26. Decision Support: Connecting Science, Risk Perception, and Decisions

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Key Messages

1. **Decisions about how to address climate change can be complex and responses will require a combination of adaptation and mitigation actions. Decision-makers – whether individuals, public officials, or others – may need help integrating scientific information into adaptation and mitigation decisions.**
2. **To be effective, decision support processes need to take account of the values and goals of the key stakeholders, evolving scientific information, and the perceptions of risk.**
3. **Many decision support processes and tools are available. They can enable decision-makers to identify and assess response options, apply complex and uncertain information, clarify trade-offs, strengthen transparency, and generate information on the costs and benefits of different choices.**
4. **Ongoing assessment processes should incorporate evaluation of decision support tools, their accessibility to decision-makers, and their application in decision processes in different sectors and regions.**
5. **Steps to improve collaborative decision processes include developing new decision support tools and building human capacity to bridge science and decision-making.**

Introduction

After a long period of relative stability in the climate system, climate conditions are changing and are projected to continue to change (Ch. 2: Our Changing Climate). As a result, historically successful strategies for managing climate-sensitive resources and infrastructure will become less effective over time. Although decision-makers routinely make complex decisions under uncertain conditions, decision-making in the context of climate change can be especially challenging due to a number of factors. These include the rapid pace of changes in some physical and human systems, long time lags between human activities and response of the climate system, the high economic and political stakes, the number and diversity of potentially affected stakeholders, the need to incorporate uncertain scientific information of varying confidence levels, and the values of stakeholders and decision-makers.[1,2,3] The social, economic, psychological, and political dimensions of these decisions underscore the need for ways to improve communication of scientific information and uncertainties and to help decision-makers assess risks and opportunities.

Extensive literature and practical experience offer means to help improve decision-making in the context of climate variability and change. Decision support literature includes topics such as decision-making frameworks, decision support tools, and decision support processes. These approaches can help evaluate the costs and benefits of alternative actions, communicate relative amounts of risk associated with different options, and consider the role of alternative institutions and governance structures. In particular, iterative decision processes that incorporate improving scientific information and learning though periodic reviews of decisions over time are helpful in the context of rapid changes in environmental conditions.[3,4] Some of the approaches described in this chapter can also help overcome barriers to the use of existing tools and improve communications among scientists, decision-makers, and the public.[5,6]

Box 26.1: Focus of this chapter

This chapter introduces decision-making frameworks that are useful for considering choices about climate change responses through the complementary strategies of adaptation and mitigation. It also includes numerous examples in which decision support tools are being employed in making adaptation and mitigation decisions. It focuses on the processes that promote sustained interaction between decision-makers and the scientific/technical community. This chapter reviews the state of knowledge and practice in the context of managing risk. Extensive literature makes clear that in many cases, decisions aided by the types of approaches described here prove more successful than unaided decisions.[3,7] Because of space limitations, the chapter describes some general classes of tools but does not assess specific decision support tools.

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What are the decisions and who are the decision-makers?

Decisions about climate change adaptation and mitigation are being made in many settings (Table 26.1). For example:

- The federal government is engaged in decisions that affect climate policy at the national and international level; makes regulatory decisions (for example, setting efficiency standards for vehicles); and makes decisions about infrastructure and technologies that may reduce risks associated with climate change for its own facilities and activities.

- State, tribal, and local governments are involved in setting policy about both emissions and adaptation activities in a variety of applications, including land use, renewable portfolio and energy efficiency standards, and investments in infrastructure and technologies that increase resilience to extreme weather events.
- Private-sector companies have initiated strategies to respond both to the risks to their investments and the business opportunities associated with preparing for a changing climate.
- Non-governmental organizations have been active in supporting decisions that integrate both adaptation and mitigation considerations, often in the context of promoting sustainability within economic sectors, communities, and ecosystems.
- Individuals make decisions on a daily basis that affect their contributions to greenhouse gas emissions, their preparedness for extreme events, and the health and welfare of their families.[8]

Many decisions involve decision-makers and stakeholders at multiple scales and in various sectors. Effective decision support must link and facilitate interactions across different decision networks.[9]

