would improve water quality using an index (one such index, produced by the Center for Environmental Quality at Wilkes University, uses specified indicators of water quality, a continuous scale, and fixed weights. To ensure accuracy in analysis, one could enter results for individual indicators on a spreadsheet and apply different weights.

Table 4-1 on page 42 provides a summary of metrics for the water sector discussed here.

Table 4-1. Summary of Water Metrics

Metric	Description	Sub-metric
Water Supply	Broad metric encompassing the amount and reliability of water resources	▪ Water supply/capita
		▪ % land or population under high water stress
		▪ Water reliability- probability of shortfall or water use restrictions
		▪ Water use per capita
		▪ Additional supply per capita[3]
Water Quality	Quality of water supply	▪ Treated water supply per capita
		▪ Various quality indicators: dissolved oxygen, temperature, turbidity, acidity, and nutrient loading

Human Health

There are numerous metrics for evaluating the effect of adaptation measures on public health. Using past work on adaptation evaluation, literature from the health sector, and consultations with experts, we have compiled a list of metrics for human health.

Mortality

With numerous human health conditions and outcomes to consider, the mortality rate serves as a unifying metric. The mortality rate, or death rate, measures the number of people who die per 1,000 people in a population. While the mortality rate masks the underlying causes of mortality and does not account for pain and suffering of those living with adverse health conditions or differences in the age distribution of the population, it is generally regarded as a good composite measure of human health since it synthesizes the combined effects of many risk factors into one metric. The simplicity of the mortality rate also makes it easier to track than many measures of human health.

The mortality rate can be applied as a metric for conditions specific to climate change, such as heat stress. This requires additional data concerning cause of death for all mortalities. The United Nations Development Programme (UNDP) set a goal of minimizing mortality and morbidity resulting from climate change and extreme events related to climate change. As an intermediate metric to heat-related mortality, the risk of death due to heat stress can be assessed and monitored as a metric.

Morbidity

A related metric to mortality, morbidity covers all aspects of impaired human health other than death. Morbidity is measured as the “prevalence” rate, which is the proportion of population with a particular ailment or set of ailments, usually standardized by 1,000 people in a population over a given year. As with mortality, considerations have been made to focus on and minimize heat-related morbidity with respect to climate change. As an intermediate metric to heat-related morbidity, the risk of illness due to heat stress can be assessed and monitored as a metric. However, it can be quite challenging to measure the effect of heat on morbidity. Hospitalization or emergency room visits is one way to measure this, but many people suffering from heat stress do not necessarily go to an emergency room or become hospitalized.

Disability-Adjusted Life Years

A Disability-Adjusted Life Years (DALYs) is calculated as "the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for incident cases of the health condition". Rather than just counting number of cases, such as the number of people who die or the rate of death, DALYs account for loss of time to mortality or morbidity.

DALYs are generally used to measure the current state of health among countries. They could also be used to compare the effectiveness of different climate change adaptation actions at the sub national level. By dividing the total DALY before the given adaptation action by the DALY total after the adaptation action, the result will show the impacts of the adaptation action on reducing DALYs.

To be sure, estimating how DALYs will change as a result of adaptation actions is important. Noteworthy is that many adaptation actions that will lower DALYs like opening clinics and public education campaigns, will have significant benefit however will be difficult to quantify. Measuring change in DALYs over time will likely be challenging to use to attribute the effectiveness of individual interventions however for community-level efforts, there will be measurable impact.

Stressors of Human Health

An alternative to monitoring health impacts once they are realized (via mortality and morbidity) is to monitor stressors of human health. The stressors and associated metrics discussed below are strongly correlated with human health outcomes. Therefore, they should be relied upon as intermediate metrics if human health outcomes are of primary interest.

Indicators of Environmental Quality

Environmental quality is a key determinant in human health outcomes. Air and water resources are two obvious pathways for human exposure to pathogens or toxins in the environment. Commonly measured air pollutants include ground level ozone, mercury, particulate matter, and sulfur oxides. Water pollutants of concern generally include lead, mercury, and microbial pathogens (e.g. fecal coli form), in addition to the water quality measures discussed above under our discussion of water resources metrics. Rather than measure direct effects to human health, indicators of environmental quality measure changes in pollution. Such indicators can be easier to apply as long as monitoring data are available, but they do not directly estimate mortality or morbidity.

Extreme Events

Extreme weather events such as heat waves, hurricanes, floods, and droughts are likely being exacerbated by climate change and the trends are very likely to continue if not accelerate. These events have significant impacts on health. Metrics relevant for measuring adaptation benefits include mortality and morbidity rates due to extreme events (including risk of morbidity or mortality), percent of population living in areas at high risk for extreme events, and property or capital value lost due to extreme events.

As with water resources, disaggregating human health metrics by area may be important if mortalities and/or morbidity are focused in particular areas. Measuring consequences by gender can also provide useful information as women often bear disproportionate risks from extreme events. Adaptation actions can then be evaluated by their ability to reduce adverse climate-related human health impacts in these geographic "hot spots." These considerations should be made for any of the above human health metrics. Table 4-2, on page 44, provides a summary of metrics for the human health sector discussed above.

Table 4-2. Summary of Human Health Metrics

Metric	Description	
Mortality Rate	Measures number of people who die per 1,000 people in population. Mortality can be measured for a specific condition, such as heat stress.	■ Age-specific mortality rate ■ Standardized mortality rate ■ Risk of mortality
Morbidity	Proportion of population with a particular ailment or set of ailments, usually standardized by 1,000 people in a population over a given year. Morbidity can be measured for a specific condition, such as heat stress.	■ Risk of Morbidity
Disability-Adjusted Life Years (DALYs)	Composite metric for mortality and morbidity. Calculated as the Years of Life Lost (YLL) due to premature mortality in the population plus the Years Lost due to Disability (YLD) for incident cases of the health condition.	
Stressors of Human Health		■ Ambient environmental quality: air and water
Extreme Events	Extreme weather events such as heat waves, hurricanes, floods and droughts are likely more intense and frequent.	■ Percent of population living in areas at high risk ■ Property or capital value lost

Examining Adaptation Options Across Sectors

Given the diversity of the metrics presented above, the challenge before decision-makers may be to trade-off benefits to different sectors and costs across a range of possible adaptation investment portfolios. CCS uses an approach effectively applied during the work of CCS with the State of Alaska during the development of the Alaskan Climate Action Plan. The Governor created a sub-cabinet task force to address climate change and the task force engaged stakeholders in identifying adaptations. One approach proposed was to rank adaptation options by applying an index to rank projects based on the relative vulnerability of the affected resource to climate and on attributes of adaptation. The criteria are as follows. (An example matrix with scores is in Appendix 4.) Two sets of criteria are described here: criteria for ranking vulnerabilities and criteria for ranking adaptations.

Ranking vulnerabilities

There are several possible vulnerability-ranking criteria. These are briefly summarized in the bullets below.

- ***Importance of affected resource:*** This is a subjective judgment of the inherent importance or value of the vulnerable resource.
- ***Certainty of impact:*** Some impacts are more certain than others either because the *type* of change in climate differs in certainty (e.g., a rise in sea level which is certain, versus a particular change in precipitation which will be less certain) or because the *effect* of a change in climate may be more or less certain.
- ***Severity of impact:*** This criterion addresses the extent of impact on a sensitive resource.
- ***Capacity for autonomous adaptation:*** This is the degree to which an affected resource can respond and adapt to climate change. Some sectors have a relatively high degree of "adaptive capacity," while others have a lesser degree of such capacity.
- ***Timing of impact:*** This criterion addresses how soon an impact will be observable or significant. Some significant climate change impacts may already be happening or may become significant within years or a few decades, while others may take many decades to become significant.

Ranking adaptation actions

There are several possible ranking criteria that can be applied to adaptation actions. These are briefly summarized in the bullets below.

- ***Benefits and effectiveness*** – This criterion compares vulnerability without adaptation to vulnerability with adaptation. Ancillary- or co-benefits should explicitly be considered if the potential action provides benefits to other sectors or for other policy objectives. Different scenarios could be used to reflect uncertainty about climate change at the scale of the affected resource or system.
- ***Costs*** – This addresses the relative costs of implementing an adaptation (and should consider initial costs, e.g., construction and long term costs such as maintenance).
- ***Adverse Impacts*** – This includes non-economic and non-quantifiable as well as economic and/or quantifiable costs in other sectors. For example, costs such as a reduction in viable habitat for significant species, loss of coastal wetlands because of armoring, or an increased impact on human health should be considered alongside more traditional costs.
- ***Distribution of Benefits and Costs*** – The distribution of benefits and costs can be a consideration, particularly if certain groups bear a disproportionate share of benefits or costs. For example, poor or indigenous communities might face relatively higher or lower costs or benefits from adaptation measures.
- ***Feasibility*** – This criterion addresses whether an adaptation can realistically be implemented. Scoring this criterion could consider the proposed action within government or other's authority or is it more appropriately the role of another level of government, NGOs, the private sector, individuals, etc? Do the necessary legal, administrative, financial, technical, and other resources exist, and are they available for use on this proposed state action?

Each component of the ranking of vulnerabilities and adaptation can be scored using a common scale such as 1 to 3 or 1 to 5.[4] This allows for the same scale of scores to be applied across different criteria.

Combined Use of Sector Metrics

Metrics within sectors can be useful for setting priorities, calculating cost-effectiveness, and for monitoring progress in sectors. Tracking change, for example, using water supply per capita or DALYs metrics can

provide useful information to decision- and policy-makers and the public on whether conditions are improving or deteriorating. These sector metrics can also be used to measure the actual effectiveness of adaptation actions once they are implemented.

Practical Role for Metrics in Adaptation Planning Processes

The characteristics of state-level adaptation planning processes are such that care must be taken to ensure that the choice of metric is well aligned with the time and resources available. Typically, such processes are envisioned to be between nine and 18 months. Much of the time is devoted to discussions to ensure that the range of local vulnerable sectors/activities and potential adaptation actions is as comprehensive as possible. The development of suitable metrics together with their characterization may be a time-consuming exercise, depending on the metrics proposed. Several examples are discussed below to provide an overview of the range in how metrics have been used and integrated into various processes.

- ***Boston.*** The approach in the use of quantitative metrics in the evaluation of adaptation actions within the Boston stakeholder-driven context was focused on an assessment of physical parameters that could be directly compared across adaptation scenarios. Critical infrastructure systems with adequate data for analysis were first identified; then the present level of their services measured with various metrics were determined in the "Base Case" scenarios used in the various analyses. Notably, this process took place over a 4-year period and benefitted from the involvement of university research staff that carried out the assessment.
- ***Maryland.*** Qualitative metrics were developed and applied within the context of prioritizing adaptation options. Three metrics were selected through extensive stakeholder discussions, namely adaptive capacity (i.e., the ability of institutions, systems, and individuals to adjust to future climate change damages), flexibility (i.e., how proposed options either limit, enhance, or are neutral toward climatic risk reduction), and capital intensity (i.e., monetary and non-monetary benefits of options). Each adaptation option was qualitatively scored using a High, Medium, and Low ranking scale relative to each of the three metrics assigned in the course of stakeholder discussions. The overall adaptation planning process unfolded over roughly a 12-month period.
- ***Chicago.*** Both quantitative and qualitative metrics were developed and applied within the context of prioritizing adaptation options. An initial list of 250 adaptation options was narrowed down to several dozen based upon two quantitative metrics, namely expected benefits and expected costs, and two key qualitative metrics, namely time horizon and barriers to implementation. A consulting firm was retained to conduct the assessment in collaboration with researchers from the University of Illinois. The overall adaptation planning process unfolded over roughly an 18-month period.

There are some key lessons that emerge from these experiences of using metrics, which may be helpful for developing an approach to the use of metrics in state, regional or local adaptation planning processes. First, the above processes were explicit in their identification of metrics to evaluate each proposed action. The evaluation itself was undertaken either by an expert group or members of individual stakeholder work groups. Second, the above processes relied on a variety of approaches ranging from highly research-oriented assessments (Boston) to expedited analysis-intensive prioritization undertaken by an expert facilitator (Chicago), to a stakeholder-driven qualitative scoring system (Maryland). Each approach yielded a comprehensive and effective adaptation strategy that is at various stages of implementation through new legislation or regulations.

Conclusions and Recommendations

The preceding discussion presents metrics available to decision-makers for the sectors of water resources and human health. An encouraging finding of this review is that the sectors can be evaluated using a small handful of metrics.

In the introduction, we noted that metrics for climate change mitigation is relatively straightforward – the dollars per ton or carbon equivalent works well because this measure enables all greenhouse gas emission reductions to be compared in a meaningful manner. In mitigation, a ton of carbon equivalent is equal to a ton of carbon equivalent because GHGs are (for the most part) well mixed in the atmosphere. So, it does not matter to the atmosphere that reduces a ton.

Such equivalency does not apply on adaptation. We can use simple standard metrics to compare cost-effectiveness of adaptation actions, but in all likelihood a unit increase in water supply or an equivalent reduction in DALYs may not have the same value in different locations. To get at that, one needs to estimate the value of improvement. That takes us back to monetization, which as noted above, is quite difficult to develop. So, the use of the metrics discussed above would be much simpler to apply and can give insight into the relative merits and, within sectors, of the cost-effectiveness of adaptation actions.

In terms of specific recommendations for consideration in the design of state, regional or local adaptation planning processes, the following principles are essential:

- ***Understand the limitations.*** Caution should be exercised in developing and using metrics in adaptation planning processes. They are not a panacea or "silver bullet" that will somehow deliver the right choice of option or the best measure of vulnerability reduction.
- ***Be aware of the potential for unintended side effects.*** Although metrics can help provide tangible quantitative measures to monitor progress and effectiveness, important characteristics of adaptation options may not necessarily be appropriately captured in a metric to measure adaptation, which could have unintended negative side effects.
- ***There is no single metric applicable in all settings.*** Stakeholder-driven adaptation planning processes need flexibility in selecting and adjusting metrics that work best in their particular context. Forcing the use of a single set of metrics may actually increase the rigidity of the evaluation process and lead to maladaptive responses.

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Endnotes

[1] Some widely used water supply metrics are discussed in the Appendix. Those metrics are not considered to be appropriate for use in setting priorities for policies or measuring the effectiveness of policies.
[2] While mitigation efforts may affect natural supply of water, we focus on these two human-influenced categories of adaptation action for the purpose of this discussion.
[3] Additional supply can be measured as the difference between supply under the proposed action and supply under the status quo.
[4] Qualitative scoring such as "low", "medium", and "high" can be used, but use of such a scoring system can make adding up individual scores to a combined score difficult and pose opening for debate that lead to policy barriers.

Chapter 5

Decision-Making: Analysis of Adaptation Actions

Introduction

This chapter discusses decision making and analysis, specifically what approaches can be used to evaluate and select adaptation actions. A standard response upon reading this might be, "Why not use the same approaches that have long been used to make decisions?" One might be tempted to say that approaches such as benefit-cost analysis or optimization schemes have long been used to manage resources and can continue to be used under climate change. That may be, but a key impediment to applying such tools is the relatively high uncertainty about how climate will change as well as what the impacts resulting from such changes will be. We are not sure what future emissions of greenhouse gases (GHGs) will be, nor can we be certain about what changes in climate will arise from particular levels of emissions. There is also additional uncertainty about the effects of climate change. This uncertainty is particularly acute at the regional and local scales at which many adaptation decisions will likely be made. For example, we cannot say exactly how much sea level or temperature will rise, and for many regions, we are not sure whether they will become wetter or drier. Note that there is certainty that climate *will* change, but *how* it will change is uncertain.

This uncertainty can be a major impediment to adaptation decision-making, i.e., incorporating climate change into decision-making. Upon seeing the wide range of potential impacts of climate change, many decision-makers are tempted to throw up their hands and not consider incorporating future impacts of climate change into their decisions. What they are tempted to do is what has been traditionally done: use past climate as a guide to future climate. This assumption of "stationarity," i.e., climate is stable and future climate will be similar to current climate, has never been correct and is most certainly wrong today. As the Intergovernmental Panel on Climate Change (IPCC) concluded in its most recent assessment, the warming of the Earth's atmosphere is "unequivocal". In addition, the IPCC found that it is highly likely that humans are already having a significant impact on the climate and the change in climate is likely to continue and accelerate.

Even with these uncertainties, decision making is possible. Indeed, it would be a mistake to ignore climate change and make decisions as if the climate is stable. With this in mind, we will review some alternate approaches for managing climate-sensitive resources in light of climate change. These approaches are discussed and evaluated with regard to their usefulness for helping make decisions on adaptation to climate change. Readers who need a quick summary of these approaches can refer to the concluding chart on page 59.

There are two basic types of decision-making approaches: optimization and uncertainty approaches. The former approach came from an engineering paradigm that it is possible to design systems to achieve the most or optimal benefits. The latter type of decision-making approach recognizes that because of uncertainty, optimization is unlikely to happen and other approaches need to be taken. We divide the discussion below into these two categories.

Optimization Approaches

The optimization approaches are traditional decision-making techniques that seek to find the "optimal" adaptation action or set of actions, that is, the adaptation action(s) that provides the greatest net benefits. These approaches attempt to maximize utility across all possible future conditions. A key underlying premise of these approaches is that outcomes and the probabilities of them occurring are known. Decision trees, which use combined probabilities and expected values for different outcomes, can be used.

Two leading types of optimization approaches are benefit-cost analysis (BCA) and cost-effectiveness analysis.

Benefit-Cost Analysis

BCA can be used to determine which alternative has the greatest net benefits (difference between benefits and costs) or have a higher benefit/cost (B/C) ratio. BCA typically relies on expressing all benefits and costs in dollars so that they can be easily compared. Total costs can be subtracted from total benefits to estimate net benefits. This approach can be used to determine which adaptation action has the greatest benefits, net of cost, to society. Alternatively, total benefits can be divided by total costs to yield a B/C ratio. This method can be used to determine which action has "the greatest bang for the buck," i.e., the greatest rate of return on the investment.

BCA is widely used in decision-making on natural resource management, particularly by the federal government. One of the challenges of applying BCA is that all benefits and costs need to be estimated and monetized. An outcome that is not monetized might not be considered in the calculus. This has led to the criticism that such approaches can overlook the true value of adverse impacts of a decision on human health or nature.

BCA can be particularly challenging in the analysis of climate change adaptation for two reasons. The first is uncertainty about climate change outcomes. If probabilities are known, they can be used with estimates of benefits of different outcomes to estimate an expected value of benefits (and costs if appropriate). If probabilities are unknown, it is unclear how different outcomes could be combined. For example, a flood control project might yield higher benefits (in terms of avoided damages) if flood potential increases rather than decreases. If, however, the likelihood of whether flooding will increase or decrease is unknown, then calculating an expected level of benefits will be difficult.

An additional complication is the timing of climate change impacts. Climate is projected to continue changing for many decades. Future benefits, particularly if they are monetary, should be discounted. That is, a benefit of $100 today is worth far more than the same benefit many years in the future because money today can be invested and grow in value over time (i.e., there is an opportunity cost associated with funds spent today with the intent of generating benefits in the future). Using positive discount rates applied over long timeframes greatly diminishes the present worth of future benefits. Further, discounting can be controversial when applied to impacts like human health or the environment, or when applied to outcomes that may span across generations.

Cost-Effectiveness Analysis

Cost-effectiveness analysis is used to compare alternatives that are expected to achieve the same or a similar or comparable goal or benefit. Since the benefit is the same, then its value does not need to be estimated. Alternatives are compared based on their relative costs, i.e., which alternative costs the least to achieve the same goal or outcome. This approach has been applied to examine options for reducing GHG emissions to achieve a particular level of GHG concentrations in the atmosphere. Metrics can be used to estimate cost-effectiveness of adaptation options (see Chapter 4). Alternatives can be compared based on which ones increase the metric one unit for the least cost. Cost-effectiveness is easier to apply than BCA because the value of benefits does not need to be estimated.

An additional advantage of cost effectiveness analysis (as contrasted to BCA) is that probabilities of outcomes, such as different climate change scenarios, may not be needed. The benefits of different options are presumed to be the same, so probabilities are not needed to calculate benefits.