Table 26.1. Examples of decisions at different scales

Individuals ↓	A farmer decides whether to adopt no-till agricultural practices.
↓ Organizations	A private firm decides whether to invest in solar or wind energy.
↓ ↓	A city develops a plan to increase resiliency to coastal floods in light of projections for sea level rise.
Communities ↓ ↓	A government agency plans incentives for renewable energy to meet greenhouse gas reduction goals.
↓ National Governments ↓ ↓	A national government develops its positions for international climate negotiations, including what commitments the government should make with respect to reducing greenhouse gas emissions.
↓ International Institutions	A United Nations agency designs a long-term strategy to manage increased flows of refugees who are migrating in part due to desertification related to climate change.

What is decision support?

Decision support refers to "organized efforts to produce, disseminate, and facilitate the use of data and information" to improve decision-making.[3] It includes processes, decision support tools, and services. Some examples include methods for assessing trade-offs among options, scenarios of the future used for exploring the impacts of alternative decisions, vulnerability and impacts assessments, maps of projected climate impacts, and tools that help users locate, organize, and display data in new ways. Outcomes of effective decision support processes include building relationships and trust that can support longer-term problem-solving capacity between knowledge producers and users; providing information that users regard as credible, useful, and actionable; and enhancing the quality of decisions.[3] Decision support activities that facilitate well-structured decision processes can result in consensus about defining the problems to be addressed, objectives and options for consideration, criteria for evaluation, potential opportunities and consequences, and trade-offs (Figure 26.1).

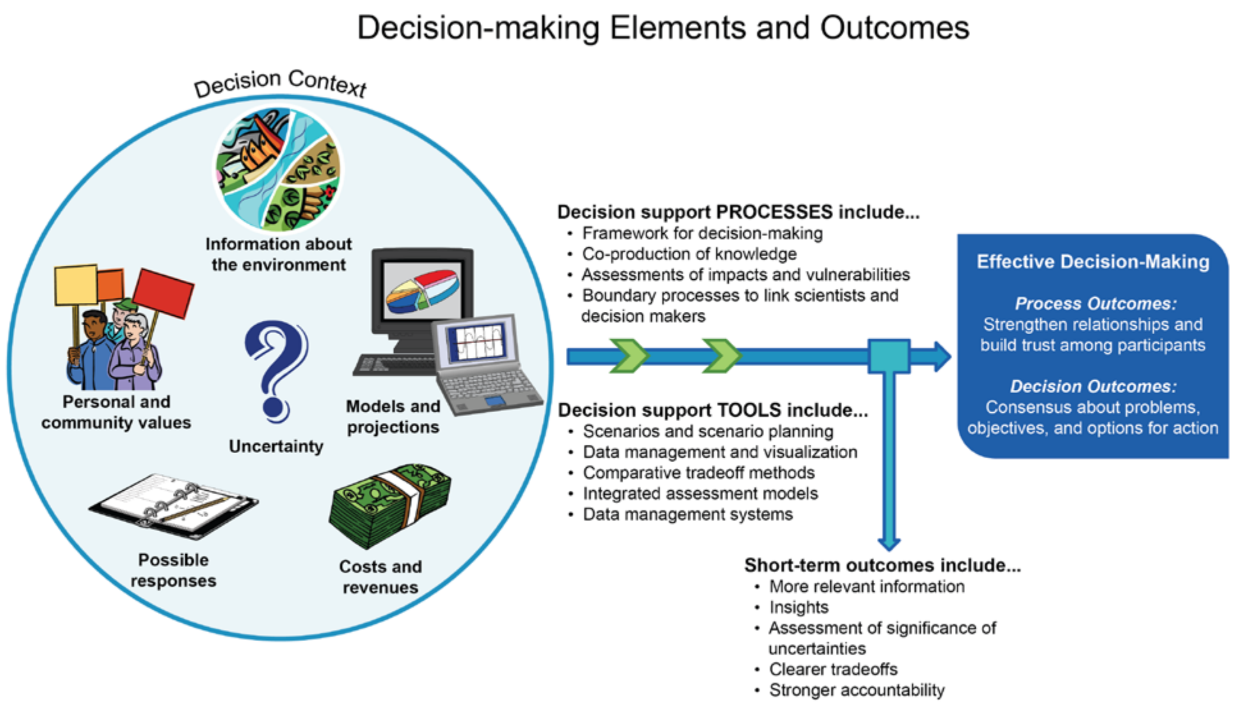

Figure 26.1: Decision-making Elements and Outcomes

Caption: Decisions take place within a complex context. Decision support processes and tools can help structure decision-making, organize and analyze information, and build consensus around options for action.

Boundary Processes: Collaboration among Decision-Makers, Scientists, and Stakeholders

Incorporating the implications of climate change in decision-making requires consideration of scientific insights as well as cultural and social considerations, such as the values of those affected and cultural and organizational characteristics. Chapter 28 (Adaptation) addresses how some of these factors might be addressed in the context of adaptation. The importance of both scientific information and societal considerations suggests the need for the public, technical experts, and decision-makers to engage in mutual shared learning and shared production of relevant knowledge.[3,10] A major challenge in these engagements is communicating scientific information about the risks and uncertainties of potential changes in climate.[11]

Efforts to facilitate interactions among technical experts and members of the public and decision-makers are often referred to as "boundary processes" (Figure 26.2). Boundary processes and associated tools include, for example, joint fact finding, structured decision-making, collaborative adaptive management, and computer-aided collaborative simulation, each of which engages scientists, stakeholders, and decision-makers in ongoing dialog about understanding the policy problem and identifying what information and analysis are necessary to evaluate decision options.[12,13,14] The use of these kinds of processes is increasing in decision settings involving complex scientific information and multiple – sometimes competing – societal values and goals. Well-designed boundary processes improve the match between the availability of scientific information and capacity to use it and result in scientific information that is perceived as useful and applicable.[6]

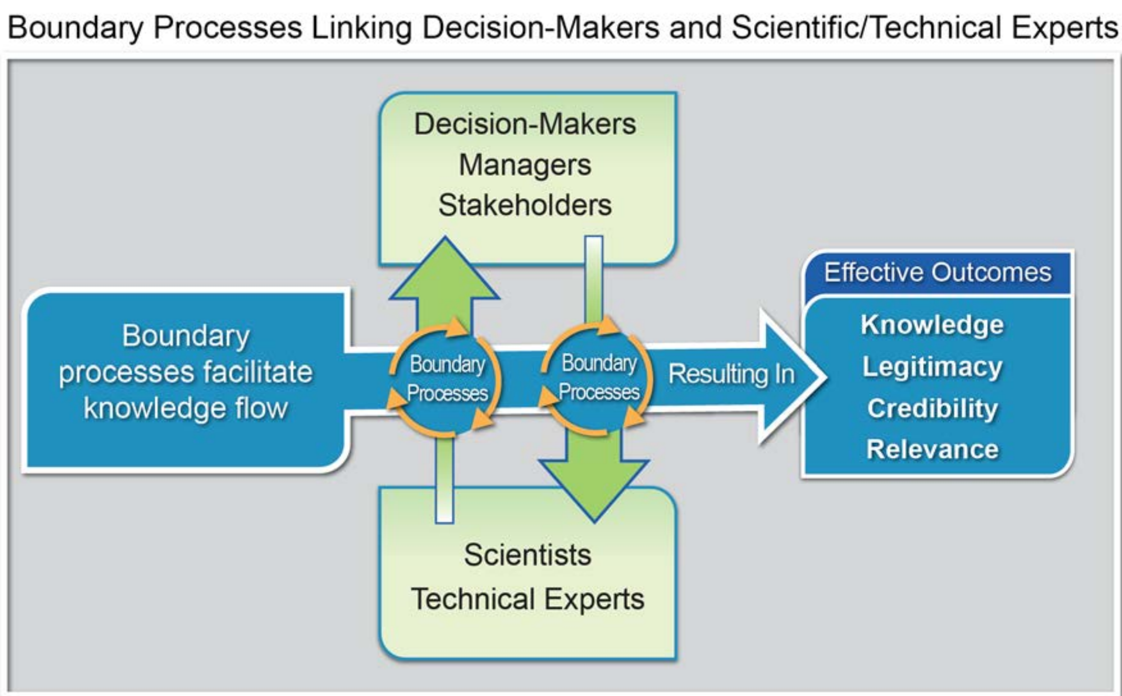

Figure 26.2: Boundary Processes Linking Decision-Makers and Scientific/Technical Experts