Using cost-effectiveness analysis to evaluate adaptation alternatives is appropriate if the objectives or benefits of the options are clear and consistent. In many cases, however, there can be multiple benefits of different adaptation actions, making it difficult to make comparisons across alternatives. In addition, some actions may cause adverse impacts (e.g., coastal barriers causing beach erosion or loss of wetlands). In such cases, the use of cost-effectiveness as a metric for evaluating adaptation alternatives can be more challenging and less informative.

Multicriteria Analysis

Multicriteria analysis (MCA) is a decision analysis approach that is useful in situations where a single criterion approach (such as CBA) is inappropriate, especially where significant environmental and social impacts cannot be assigned monetary or other common values. In MCA, the analyst or stakeholders specify the range of activity objectives, the corresponding attributes or indicators, and the relative weight each attribute or indicator is given. The options are then ranked according to how well they meet each indicator and the relative weight of that indicator. This approach explicitly recognizes that a variety of monetary and nonmonetary objectives are important in decision-making. Because the indicators do not need to be expressed in monetary or even quantitative terms, a range of different environmental and social indicators may be used together with quantitative measurements of economic costs and benefits.

In comparing and ranking adaptations, options can be compared based on how well they satisfy multiple criteria. For example, their relative effectiveness in reducing vulnerability, costs, and feasibility can be assessed. Typically, ordinal or cardinal scoring can be used to rank options. One approach is to assign a score of high, medium, or low. For example, adaptation option 1 might get a score of high on reducing vulnerability, but low on feasibility. To keep the scoring consistent, cost should be “low cost.” That is a high on that criterion means that costs are relatively low.

Another option is to use a numeric scale such as 1 to 5. Each adaptation option for each criterion is given a score of 1 to 5 (or 1 to any number). The advantage of doing so is that it can be easy to add up or average scores. In addition, weights can be applied to different criterion. Perhaps, reduction in vulnerability is considered twice as important as cost, so vulnerability scores are doubled. The disadvantage of using a numeric scale is the difference between scores is arbitrary. Thus a score of 4 is not necessarily twice as good as a score of 2.

An advantage of MCA is that participants or stakeholders can fill in matrixes together. Outside analysis may not be necessary. A disadvantage is that scores and weights can be manipulated to favor certain options.

Uncertainty Approaches

Uncertainty approaches recognize that a range of future climate conditions exists and that we probably cannot specify the range of climate change outcomes, nor the probabilities of outcomes within the range. These approaches attempt to apply techniques to make decisions in light of the uncertainties. Many of these approaches share characteristics that are not necessarily mutually exclusive.

The first four approaches: no regrets, low regrets, adaptive management, and risk management are not tools or approaches for selecting an adaptation action, but can aid decision-makers in identifying adaptation actions that might be appropriate to adapt to climate change. Chapter 3 provides a catalogue of adaptation actions. The second set of approaches: triple bottom line, robust decision-making, portfolio management, and regrets analysis, are approaches that can be used to compare and select adaptation actions.

Identification of Adaptation Actions

No Regrets Adaptation

A “no regrets” adaptation action is one that can be justified under current climate conditions, but one that also makes even more sense under climate change. Thus, climate change is not needed to justify adopting a “no regrets” adaptation action or plan, but can provide further justification for doing so. The origin of the term is based on the recognition that should climate not change as expected, there is no regret in selecting that option.

No regrets decisions might include use of market mechanisms to allocate water supplies or removing subsidies that encourage risky behavior. A water market will allocate water resources in a more economically efficient manner than a fixed allocation scheme such as prior appropriations. Given the potential for reduced or, in some places, increased water supplies under climate change, market mechanisms will provide additional benefits by allocating tight or excess water supplies to the highest value users.

If insurance for building in a flood plain is subsidized, it could encourage building in flood-prone areas, which already poses risks. Should climate change increase flood risks, the risks increase. Removing the subsidy for insurance would be a no regrets adaptation.

One of the appeals of no regrets is that justification for the adaptation need not rest on arguments of climate change. That can be of help in trying to convince audiences or individuals skeptical of climate change about the wisdom of supporting such adaptations.

A downside to no regrets decision-making is that it may promote incremental adaptation actions at the expense of more far-reaching adaptations. Incremental decisions might be fine if climate change is limited. However, more severe climate change might require more far-reaching adaptation actions. For example, incremental adaptations might involve strengthening coastal defenses to protect low-lying coastal areas from sea level rise. That approach might be fine for a limited amount of sea level rise. But the approach may not work if sea level rise is high and more difficult options such as relocation of people and assets may be needed.

Low Regrets Adaptation

Low regrets are adaptation actions that are specifically designed to address vulnerabilities from climate change. They involve taking an action that would not be done if climate were stable (not changing). They are considered “low regrets” to the extent that their costs or other impacts are considered to be relatively modest. Hence, low regrets options are akin to being able to purchase inexpensive insurance.

Taking action in anticipation of future climate change may make sense when long-term decisions are being made. Thus, low regrets adaptations can include changing the design of infrastructure that is intended to last many decades and whose performance may be affected by climate change. For example, reservoirs, sea walls, highways, bridges, and other investments are typically intended to last many decades and they may well be affected by climate change impacts. Decisions on development can tend to have long lifetimes. Development of low-lying coastal areas or flood or drought prone areas are other examples of decisions with long timeframes. Such decisions may be altered to account for climate change risks.

There are two significant difficulties, however, with trying to make low regrets adaptation actions. One is knowing what to plan for. Let us say that flood protection for the next 50 years is being built to control against the 1 in 100-year floods. Climate change may result in increased flood risks so that the 1 in 100-year flood might become the 1 in 50-year flood. The difficulty is that it is not possible to predict exactly how much flood risks will increase over 50 years, or what the new 1 in 100-year flood would look like. Infrastructure must be designed for specific outcomes. A decision would need to be made on whether to

increase flood protection against a very likely outcome (a small increase in flood levels), an unlikely outcome (a large increase in flood risks), or some intermediate probability outcome.

A further difficulty of using low regrets adaptation actions is that in preparing for climate change, the benefits of the investment may not be realized for many decades (and in the case of preparing for extreme events, may not be realized during the lifetime of the project). If benefits are discounted back to present values, then only a small investment in the costs of the project may be justified.

These considerations lead to the term "low regrets." There could be regrets with the investment because climate may not change as expected or planned for. However, if investment costs are minimized (e.g., because of discounting future benefits), then any regrets may be "low."

One form of low regrets adaptation actions is to make incremental decisions to incorporate climate change impacts. If a sea wall is being built anyway, its height might be increased to account for sea level rise. *Targets of opportunity* are long-lifetime climate-sensitive decisions that are being made regardless of climate change. The target of opportunity is that climate change could be a consideration in designing the sea wall. Not considering climate change may mean basing the design on historical flood risks, which may result in inadequate protection against future floods. The target of opportunity is to incorporate climate change into the design.

Adaptive Management

Adaptive management is a process by which management decisions can be regularly revisited based on monitoring conditions, new science, or other information. It explicitly recognizes that there are uncertainties about the future and conditions are changing, which creates a process by which adaptation actions can be made over time. Adaptive management promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood

Thus, adaptive management stands in contrast to attempting to make a decision in the present that is intended to be good for the lifetime of a project or for many years in the future. In some respects, that is what many natural resource managers tried to do in the past in managing such risks as flooding. The approach of making a long-term and static decision is consistent with the belief in a stationary climate.

Adaptive management is not a process for selecting specific adaptations, but encourages the selection of adaptation actions that can be adjusted over time (e.g., building a sea wall where the height may be raised in the future if evidence mounts that sea level rise is proceeding faster than originally believed).

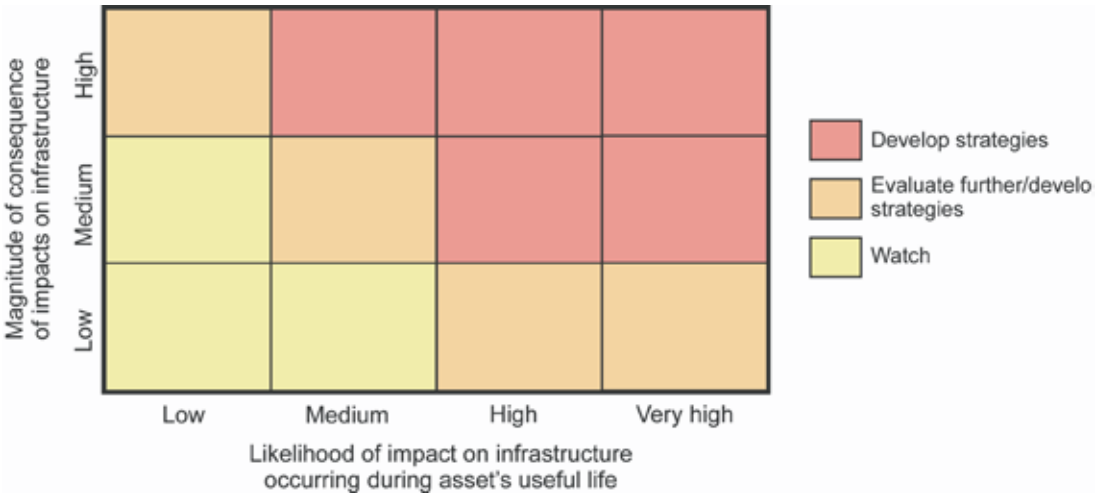
Risk Management

Risk management is a process by which risks are identified, assessed, and then managed as appropriate. Risk management considers the impacts and likelihood of outcomes and the expected consequences in adopting management strategies.

New York City used risk management to assess its vulnerabilities to climate change and develop adaptation strategies. Risks are placed in the matrix based on the relative magnitude of impact and likelihood of occurrence. What kind of response — in this case, whether to develop strategies, evaluate strategies, or watch — depends on where outcomes are placed in the matrix. Those outcomes with higher consequences and likelihoods are given the highest priority for response. In this case, outcomes with either low likelihood of occurrence or low consequence did not warrant immediate action. To be sure, applications of risk management could place higher priority on very high-consequence outcomes, even if they are of low probability.

Figure 5-1. Risk Matrix Used by New York City Task Force.

Source: Major and O'Grady, 2010.



Risk management can be useful to help set priorities regarding which outcomes should receive higher or lower priority for developing adaptations. Further analysis may be needed to determine which adaptations are best or most desirable to address the highest-priority risks.

Options for Selecting Adaptations under Uncertainty

These approaches can help decision-makers select adaptations when future conditions are uncertain. Note that these options do not necessarily involve mutually exclusive methods. There are some common attributes across a number of the options.

Important to note is that these approaches are not independent on one another. In fact, decision-makers could benefit by using a number of these approaches and comparing results.

Triple Bottom Line

The concept of Triple Bottom Line (TBL) is to help businesses and government consider environmental and social consequences, along with financial considerations. The notion of TBL is that three "bottom lines" can be used. The bottom line that is best understood is the financial bottom line. Under it, revenues should exceed costs and businesses make a profit.

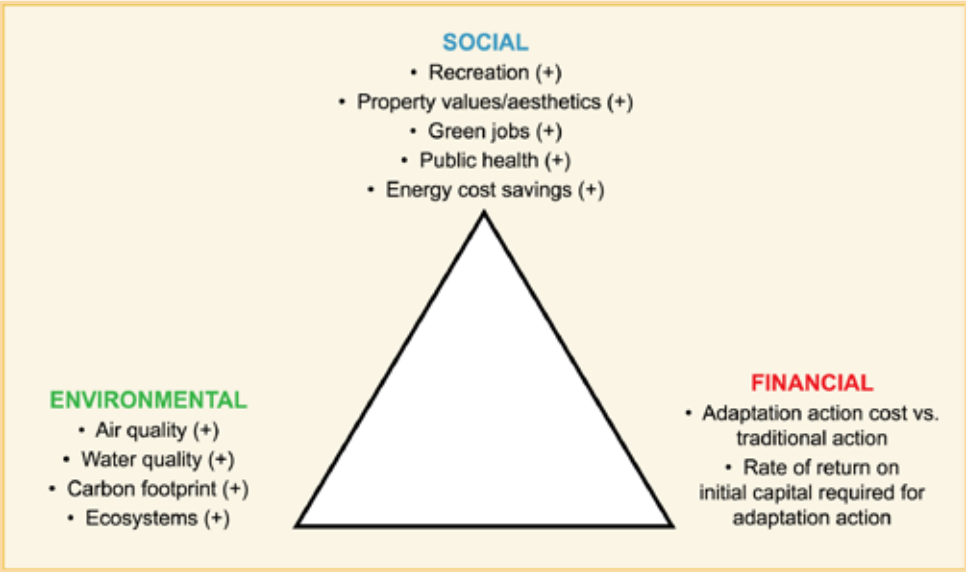
TBL brings in the additional considerations of an "environmental bottom line" and a "social bottom line." The environmental bottom line considers impacts of decisions on the environment and can be measured as degradations or additions to natural capital. Natural capital can encompass many environmental outcomes and metrics such as stocks of clean air, clean water, non-degraded land, and biodiversity. Social capital is more vague but has to do with the functioning of society and social systems. It includes equity, livability and human health.

Rather than attempt to reduce all outcomes to a common metric such as dollars as might be done in BCA, TBL identifies the broader range of impacts and places these considerations within the appropriate bottom line. That is, financial outcomes would count toward the financial bottom line, environmental outcomes would be considered under the environmental bottom line, etc. Indexes could be applied within each bottom line or different outcomes could be listed within the appropriate bottom line (e.g., list environmental impacts in an environment column and social impacts in a social column). Adaptation

options could be compared based on their relative impacts on each bottom line. Figure 5-2 shows how results might be displayed in a TBL analysis.

TBL will not yield an answer as to which option is "best," but it can organize information along the three bottom lines so that decision-makers can more readily examine tradeoffs among the different outcomes.

Figure 5-2. Triple Bottom Line at the State, Regional or Local Levels



Robust Decision-making

Robust decision-making (RDM) is a way to make decisions under deep uncertainty. Under RDM, decision-makers can consider many scenarios of future conditions, including many climate change scenarios (the kind of situation that typically confronts decision-makers because of the many climate models and downscaling techniques now available). The decisions need to be "robust" against a wide variety of conditions. This approach is particularly useful when probabilities are unknown or stakeholders cannot agree on probabilities. RDM can include decisions that can be modified as new information becomes available.

A potential downside of RDM is that it designs adaptations that are robust against all scenarios, without consideration of probability. While it is challenging to assign reliable probabilities to climate change outcomes, some outcomes are more probable than others. A very high rate of sea level rise (e.g., 6 feet) is far less probable than a rate such as 3 feet by 2100. RDM would rule out options that do not protect against the highest amount of sea level rise, even if these options cost less or provide more benefits under lower amounts of sea level rise. Also, a robust option is not necessarily the best choice, depending on what criteria are important to the decision makers.

Portfolio Management

Portfolio management is a concept that comes from finance and is essentially about risk spreading. In an environment where any single adaptation approach entails risk, one way to reduce risk is to invest in a number of options. As opposed to putting all resources into one investment, which might completely succeed or fail, by making multiple and diverse investments, the chance that a single investment or set of investments is successful is increased.

Portfolio management is particularly applicable where a single adaptation strategy may perform well in certain circumstances (e.g., under some climate change scenarios), but different strategies perform well under different scenarios. It may be applicable in addressing risks of climate change to water supply, crops, and tourism, among other sectors. Diversifying water supplies among surface water, groundwater, intra-basin transfer, desalination, and other sources can lower the risk of supplies being reduced because of drought. Diversifying crops to include crops with different climate requirements can increase the likelihood of having at least some crops with a good harvest. Even diversifying tourism between winter and summer activities can increase the chances that a tourist resort will continue to prosper under climate change.

Decision-makers must also accept the risk that a diversified portfolio will involve some investments that have benefits and others that do not under particular scenarios. Thus, individual investments within a diversified portfolio may not yield positive returns or will yield lower returns than other parts of the portfolio. Optimizing the portfolio to reduce risk can be challenging when probabilities of outcomes are uncertain — as is the case with climate change. Additionally, outcomes resulting from mitigation actions should be part of the consideration and ideally designed part and parcel with adaptation actions to establish a comprehensive approach as is intended with portfolio management.

Regrets Analysis

Regrets analysis, also referred to as "mini-max," which is short for minimizing maximum regret, relies on avoiding the largest potential losses or most unacceptable situation (or situations). Rather than looking for an option that maximizes outcomes or works under all possible future conditions, a regrets approach focuses on avoiding the largest or maximum regret. A decision-maker may be particularly concerned with avoiding failure of a system such as having water supplies inadequate to meet domestic needs (or having an order to boil water to make it potable).

Under a regrets analysis approach, the decision-maker would select options that avoid the undesirable outcome. This option might cost more than others or not have as many benefits under other scenarios, but it is selected because it would most effectively avoid the most undesirable outcome.

One advantage of regrets analysis is that it does not need to consider probabilities of outcomes. The point is to avoid a worst-case outcome, whatever the probability. To be sure, a decision-maker could use some discretion and not be concerned with very low probability outcomes.

A disadvantage of using regrets analysis to select adaptation actions is that it does not consider the performance of options across all or even many climate change scenarios. For example, in the example above, a decision-maker might focus exclusively on ensuring that water supplies are always adequate. One adaptation option might be to invest in a large water storage system at a high financial and environmental cost. This would ensure an adequate water supply even in the event of an extreme drought, but might result in stranded costs and environmental harm should extreme drought not occur in the lifetime of the project.

Multi-Attribute Decision Making (MADM)

Multi-attribute decision making (MADM) focuses on a specific and finite set of alternatives, in this instance assessment approaches, thereby facilitating the process for organizing and analyzing a range of adaptation actions and ultimately decision making. Essentially MADM finds the absolute best action within constraints specific to a given region.

As discussed above, climate change is an area of deep uncertainties, so that it is better to keep an approach as robust and comprehensive as possible keeping in mind the fundamentals including resource availability, public infrastructure and political will.

Conclusion

A number of different approaches for selecting adaptation actions to be considered and making choices among them are presented in this chapter and summarized in Table 5-3.

Table 5-3. Approaches to selecting adaptations

Approaches	Description
I. Optimization Approaches	
Benefit-cost analysis	Compares benefits and costs in common metric to maximize net benefits
Cost-effectiveness analysis	Compares relative costs of achieving common outcome to determine which option has the least cost
II. Uncertainty Approaches	
Identification of adaptations	
No regrets adaptations	Adaptations justified under current climate and more justified under climate change
Low regrets adaptations	Adaptations justified only if climate changes
Adaptive management	Adaptations can be adjusted for new information; rely on monitoring
Risk management	Consider consequence and probability of outcomes in setting priorities for vulnerabilities to address
Adaptation selection approaches	
Triple Bottom Line	Consider financial, environmental, and social bottom lines
Robust decision-making	Select adaptations that provide sufficient benefits under all outcomes (scenarios)
Portfolio management	Spread risk by investing in suite of adaptations that provide complementary benefits under different conditions
Regrets analysis	Invest in adaptations that best avoid worst or unacceptable outcomes
Multi-Attribute Decision-Making	Aims to establish the very best adaptation actions based on local attributes and context

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Chapter 6

Scoping of Mechanisms and Approaches to Integrate Climate Mitigation and Adaptation Actions

Introduction

Synergies can exist between mitigation and adaptation; a fact that is being increasingly recognized as both types of responses mature. One can imagine several types of initiatives in which mitigation and adaptation might be complementary and reinforce each other. One example is the way improvements in building energy efficiency can also reduce the need for increases in air-conditioning, which will yield public health benefits).

The pursuit of these win-win opportunities, however, is in its early stage. Typically, stakeholders arrive at one catalogue of actions for mitigation and another separate catalogue of actions for adaptation. Few have taken the next step—to identify actions that simultaneously meet adaptation and mitigation goals to maximize local/global benefits. One reason is that adaptation and mitigation have traditionally been viewed as distinct and separate. Adaptation benefits are felt locally and more immediately, while mitigation benefits are longer-term and global in scale.

Comparisons are difficult to come by because of large methodological hurdles to the reliable estimation of costs and benefits for options that have different temporal/spatial scales, different goals/measures of benefits, and different metrics to monitor and evaluate progress. Nevertheless, there is growing recognition in the literature that there exist many points of overlap between adaptation and mitigation and that these represent important synergies that should be understood, addressed and encouraged in future comprehensive climate change planning. The potential to leverage investment of political, financial and infrastructure capital in joint implementation of adaptation and mitigation should be considered in any comprehensive climate action planning process.