Caption: Boundary processes facilitate the flow of information and sharing of knowledge between decision-makers and scientists/technical experts. Processes that bring these groups together and help translate between different areas of expertise can provide substantial benefits.

Though boundary processes developed to support climate-related decisions vary in their design, they all involve bringing together scientists, decision-makers, and citizens to collaborate in the scoping, conduct, and employment of technical and scientific studies to improve decision-making. Boundary processes can involve establishing specialized institutions, sometimes referred to as boundary organizations, to provide a forum for interaction amongst scientists and decision-makers.[15] One such boundary activity is the National Oceanic and Atmospheric Administration's (NOAA) Regional Integrated Science and Assessment (RISA) Program. Interdisciplinary RISA teams are largely based at universities and engage regional, state, and local governments, non-governmental organizations, and private sector organizations to address issues of concern to decision-makers and planners at the regional level. RISA teams help to build bridges across the scientist, decision-maker, and stakeholder divide.[16] But effective engagement may also occur through less formal approaches by incorporating boundary processes that bring scientists, stakeholders, and decision-makers together within a specific decision-making setting rather than relying on an independent boundary organization. Sustained conversations among scientists, decision-makers, and stakeholders are often necessary to frame issues and identify, generate, and use relevant information.[17]

Some analysts have emphasized the importance of boundary processes that are collaborative and iterative.[18] In one example, federal, state, and local agencies, water users, and other stakeholders are using a collaborative process to manage the Platte River to meet species protection goals and the needs of other water users. The Platte River Recovery Implementation Program brings together participants on an ongoing basis to help set goals, choose management options, and generate information about the effectiveness of their actions.[19] Scientists engaged in the process do not make policy decisions, but they engage directly with participants to help them frame scientific questions relevant to management choices, understand available information, design monitoring systems to assess outcomes of management actions, and generate new knowledge tailored to addressing key decision-maker questions. The process has helped participants move beyond disagreements about the water-flow needs of the endangered species and move to action. Through monitoring, participants will evaluate whether the water flows and other management practices are achieving the goals for species recovery set out in the Platte River Recovery Implementation Plan.

In a number of other examples, boundary processes involve the use of computer simulation models.[14] Scientists, stakeholders, and decision-makers develop a shared understanding of the problem and potential solutions by jointly designing models that reflect their values, interests, and analytical needs. The U.S. Army Corps of Engineers has developed this type of boundary process in their "shared vision planning."[20] A comprehensive website provides a history of the process, demonstrations and case studies, and tools and techniques for implementing the process.[21]

Recently, the International Joint Commission used the shared vision planning process in decisions about how to regulate water levels in both the Lake Ontario – St. Lawrence River system[22] and in the Upper Great Lakes.[23,24] Both studies engaged hundreds of participants from the United States and Canada in discussions about water level management options and the impacts of those options on ecosystems; recreational boating and tourism; hydropower; commercial navigation; municipal, industrial, and domestic water use; and the coastal zone. The models used in the studies incorporated information about ecosystem responses, shoreline dynamics, economics, and lake hydrology, and the potential operating plans were tested using multiple climate change scenarios. Although the shared vision planning process did not ultimately lead to consensus on a single recommended plan in the Lake Ontario-St. Lawrence River Study, the process did help improve participants' understanding of the system and develop a shared vision of possible futures.[22,25] Building on lessons from the Lake Ontario-St. Lawrence River Study, the Upper Great Lakes Study's use of shared vision planning did result in a single recommended plan.[24]

Using a Decision-Making Framework

The term "adaptive management" is used here to refer to a specific approach in which decisions are adjusted over time to reflect new scientific information and decision-makers learn from experience. The National Research Council (NRC) contrasts the processes of "adaptive management" and "deliberation with analysis."[3] Both can be used as part of an "iterative adaptive risk management framework" that is useful for decisions about adaptation and ways to reduce future climate change, especially given uncertainties and ongoing advances in scientific understanding.[8,26] Iterative adaptive risk management emphasizes learning by doing and continued adaptation to improve outcomes. It is especially useful when the likelihood of potential outcomes is very uncertain.