In this chapter, we seek to directly address these issues in posing the following key questions:

- What evidence has emerged from recent studies that synergies can indeed be exploited between adaptation and mitigation?
- How can such synergies between adaptation and mitigation be integrated into state, regional and local planning processes?
- What are the key implications for decision-makers regarding the execution of synergies between mitigation and adaptation in planning processes?

Capturing Adaptation and Mitigation Synergies within Sub National Adaptation Planning Processes

This section offers a two-step approach for the integration of adaptation and mitigation options into an integrated catalogue of options that could be used in state, regional or local planning processes. The first step seeks to identify climate risks that are cross-cutting to both vulnerable sectors and GHG-emitting sectors. The second step offers a matrix evaluation framework as a means for the prioritization of synergies associated with the development of an integrated catalogue.

Step 1: Assess cross-cutting climate risks and synergistic impacts

Vulnerability to climate change is the starting point for this step. Vulnerabilities are identified depending upon those GHG-emitting sectors and other systems where failure or reduction is likely to carry the most significant consequences. We consider that a focus on key vulnerabilities is an essential first step to help stakeholders begin to think in an integrated way to assess synergies and levels of risk. In most instances, the identification of vulnerabilities will be qualitative, based on expert knowledge and relevant climate parameters. The basic structure is a matrix containing the four key vulnerable systems and the four key GHG-emitting sectors.[1] The challenge is to identify how the three major climatic hazards (i.e., heat stress, extreme precipitation or drought, and sea level rise) contribute to vulnerabilities that overlap both categories. An example appears in Table 6-1 below. (For simplicity, the "cross-cutting" system is not included in the matrix.)

Table 6-1. Example matrix of impacts of climatic risks on GHG-emitting sectors and vulnerable systems

	Vulnerable system/sector			
GHG-emitting sector	**Economic Activities**	**Health and Society**	**Infrastructure & Built Environment**	**Natural Systems**
Energy supply (ES)	Reduced precipitation regimes increase risk of unforced outages due to cooling water shortages	High electric loads from increased temperatures leads to decline in urban air quality	Coastal inundation as well as extreme precipitation leads to increased vulnerability of power plants	High electric loads from increased temperatures leads to increased mercury deposition in lakes/streams
Residential, Commercial, and Industrial (RCI)	Potential changes to drinking supply could increase electric load for filtration	Increased heat stress leads to increased demand for space cooling	Increased heat stress leads to departure of industrial operations that are heat-sensitive	Increased heat stress leads to increased electricity demand leads to increased ozone levels with impact sensitive habitats
Transportation and Land use (TLU)	Increased risk of storm surge-related flooding leads to alternative long distance cargo hauling routes	Increased risk of storm surge-related flooding leads to alternative land uses	Extreme precipitation leads to increased vulnerability of road infrastructure	Increased risk of storm surge-related flooding leads to pressure for residential development of sensitive ecosystems
Agriculture, Forestry, and Waste (AFW)	Heat stress may lead to decline in dairy milk production and manure production for biogas systems	Permanent inundation of coastal forest habitats leads to reduced CO2 sequestration options	Increased risk of storm surge-related flooding leads to threat to landfill methane capture	Potential permanent inundation of coastal lands including areas for carbon sequestration

Step 2: Evaluation framework to prioritize potential synergies

This step focuses on populating a risk assessment matrix to assess the magnitude of consequence of the risks identified in the previous step. The aim of Step 2 is to develop a ranked set of synergies for further exploration for integrated adaptation/mitigation catalogue development. Using insights from the range of

perspectives from an expert stakeholder group as a guide, the rankings can be organized as outlined in the following bullets:

- ***High:*** High priority for further explorations to include in an integrated catalogue of adaptation/mitigation options
- ***Medium:*** Medium priority for further explorations to include in an integrated catalogue of adaptation/mitigation options
- ***Low:*** Low priority for further explorations to include in an integrated catalogue of adaptation/mitigation options

There are at least three layers of uncertainty that need to be considered to yield an approximate ranking of the overall level of a particular synergy between adaptation and mitigation:

- probability of a given climate hazard,
- likelihood of impact occurrence, and
- magnitude of the impact.

To a certain extent, these uncertainties should have already been considered in the completion of the Step 1 matrix. However, they are very influential in the ranking process and care will need to be exercised to ensure that they are further considered in Step 2. The underlying intent is to deal with uncertainty explicitly, although in a qualitative way. An illustrative completed matrix is shown in Table 6-2.

Table 6-2. Matrix of adaptation/mitigation priority rankings

	Vulnerable system/sector			
GHG-emitting sector	**Economic Activities**	**Health and Society**	**Infrastructure & Built Environment**	**Natural Systems**
Energy supply (ES)	Reduced precipitation regimes increase risk of unforced outages due to cooling water shortages **(LOW)**	High electric loads from increased temperatures leads to decline in urban air quality **(HIGH)**	Coastal inundation as well as extreme precipitation leads to increased vulnerability of power plants **(HIGH)**	High electric loads from increased temperatures leads to increased mercury deposition in lakes/streams **(HIGH)**
Residential, Commercial, and Industrial (RCI)	Potential changes to drinking supply could increase electric load for filtration **(LOW)**	Increased heat stress leads to increased demand for space cooling **(HIGH)**	Increased heat stress leads to departure of industrial operations that are heat-sensitive **(LOW)**	Increased heat stress leads to increased electricity demand leads to increased ozone levels with impact sensitive habitats **(MEDIUM)**
Transportation and Land use (TLU)	Increased risk of storm surge-related flooding leads to alternative long distance cargo hauling routes **(MEDIUM)**	Increased risk of storm surge-related flooding leads to alternative land uses **(HIGH)**	Extreme precipitation leads to increased vulnerability of road infrastructure **(HIGH)**	Increased risk of storm surge-related flooding leads to pressure for residential development of sensitive ecosystems **(HIGH)**
Agriculture, Forestry, and Waste (AFW)	Heat stress may lead to decline in dairy milk production and manure production for biogas systems **(LOW)**	Permanent inundation of coastal forest habitats leads to reduced CO2 sequestration options **(MEDIUM)**	Increased risk of storm surge-related flooding leads to threat to landfill methane capture **(HIGH)**	Potential permanent inundation of coastal lands including areas for carbon sequestration **(LOW)**

Key Implications for Decision Makers

The preceding discussion presents an approach to exploring synergies between mitigation and adaptation in sub national comprehensive climate action planning processes. An encouraging finding of this review is that addressing mitigation/adaptation synergies is clearly called for in the literature and that this can be achieved using a fairly straightforward approach using available tools within a stakeholder-driven planning process. In terms of specific recommendations for consideration in the design of sub national adaptation planning processes, we offer the following:

- *Incorporate synergies from the beginning.* Putting adaptation and mitigation options in separate evaluation silos is an unsatisfactory approach as there are important complementarities and synergies that would be overlooked, driven by the design of the process. Moreover, there are mitigation and adaptation options that may work at cross-purposes with each other that would not be caught.
- *Expand planning process to include a focus on synergistic effects.* This refers to the need to include an integrating component in future climate action planning processes. This could take the form of a Technical Working Group that builds upon the work of adaptation and mitigation
- *Focus on implementation.* Once synergies have been prioritized, it will be important to consider not only what to do but also how it would be done. This includes identifying capacities for implementation and the processes, mechanisms, institutions, and constituencies that would be implicated in future implementation activities.

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Chapter 7

Government Experience in Developing Climate Change Adaptation Actions

In this chapter, we examine the experiences of ten governments in developing climate change adaptation plans in order to describe the options, approaches, and outputs that can inform the development of a robust framework for state adaptation planning processes. These governments, which were discussed in Chapter 3, include nations (Spain, Australia), states (Maryland, Florida, Alaska), counties (King County, Washington; Miami-Dade County, Florida), and cities (Boston, Chicago, Los Angeles, New York). It is important to note that every process is unique, driven by local considerations that involve planning culture, demographic characteristics, and economic/physical vulnerabilities that necessarily differ from one location to another.

Building Off the Experience at National, State, Regional, and Local Adaptation Action Planning Scales

The first part of this chapter synthesizes the key lessons learned and experiences of ten governments that have launched and completed adaptation planning processes. It focuses on five key areas of adaptation planning, namely, sectoral coverage, stakeholder engagement, use of metrics, role of cost-benefit analysis, and key outputs.

A. Sectoral Coverage

Vulnerable sectors were identified and characterized in a variety of ways across the different adaptation plans. With the exception of Los Angeles, all adaptation plans have strong sectoral coverage. The most common sectors are water resources, coastal zones, health, and infrastructure. More location-specific issues, such as tourism, insurance, forestry, and mountains, are less common.

Of the ten groups, Australia, Spain, and Florida have the broadest sectoral coverage. Each one addresses water resources, biodiversity, coastal regions, agriculture, fisheries, forestry, health, tourism, and infrastructure, with Spain and Florida also addressing a number of more location-specific issues. Spain has a pronounced emphasis on capacity development, while Australia focuses on implementation.

In contrast with Florida's broad sectoral coverage, Maryland and Washington maintain a limited focus on infrastructure, health, and natural resources. One reason for this difference is that when defining its adaptation options, Florida had access to two recent state-specific impact studies, as well as the work on adaptation done in North Carolina, Washington, Maryland, and Australia.

There is greater sectoral coverage within the county-level plans. The processes in King and Miami-Dade counties address climate science, health, emergency preparedness, water, infrastructure, and economic impacts, with Miami-Dade also focusing on ecosystem and intergovernmental affairs. This county-level emphasis on intergovernmental affairs is in keeping with Florida's state-level adaptation priorities, which emphasize government coordination, funding, and planning.

Of all entities, Los Angeles has the least sectoral coverage, addressing only coastal zones, infrastructure, and public awareness. This is an indicator of how local concerns can dominate adaptation planning, as these were identified in advance as sectors to examine. Boston considered five priority sectors (sea level rise, river flooding, public health, energy, and water supply), while Chicago focused on six (heat management, precipitation management, infrastructure, ecosystems, public awareness, and business engagement).

Two key points emerge from the review of sectoral coverage. First, county and municipal plans define their sectors differently from national and state plans. That is, these planning processes tend to be more highly focused or detailed, breaking out broad sectors, such as water resources into river flooding or health into heat wave control. Second, in national and state plans, activities such as public awareness building and business engagement tend to be grouped within a sector such as water or health. In county and municipal plans, they tend to be addressed as sectors in their own right.

B. Stakeholder Engagement

A key lesson that emerged across all plans was the prominent role of stakeholders in the decision-making process. Stakeholder engagement was emphasized in all ten climate plans. The degree of emphasis differed. For example, Maryland and Florida used stakeholders to first identify vulnerable sectors and then evaluate adaptation options proposed by the Technical Working Groups of each state. In Washington and King counties, stakeholders were involved in proposing or assessing actionable items within a set of preselected sectors. In a similar fashion, Boston's process used the stakeholder community to evaluate and provide feedback on emerging results provided by the research community, which led to a consensus-building effort to identify vulnerable sectors and actionable items.

It is important to note that Boston's process is unique in that it unfolded over a period of four years, much longer than the usual timeframe, and ensured stakeholder engagement through a specific body—the Metropolitan Area Planning Council that was dedicated to coordinating stakeholder evaluations and recommendations. The Boston process stands out as a good example of a long-term partnership among research, local government, and the general public; the process was much more interactive than models followed elsewhere.

In contrast, Chicago used stakeholder consultations but relied more heavily on expert input when selecting sectors and prioritizing actions. The Chicago process was shaped more by rigorous expert analysis than by stakeholder participation. Although information on the role of stakeholder involvement is not readily available for Australia or Los Angeles, both processes imply a high degree of stakeholder engagement.

Two key points emerge from the review of stakeholder engagement. First, with local considerations dominating adaptation priorities, a diverse group of stakeholders is absolutely essential to the development of a robust adaptation action plan. Second, there should be a collaborative, capacity-building relationship between any experts recruited to support the process (e.g., climate predictions, characterizing impacts on vulnerable systems/sectors) and stakeholders who may not be well versed in the technical details of the evidence.

C. Use of Metrics

A key lesson that emerged across all plans was that the identification and application of suitable metrics to prioritize and measure the effectiveness of adaptation strategies was difficult. In some settings (i.e., Los Angeles, Spain, Australia, King County, Miami-Dade County), specific metrics or evaluation criteria do not seem to have been applied in a systematic way. In Florida, metrics were chosen but their use was marginalized during the process with the result that they had little impact on the eventual list of options. Maryland proposed the use of adaptive capacity, flexibility and capital intensity as evaluation metrics though like Florida, these metrics were underused during the adaptation option prioritization process.

In contrast, the State of Washington, Boston and Chicago all relied on metrics to prioritize adaptation options. Because of a tight timeline that would not necessarily lend itself to some of the more traditional ways of choosing metrics and then prioritizing on the basis of those metrics (e.g., cost/benefit analysis and/or evaluating the effectiveness of options), Washington chose a set of simple metrics that included action, flexibility, complement and prominence. Chicago's used four explicit metric – benefits, costs, time and barriers – to evaluate each option and narrow the initial list of 250 options to several dozen. Notably, Boston focused on quantitative metrics to measure physical parameters that could be directly compared across adaptation scenarios (e.g. for coastal zones the metrics would be hectares of floodplain inundated and damages costs per hectare inundated).

Two key points emerge from the review of the use of metrics in adaptation planning processes. First, all settings struggled to some degree with the role of metrics. On the one hand, they offer a compelling way to rationalize the option selection process; on the other hand quantitative metrics are difficult to measure within the time/resource constraints and qualitative measure tend to be subjective. Second, the use of a rigorous set of quantitative metrics is possible, as evidenced by Boston and Chicago. New York City identified specific actions to be taken in implementing its plan. However, such processes were characterized by longer time frames and academic/consulting backstopping that most adaptation planning processes would likely find difficult to accommodate.

D. Role of Economic Analysis

A key lesson that emerged across all plans was that the analysis of economic impacts was rarely undertaken. There was no publicly available information or results on the economic impacts of adaptation options for most of the setting examined (i.e., Spain, King County, Australia, Miami-Dade County and Los Angeles. In other settings, there was explicit mention that none of the options were analyzed relative to their economic impacts due to the difficulty in developing reliable, policy-relevant estimates (i.e., Washington, Maryland and Florida).

On the other hand, Boston's adaptation process included a robust analysis of costs of adaptation versus long-term costs of no adaptation. And, in Chicago, the outputs of an analysis of economic impacts were used to assign values to metrics. It is important to note that the Boston and Chicago processes are distinguished by the length of time devoted to the process (including Boston, the process lasted four years) and the role of technical backstopping (in Chicago, a technical consultant was retained to conduct analyses; in Boston, scientists at Tufts University were involved in the analysis of climate scenarios and impacts).

Significantly, most settings opted from the start not to address the issue of the economic impacts of the options proposed. One can infer from the resulting plans that such a decision was predicated on the fact that it would have been difficult to assign meaningful numbers given the uncertainty in climate change impacts and the difficulties in linking the adaptation options to the resulting reduction in vulnerability to climate change impacts. In the case of Boston, which is the best example of economic impacts, the process was supported over time with university-based specialists.

E. Key Outputs

A key lesson that emerged across all plans was that the outputs, while taking various forms, all focused on a list of priority adaptation options that the setting was committed to pursue. At the country level, Australia grouped adaptation outputs into three major categories: technical capacity strengthening, new institutional arrangements, and sectoral action plans. Spain used a phased approach to presenting outputs. In Phase I, three priority vulnerable sectors were to be examined in more detail. In Phase II, impacts on the remaining twelve of the sectors were to be examined. Notably, Spain mapped which government agencies would be responsible for which portion of the work, and created relevant climate change bodies as deemed necessary. Additionally, with an eye to the EU adaptation policy process, Spain sought to ensure that its national policies would consistent with EU policy. Though this is not currently relevant to US states, it likely will be in future specific to state and federal policy frameworks.

At the state level, for example, Washington presented each recommended adaptation strategy with information on what would be needed for implementation, barriers to implementation, which state agencies would need to be involved in implementation, and who in addition to state agencies would need to be involved or included. At the city level, Chicago compiled a list of best practice adaptation methods to address the highest risks and prioritized the list based upon adaptation and mitigation benefits, costs, and catalytic potential. Boston used modeling to develop a range of adaptation scenarios to clarify adaptation options and the cost of doing nothing.

Conclusion

This Guidebook was written based on a process that the Center for Climate Strategies (CCS) developed and applied for state governments to use in working with stakeholders to develop strategies for adapting to climate change. The process described herein draws on CCS' experience as well as development of other adaptation plans by municipalities and other countries. The CCS process involves working with stakeholders to identify the most vulnerable sectors that need to be addressed and identify, evaluate, and if appropriate, recommend adaptations to increase resilience and reduce those vulnerabilities. The process can incorporate quantification of vulnerabilities and metrics to measure reduction in vulnerability, but it does not require application of quantitative methods. CCS' experience is that the process can be completed in less than one year and can be applied at the state, regional or local levels of government.

The steps in the process are as follows and correspond with chapters in the Guidebook.

- The first step is getting organized and involves bringing in stakeholders to consider climate change risks and adaptation. A committee composed of government officials and non-government stakeholders can be created to oversee the process.
- The second step in the process is organizing vulnerabilities by major topic areas. Determining which vulnerabilities should be of highest priority should be done based on risk analysis. Technical working groups can focus in on these topic areas.
- The next step is to identify adaptation options that can increase resilience and reduce vulnerability to climate change. The Guidebook includes a catalogue of adaptations drawn from adaptation efforts in U.S. states and municipalities, as well as from other countries. Note that many of these options will also reduce vulnerability risks from current climate such as climate variability and extreme events.
- A systematic and preferably quantitative process should be used to measure the cost-effectiveness of adaptation options. The Guidebook describes how metrics can be developed and applied. These metrics can be used to evaluate adaptation options, but many can also be used to measure the success or failure of adaptations once they are implemented.
- Following that, the adaptation options need to be evaluated and if appropriate sorted into recommendations or selections. Different approaches for making decisions about which adaptations to select are discussed. A key challenge faced by those adapting to climate change is evaluating options in light of the significant uncertainty about how climate will change at the regional, state, or municipal scale.
- It is important that adaptation to climate change consider other related consequences. The Guidebook addresses the effects of adaptation on mitigation (reduction) of greenhouse gas emissions. Consideration, particularly when evaluating adaptation options, should also be given to the implications adaptation in one sector or geographic area might have for other sectors or areas or for how certain such as the poor or indigenous communities might be affected by climate change adaptations.

The process is one that can produce a comprehensive adaptation plan in a reasonable amount of time and build broad support through involvement of stakeholders. The process is the beginning of what is recognized as iterative and should be revisited and updated with regularity (e.g., every three years). Adaptation is not a one-off process in which decisions can be made at one point to stand for all time. Adaptation actions will be implemented and they must be evaluated to make corrections to those that need improvement or make major changes or cease those that are not working at all. In addition, conditions will change and these will require a review and reassessment of risks and progress. As the climate continues to change and the science improves, we will better understand vulnerabilities to climate change. This knowledge will need to be incorporated into comprehensive adaptation planning processes and the resulting plans as part of the regular updating the plans and policies require.

By preparing and implementing comprehensive climate action plans that give equal priority to adaptation and mitigations, parparedness for the changing climate as well as investment in the opportunity climate impacts represent, will render substantial benefits and lower risk. Sub national goverments- states, regions, citites and counties will realize near- and long-term benefits while reducing the consequential impacts from more frequent and intense climate events. Through this future based planning, state, regional and local governments can demonstrate that bottom up action leads to progressive results that ultimately build the nation's economic and energy security as well as its ranking in the emerging energy economy of the 21st century. Bottom up action reinforces and positions nations to lead and succeed in an era of opportunity and innovation, rather that fall victim to the fears and consequences of a lack of comprehensive planning.

Appendix 1

Relevant Baseline Datasets for Identification of Priority Risks

This technical appendix identifies and very briefly describes some major examples of key sources for use in identifying priority risks for focus and policy development in adaptation planning. The listed items include both sources of baseline climate data and projections, and assessments of projected climate changes and resulting risks and impacts. The descriptions are intended to be useful to decision-makers, stakeholders, and others in deciding whether an individual source warrants review. Chapter 2 describes how these sources of information can be used in an adaptation planning process to assess impacts and risks of climate impacts as a basis for identifying priority risks to be considered in the planning process.

The appendix is divided into three main sections:

I. National, Regional, and Local Climate Change Data and Projections

Included in this section are sources that enable adaptation planning managers to construct their own sets of customized, downscaled temperature, precipitation, and/or seal level rise projections for their particular region. Also included are links to six Regional Climate Centers supported by the National Oceanic and Atmospheric Administration (NOAA), often the best sources for state and local historical climate information, and links to NOAA's eight Regional Integrated Sciences and Assessments (RISA) program centers, which often have publications and information on historical and future climate projections and impacts at a regional level.

II. Overall Assessments

This section includes sources of overall assessments of risks and impacts. Sources include assessments that are global and national in scope, produced by the U.S. Global Change Research Program and the Intergovernmental Panel on Climate Change; and exemplary multi-state regional, state-level, sub-state regional, and local assessments from around the nation. Individual sources often include as many as hundreds of references to sources on particular risks/impacts.

III. Assessments by Categories

This section includes sources on particular risks and impacts, listed according to the categories in this report's framework: Economic Activities, Health and Society, Infrastructure and Built Environment, and Natural Systems, and by subcategories within those major categories. Included are only a very few scientific journal articles on particular risks and impacts, which are primarily examples of sources that provide more detailed information than overall national assessments on how some climate change risks and impacts may vary by region or locality. Many more scientific articles include this kind of information; many are listed among the references in the overall assessments in section II of this Appendix.

Some assessments and sources are listed more than once; subsequent listings refer to the sections where the entry is initially described.

Source	Description
I. National, Regional, and Local Climate Change Data and Projections	
"Program for climate model diagnosis and intercomparison," Lawrence Livermore National Laboratory and others, http://www-pcmdi.llnl.gov/projects/cmip/index.php	The Coupled Model Intercomparison Project (CMIP): A source for anybody to use to produce customized, downscaled temperature and/or precipitation projections for any area in the contiguous 48 states, for one or more years through 2099, using one or more of 16 global climate models (some with multiple runs available) and any of 3 IPCC emissions scenarios.
"Climate change and sea level," Environmental Studies Laboratory, Department of Geosciences, University of Arizona, http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise.htm	An online source for any user to produce maps of how sea level rise of 1, 2, 3, 4, 5, or 6 meters may inundate any user-selected coastal areas in the contiguous United States, Puerto Rico, or the U.S. Virgin Islands, based solely on elevation of land above current sea level. Does not include consideration of local land subsidence, tidal ranges, or other factors.
Regional Climate Centers of the National Oceanic and Atmospheric Administration (NOAA), http://www.wrcc.dri.edu/rcc.html	Six U.S. Regional Climate Centers provide climate services including historical climate information, data analyses, and research. • High Plains Regional Climate Center • Midwestern Regional Climate Center • Northeast Regional Climate Center • Southeast Regional Climate Center • Southern Regional Climate Center • Western Regional Climate Center
Regional Integrated Sciences and Assessments (RISA) program of the National Oceanic and Atmospheric Administration (NOAA), http://www.climate.noaa.gov/cpo/cpo_pa/risa/	The Regional Integrated Sciences and Assessments (RISA) program supports research that addresses climate issues of concern to decision-makers and policy planners at a regional level. RISA research team members are primarily based at universities though some of the team members are based at government research facilities, non-profit organizations, or private sector entities. Research focus areas include agriculture, coastal restoration, public health, fisheries, water, and wildfire. • Alaska Center for Climate Assessment and Policy (ACCAP) • California-Nevada Applications Program (CNAP) • Carolinas Integrated Sciences and Assessments (CISA) • Climate Assessment for the Southwest (CLIMAS)

Source	Description
	• Climate Decision Support Consortium (CDSC) • Consortium on Climate Risk in the Urban NE (CCRUN) • Great Lakes Regional Integrated Sciences and Assessments Center (GLISA) • Pacific RISA • Southeastern Climate Consortium (SECC) • Southern Climate Impacts Planning Program (SCIPP) • Western Water Assessment (WWA)
II. Overall Assessments	
A. Global and national assessments	
Global Climate Change Impacts in the United States, U.S. Global Change Research Program (2009) http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/download-the-report	Compiled by a U.S. government interagency team, this is the government's 2009 national assessment of how climate change may affect the United States. The impacts are described in two primary sections: (1) on a regional basis and (2) according to social and economic sectors. (1) Regional basis: Impacts are described for eight major U.S. regions (Northeast, Southeast, Midwest, Great Plains, Northwest, Southwest, Alaska, and Islands of the Pacific and the Caribbean) and also for coasts nationwide. (2) Social and economic sectors include: • Water resources (precipitation patterns and intensity, drought incidence, melting of snow and ice, atmospheric water vapor, evaporation rates, water temperatures, lake and river ice, and soil moisture and runoff). • Energy supply and use (sources of emissions, changes in use and demand, changes in production such as hydroelectric capacity and marine oil and gas vulnerability to storms). • Transportation (disruption of service from extreme storms, impacts on infrastructure from storms and sea level rise). • Agriculture (crop responses to changes in temperature, water supply, and carbon dioxide; effects on growing seasons and shift of ideal crop-growing latitudes). • Ecosystems (processes such as growth and decomposition; shifts in species ranges and timing of migration; disruption from fires, insect pests, disease pathogens, and invasive weeds; particularly vulnerable habitats such as coastal areas, deserts and drylands, mountaintop, and coldwater streams and lakes). • Human health (heat waves, air quality, transmission of diseases, extreme storms, allergens, and vulnerable populations). • Society (relation to population shifts and development patterns, particularly vulnerable populations, population center infrastructure and services, insurance industry and risk management, relation to global change).

Source	Description
Climate Change 2007: The Physical Science Basis, Working Group 1, Intergovernmental Panel on Climate Change (2007) http://www.ipcc-wg1.unibe.ch/publications/wg1-ar4/wg1-ar4.html	Using information available through mid-2006, comprehensively states the then-current understanding of the physical science of climate change. It includes: • An overview of the methods used in climate change science, the role of climate models and evolution in the treatment of uncertainties; • Changes in atmospheric constituents (both gases and aerosols) that affect the radiative energy balance in the atmosphere and determine the Earth's climate; • Observed changes in the atmosphere, the earth's surface for snow, ice, frozen ground, and oceans (including sea level rise); • Palaeoclimatic evidence and applications to current modeling; • Description of modeling techniques and evaluation of effectiveness; • Attribution to natural and anthropogenic forces; • Projections of global climate conditions (including their uncertainties) under different levels of future greenhouse gases; • Regional climate change projections, in Chapter 11 (including projections for broad sub-continental regions, such as western, central, and eastern North America); and • A summary for policymakers.
Climate Change 2007: Impacts, Adaptation and Vulnerability, Working Group 2, Fourth Assessment Report, Intergovernmental Panel on Climate Change (2007) http://www.ipcc-wg2.gov/publications/AR4/index.html	See previous entry for IPCC overview. Describes observed and projected impacts on resource and regional bases and potential adaptation responses, including: • Observed changes and responses in natural and managed systems, and assessment of future impacts, regarding: – Freshwater resources and their management; – Food, fiber and forest products; – Coastal systems and low-lying areas; – Industry, settlement and society; and – Human health. • Regional assessments of future impacts and adaptation for eight worldwide regions. • An assessment of potential responses to impacts, including: – Adaptation practices, options, constraints, and capacity; – Inter-relationships between adaptation and mitigation; – Assessing key vulnerabilities and the risk from climate change; and – Perspectives on climate change and sustainability.
The Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science, http://www.copenhagendiagnosis.com	A synthesis report, primarily by lead authors of the 2007 IPCC reports, updating the state of scientific knowledge since the close-off date (mid-2006) of information for consideration in the IPCC's 2007 reports. Covers the range of topics evaluated by IPCC Working Group I, the Physical Science Basis, including: • Greenhouse gas emissions and their atmospheric concentrations, as well as the global carbon cycle; • Coverage of the atmosphere, the land-surface, the oceans, and all of the major components of the cryosphere (land-ice, glaciers, ice shelves, sea-ice and permafrost); • Paleoclimate, extreme events, sea level, future projections, abrupt change and tipping points; and • Separate boxes devoted to explaining some of the common misconceptions surrounding climate change science.

Source	Description
B. Multi-state regional assessments	
Northeastern United States: *Northeast Climate Impacts Assessment,* Union of Concerned Scientists (2007) http://www.northeastclimateimpacts.org/	Compiled by the Union of Concerned Scientists and a team of independent experts to develop an assessment of climate change, impacts on climate-sensitive sectors, and solutions in the northeastern United States. The main report, Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions, includes impacts on: • Climate (heat, precipitation, seasonal shifts, and drought frequency), including changes already documented and projections to 2100 for low- and high-emissions scenarios; • Coasts (flooding and shoreline changes); • Marine (ocean dynamics, water temperatures, and special focus on cod and lobster); • Forests (changes in forests and their ecosystem services, with detail on spruce/fir, hemlock, and hardwood forests); • Water (timing and amount of streamflows, more winter rain and less snow, increased droughts, heat leading to higher demands, storm intensity, and sea level rise); • Agriculture (dairy, crop productivity, weeds, and pests); • Winter recreation (snowmobiling and skiing); and • Human health (heat waves, vector-borne diseases, and air quality). A short section on adaptation strategies is also included.
"Regional climate change projections for the Northeast U.S." Hayhoe, et al. (2007). http://www.northeastclimateimpacts.org/pdf/miti/hayhoe_et_al.pdf	Describes downscaling general circulation model output to simulate spatial and temporal variability in temperature and precipitation across the region. Presents projections of future temperature and precipitation changes using IPCC emission scenarios combined with these downscaling methods.
Northwestern United States: *Scenarios of future climate for the Pacific Northwest,* Climate Impacts Group, University of Washington (2008), http://www.cses.washington.edu/db/pdf/moteetal2008scenarios628.pdf.	Using 20 models and 3 emissions scenarios, makes projections of future temperature and precipitation for the Northwest: Washington, Oregon, Idaho, and western Montana. Annual and seasonal means for temperature and precipitation is shown for the 2040s, 2060s, and 2080s. Also includes projections for coastal ocean temperatures and upwelling cycles and for extreme storms.
Southwestern United States: *Global Warming in the Southwest - Projections, Observations and Impacts,* Climate Assessment for the Southwest (2007) http://www.climas.arizona.edu/files/climas/pubs/GWSouthwest.pdf	Focused primarily on Arizona and New Mexico, the report describes impacts on: • Climate regimes (temperatures, drought, effects of ocean currents, monsoons, and hurricane intensity); • Water resources (Colorado River basin flows, groundwater recharge, and relation to energy demand); and • Landscapes (beetle infestations, forest composition, earlier springs, grassland dynamics, and wildfires).

Source	Description
C. State assessments	
Alaska: *Final Commission Report,* Alaska Climate Impact Assessment Commission (2008) http://www.housemajority.org/coms/cli/cli_finalreport_20080301.pdf	Created by the state legislature, the commission conducted widespread public hearings to identify impacts. Also recommends adaptation options. Impact categories include: • Economic impacts (resource extraction industries, fishing and hunting, insurance industry, marine transport, tourism); • Communities (land use issues, storm surge and sea level rise, river flooding, severe erosion, emergency preparedness); • Natural resources (resource development, fisheries, and forestry and wildfire); and • Implications for state agencies in charge of natural resources, health and social services, infrastructure, and utilities.
California: "Emissions pathways, climate change, and impacts on California," K. Hayhoe and others, *Proceedings of the National Academy of Sciences* (2004) http://www.pnas.org/content/101/34/12422.full.pdf+html	Describes downscaling two general circulation models under high- and low-emission scenarios to derive 2020-2049 and 2050-2090 projections for the state's temperature, precipitation, snowpack, runoff, water supply, heat waves, agriculture, and vegetation distribution.
California: *Indicators of Climate Change in California,* California Environmental Protection Agency (2009) http://oehha.ca.gov/multimedia/epic/pdf/ClimateChangeIndicatorsApril2009.pdf	Presents information on key indicators that climate change is underway in California, the drivers of these changes, and their impacts. This is not an overall assessment; only selected indicators are covered and projected future trends are covered in only a cursory way. Included are: • Background indicators (population, economy, energy consumption, transportation, vegetative cover); • Climate change drivers (trends in emissions of heat-trapping gases and atmospheric carbon dioxide); • Changes in climate (trends for temperature, heat waves, winter chill indicators, and precipitation); • Impacts on physical systems (snowmelt and snow/water content, sea level rise, freshwater and coastal ocean temperatures, and ocean current oxygen content); • Impacts on biological systems (mosquito-borne diseases, heat-related mortality, vegetation patterns, forest health, wildfires, and selected animal species representing shifts in bird migration dates, seabird populations, and shifts in small mammal and insect ranges); and • Discussions of the data relied on and any weaknesses in it.
Florida: *Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change,* Florida Atlantic University and National Commission on Energy Policy (2008), http://collaborate.csc.noaa.gov/climateadaptation/Lists/Resources/DispForm.aspx?ID=322	Conducted in collaboration with a task force from Miami and Dade Counties, the report is designed to assist the state in (1) assessing the likely impacts of climate change on its coastal regions and communities, and (2) developing and adopting policies and programs that will enable the state and its communities to adaptively manage those impacts. Particular attention is given to sea level rise impacts and policies.

Source	Description
	Included are: (1) Impacts section that focuses on sea level rise and hurricane activity and on research needs. (2) Adaptation section that includes discussion of a general policy-making framework, and describes critical issues and policy recommendations for land use planning and building regulation, water resource management, transportation and other infrastructure, conservation of natural lands and ecosystems, beach management, emergency preparedness, insurance, economic development, public health and other social effects, and state funding and financing options.
Maine: *Maine's Climate Future: An Initial Assessment*, University of Maine (2009) http://climatechange.umaine.edu/files/Maines_Climate_Future.pdf	Compiled at the request of the state legislature, the report includes impacts on: • Climate conditions (past and present trends, projections to 2100 based on a medium emissions future, for temperatures and precipitation on seasonal and sub-regional bases); • Gulf of Maine (water temperatures, chemistry, sea level rise, ecosystem shifts, cod and lobster fisheries, coastal flooding and inundation); • Freshwater ecosystems (cold-water fisheries, ice fishing season, local flooding and stream erosion damage, freshwater supply); • Forests (species composition, growth rates, diseases, insect infestations, wildfires); • Biodiversity (plant and animal in-migration and out-migration, endangered species, increases in warm-water fish and invasive species); and • Indigenous peoples (geographical range changes of plant and animal species, effects of loss of traditional resources affecting tribal culture and economies, and government budgets). .
Maryland: *Global Warming and the Free State,* State of Maryland (2008) http://www.umces.edu/sites/default/files/pdfs/global_warming_free_state_report.pdf	The climate impact assessment chapter from the state's 2008 Plan of Action released by the Maryland Commission on Climate Change. Included are impacts on: • Climate (temperatures, heat waves, precipitation, intense storms and associated flooding and runoff pollution); • Environment (sea level rise, terrestrial wildlife and marine fisheries, and Chesapeake and coastal bays warming and water quality); • Economy (agricultural and forestry production near and long term); and • Human health (heat waves, respiratory illnesses, and diseases).
Pennsylvania: *Climate Change in Pennsylvania: Impacts and Solutions for the Keystone State,* Union of Concerned Scientists (2008) http://www.northeastclimateimpacts.org/assets/climate-change-in-pennsylvania_impacts-and-solutions.pdf	Compiled by the Union of Concerned Scientists and a team of independent experts to develop an assessment of climate change, impacts on climate-sensitive sectors, and solutions in Pennsylvania. The report includes impacts on: • Climate (heat, precipitation, seasonal shifts, drought frequency), including changes already documented and projections to 2100 for low- and high-emissions scenarios; • Cities and towns (heat waves, air quality, and infrastructure);

Source	Description
	• Agriculture (dairy, grapes, apples, corn, other crops); • Forests (trees, birds, industries and livelihoods); and • Winter recreation (snowmobiling and skiing). *Short sections on emission reduction and adaptation strategies are included.*
Washington: *Washington Climate Change Impacts Assessment,* *Climate Impacts Group, University of Washington (2009)* http://cses.washington.edu/cig/res/ia/waccia.shtml	*Conducted by the Climate Impacts Group and other experts, the report describes regional climate modeling downscaled from global climate models* and assesses the impacts of climate change for time periods centered on 2040, 2060, and 2080. Sectors included: • Water (statewide hydrology, Puget Sound water management, agricultural water supplies); • Energy demand (heating and cooling demand changes tied to populations' growth); • Agriculture (eastern Washington, for apples, potatoes, and winter and spring dryland wheat); • Salmon freshwater habitat (summer stream temperatures, seasonal low flows, frequency and magnitude of peak-flow events); • Coasts (inundation, storm surges, bluff erosion, shifting beaches, saltwater intrusion in freshwater aquifers, ocean temperature and acidity increases). • Forests (Douglas fir forests, species turnover, beetle infestations, wildfire incidence); • Human health (projected mortality risks due to heat events and air pollution); and • Urban stormwater infrastructure (changes in precipitation using downscaled climate models, streamflow projections, and engineering implications).
D.Sub-state regional assessments	
Southwest Florida: *DRAFT Southwest FL Climate Change Vulnerability Assessment*, Southwest Florida Regional Planning Council and Charlotte Harbor Estuary (2009) http://community.csc.noaa.gov/climateadaptation/index.php?option=com_fireboard&Itemid=31&func=view&id=33&catid=6	Compiled by a public-private partnership for the 4,700-square-mile Charlotte Harbor National Estuary Program study area in southwest Florida, three future climate scenarios are used to project impacts to 2100 on: • Critical facilities (emergency services, communications, solid waste, water supply and wastewater, transportation, energy supply); • Economic activities (agriculture, forestry, tourism, building, ocean economy, mining); • Cultural resources (historic districts and lighthouses); • Human health (weather-related mortality, infectious diseases, respiratory illnesses); • Coastal resources (beach erosion, inundation, costs to mitigate); and • Wildlife and ecosystems (shift in ecological zones, loss of habitat and species, damage to habitats).