An idealized iterative adaptive risk management process includes clearly defining the issue, establishing decision criteria, identifying and incorporating relevant information, evaluating options, and monitoring and revisiting effectiveness (Figure 26.3). The process can be used in situations of varying complexity, and while it can be more difficult for complex decisions,[27] the incorporation of an iterative approach makes it possible to adjust decisions as information improves. Iterative adaptive risk management can be undertaken through collaborative processes that facilitate incorporation of stakeholder values in goal-setting and review of decision options.[28] Examples of the process and decision support tools that are helpful at its different stages are included in subsequent sections of this chapter.

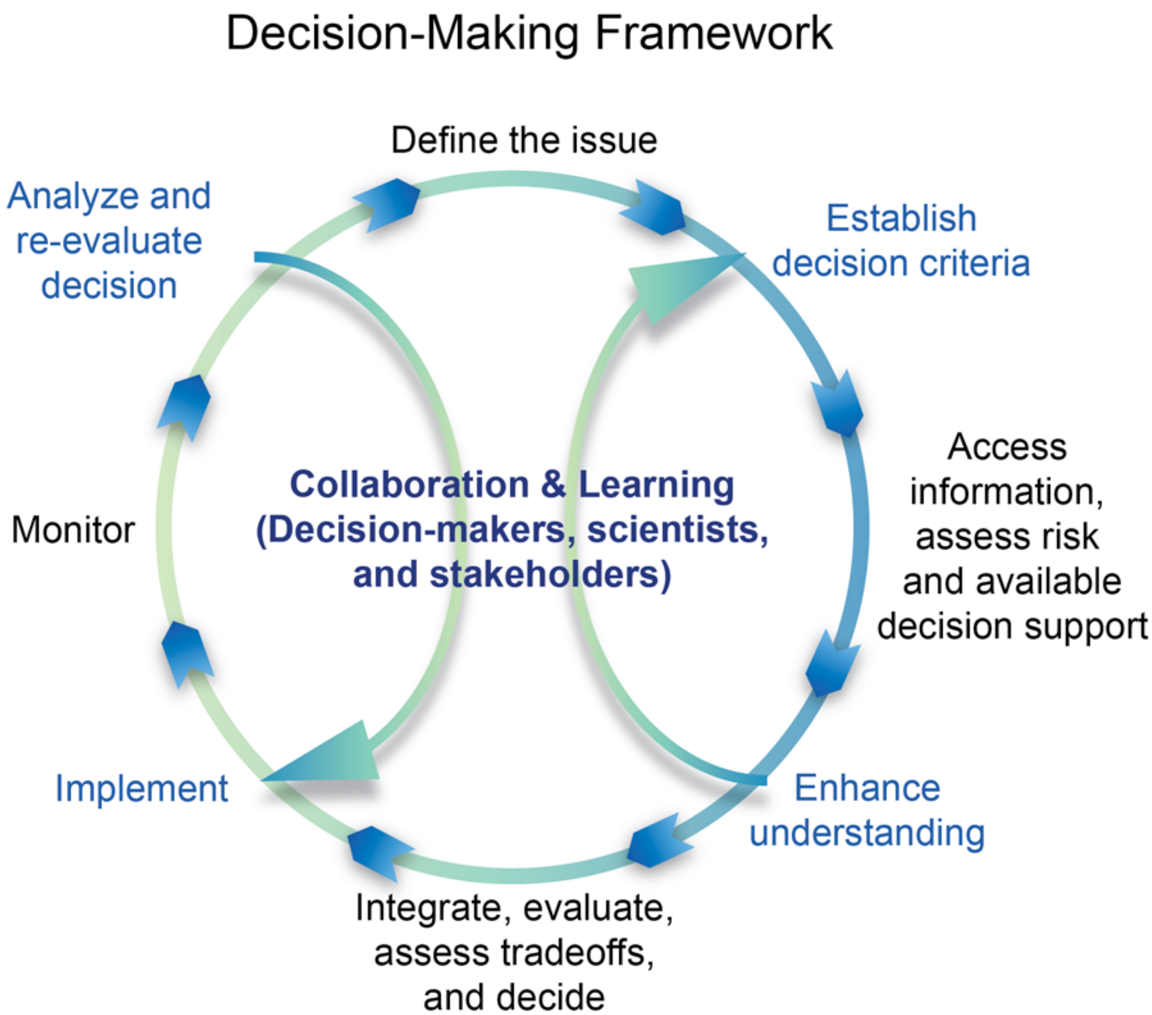

Figure 26.3: Decision-Making Framework

Caption: This illustration highlights several stages of a well-structured decision-making process. (Figure source: adapted from NRC 2010 and Willows and Connell 2003[8,26]).

Defining the Issue and Establishing Decision Criteria

An initial step in a well-structured decision process is to identify the context of the decision and factors that will affect choices – making sure that the questions are posed properly from scientific, decision-maker, and stakeholder (or public) perspectives (corresponding to the first two steps in Figure 26.3). An important challenge is identifying the stakeholders and how to engage them in decision-making processes. There are often many categories of stakeholders, including those directly and indirectly affected by or interested in the outcomes of decisions, as well as the decision-makers, scientists, and elected officials.[29] Other important considerations often overlooked but critical to defining the issue are:

- Understanding the goals and values of the participants in the decision process,
- Identifying risk perceptions and the sense of urgency of the parties involved in the decision,
- Being clear about the time frame of the decision (short- versus long-term options relative to current and future risk levels) – and when the decision must be reached,
- Acknowledging the scale and degree of controversy associated with the risks and opportunities as well as the alternatives,
- Assessing the distribution of benefits or losses associated with current conditions and the alternatives being considered,
- Reaching out to communities that will be affected but may lack ready access to the process (for example, considering environmental justice issues),
- Recognizing the diverse interests of the participants,
- Recognizing when neutral facilitators or trained science translators are needed to support the process, and
- Understanding legal or institutional constraints on options.