Source	Description
Western Oregon: *Preparing for Climate Change in the Upper Willamette River Basin of Western Oregon,* University of Oregon and National Center for Conservation Science and Policy (2009) http://climlead.uoregon.edu/sites/climlead.uoregon.edu/files/reports/willamette_report3.11FINAL.pdf	Compiled by a multi-agency team, assesses the risks for built, human, and economic systems within the basin, and makes adaptation recommendations for these sectors. Included are impacts on future climate conditions, sector risk assessments, and adaptation recommendations: • Future climate conditions, using three downscaled global climate models to 2100, for temperature, precipitation and snowpack, storms and flooding, wildfire, and vegetation change. • Natural systems (aquatic and terrestrial species and invasive species); • Built, human, and economic systems **(i**nfrastructure, transportation and buildings; energy systems; public health and emergency service; agriculture and forestry; manufacturing, retail and service sectors). Also discusses strategies to modify governance structures to accommodate climate change.
E. Local assessments	
Chicago: "Climate Change and Chicago: Projections and Potential Impacts," Chicago Climate Action Plan web site, Research and Reports http://www.chicagoclimateaction.org/pages/research___reports/8.php	Representative of impacts to a large Upper Midwest urban area, including effects of climate disruption on the Great Lakes. Compiles contributions from public and private sector experts for the development of the Chicago Climate Action Plan. Detailed reports and summary fact sheets cover: • Existing changes in climate and projections to 2100 under low- and high-emissions scenarios (temperature, timing and amount of precipitation, seasonal shifts), based on downscaling of global climate models; • Impacts on water (seasonal and annual variations in streamflows, lake levels, and lake ice for streams and Lake Michigan, water quality including beaches, and the Lake Michigan aquatic ecosystem); • Health impacts (intensity and frequency of heat waves, air quality [particularly ozone], and disease outbreaks); • Infrastructure impacts (seasonal changes in energy use with a special focus on heat waves, stresses on emergency services, maintenance costs for roads and transit, building capital and maintenance costs, landscaping costs, harbor dredging costs, property insurance costs, employee absences, loss of tourism); • Impacts on ecosystems and agriculture (shifts in plant communities; changes in fish, insect, birds, and mammal species; increase in plant and animal pests and diseases; decreases in soybean production; heat, drought, and storm impacts on crops); and • Adaptation strategies based on impacts already occurring.
New York City: *Climate Risk Information*, New York City Panel on Climate Change (2009) http://www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf	One of three reports prepared for the New York City Panel on Climate Change, this assessment focuses on climate change risks to New York City's infrastructure. It includes: • Key climate hazards for the city and the surrounding region, likelihoods of the occurrence of the hazards, and a list of initial implications for the city's critical infrastructure (energy, transportation,

Source	Description
	and water systems). Much of focus is on sea level rise and coastal flooding. • Includes information on climate change scenarios, observed changes, future projections, indicators and monitoring, and technical appendices. Future reports will include an Adaptation Assessment Checklist and a Climate Protection Levels workbook to evaluate infrastructure.
San Diego: *San Diego's Changing Climate: A Regional Wake-Up Call,* San Diego Foundation (2008) http://meteora.ucsd.edu/cap/pdffiles/Focus2050glossySDF-ClimateReport.pdf (summary report) *Climate Change Related Impacts in the San Diego Region by 2050,* San Diego Foundation (2008) http://www.sdfoundation.org/news/pdf/Focus2050_whitepaper_final.pdf (working papers) "Climate Change-Related Impacts in the San Diego Region By 2050," California Climate Change Center (2009) http://www.energy.ca.gov/2009publications/CEC-500-2009-027/CEC-500-2009-027-F.PDF (detailed technical bases)	The summary report and white paper are intended to be sources for policy-makers and include science-based findings on impacts to the region to 2050. Included are impacts on: • Regional climate conditions using three climate models and two emissions scenarios; • Sea level rise (beaches, erosion of bluffs, storm water surge, flooded properties, loss of tide pools and freshwater marshes); • Urban water supply shortages; • Wildlife frequency; • Public health (heat waves, respiratory and cardiac health, smoke inhalation from fires, infectious diseases, and health services capacity). • Ecosystems (migration of terrestrial and marine species, extinctions, and forest health); and • Energy needs (increases in peak demand and air conditioning).
Seattle area: *King County 2007 Climate Plan,* King County, Washington (2007) http://your.kingcounty.gov/exec/news/2007/pdf/ClimatePlan.pdf	A comprehensive climate plan for the Seattle region that includes sections on future climate projections and on impacts to sectors. Also includes recommendations for mitigation and adaptation actions. Included are impacts on: • Regional climate conditions (temperature, precipitation, extreme storms, sea level rise); • Hydrology (snowpack and glaciers, temporal runoff shifts, flooding, erosion, seasonal low flows); • Public health and safety (heat waves, flooding, infectious and water-borne diseases, and workforce capacity); • Land use, transportation, and buildings (flooding, shoreline inundation and erosion, nearshore habitat, parks and recreation facilities, historic and cultural resources, and transit services and transportation infrastructure); • Water supply and quality (reservoir yields, shifts in demand, aquifers, wastewater and stormwater operations, freshwater quality); • Biodiversity and ecosystems (salmon and coldwater fish, coastal birds, wetland systems, marine fisheries, and forests and open space); and • Economy (insurance industry, agriculture, power demand and production, workforce capacity).

Source	Description
III. Assessments by Categories	
A. Economic Activities	
Agriculture	
The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.3 (2008) http://www.climatescience.gov/Library/sap/sap4-3/final-report/default.htm	Compiled by federal agency scientists, the report is an analysis and assessment of scientific understanding of impacts on: • Agriculture (cropping systems, pasture and grazing lands, and animal management); • Land resources (forests and arid lands); • Water resources (quantity, availability, accessibility, and quality); and • Biodiversity (species diversity and rare and sensitive ecosystems. Time period focuses on recent past and next 25-50 years. Where feasible, levels of certainty are assigned to impacts. Included are over-arching conclusions on climate conditions, widespread tendency for climate change to add to existing stressors, and recognition that much is still not known about the accurate projection of future impacts.
Tourism and recreation	
Analyses of the Effects of Global Change On Human Health and Welfare And Human Systems, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.6 (2008) http://www.climatescience.gov/Library/sap/sap4-6/final-report/default.htm	Compiled by federal agency scientists, the report is written in a broad context of effects on human health and welfare. Portions specific to tourism and recreation: • Effects on human settlement (regional vulnerabilities to changes in climate conditions such as snowmelt, heat waves, urban island effects, drought, wildfires, sea level rise, and extreme storms); and • Effects on economic welfare, with recognition that it is not yet a well-studied area. Recreation-specific topics include impacts on enjoyment and comfort of the outdoors, recreation visits, and recreation benefits such as physical and mental well-being. Direct impacts are related to climate conditions (temperature, precipitation, extreme storms, and sea level rise). Indirect impacts are related to climate change induced changes in vegetation and forests, stream flows, reservoir levels, recreational fisheries, wildlife populations, miles of beaches, snow and ice, and length of season.
Climate Change and Aspen: An Assessment of Potential Impacts and Responses, Aspen Global Change Institute (2006) http://www.agci.org/dB/PDFs/Publications/2006_CCA.pdf	Focused on Roaring Fork valley in Colorado, downhill skiing impacts are the primary focus, but additional natural resources are considered. Some recommended adaptation strategies are also included. Included are impacts on: • Regional temperature, precipitation, snowfall, and snowpack, projected to 2030 and 2100, through downscaled global climate

Source	Description
	models under three emission scenarios; • Snow quantity and quality, particularly regarding seasonal snow level elevation changes on ski slopes; • Socioeconomic conditions, including limited modeling on economic impacts; • Ecosystems (life zones, fire, and forest pests); and • Roaring Fork River (flows, user activities, water rights).
Climate Change in Park City: An Assessment of Climate, Snowpack, and Economic Impacts, Stratus Consulting Inc. (2009) http://www.parkcitygreen.org/Documents/2009-Climate-Change-in-Park-City-Report.aspx	Focused on Utah's Park City ski area and on downhill skiing impacts. Included are: • Review of historic regional climate trends; • Projections of regional temperature, precipitation, snowfall, and snowpack to 2030, 2050, and 2075, through downscaled global climate models under several emission scenarios; • Impacts on length of the ski season, the timing of snowpack buildup and melt, and daily values of snow depth and coverage from the bottom to the top of the mountain; • Impacts on skier days and effects on local economy; and • Recommended adaptation strategies.
B. Health and Society	
Human health	
Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.6 (2008) http://www.climatescience.gov/Library/sap/sap4-6/final-report/default.htm	See entry under Assessments by Categories, Economic Activities, Tourism and Recreation.
Weather and Climate Extremes in a Changing Climate, U.S. Climate Change Science Program, Synthesis and Assessment Product 3.3 (2008) http://www.climatescience.gov/Library/sap/sap3-3/default.php	Compiled by federal agency scientists, the report is an analysis and assessment of scientific understanding of impacts of climate extremes, done on a regional basis (North America, Hawaii, Caribbean, and U.S. Pacific Islands). Assessments of observed changes over the last 50 years, likelihood of linkage to human activities, and likelihood of continued future changes to 2100 are included for: • Warmer and fewer cold days and nights; • Hotter and more frequent hot days and nights; • More frequent heat waves and warm spells; • More frequent and intense heavy downpours and higher proportion of total rainfall in heavy precipitation events; • Increases in area affected by drought; and • More intense hurricanes.
"Fine-scale processes regulate the response of extreme events to	Uses a regional climate model with a high-resolution grid to project increases in extreme temperature and precipitation events. Relevant to

Source	Description
global climate change," N. Diffenbaugh and others, *Proceedings of the National Academy of Sciences* (2005) http://www.pnas.org/content/102/44/15774.full.pdf+html	heat waves. Maps show regional projections.
"More intense, more frequent, and longer lasting heat waves in the 21st century," G. Meehl and C. Tebaldi, *Science* (2004) http://www.sciencemag.org/cgi/content/full/305/5686/994	Maps show regional projections for future heat waves.
C. Infrastructure and Built Environment	
Infrastructure and built environment in general	
New York City: *Climate Risk Information*, New York City Panel on Climate Change (2009) http://www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf	See entry under Overall Assessments, Local assessments. This assessment focuses on New York City's infrastructure.
Energy supply and use	
Effects of Climate Change on Energy Production and Use in the United States, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.5 (2007) http://www.climatescience.gov/Library/sap/sap4-5/final-report/default.htm	Compiled by federal agency scientists, the report acknowledges that the impacts on the energy sector from climate change have been under-studied and that impacts are much inter-related with other potential impacts, such as patterns of economic growth and land use, patterns of population growth and distribution, technological change, and social and cultural trends. Examined are impacts on: • Energy consumption (less for heating, more for cooling, and an overall increase); • Energy production and supply (effects of extreme weather, reductions in water supply, reduction of thermoelectric production due to temperature increases, and siting decisions); and • Indirect effects (changes in energy production technology, energy security, risk-driven investment priorities, and global markets).
Flooding	
Weather and Climate Extremes in a Changing Climate, U.S. Climate Change Science Program, Synthesis and Assessment Product 3.3 (2008) http://www.climatescience.gov/Library/sap/sap3-3/default.php	See entry under Assessments by Categories, Health and Society, Human Health.

Source	Description
"Going to the extremes: An intercomparison of model-simulated historical and future changes in extreme events," C. Tebaldi and others, *Climatic Change* (2006) http://www.cgd.ucar.edu/ccr/publications/tebaldi_extremes.pdf	See entry under Assessments by Categories, Health and Society, Human health.
When it Rains, it Pours: Global Warming and the Rising Frequency of Extreme Precipitation in the United States, Environment New Hampshire (2007) http://www.environmentnewhampshire.org/uploads/Rx/_8/Rx_8sa-lUrwjnmsIIL1Xyg/When-It-Rains-It-Pours.pdf	Includes projections of extreme precipitation events for the U.S., as well as a description of the interface with increased drought and precipitation falling as rain rather than snow. Documents frequency of storms by region and by state from 1948-2006.
Transportation	
Impacts of Climate Variability and Change on Transportation Systems and Infrastructure — Gulf Coast Study, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.7 (2008) http://www.climatescience.gov/Library/sap/sap4-7/final-report/	Examines historical trends and future climate scenarios to assess the potential effects of climate change during the next 50 – 100 years on all major transportation modes within the region from Galveston, Texas to Mobile, Alabama. In the context of warming temperatures, changes in precipitation patterns, increased storm intensity, and sea level rise (taking into account general sinking of the land surface), describes potential impacts regarding: • Effects of warming temperatures on materials, maintenance, and operational choices (heat tolerance of materials, restrictions on work crews, buckling railway tracks, cooling and air conditioning needs for transportation terminals); • Short-term flooding (drainage systems, traffic management, accident rates, airline schedules, infrastructure damage); • Inundation from sea level rise (risk assessments based on rise amount scenarios and effects on contiguous transportation links); and • Storm intensity (service disruption and infrastructure damage).
D. Natural Systems	
Ecosystems	
The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.3 (2008) http://www.climatescience.gov/	See entry under Assessments by Categories, Economic Activities, Agriculture

Source	Description
Library/sap/sap4-3/final-report/default.htm	
Thresholds of Climate Change in Ecosystems, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.2 (2009) http://www.climatescience.gov/Library/sap/sap4-2/final-report/default.htm	Compiled by federal agency scientists, the report reviews threshold changes (i.e., sudden or abrupt) in North American ecosystems that are potentially induced by climatic change and addresses the significant challenges these threshold crossings impose on resource and land managers. Uses case studies to describe thresholds for Alaska ecosystems, mid-continent prairie potholes, southwestern forest diebacks, and coral-reef ecosystems.
Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations, C.R. Pyke and others, Chesapeake Bay Program Science and Technical Advisory Committee (2008) http://www.chesapeake.org/stac/Pubs/climchangereport.pdf	Compiled by scientific and technical advisors to the EPA'S Chesapeake Bay Program, the report draws on existing scientific reports and projections to project impacts on the region's natural resources and economy to 2100. Included are impacts to: • Climate and hydrologic conditions (atmospheric composition, water temperature, precipitation, streamflow, sea level, and storms); • Watershed fluxes in nutrients and sediments (non-point and point source pollution, nitrogen deposition, and wetlands); • Bay waters response (circulation, salinity, suspended sediment); • Living resources (food webs, plankton and biogeochemistry; submerged aquatic vegetation, estuarine wetlands, and fish and shellfish); and • Society and economy (limited coverage and recognition that the topics are not yet well studied).
Climate Change and Massachusetts Fish and Wildlife: Volume 2 Habitat and Species Vulnerability, Manomet Center for Conservation Sciences and Massachusetts Division of Fisheries and Wildlife (2010) http://www.mass.gov/dfwele/dfw/habitat/cwcs/pdf/climate_change_habitat_vulnerability.pdf	Designed to supplement the Massachusetts State Wildlife Action Plan. Describes an iterative process, combining scientific evaluation and expert opinion, to identify the vertebrate species most vulnerable to climate change based on the vulnerability of their habitats.
Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment, P. Glick and B.A. Stein, editors, National Wildlife Federation (2010) http://www.nwf.org/Global-Warming/Climate-Smart-Conservation/Safeguarding-Wildlife/~/media/PDFs/Global%20Warming/NWF_Scanning_the_Conservation_Horizon.ashx	Designed to support wildlife conservation and ecosystem-based adaptation. Provides guidance on assessments of species, habitats, and ecosystems. Included are seven case studies, profiling efforts of varying scope and complexity and employing different analytical approaches (e.g., expert opinion vs. computer models), conservation targets (e.g., species vs. habitats), and spatial scales (e.g., states vs. regions).
"Warming and earlier spring increases western U.S. forest wildfire activity," A. Westerling and others, *Science* (2006) http://www.sciencemag.org/cgi/content/full/313/5789/940	Compares increasing incidence and severity of western U.S. wildfires during period from 1986-2003 compared to 1970-1986 and attributes the changes to climatic variables (warming temperatures, timing of spring snowmelt, and drought incidence). Describes corresponding increases in wildfire activity (frequency, intensity, acres burned, length of season, and regional differences).

Source	Description
Sea Level Rise	
Abrupt Climate Change, U.S. Climate Change Science Program, Synthesis and Assessment Product 3.4 (2008) http://www.climatescience.gov/Library/sap/sap3-4/final-report/default.htm	Compiled by federal agency and other scientists. Includes assessment of likelihoods of some abrupt climate changes. Those related to sea level rise include: • Rapid change in glaciers, ice sheets, and hence sea level; • Widespread and sustained changes to the hydrologic cycle; and • Abrupt change in the northward flow of warm, salty water in the upper layers of the Atlantic Ocean. The report does not focus on specific effects on human and natural systems as a result of abrupt change.
Weather and Climate Extremes in a Changing Climate, U.S. Climate Change Science Program, Synthesis and Assessment Product 3.3 (2008) http://www.climatescience.gov/Library/sap/sap3-3/default.php	See entry under Assessments by Categories, Health and Society, Human health.
Coastal Climate Adaptation Resources, National Oceanic and Atmospheric Administration, http://community.csc.noaa.gov/climateadaptation/	A compilation of resources that can be sorted by category or by U.S. coastal state for: • Adaptation and Action Plans; • Case Studies and Strategies; • Climate Change Communication; • Climate Change Science and Impacts; • Guidance and Guidebooks; • Outreach Materials; • Policies and Legislation; • Risk and Vulnerability Assessments; • Stakeholder Engagement; and • Training and Workshop Materials.
The Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science, http://www.copenhagendiagnosis.org/	See entry under Overall Assessments, National Assessments. Concludes that by 2100, global sea level is likely to rise at least twice as much as projected by Working Group 1 of the IPCC AR4 emissions scenario; for unmitigated emissions it may well exceed 1 meter. The upper limit has been estimated as up to 2 meters sea level rise by 2100.
"Climate change and sea level," Environmental Studies Laboratory, Department of Geosciences, University of Arizona, http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise.htm	See entry under National/Regional/Local Climate Change Data and Projections.
"Adaptive coastal planning," Climate Adaptation Library, Florida Institute of Technology, http://research.fit.edu/sealevelriselibrary/	An internet-based worldwide source list targeted towards coastal planning in the context of climatic change. For the U.S., includes national reports as well as those relevant to regions — Florida, East Coast, Gulf Coast, and West Coast and Hawaii.

Source	Description
Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.1 (2009) http://www.climatescience.gov/Library/sap/sap4-1/final-report/default.htm	Compiled by federal agency and other scientists, the report uses the mid-Atlantic coasts (from Long Island to South Carolina) as a focus area to explore how addressing both sensitive ecosystems and impacts to humans will be a challenge along all coastlines. Using current scientific literature and expert panel assessments, it examines potential risks, possible responses, and decisions that may be sensitive to sea level rise. Featured topics include: • Impacts on physical environment (erosion, land forms, wetlands, and most vulnerable wildlife habitat); • Society impacts (shoreline structures, population, land use, and infrastructure); and • An extensive appendix on localized wildlife impacts and on individual state and local government coastal protection policies.
Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations, C.R. Pyke and others, Chesapeake Bay Program Science and Technical Advisory Committee (2008) http://www.chesapeake.org/stac/Pubs/climchangereport.pdf	See entry under Assessments by Categories, Natural Systems, Ecosystems.
StormSmart Coasts, Massachusetts Office of Coastal Zone Management, http://www.mass.gov/czm/stormsmart/	A resource guide intended for use by community elected officials and agency staff, covering: • Hazard Identification & Mapping; • Planning; • Regulations & Development Standards; • Mitigation & Shore Protection; • Infrastructure; • Emergency Services; • Education & Outreach; and • Property rights and other legal information.
Sea Level Rise Task Force, New York Department of Environmental Conservation (2009) http://www.dec.ny.gov/energy/45202.html	Describes structure, findings, and proceedings of legislatively established task force to assess impacts to the state's coastlines from rising seas. Also includes recommended protective and adaptive measures. Report is due by January 1, 2011.
Water Supply	
Abrupt Climate Change, U.S. Climate Change Science Program, Synthesis and Assessment Product 3.4 (2008) http://www.climatescience.gov/Library/sap/sap3-4/final-report/default.htm	See entry under Assessments by Categories, Natural Systems, Sea level rise.

Source	Description
The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.3 (2008) http://www.climatescience.gov/Library/sap/sap4-3/final-report/default.htm	See entry under Assessments by Categories, Economic Activities, Agriculture.
Weather and Climate Extremes in a Changing Climate, U.S. Climate Change Science Program, Synthesis and Assessment Product 3.3 (2008) http://www.climatescience.gov/Library/sap/sap3-3/default.php	See entry under Assessments by Categories, Health and Society, Human health.
Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations, C.R. Pyke and others, Chesapeake Bay Program Science and Technical Advisory Committee (2008) http://www.chesapeake.org/stac/Pubs/climchangereport.pdf	See entry under Assessments by Categories, Natural Systems, Ecosystems.
"Changes in snowmelt runoff timing in western North America under a 'business as usual' climate change scenario," I. Stewart, D. R. Cayan, and M. D. Dettinger, *Climatic Change* (2004) http://tenaya.ucsd.edu/~dettinge/stewart_acpi.pdf	Based on 1948 – 2000 data from 279 western U.S. streams dominated by snowmelt, streamflow timing changes for 1995–2099 are projected using the Parallel Climate Model under business-as-usual greenhouse-gas emissions. Projected changes in date of projected central point of peak flow are consistent with observed rates and directions of change during the period of record, and are strongest in the Pacific Northwest, Sierra Nevada, and Rocky Mountains, where many rivers may eventually run 30–40 days earlier. Illustrative graphics effectively compare changes for the entire West. Maps show regional trends and projections.
"Declining mountain snowpack in western North America," P.W. Mote and others, *Bulletin of the American Meteorological Society*, (2005) http://journals.ametsoc.org/doi/abs/10.1175/BAMS-86-1-39	Based on 1916–2002 data, demonstrates declining spring snowpack levels in mountain regions, despite increases in winter precipitation in many places. Analyses isolate climatic trends as the dominant factor over changes in land use, forest canopy, or other factors. Shows the largest decreases have occurred where winter temperatures are mild, especially in the Cascade Mountains and northern California, and that in most mountain ranges, relative declines grow from minimal at ridgetop to substantial at snow line. Maps show regional trends.
"Model projections of an imminent transition to a more arid climate in the southwestern North America," R. Seager and others, *Science* (2007) http://www.ldeo.columbia.edu/cicar/documents/Sc_Express_Model_Predictionsv2.pdf	Using 19 models based on 1950-2000 data, makes projections for the southwest U.S. under a moderate emissions scenario (A1B) for the period from 2021-2040. Finds that a drying trend will continue as northern latitudes get wetter due to shifts in global circulation patterns, and that the Dust Bowl conditions and 1950s droughts could become the new norm.

Source	Description
"Seasonal Climate Shifts in Hydroclimatology over the western United States," S. Regonda and B. Rajagopalan, *Journal of Climate* (2005) http://civil.colorado.edu/~balajir/my-papers/Regondaetal.pdf	Measurements of streamflow, snow water equivalent (SWE), precipitation and temperature are used to assess shifts in the seasonal cycle of snowmelt runoff in snowmelt-dominated streams of the West over the period 1950–1999. Finds earlier peak flows at mid- to low-elevation sites, particularly in the Northwest; declining SWE at sites mostly in the Northwest and other northerly states; increasing temperatures; and more winter precipitation falling as rain rather than snow. Maps show regional trends.
"Trends and variability in snowmelt timing in western United States," G. McCabe and M.Clark, Journal of Hydrometeorology (2005) http://ams.allenpress.com/perlserv/?request=get-document&doi=10.1175%2FJHM428.1	Examines streamflow data from 84 Hydroclimatic Data Network stations in the western U.S. from 1950–2003, and finds snowmelt timing shifting to earlier in the spring, particularly in the Northwest and central Rockies, and at lower elevations. Also finds it has not been a gradual trend; in the mid-1980s, there was a significant step-trend to earlier in the spring, correlated to April-May-June-July temperature increases. Maps show regional trends.
"Trends in snowfall versus rainfall for the western United States, 1949-2004," N. Knowles, M. D. Dettinger, and D. R. Cayan, *Journal of Climate* (2006) http://www.nwf-wcr.org/PDFs-ClimateChangeFWP/NRNRC-GW-FWP-Knowles-Paper-2005.pdf	Examines winter snow depth, precipitation, and temperature data from the Hydroclimatic Data Network from over 1,600 western U.S. stations for the period 1948-2004. Finds that during mid-winter, more precipitation falls as rain rather than snow mostly at lower West Coast elevations, but in spring, the trend is towards more rain at all sites. Maps show regional trends.
Colorado Climate Change: A Synthesis to Support Water Resource Management and Adaptation, Western Water Assessment, for the Colorado Water Conservation Board (2008) http://cwcb.state.co.us/Home/ClimateChange/ClimateChangeInColoradoReport/	Summarizes Colorado-specific findings from peer-reviewed regional studies, and presents new graphics derived from existing datasets. Focuses on observed trends, modeling, and projections to 2050 on statewide and regional bases, for temperature (annual and seasonal), precipitation, snowpack, snowmelt, and timing of runoff. Describes implications for agricultural and urban irrigation, water supply infrastructure, legal framework, water quality, energy demand, mountain habitats, interface with forests and beetle infestations, riparian and aquatic habitats, and snow- and water-based recreation.
The Impact of Climate Change on New Mexico's Water Supply and Ability to Manage Water Resources, New Mexico Office of the State Engineer/Interstate Stream Commission (2006) http://www.nmdrought.state.nm.us/ClimateChangeImpact/completeREPORTfinal.pdf	Developed as input for the state Climate Change Advisory Group and the State Water Plan, the report uses global climate models and a downscaled regional global climate model, a business-as-usual emissions scenario, and the Variable Infiltration Capacity (VIC) hydrology model to project impacts to 2100 on statewide and sub-region temperatures (annual and seasonal), precipitation, snowpack, and evapotranspiration.

Appendix 2

Metrics

Water Metrics

There are a number of metrics for measuring key aspects of water resources that are widely used. These metrics have been developed over many years. They serve to transmit information on the availability of supplies as well as warn the water resources community if supplies are tight (or very high in the case of flooding). These indexes have not been designed to set priorities for policies or to measure the effects of policies. It is unclear if they could be used for such purposes. They are generally meant to indicate the state of the system, i.e., if water supplies are sufficient for an upcoming season or year. Thus, they can be used to trigger policy responses such as a declaration of water use restrictions or a drought emergency should the index exceed a predetermined level corresponding with drought or severe drought.

Water Supply Metrics

Metrics to measure water supply are in use. For example, in snowmelt-dominated states of the West, the Surface Water Supply Index (SWSI) is used to measure and forecast water availability for the upcoming irrigation year. The SWSI combines the measurement of current storage in reservoirs with estimates of snowpack, precipitation, and streamflow. In winter months, streamflow is not measured; however, in summer months, streamflow is measured but not snowpack (Goddard Space Flight Center, 2010).

Drought Metrics

There are numerous metrics for measuring drought and some are presented below. Drought indexes tend to have the common attribute of serving as warning systems to alert water managers and others about the onset of drought.

Some examples of drought metrics (based on Hayes, 2010) are provided below.

- ***Percent of Normal Precipitation***

  This index compares cumulative precipitation over a year or season to average precipitation. This has the virtue of being a very simple and easy to understand index. A criticism of this index is that it would be better to compare precipitation to median amounts (or even a standard deviation below mean amounts).

- ***Standardized Precipitation Index (SPI)***

  This index compares current precipitation to historical distributions of precipitation and use probabilities. The SPI is measured on a plus or minus 2-point scale with 0 being median precipitation and negative values corresponding with reduced precipitation. It is site specific and relatively simple because it only uses precipitation data.

❖ ***Palmer Drought Severity Index (PDSI)***

The PDSI is a widely used measure of sustained drought. It focuses on estimating soil moisture, not precipitation, and thus uses more variables than just precipitation. Developed in the 1960s, it combines precipitation, temperature, and available water content of soils.

The PDSI uses a plus or minus 4-point scale where 0 corresponds to normal conditions and negative numbers to dry conditions. As with the other indexes, it is intended to be site specific, so the relative severity of a drought is estimated. It is measured using monthly data and is intended to integrate multiple months so that longer-term soil drought can be estimated.

❖ ***Crop Moisture Index (CMI)***

The CMI, developed by the same scientist who developed the PDSI, measures shorter-term drought conditions than the PDSI. It combines weekly measures of temperature and precipitation along with the CMI index from the previous week. The CMI is intended to provide useful information to the agricultural community, not drought managers. Indeed, the CMI is very sensitive to short-term variations such as a wet week, which may not alleviate long-term drought.

Applying Monetization to Trade-Off Options

A hypothetical example loosely based on literature is developed in this section to illustrate how monetizing potential benefits of adaptation options could be used to compare cost-effectiveness. We also examine how monetization can be used to examine "net benefits," the difference between benefits and costs. The numbers used here, unless cited, are only for illustrative purposes and should not be used in policy-making exercises.

We compare the cost of building a water supply project, a reservoir, with a heat watch warning system. The costs and benefits of building the reservoir system are loosely based on U.S. Department of the Interior data (U.S. DOI Bureau of Reclamation, 2008), and the costs and benefits of the heat watch warning system are based on Ebi et al. (2004; and adjusted for inflation to 2008$). A full cost-benefit analysis would use a range of estimates for benefits to reflect uncertainty about how benefits are monetized.

The capital costs for a new reservoir are assumed to be $3 billion. Assuming a 30-year amortization of the amount at an interest rate of 5.00% (and not accounting for operating and maintenance costs), the annual amortization costs are $193 million. We assume that the annual yield of water for consumptive purposes is 500,000 acre-feet. Note that the reservoir might also provide flood control and recreational benefits. On the other hand, it may create environmental harm and displace some uses such as whitewater rafting. These omissions are significant and the rough calculations presented here should not be considered a full cost-benefit analysis.

We assume that 80% of the consumed water is used for agriculture and the rest for municipal and industrial uses. Based loosely on Gibbons (1986), Booker and Colby (1995), Michelsen et al. (1998), and Raucher et al. (2005), adjusted for inflation, we assumed that the marginal value of unrestrained water is $500 per acre-foot for municipal use and $60 per acre-foot for agricultural use, which yields a total value of $74 million per year. The benefit-cost ratio is 0.38. A ratio of higher than 1.0 is needed to show that benefits exceed costs. The annual net benefits (i.e., the benefits minus the costs) are -$119 million; that is, the costs exceed the benefits by $119 million per year.

Ebi et al. (2004) estimated the costs and benefits of a heat watch warning system for Philadelphia. The annual costs of running the heat watch warning system is approximately $80 thousand in 2008$. They estimated that it would save 117 lives over a three-year period, or 39 lives per year. Assuming a "statistical value of life" of $4 million,[1] the annual "statistical value" of the saved lives is $156 million. The benefit-cost ratio is an astounding 1,950. The net benefits of the heat watch program is thus expected to be over $155 million.

The benefit-cost ratio for the heat watch warning system is thousands of times higher than the reservoir. The net benefits of the two projects are of opposite sign, but of similar magnitude. Had the reservoir had positive net benefits, then it would be a closer call as to which adaptation option is preferred. To be sure, these examples are loosely based on the literature. But they demonstrate how estimating costs and benefits in monetary terms can facilitate comparison of adaptation alternatives in different sectors.

Other considerations can also be used, one being total cost. The heat watch warning system's costs is under $100,000 per year while the reservoir is nearly $200 million per year. A second consideration is feasibility. A heat watch warning system is unlikely to generate significant opposition. In contrast, building a reservoir, particularly if it is in an environmentally-sensitive habitat, is likely to be highly controversial.

A third consideration is relative benefits. Even ignoring the costs, the annual value of the benefits of the heat watch warning system is estimated to be more than $100 million, while the annual benefits of the reservoir is estimated to be about $75 million.

So, the comparison of the reservoir versus the heat-watch warning system is easy. No matter what method of comparison is used, e.g., benefit-cost ratio, net benefits, total costs, total benefits, or feasibility, each method points to the heat watch warning system as being superior. Comparisons of other options may not yield such clear results.

Criteria to Set Priorities

Table A2-1, on page 96, was developed by consultants advising the State of Alaska on processes to identify and rank adaptations. The scores are illustrative and were neither developed nor endorsed by the State of Alaska. Nonetheless, the table can be used as a template for scoring indexes of vulnerability and adaptation in order to rank or group adaptations.

Table A2-1. Example of using indexes to compare adaptation options

Impact Framework		Current Impact	ojected Imp	Certainty (Criteria #1)		Sensitivity (Criteria #2)		Intervention Need (Criteria #3)		Economic Importance (Criteria #4)		Social Importance (Criteria #5)	
Infrastructure and Transportation	Subsector	Description of climate change impact	Projection of impact in the future	Likelihood of the climate change impact occurring	Certainty	Degree to which the subsector is affected by climate change	Sensitivity	Intervention need is high for subsectors that cannot easily adjust to climate change	Intervention Need	Importance of the affected resource to economic values	Economic Importance	Importance of the resource to cultural, social, or other values	Social Importance
				high = 3; medium = 2; low = 1		high = 3; medium = 2; low = 1		high = 3; medium = 2; low = 1		high = 3; medium = 2; low = 1		high = 3; medium = 2; low = 1	
Infrastructure	Highways, Roads, and Bridges	Highway, road and bridge damage from **melting/warming permafrost**: Current - costly (at least $10 million/yr - ADOT estimate) and potentially dangerous (e.g. highways surrounding Fairbanks); larger construction costs (e.g. need thicker embankments, at least 4 feet thicker, and Air Convection Embankments); damage to the highway's surface, road bed, and integrity. Future - Additional damage from melting/warming permafrost: substantial rehabilitation/reconstruction and/or relocation needed; Road slope sloughing, filling ditches and plugging culverts;			3	Warming permafrost and the resulting damage to highways impacts a large number of highways and roads in Alaska (Richardson, Glenn, Alaska, Dalton, Steese and Tok cut-off Highways), and the additional costs are meaningful fraction of the total ADOT maintenance budget ($10/year out of total AK DOT northern region budget of $55 million)	2	Intervention is essential. Possible actions include: repair; more maintenance (such as cleaning culverts and ditches); better initial design; better materials, better siting, use of thermocouplers, etc.	3	Safe and traversable roads are important to the economy, especially with respect to the movement of goods by truck, tourism, and recreation economy.	2	Safe and traversable roads are important for social and cultural interactions, including visiting family and personal recreation. A major highway or bridge failure could have especially major impacts.	2
		Highway and road damage from temperature changes. Current: more freeze/thaw cycles with accelerated road damage (e.g. Anchorage). Future: Greater accelerated damage from milder winters and more freeze/thaw cycles; pavement damage from higher temperatures resulting in softening asphalt and rutting			3	Climate change has a moderate impact on more freeze/thaw cycles and a larger impact on road surface temperatures with the resulting damage to highways and roads, but road surfaces are also impacted by studs, vehicle weight, and traffic volume	2	Intervention is essential. Possible actions include: more frequent repair and resurfacing, more durable materials, faster response to repairs to minimize size of "potholes", better reporting systems; alternatives materials research	3	Safe and traversable roads are important to the economy, especially with respect to individual and business commerce, the movement of goods by truck, tourism, and recreation economy.	2	Safe and traversable roads are important for social and cultural interactions, including visiting family and personal recreation, however most Alaskans have adapted to road rutting and potholes	1

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Endnotes

[1] Studies such as Kochi et al. (2006) suggest that the statistical value of life could be several million dollars a year higher than this figure.

Appendix 3

Catalog

Infrastructure Built Environment

Natural Systems

Health and Society

Economic Activities

Cross-Cutting Issues

Option No.	Adaptation Policy Option
IBE-1	**LAND USE PLANNING**
IBE-1.1	Review planning laws, maps, plans, and development guidelines for Effective Response to Climate Impacts such as sea level rise, salt water intrusion, drought, more frequent and intense storms, storm surges and flooding, erosion, heat waves.
IBE-1.2	Review land use plans in anticipation of change development pressures and shifts in development patterns due to climate change
IBE-1.3	Support/Conduct Comprehensive Land Use Planning that incorporates adaptation strategies
IBE-1.4	Engage in regional planning processes in relationship to climate change
IBE-1.5	Develop a series of models for adaptive land use planning for decision-makers at all jurisdiction levels
IBE-1.6	Require consideration of climate change projections in urban planning
IBE-1.7	Integrate critical area planning requirements with comprehensive planning laws, including emergency planning and infrastructure planning requirements
IBE-1.8	Include online mapping capability in planning information for multiple audiences including local governments
IBE-1.9	Create visualization tool for sea level rise and associated hazards
IBE-1.10	Require that counties act on comprehensive planning requirements
IBE-1.11	Conduct assessment of trends in change in land use and stability of natural landscapes
IBE-1.12	Strengthen existing critical area planning and implement requirements to address sea level rise and associated coastal hazards
IBE-1.13	Guide future development out of areas vulnerable to sea level rise and associated hazards
IBE-1.14	End permitting of new home construction in areas vulnerable to sea level rise and associated hazards
IBE-1.15	Support ongoing collection and analysis of sea level rise, storm surge, and tidal data by existing institutions
IBE-1.16	Develop a strategy to regularly update floodplain maps
IBE-1.17	Identify high hazard areas (at risk for flooding, sea water inundation, landslides, thermal extremes, wildfires, etc.)
IBE-1.18	Assess threat of increased wildfires
IBE-1.19	Increase erosion and hazard planning focused on sheltered coastlines
IBE-1.20	Add climate change considerations to taxation and budget reform
IBE-2	**TRANSPORTATION INFRASTRUCTURE PLANNING**
IBE-2.1	Integrate transportation and land use planning
IBE-2.2	Ensure climate change is considered in reviews of state transportation plan
IBE-2.3	Create or review Department of Transportation's future corridors initiative
IBE-2.4	Require/enable metropolitan planning organizations to take climate change into account
IBE-2.5	Review existing coastal programs for coverage of sea level rise & other climate impacts on transportation
IBE-2.6	Develop a strategy for managing the retreat of (small and large) ports and associated infrastructure, such as rail and roads
IBE-2.7	Coordinate emergency evacuation and supply transportation routes with emergency preparedness systems to ensure capacity and resilience of escape routes compromised by natural disasters related to climate change
IBE-2.8	Identify and revaluate use of transportation routes in floodplains and coastal hazard zones
IBE-2.9	Develop joint transportation strategies with adjacent communities, regions and states to accommodate changing conditions and transportation system use
IBE-3	**INFRASTRUCTURE PLANNING**
IBE-3.1	Establish Climate Change and Public Infrastructure Task Force

Option No.	Adaptation Policy Option
IBE-3.2	Create a system for key data collection, analysis, monitoring and access
IBE-3.3	Establish a coordinating mechanism to assure that local governments act in concert with the state to reduce future impacts from climate change SLR and associated hazards
IBE-3.4	Review State Building and Design Codes to promote resiliency of communities, to mitigate storm and flood damage.
IBE-3.5	Build to last: build resiliency into public infrastructure
IBE-3.6	Establish a mechanism to evaluate and recommend new design standards for structures (and placement of mechanical and electrical equipment) that may be vulnerable to SLR and associated hazards
IBE-3.7	Limit infrastructure investments in hazard-affected coastal areas
IBE-3.8	Design industrial systems to reduce vulnerability to future sea level rise and associated hazards
IBE-3.9	Institute new hazard-resistant building codes and design standards to reduce vulnerability of structures to future sea level rise and associated hazards
IBE-3.10	Increase infrastructure design standards to address lower probability events
IBE-3.11	Synchronize future design with emergency planning infrastructure requirements
IBE-3.12	Create incentives for individuals and businesses to reduce risk of losses due to climate through building design codes
IBE-3.13	Engage Utility Sitting Board in incorporating climate risk factors
IBE-3.14	Improve sewage and solid-waste management infrastructure to reduce vulnerabilities to climate change (i.e. storm surge, flooding, inundation)
IBE-3.15	Evaluate and improve capacity of storm water infrastructure for high intensity rainfall events
IBE-3.16	Minimization of paved surfaces and use of trees to reduce flooding
IBE-3.17	Create standards for floating piers
IBE-3.18	Promote improvements and use current best practices
IBE-3.19	Require consideration of climate change projections in building guidelines
IBE-3.20	Support/Conduct Comprehensive Building Regulation that incorporates adaptation strategies and requirements
IBE-3.21	Review existing building and plumbing codes that are likely to be effected by climate change
IBE-3.22	Update building codes, design standards to include setback zones and phased-out or no development in exposed areas
IBE-3.23	Prohibit or reduce hardening of estuarine shorelines
IBE-3.24	Limit construction in 100-year floodplain to temporary installations
IBE-3.25	Use beach nourishment to protect infrastructure in coastal areas
IBE-3.26	Significantly increase estuarine buffers and oceanfront setbacks
IBE-3.27	Increase the number and height of flood barriers, levees and dams
IBE-4	**MANAGED RETREAT/RELOCATION**
IBE-4.1	Survey vulnerable current inhabited areas; develop relocation plans and contingency measures in the event of emergencies.
IBE-4.2	Develop retreat strategies for the management of existing structures or conditions that may become submerged hazards to navigation or public health (e.g. effluent outfalls, water intakes, septic fields, rock walls, docks and piers)
IBE-4.3	Develop strategies to address situations of changing ingress/egress to structures as support for access roads in areas vulnerable to sea level rise and associated hazards is withdrawn
IBE-4.4	Investigate potential and limitations of eminent domain, vesting, grandfathering, and amortizing strategies to support retreat activities
IBE-4.5	Analyze forced, subsidized migration
IBE-4.6	Identify financial and economic support mechanisms in response to relocation