Identifying and agreeing on decision criteria – metrics that help participants judge the outcomes of different decision options – can be extremely helpful in clarifying the basis for reaching a decision. Based on the relevant objectives, decision criteria can be established that reflect constraints and values of decision-makers and affected parties. Criteria can be quantitative (for example, obtaining a particular rate of return on investment) or qualitative (for example, maintaining a community's character or culture). If the issue identified is to reduce the risks associated with climate change, decision criteria might include minimizing long-term costs and maximizing public safety. Related sections below provide information on tools for valuing and comparing options and outcomes and provide a basis for using decision criteria.

Decision framing and establishment of decision criteria can be facilitated using various methods, including brainstorming, community meetings, focus groups, surveys, and problem mapping;[3,29] selecting among techniques requires consideration of a number of context-specific issues.[30] There are a variety of techniques for organizing, weighting information, and making trade-offs for the goals that are important for a decision,[31,32] several of which are discussed in more detail in the section "Examples of Decision Support Tools and Methods."

Accessing Information

Developing a solid base of information to support decision-making is ideally a process of matching user needs with available information, including observations, models, and decision support tools. In some cases, needed information does not exist in the form useful to decision makers, thus requiring the capacity for synthesis of currently available information into new data products and formats. For decisions in the context of climate change and variability, it is critical to consult information that helps clarify the risks and opportunities to allow for appropriate planning and management. An example of information systems that synthesize data and products to support mitigation and adaptation decisions is the National Integrated Drought Information System (NIDIS), a federal, interagency effort to supply information about drought impacts and risks as well as decision support tools to allow sectors and communities to prepare for the effects of drought.[33] Learning from the successes of such efforts, the National Climate Assessment

(NCA) is currently developing an indicator system to track climate changes as well as physical, natural, and societal impacts, vulnerabilities, and responses.[34] This effort is building on existing indicator efforts, such as EPA's (Environmental Protection Agency) Climate Change Indicators,[35] NASA Vital Signs,[36] and NOAA indicator products,[37] as well as identifying when new data, information, and indicator products are needed.