Option No.	Adaptation Policy Option
IBE-4.7	Buyout unused properties in areas vulnerable to sea level rise and associated hazards
IBE-4.8	Retreat from highest risk barrier islands and low-lying lands, removing infrastructure that may exacerbate flooding and natural processes
IBE-4.9	Site industrial systems away from areas vulnerable to extreme changes in weather conditions
IBE-4.10	Consider relocation of threatened structures
IBE-4.11	Enact law that authorizes the state to secure a rolling property easement as sea level rises
IBE-5	**PROTECTION OF COMMUNITIES**
IBE-5.1	Require that local government coastal land use plans include a strategic plan for responding to sea level rise, and other climate risks.
IBE-5.2	Ensure adequate food security and food distribution systems for emergencies and over the long term
IBE-5.3	Develop new criteria for 'climate safe' communities and developments
IBE-5.4	Conduct a vulnerability assessment for cultural resources such as museums and historical sites
IBE-5.5	Update real estate transaction disclosure requirements for hazards related to climate change
IBE-5.6	Enact legislation to require sellers of coastal properties to disclose potential hazards to buyers. Coastal hazards disclosure should accompany all real estate transfers of properties in coastal counties
IBE-5.7	Strengthen building codes and increase building inspection frequency
IBE-5.8	Install hard structural protections such as dikes, levees, floodwalls, saltwater intrusion barriers to protect irreplaceable, immovable structures
IBE-5.9	Investigate consequences of installation of hard structural options (such as dikes, levees, floodwalls, and saltwater intrusion barriers) and soft structural options (such as dune restoration and creation wetland restoration, periodic beach nourishment temporary barriers) to ensure comprehensive and effective response
IBE-5.10	Protect shorelines with soft structural options such as dune and wetland restoration and creation, tree and other plantings, and periodic beach nourishment
IBE-5.11	Review construction standards for piers and wharves for wave strength resistance
IBE-5.12	Provide assistance or incentives for improving hazard preparedness of homes
IBE-5.13	Create upland buffers for expanded human and wildlife habitat
IBE-5.14	Minimize paved surfaces and use trees to reduce flooding
IBE-5.15	Raise shoreline structures
IBE-5.16	Assess financial impact of property value changes
IBE-5.17	Community education on hazards that addresses the relationship between climate variability and climate change
IBE-5.18	Establish structured training and vocational support for trades and others involved in implementation of new design standards
IBE-5.19	Integrate climate change and adaptation issues into advanced training in university, community college, and technical training programs
IBE-5.20	Make sure urban housing stock, including multi-family homes and public housing units are resilient to likely climate change effects
IBE-6	**ACCOMMODATION**
IBE-6.1	Promote hazard insurance for home owners and businesses
IBE-6.2	Evaluate and improve capacity of storm water infrastructure for high intensity rainfall events
IBE-6.3	Initiate surveillance and monitoring of sea-level rise related to storm-surge early warning systems and ensure adequate response/ evacuation plans
IBE-6.4	Strictly regulate of activities in hazard zones
IBE-6.5	Create inventory of infrastructure vulnerable to future SLR and associated hazards

Option No.	Adaptation Policy Option
IBE-6.6	Update guidance on landscaping, including a climate zone map
IBE-6.7	Establish structured capacity building and training for key adaptation sectors including building trades, infrastructure, finance and insurance, landscapers and others
IBE-6.8	Establish structured capacity buildings and training for public servants
IBE-6.9	The Department of Education should include considerations of likely climate change impacts when making decisions about new buildings
IBE-7	**WATER SUPPLY AND DELIVERY**
IBE-7.1	Evaluate the vulnerability of the water supply systems and networks to climate change related impacts. Develop strategies to add resilience to these systems.
IBE-7.2	Municipal water providers evaluate water conservation savings, demand management practices, and the best uses of conserved water in their systems
IBE-7.3	Review and consider revising older water resource policies, regulations, acts, agreements and regional water supply plans, that limit the ability to manage water resource problems caused by climate change
IBE-7.4	Develop a strategy to assure long-term public access to water
IBE-7.5	Expanded use of water markets to reallocate water to highly valued uses
IBE-7.6	Public officials exercise leadership in addressing climate change effects on water supplies
IBE-7.7	Assess estimated changes in water supply and base water policies on these assessments (taking note that past is no longer indicator of future)
IBE-7.8	Consider climate change in all water supply decisions and evaluate innovative options to meet water demand (e.g. reclaim and purify wastewater; institute water conservation strategies;
IBE-7.9	Improve water storage and transportation infrastructure to minimize loss and undersupply
IBE-7.10	Manage reservoirs to respond to changes in temperature and precipitation regimes
IBE-7.11	Increase water use efficiency and water recycling in residential and commercial buildings
IBE-7.12	Employ water conservation techniques such as reuse wastewater from tertiary treatment plants, cisterns and rain barrels
IBE-7.13	Provide tax credits for purchasing on-site water cisterns
IBE-7.14	Shift industrial water use to recycled water
IBE-7.15	Increase water use efficiency and water recycling in industrial and power station cooling
IBE-7.16	Increase capacity of water re-use infrastructure
IBE-7.17	Continue to investigate and invest in the development of large and small scale water storage, including ground water storage
IBE-7.18	Increase reservoir capacity
IBE-7.19	Improve management of underground water resources as population and demand grows
IBE-7.20	Inject fresh water into aquifers when available to increase water supplies in times of stress
IBE-7.21	Design of sewer and storm water systems to prevent fresh water contamination
IBE-7.22	Improve the design and function of septic systems to minimize groundwater contamination
IBE-7.23	Enhance water treatment works
IBE-7.24	Reduce volume of effluent into wastewater treatment plants
IBE-7.25	Assess, monitor and create mitigation plans to address threat of salt water intrusion into water supply. Pursue methods to protect potable water supply from salt water intrusion
IBE-7.26	Desalinize sea water to increase potable supplies
IBE-7.27	Monitor groundwater salinity increase
IBE-7.28	Improve erosion and sediment transport prevention techniques to maintain water quality and clarity
IBE-8	**STORM WATER INFRASTRUCTURE**
IBE-8.1	Manage storm water onsite, utilize low-impact development techniques
IBE-8.2	Legislate a requirement for developments to capture and treat storm water onsite from the 10-year 24-hour storm.

Option No.	Adaptation Policy Option
IBE-8.3	Create a low-impact development unit within the Division of Water Quality to assist developers reduce impact to protect water quality, prevent flooding and facilitate water re-use by managing storm water onsite
IBE-8.4	Increase the use of natural storm water amelioration techniques (man-made ponds, vegetated swales, marshes, etc.)
IBE-8.5	Incorporate future sea level rise concerns and other climate change impacts in prioritization for funding, design, and post-project operation and maintenance.
IBE-8.6	Evaluate and improve capacity of storm water infrastructure for high intensity rainfall events.
IBE-8.7	Increase maintenance and cleaning of gutters, drainages ditches and culverts
IBE-9	**COMMUNICATIONS INFRASTRUCTURE**
IBE-9.1	Identify key communications infrastructure (networks or points of production or distribution) that may be affected by climate change impacts
IBE-9.2	Map locations of communications infrastructure vulnerable to floods, storm surges, extreme thermal or precipitation events, wildfire, etc.
IBE-9.3	Identify construction materials and design weaknesses in communication infrastructure in the face of extreme events
IBE-9.4	Incorporate modifications to communications infrastructure to increase resiliency during routine maintenance and upgrades
IBE-9.5	Identify redundancies and re-routing potential in communication infrastructure for emergency switching should primary systems fail
IBE-9.6	Adequately insure communications infrastructure to ensure that reconstruction can occur in the event of a climate related disaster
IBE-10	**ENERGY INFRASTRUCTURE**
IBE-10.1	Identify key energy infrastructure (networks, pipelines, power lines or points of production or distribution) that may be affected by climate change impacts
IBE-10.2	Map locations of energy infrastructure vulnerable to floods, storm surges, extreme thermal or precipitation events, wildfire, etc.
IBE-10.3	Identify construction materials and design weaknesses in energy infrastructure in the face of extreme events
IBE-10.4	Incorporate modifications to energy infrastructure to increase resiliency during routine maintenance and upgrades
IBE-10.5	Identify redundancies and re-routing potential in energy infrastructure for emergency switching should primary systems go down
IBE-10.6	Adequately insure energy infrastructure to ensure that reconstruction can occur in the event of a climate related disaster

Option No.	Adaptation Policy Option
NS-1	**OVERARCHING NATURAL SYSTEMS CONCERNS**
NS-1.1	Map vulnerability of full spectrum of biodiversity (terrestrial, aquatic and marine)
NS-1.2	Map vulnerability of areas subject to desertification and erosion under different climate scenarios
NS-1.3	Consolidate and cross-reference ecological monitoring networks
NS-1.4	Develop a system of biological indicators for impact assessment
NS-1.5	Assess the vulnerability of special designation areas, areas of unique flora and fauna and areas of essential ecosystem goods and services
NS-1.6	Develop climate change scenarios with an emphasis on the effect on and response of natural systems
NS-1.7	Develop a monitoring system to assess high elevation reactions to climate change
NS-1.8	Develop a monitoring system to assess land degradation, desertification, erosion and soil carbon levels
NS-1.9	Develop maps of ecosystem interconnectivity to understand climate effects on species and ecosystems and plan for population migrations
NS-1.10	Ensure sustainable land practices are implemented in all sectors
NS-1.11	Improve mapping and characterization of likely storm and precipitation impacts to watersheds and riverine flood zones.
NS-2	**CONSERVATION OF NATURAL LANDS AND MARINE SYSTEMS**
NS-2.1	Complete a vulnerability assessment to identify specific species, habitats, landscapes, ecosystem functions, and cultural resources that may be most sensitive to climate change.
NS-2.2	Assess implications of climate impacts for state-managed natural resources
NS-2.3	Evaluate the effectiveness of current conservation regulations and strategies in the face of climate change vulnerabilities
NS-2.4	Assess economic value of environmental services to develop accurate cost/benefit analyses
NS-2.5	Coordinate federal public land management objectives with states to improve ecosystem resiliency
NS-2.6	Create programs and incentives to encourage the consolidation or cooperative management of natural resources (e.g., water, forests, fish and wildlife).
NS-2.7	Integrate statewide conservation priorities with climate impact data
NS-2.8	Implement 'Incremental Adaptive Management' (IAM)
NS-2.9	Develop and implement an environmental scorecard that would track ecosystem change
NS-2.10	Institutionalize ready access to best available science from regional to site-specific scales, relating science to climate change impacts on stream hydrology and aquatic resources
NS-2.11	Develop a clearinghouse for scientifically credible field-level best practices to address natural system responses to climate change.
NS-2.12	Evaluate land acquisition for adaptation purposes, (considering sea level rise, increase in frequency of severe storms, wildfire threat, loss of wildlife and fisheries habitat, etc.)
NS-2.13	Protect and restore coastal landforms (coral reefs, barrier islands) and wetland ecosystems (mangroves, marshes) which provide a natural first line of protection from storm surges and flooding
NS-2.14	Increase planning and implementation of erosion prevention and hazard mitigation
NS-2.15	Develop new state-level standards for terrestrial non-point source pollution
NS-2.16	Integrated ecological monitoring to identify anthropogenic changes to oceans and waterways, including shifts in currents, and pH changes.

Option No.	Adaptation Policy Option
NS-3	**CONSERVATION OF WILDLIFE AND FISH**
NS-3.1	Adapt Land Use planning to allow species and habitat migration (e.g. 'Adaptive Corridors' concept)
NS-3.2	Assess climate impact including sea level rise, drought, etc. on habitat for terrestrial species in early life stages
NS-3.3	Conduct an assessment of the effects of climate change on threatened and endangered species
NS-3.4	Provide for adaptive management of fish and wildlife
NS-3.5	Develop guidelines to address climate impacts through habitat restoration and protection projects, and direct state and local governments to use them.
NS-3.6	Organization of marine biosphere reserves and protected areas for the habitat of marine mammals
NS-3.7	Develop strategies to respond to potential increases in undesirable exotic and invasive species.
NS-3.8	Place the highest priority for permitting estuarine shoreline stabilization on techniques that protect fisheries habitat.
NS-4	**FOREST ECOSYSTEMS**
NS-4.1	Compile and evaluate existing research on the effects of a warmer and/or dryer climate on forest ecosystems and commercially grown tree species and potential impacts on the forest products and tree industries
NS-4.2	Develop a better understanding of likely impacts on tree species, evaluate strategies and begin to implement risk management strategies to ensure perpetuation of tree genetic resources
NS-4.3	Develop a system of climate change indicators for forests and implement an early warning system for major forest disruptions
NS-4.4	Adapt forest conservation, management and forest products industries to severe storms and drought, invasive species and pests and other climate changes impacts
NS-4.5	Identify and maintain protected forest areas that may be capable of sustaining at-risk species
NS-4.6	Promote reforestation and afforestation of marginal lands to increase soil moisture retention, provide shade and increase habitat for species under stress
NS-4.7	Assess potential new pest problems and their impact to forest resources, plants and animals
NS-4.8	Research alternative methods for addressing new pests through improved management techniques.
NS-4.9	Create scientific advisory committees to assist decision-makers in responding to extreme forest health and fire hazard problems.
NS-4.10	Assess threat of increased wildfires
NS-4.11	Collaborate across multiple jurisdictions, landowners, and stakeholders to promote agreement on forest health and fire hazard response approaches.
NS-4.12	Evaluate the carbon balance and methods of maximizing soil and plant carbon sequestration
NS-4.13	Evaluate above and below-ground biomass by ecosystem type to determine carbon carrying capacity
NS-5	**FISHERIES AND MARINE RESOURCES**
NS-5.1	Assess the effectiveness of current marine conservation strategies in the face of climate change
NS-5.2	Conduct research and integrated management of fisheries within coastal and open marine ecosystems
NS-5.3	Predict marine life viability and biodiversity trends under various climate scenarios

Option No.	Adaptation Policy Option
NS-5.4	Organize of marine biosphere reserves and protected areas to provide habitat of marine mammals
NS-5.5	Research, measure and monitor climate effects on coral reefs. Develop higher resilience through management of human activities
NS-5.6	Use emerging predictive information related to natural climate variability (e.g., ENSO) to support fishery management and planning.
NS-5.7	Assess climate impact including sea level rise, drought, etc. on habitat for fisheries in early life stages
NS-5.8	Incorporate climate change into fisheries management and assist fishing communities and users in adaptation
NS-5.9	Modify and improve of the technology of the fishing industry and management of the fish trade
NS-5.10	Include in emergency preparedness plans to stock creeks with fish post-storm and flooding
NS-6	**HYDROLOGIC SYSTEMS**
NS-6.1	Implement integrated monitoring systems in productive marine and estuarine areas, aimed at obtaining systematic information on hydrological, hydrophysical, hydrochemical and hydrobiological processes
NS-6.2	Develop complete climate-hydrology models to create reliable scenarios of all aspects of the hydrological cycle, including extreme events
NS-6.3	Assess adequacy of current natural water management options and conservation strategies
NS-6.4	Support healthy rivers, streams and riparian vegetation to maintain water quality
NS-6.5	Increase environmental quality standards to enhance resilience of natural water systems
NS-6.6	Establish river stream gauging network to monitor long- and short-term trends in flow in order to improve resource allocation and emergency response preparedness.
NS-6.7	Improve and protect in-stream flows for environmental and resources values
NS-6.8	State government shall develop mechanisms for compact calls for each major river basin
NS-6.9	Modify land topography to reduce runoff, improve water uptake, reduce erosion and sedimentation in streams
NS-6.10	Assess climate change impacts on mountain ranges, glaciers and snowpacks as the source of fresh water.
NS-6.11	Increase wetland protection and restoration
NS-6.12	Remove invasive non-native vegetation from riparian areas
NS-6.13	Improve flood plain mapping given increasing frequency of major flood events
NS-6.14	Curb floodplain and riparian area development and disturbance
NS-7	**COASTLINE AND BEACHES**
NS-7.1	Create integrated coastal zone management (ICZM) plans and support Coastal Zone Management program
NS-7.2	Develop morphodynamic and ecological response models of primary coastal zones according to different climate scenarios
NS-7.3	Inventory and map the estuarine and ocean shoreline and its bathymetry, sediments, and vegetation. Assess vulnerability.
NS-7.4	Establish a series of permanent monitoring stations to measure the absolute changes in sea level rise in coastal areas and characterize the dynamics of estuarine storm surges, astronomical and wide tides and water flow.
NS-7.5	Conduct coastal re-alignment planning including conversion of land to salt marsh and grassland to provide sustainable sea defenses (IPCC)
NS-7.6	Develop coastal resource action policies for adapting to more frequent severe storms, sea level rise, drought, erosion, and acute flooding events

Option No.	Adaptation Policy Option
NS-7.7	Conduct a shoreline impact assessment to establish baseline of data on the existing coastal resources and the projected impacts of sea level rise, include tides, weather
NS-7.8	Create a Coastal Adaptation Program
NS-7.9	Support ongoing collection and analysis of sea level rise, storm surge, and tidal data by existing institutions
NS-7.10	Create or update State Beach Nourishment Program
NS-7.11	Create or update Strategic Beach Management Plan with climate impacts
NS-7.12	Consider any possible legal issues associated with sand for beach nourishment
NS-7.13	Reforest coastal areas
NS-7.14	Evaluate abandonment and retreat strategies, or protection strategies under different scenarios of sea level rise.
NS-7.15	Improve mapping and characterization of sea level rise vulnerability for all coastal areas.
NS-7.16	Given sea level rise, assess potential loss of barrier islands, and property damage under a range of scenarios.
NS-7.17	Reduce loss of wetlands due to hardening of estuarine shoreline
NS-7.18	Reduce or eliminate ocean outfalls

Option No.	Adaptation Policy Option
HS-1	**IMPACTS TO HUMANS AND SOCIETY – OVERARCHING ISSUES**
HS-1.1	Assess comprehensive climate impacts on health, human welfare & safety
HS-1.2	Work with insurance industry in design of enhanced programs to increase individual security
HS-1.3	Evaluate community health impact and trends
HS-1.4	Develop a comprehensive plan to promote social and economic equity, reduce poverty, increase consumption efficiencies, decrease the discharges of wastes, environmental management, and increase the quality of life of vulnerable
HS-1.5	Identify health-related vulnerabilities of people, region, infrastructure and the economy
HS-1.6	Research the critical gaps in information needed by decision-makers regarding impacts of climate change on human health
HS-2	**CULTURAL AND SOCIAL VULNERABILITIES**
HS-2.1	Complete vulnerability assessments to identify cultural lifeways that may be disrupted or suffer as a result of climate change
HS-2.2	Complete a vulnerability assessment to identify specific cultural resources that may be most sensitive to climate change.
HS-2.3	Analyze and prepare for forced, subsidized migration within jurisdictional area and neighboring states
HS-2.4	Anticipate and prepare for potential climate-driven immigration from neighboring countries, especially along border states
HS-2.5	Provide funding for local communities to develop and implement location appropriate adaptation strategies
HS-3	**ECONOMICS AND ENVIRONMENTAL JUSTICE IMPACTS**
HS-3.1	Assess potential social impacts of climate change on incomes, and other measures of well-being in vulnerable communities
HS-3.2	Design assistance programs to respond to potential economic impacts, housing needs, dislocation and chronic deficiencies impacting health and quality of life in communities
HS-3.3	Establish “Climate Change Environmental and Economic Fairness Task Force” to ensure that no economic region or group bears a disproportionate share of the economic transition
HS-3.4	Address increased insurance costs, especially in disaster sensitive, remote and/or economically challenged areas
HS-3.5	Ensure equity and environmental justice to prevent disparate impacts to economically challenged sectors in Environmental Assessments and Environmental Impact Statements
HS-4	**HEALTH CONCERNS – The Built Environment**
HS-4.1	Adapt the built environment to reduce the impacts of climate change on human health
HS-4.2	Require consideration of human health aspects due to climate change in building guidelines and urban planning
HS-4.3	Increase urban vegetation- plant trees, roof gardens through planned growth and local ordinances protecting vegetation and open space.
HS-4.4	Enact planning laws that prevent new-construction in vulnerable zones
HS-4.5	Provide economic incentives for building in non-risk zones
HS-4.6	Adapt the built environment to make communities more walkable and pedestrian friendly, and ensure consideration of climate change planning
HS-5	**HEALTH CONCERNS – Extreme Events**
HS-5.1	Mitigate mortality and morbidity from extreme weather events through proactive planning and preparedness exercises involving all responsible parties
HS-5.2	Activate acclimatization programs to build resilience to thermal extremes

Option No.	Adaptation Policy Option
HS-5.3	Develop and publicize community shelters and response techniques to thermal extremes
HS-5.4	Implement educational programs on appropriate behavior prior to and following extreme events
HS-5.5	In the aftermath of extreme events, prepare for additional trauma due to dispossession, mental health challenges and post-traumatic stress disorder
HS-5.6	Develop a strategy for providing and communicating heat wave behavioral adaptations such as air conditioning availability and increased fluid intake.
HS-6	**HEALTH CONCERNS – Disease Prevention**
HS-6.1	Augment vector surveillance and control programs for vector borne diseases that are likely to become more common or widespread with climate change
HS-6.2	Increase collaboration between the departments of Health and Agriculture on zoonotic disease surveillance improvements
HS-6.3	Design programs to monitor for the appearance of vector- and waterborne diseases following floods and storms
HS-6.4	Develop syndromic surveillance program to identify outbreaks of waterborne diseases
HS-6.5	Enhance preparedness for disease prevention of vector-borne and water-borne diseases following floods and storms
HS-6.6	Increase overall efficiency and sensitivity of the current surveillance systems to monitor and respond to disease events
HS-6.7	Initiate vaccination campaigns
HS-7	**EDUCATION & OUTREACH**
HS-7.1	Provide educational outreach on sanitation in relation to water use, conservation and efficiency
HS-7.2	Provide outreach to the public and others to plan and prepare for climate change
HS-7.3	Provide education about the importance of vaccines and hygiene in the wake of disaster
HS-7.4	Engage public and private universities with private sector in research partnerships e.g. Centers of Excellence
HS-7.5	Link science to public health education effort
HS-7.6	Public education/prevention programs targeting most at-risk, vulnerable populations
HS-7.7	Implement educational programs for schools and the public on how to help control vector breeding sites
HS-8	**ACCESS TO HIGH QUALITY WATER, FOOD AND AIR**
HS-8.1	Assess food security for all sectors of society in the state/region
HS-8.2	Address increased water costs, especially in remote or economically challenged areas
HS-8.3	Safeguard freshwater supply against contamination, degradation and loss
HS-8.4	Identify methods and Incentives for storm water collection and re-use by industry and households
HS-8.5	Establish water conservation, reclamation, recycling, and reuse goals and an accountability system to ensure goals are met
HS-8.6	Strengthen regulations governing water quality, e.g., agricultural run-off, industrial waste water, site development, etc.
HS-8.7	Strengthen and enforce watershed contamination protection laws
HS-8.8	Determine air quality strategies necessary to compensate for increased emissions associated with increasing temperatures.
HS-8.9	Support local sustainable agriculture to improve food security
HS-9	**EMERGENCY PREPAREDNESS AND RESPONSE**
HS-9.1	Review the goals, strategies and plans of emergency preparedness, response and recovery under conditions induced by climate-related disruptions such as heat/cold waves, migrating disease vectors, flooding and storm surges

Option No.	Adaptation Policy Option
HS-9.2	Review or create emergency management planning requirements and guidelines for heat waves and emergency preparedness exercises
HS-9.3	Develop or strengthen joint protocols for multi-jurisdictional response to a broad spectrum of climate-related emergencies and disasters
HS-9.4	Re-evaluate evacuation routes to ensure safety, capacity and resilience to damage or loss
HS-9.5	Include sea level rise data in hurricane preparedness, evacuation and recovery plans
HS-9.6	Establish communication mechanism to coordinate efforts between disaster relief and public health agencies.
HS-9.7	Develop early warning systems for extreme weather coupled with adequate response plan
HS-9.8	Improve cooperative efforts among agencies at all levels to assure needed redundancy in disaster/severe weather situations

Option No.	Adaptation Policy Option
EA-1	**ECONOMIC DEVELOPMENT: ASSESSMENT & PLANNING**
EA-1.1	Establish leadership in climate adaptation technology and career fields: engineering and design services, climate-sensitive infrastructure systems, ecosystem and beach management, economic security and services related to human health and safety.
EA-1.2	Initiate an economic development strategy focused on the goods and services that will be required to implement climate adaptation
EA-1.3	Fully account for environmental values using ecological economics to ensure accurate evaluation of proposals on resources vital to climate change resilience and adaptation
EA-1.4	Assess potential disruption to states major economic sectors due to climate change
EA-1.5	Identify methods and programs to adapt state economy to region-specific disasters (e.g. hurricane, flood, sea level rise, etc.)
EA-1.6	Improve flood warning and information dissemination
EA-1.7	Market state research agenda and products to provide essential knowledge and attracts funding
EA-1.8	Assess full value of beach services including habitat, tourism, storm buffer, etc
EA-1.9	Assess impacts of changes in hydrologic cycle to heavily water dependent industries and businesses.
EA-2	**ECONOMIC DEVELOPMENT: LABOR**
EA2.1	Pursue business and job opportunities in emerging green sectors where the state has a comparative advantage, e.g. solar, wind, geothermal
EA2.2	Education and job training programs to re-tool workforce to take advantage of green economy growth
EA2.3	Analyze long and short term jobs trends to identify which sectors/occupations will be positively/negatively impacted, with an emphasis on job creation opportunities
EA-3	**ECONOMIC DEVELOPMENT: BUSINESS & INDUSTRY**
EA-3.1	Support economic remediation/transition programs for most-affected industries
EA-3.2	Engage the private sector as a partner through market and investment opportunities.
EA-3.3	Encourage private insurers, as investors, and the state pension funds to consider climate impact prevention in the prudent investment of portfolios.
EA-3.4	Create incentives for private investment in creating ‘climate safe’ development
EA-3.5	Adapting state industries to more frequent severe weather events and disruption of once predictable patterns
EA-3.6	Identify methods and programs to support adaptation of state resource-based industries to more frequent extreme weather events and service disruptions
EA-3.7	Identify and engage representatives of key business areas potentially vulnerable to specific climate change effects
EA-3.8	Identify opportunities for businesses to take advantage of climate impacts that may demand new products and services
EA-4	**AGRICULTURE: RESEARCH & ASSESSMENTS**
EA-4.1	Assess climate impacts of sea level rise, severe storms and drought, salt water intrusion, invasive species and pests on state’s agriculture sector
EA-4.2	Conduct research as needed to identify the potential effects of a warmer climate on the agricultural industry
EA-4.3	Compile and evaluate existing research on the effects of a warmer climate on crop species to assess potential effects of a warmer climate on the agricultural industry
EA-4.4	Prepare an atlas of the agroclimate areas as they change under different climate change scenarios
EA-4.5	Develop simulation models of different primary crops and continued economic viability under different regional climate scenarios

Option No.	Adaptation Policy Option
EA-4.6	Conduct research to develop new crop varieties
EA-4.7	Develop policies concerning controversial agribusiness issues in the face of potential and direct consequences of climate change
EA-4.8	Identify cost-effective short-, mid- and long-term agricultural adaptative strategies for key crops
EA-4.9	Develop behavior simulation models of pathogen agents under different climate conditions.
EA-4.10	Develop a risk map for the most persistent and impactive pests and disease
EA-4.11	Assess potential new pest problems and their impact to agricultural production.
EA-4.12	Research alternative methods for addressing new agricultural pests and invasive species through improved management techniques
EA-4.13	Sponsor gene manipulation work to adapt existing crops
EA-4.14	Create adaptation plans in areas where water supply may become inadequate for farming
EA-5	**AGRICULTURAL PRACTICES**
EA-5.1	Change farming practices to conserve soil moisture and nutrients, reduce runoff and control soil erosion
EA-5.2	Evaluate the effects of climate change on pasture and rangelands; identify management strategies to aid in adaptation (rotation, stocking levels, restoration, grazing systems, alternative or mixed livestock, etc.)
EA-5.3	Ensure farmers, especially in remote, rural locations have access to most up-to-date weather forecasts
EA-5.4	Increase adoption of new technologies and best management practices
EA-5.5	Identify alternate crops that respond well to hotter and/or dryer temperatures
EA-5.6	Consider growing in controlled environments and conditions
EA-5.7	Modify land use and agricultural practices including aquaculture, saline-resistant crops, depending on location and purpose
EA-5.8	Identify specific techniques, and tools to distribute the information, to allow adaptation of agricultural industries to severe storms and drought, invasive species and pests and other climate change related impacts
EA-5.9	Improve adoption of risk management and business management skills by farmers and ranchers,
EA-5.10	Change farming practices to conserve soil moisture and nutrients, reduce runoff and control soil erosion
EA-5.11	Modify land topography to reduce runoff, improve water uptake and reduce wind erosion
EA-5.12	Reduce water demand for irrigation by changing the cropping calendar, crop mix, irrigation method, and area planted
EA-5.13	Subdivide large fields, improve runoff channels in large fields
EA-5.14	Curb agricultural development in floodplains
EA-5.15	Reduce ground water for irrigation until recharges match discharges
EA-5.16	Promote alternatives to chemical use which could contaminate water
EA-5.17	Investigate and invest in the development of large scale and small-scale water storage for irrigation.
EA-5.18	Increase flood protection, e.g., levees, reservoirs, on key agricultural areas
EA-5.19	Create incentives and programs to transfer knowledge and technologies to assist farmers with new production methods, drought tolerant species, etc.
EA-5.20	Minimize effects of water-rights transfers on agricultural economies.
EA-5.21	Target farmers in early warning systems for extreme events
EA-6	**FORESTRY**

Option No.	Adaptation Policy Option
EA-6.1	Compile and evaluate **existing research** on the effects of a warmer and/or dryer climate on forest ecosystems and commercially grown tree species and potential impacts on the forest products and tree industries.
EA-6.2	Conduct **additional research** to identify the potential effects of a warmer and/or dryer climate on forest ecosystems and potential impacts on the forest products and tree industries.
EA-6.3	Develop and apply forest growth models under different climate change scenarios.
EA-6.4	Assess impact of warmer climate and disrupted weather patterns on the types of tree species that can be grown economically.
EA-6.5	Assess alternate forest cropping systems to maintain productivity of existing species and add diverse forest products to the marketplace.
EA-6.6	Search for alternate economic ventures to replace the impacted industry and/or planting other tree species that do well in hotter climates.
EA-6.7	Assess gene manipulation work to adapt existing tree species to warmer/drier climate and/or abrupt changes in weather patterns and/or new pests thriving in changed climatic conditions
EA-6.8	Increase flood protection (e.g., levees, reservoirs) for key forest production sites
EA-6.9	Assess potential new pest problems and their impact to forest production.
EA-6.10	Research alternative methods for addressing new forest pests and invasive species through improved management techniques and/or biological controls
EA-7	**MARINE RESOURCES & INDUSTRIES**
EA-7.1	Conduct research and integrated management of fisheries within coastal and open marine ecosystems in response to climate change
EA-7.2	Integrate ecological monitoring to identify anthropogenic changes, including climate change, and to predict fish productivity
EA-7.3	Evaluate the effects of climate change on invasive marine species, on marine commercial species and on the carrying capacity of ecosystems for marine farming.
EA-7.4	Organize marine biosphere reserves and protected areas for the habitat of marine mammals to maintain critical breeding grounds.
EA-7.5	Use emerging predictive information related to natural climate variability (e.g., El Nino Southern Oscillation) to support fishery management and planning.
EA-7.6	Modify and improve the technology of the fishing industry and management of the fish trade
EA-8	**TOURISM AND RECREATION**
EA-8.1	Conduct a climate change impact assessment by tourist region and resources, with a focus on most vulnerable sectors and locations
EA-8.2	Assist the tourism industry to build resilience and capacity to adapt to the challenges and opportunities of climate change
EA-8.3	Assess effects of impacts of climate change on cultural resources and lifeways and the resulting effect on tourism
EA-8.4	Develop tourism policies integrating economic and resource conservation issues in the face of potential and observed consequences of climate change
EA-8.5	State government consider ways to reduce climate change effects on water-related recreation and tourism
EA-8.6	Ensure accurate information reaches current and potential tourists on behaviors and uses that ensure environmental quality and ecosystem resiliency at popular travel destinations
EA-8.7	Implement aggressive water conservation, energy conservation and efficiency and recycling/waste management at popular travel destinations
EA-8.8	Assess the effects of climate change on hunting and fishing opportunities and the related tourism industry

Option No.	Adaptation Policy Option
EA-8.9	Assess the effects of climate change on special designated natural areas that attract tourists such national parks and forests
EA-8.10	Assure that all state programs involved in acquisition of, or access to and use of, public lands include climate change adaptation in planning and decision making
EA-8.11	Organize marine biosphere reserves and protected areas for the habitat of marine mammals to enhance tourism industry

Option No.	Adaptation Policy Option
CC-1	**SCIENCE & RESEARCH**
CC-1.1	Monitor climate change, climate change impacts, adaptation and develop related indices to accurately capture trends
CC-1.2	Integrate current systems for environmental monitoring that support climate change adaptation activities and address monitoring gaps
CC-1.3	Foster and support a climate science research agenda to assess short, medium and long term climate change impacts.
CC-1.4	Undertake specific analyses of uncertainties and contingencies in climate scenarios
CC-1.5	
CC-1.6	Establish a state climate change data bank and network, with explicit and transparent protocols for access and use of the data
CC-1.7	Establish new Climate Change Scientific Advisory Council to advise state
CC-1.8	Build decision support structure to guide state-specific research agenda
CC-1.9	Collaborate with adjacent states for applied research and technical assistance in climate change adaptation
CC-1.10	
CC-1.11	Identify thresholds where key natural systems are at risk of disruption
CC-1.12	Evaluate effectiveness of adaptation strategies at regular intervals
CC-1.13	Establish and identify long term funding to support research
CC-1.14	Develop rapid technology transfer mechanisms to facilitate the use of modeling information in plans and prioritization.
CC-1.15	
CC-2	**PLANNING AND DECISION-MAKING**
CC-2.1	Develop climate change scenarios that will aid in identifying vulnerabilities, risks and potential proactive solutions
CC-2.2	Incorporate best available climate change data and information into local government planning to promote resiliency of ecological systems and communities.
CC-2.3	Establish Water & Climate Change Task Force
CC-2.4	Establish interregional planning based on hydrologic systems rather than administrative boundaries
CC-2.5	Ensure existing regulations for energy, zoning, building codes, transportation and drainage are conducive to adaptation strategies and needs
CC-2.6	
CC-2.7	
CC-2.8	Engaging and coordinating scientists, policymakers, the media and the public in decision-making processes
CC-2.9	Engage business and industry leaders to address challenges and develop integrated solutions
CC-2.10	Establish timelines for implementation of key adaptation strategies
CC-2.11	Set goals for implementing and accomplishing adaptive strategies
CC-2.12	Establish and utilize a policy framework at the federal, state and local level that recognizes the inter connected nature of climate adaptation impacts, effects, research and planning needs
CC-2.13	Cooperatively, across sectors, develop information on climate change effects in each major river basin.
CC-2.14	Encourage the development of climate risk assessment and management in all sectors
CC-2.15	Assess knowledge, data and data systems that increase understanding of climate change effects on a wide-range of critical resources, such as water, food and energy
CC-2.16	Map relationships between energy and water use and apply that knowledge in decision-making
CC-2.17	Establish information exchanges on effects of climate change on critical resources
CC-2.18	Integrate Adaptation strategies into greenhouse gas mitigation plans and hazard mitigation plans

Option No.	Adaptation Policy Option
CC-2.19	Monitor Adaptation Plans, including establishing indicators and baselines to assess progress and apply adaptive management and revisions as necessary
CC-2.20	Identify a group of "leading indicators" and the state's position along those gradients of change where known.
CC-2.21	Develop and disseminate tools that will allow local and regional planning authorities to initiate and implement their own adaptation planning processes
CC-3	**INSURANCE**
CC-3.1	Develop and use specific vulnerability models for the insurance sector to evaluate effects of extreme climate events on infrastructure, crops and residences
CC-3.2	Incentivize property owners to adopt climate protective practices
CC-3.3	Review citizen's insurance guidelines and performance accountability in the light of climate change predictions.
CC-3.4	Require sellers of coastal properties to disclose potential hazards to buyers.
CC-3.5	Develop and use insurance policies to drive and support retreat activities
CC-3.6	Review casualty and property insurance requirements to ensure equitable and effective response to climate-related impacts
CC-3.7	Insure essential infrastructure to allow reconstruction in case of damage from extreme events related to climate change
CC-4	**STATE FUNDING AND FINANCING**
CC-4.1	Seek federal funds for climate costs
CC-4.2	Establish a consortium of state universities to undertake continuous economic analysis to develop the costs and benefits of different aspects of climate adaptation
CC-4.3	Establish a Climate Change Trust Fund with dedicated revenue sources and bonding authority
CC-4.4	Explore potential of insurance industry to contribute to funding as beneficiaries of reduced risk
CC-4.5	Explore potential of state pension funds investment in climate change adaptation
CC-4.6	Prepare strategy for utilizing cap and trade revenues
CC-4.7	Encourage private insurers to invest in climate science as a 'present value of avoided future costs' strategy.
CC-4.8	Establish a dedicated State Preparedness Infrastructure Fund
CC-4.9	Ensure publicly funded projects maximize energy efficiency and water conservation opportunities and do not exacerbate climate change adaptation
CC-4.10	Review public funding criteria for climate risk
CC-4.11	Establish short-, mid- and long-term budgets that include adaptation strategies and capital investments over time
CC-5	**ORGANIZING STATE GOVERNMENT FOR LONG-TERM ADAPTATION**
CC-5.1	Build understanding and adaptive capacity through integration of vulnerability assessments in other planning efforts
CC-5.2	Improve regional climate change information and decision-making tools including practical guides
CC-5.3	Create a center for climate change adaptation
CC-5.4	Establish the role of "Climate Change Officer," in the state CFO function to enable the office to review local government decisions that have climate aspects
CC-5.5	Build institutional capacity and knowledge to address impacts associated with climate change.
CC-5.6	Establish an ongoing state-level decision making mechanism for climate adaptation
CC-5.7	Establish a state climate change data bank and network, with explicit and transparent protocols for access and use of the data
CC-5.8	Encourage all local governments to develop and adopt climate adaptation strategies
CC-5.9	Prepare to transition from adaptation to sustainable development and practices over the long term

Option No.	Adaptation Policy Option
CC-5.10	Improve coordination of regulatory requirements to remove unneeded barriers to preparation and adaptation.
CC-5.11	Foster regulatory approaches that utilize multi-agency and public/private collaboration to address climate change adaptation issues
CC-5.12	Integrate carbon impact assessments of all major state expenditures from procurement, and state facilities, to state- funded infrastructure projects to avoid contributing additional greenhouse gasses
CC-6	**COORDINATION WITH OTHER STATES AND FEDERAL GOVERNMENT**
CC-6.1	Partner with adjacent states in ecosystem restoration projects
CC-6.2	Encourage establishment of a National Catastrophe Fund
CC-6.3	Encourage a humane and compassionate national policy that addresses effectively the possibility of climate impact refugees, particularly from neighboring nations
CC-6.4	Anticipate and prepare to effectively engage in emerging national systems or agreements e.g. cap and trade systems with revenues directed towards adaptation
CC-6.5	Monitor and take positions in state's interest on federal climate legislation
CC-6.6	Convey state's adaptation interests and concerns to the state's congressional delegation
CC-7	**PUBLIC EDUCATION AND OUTREACH**
CC-7.1	Develop public education programs on climate adaptation
CC-7.2	Create adaptation training opportunities for technical and professionals across all sectors
CC-7.3	Outreach to the public and others to plan and prepare for climate change using effective examples and applicable solutions for specific problems
CC-7.4	Engage business and industry leaders to address challenges
CC-7.5	Prepare public education materials to increase awareness of species disturbance and lost habitat.
CC-7.6	Inform property purchasers and investors regarding risk of sea level rise that may affect coastal property.
CC-7.7	Provide comprehensive data and information to landowners, policy-makers, and the public about existing and developing forest health and fire hazard conditions.
CC-7.8	Promote climate change science trough K-12 education
CC-7.9	Institute on-going climate change information and education opportunities to educate state policymakers
CC-8	**EXTREME EVENTS: PREPAREDNESS AND RESPONSE**
CC-8.1	Appropriate statewide drought management strategies that account for evolving drought risks in a drier climate.
CC-8.2	Fund accounts for drought preparedness and emergency water supply
CC-8.3	Comprehensive review of drought policies
CC-8.4	Develop regionally consistent zoning and coordinated emergency response plans

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