Information technology systems and data analytics can harness vast data sources, facilitating collection, storage, access, analysis, visualization, and collaboration by scientists, analysts, and decision-makers. Such technologies allow for rapid scenario building and testing using many different variables, enhancing capacity to measure the physical impacts of climate change. These technologies are managing an increasing volume of data from satellite instruments, in situ (direct) measurement networks, and increasingly detailed and high-resolution models.[38] The box "Information technology supports adaptation decision making" highlights use of an open platform data system that facilitated collaboration across multiple public and private sector entities in analyzing climate risk and adaptation economics along the U.S. Gulf Coast.

While progress is being made in development of data management and information systems, multiple challenges remain. Specific issues highlighted in the recent USGCRP Global Change Research Plan include data permanence, volume, transparency, quality control, and access. For data on socioeconomic systems – important for evaluating vulnerabilities, adaptation and mitigation – privacy, confidentiality, and integration with broader systems of environmental data are important issues.[38] Experience with adaptation and mitigation decisions is often an excellent source of information and knowledge but is difficult to access and validate. Several organizations have been developing knowledge management systems for integrating this highly dispersed information and providing it to a network of practitioners (for example,[39]). Addressing these and other challenges is essential for making progress in establishing a sustained assessment process and meeting the challenge of informing decision making.[40]

Box 26.2: Information technology supports adaptation decision-making

Entergy (a regional electric utility), Swiss Re (a reinsurance company), and the Economics of Climate Adaptation Working Group (a partnership between several public and private organizations) integrated natural catastrophe weather models with economic data to develop damage estimates related to climate change adaptation.[41] An extension of this work is the first comprehensive analysis of climate risks and adaptation economics along the U.S. Gulf Coast.[42] Another example is a simplified model, developed with support from EPA, to look at flooding risks associated with coastal exposure in southern Maine.[43] Use of an "open platform" system that allows multiple users to input and access data resulted in spreadsheets, graphs, and three-dimensional imagery displayed on contour maps downscaled to the city and county level for local decision-makers to access.[44]

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Assessing, Perceiving, and Managing Risk

Making effective climate-related decisions requires balance among actions intended to manage, reduce, and transfer risk. Risks are threats to life, health and safety, the environment, economic well-being, and other things of value. Risks are often evaluated in terms of how likely they are to occur (probability) and the damages that would result if they did happen (consequences). As noted by the Intergovernmental Panel on Climate Change,[45] human choices affect the risks associated with climate variability and change. Such choices include how to manage our ecosystems and agriculture, where to live, and how to build resilient infrastructure. Choices regarding a portfolio of actions to address the risks associated with climate variability and change are most effective when they take into consideration the range of factors affecting human behavior, including people's perception of risk, the relative importance of those risks, and the socioeconomic context.[45,46] The process shown in Figure 26.4 is designed to help take such factors into consideration.

The next few sections describe the “integrate, evaluate, and decide” steps in Figure 26.3, which aim to help decision-makers choose *risk management* strategies. While a full quantitative risk analysis is not always possible, the concept of *risk assessment* coupled with understanding of *risk perception* provides a powerful framework for decision-makers to evaluate alternative options for managing the risks that they face today and in the future.[47] As described below, methods such as multiple criteria analysis, valuation of both risks and opportunities, and scenarios can help to combine experts’ assessment of climate change risks with public perception of these risks, both influenced by the diverse values people bring to these questions[48] and in support of risk management strategies more likely to achieve both public support and their desired objectives.[46] To illustrate how this framework can be applied to resource management decisions, we use an example of coastal risk management decisions in the context of climate change.[49]

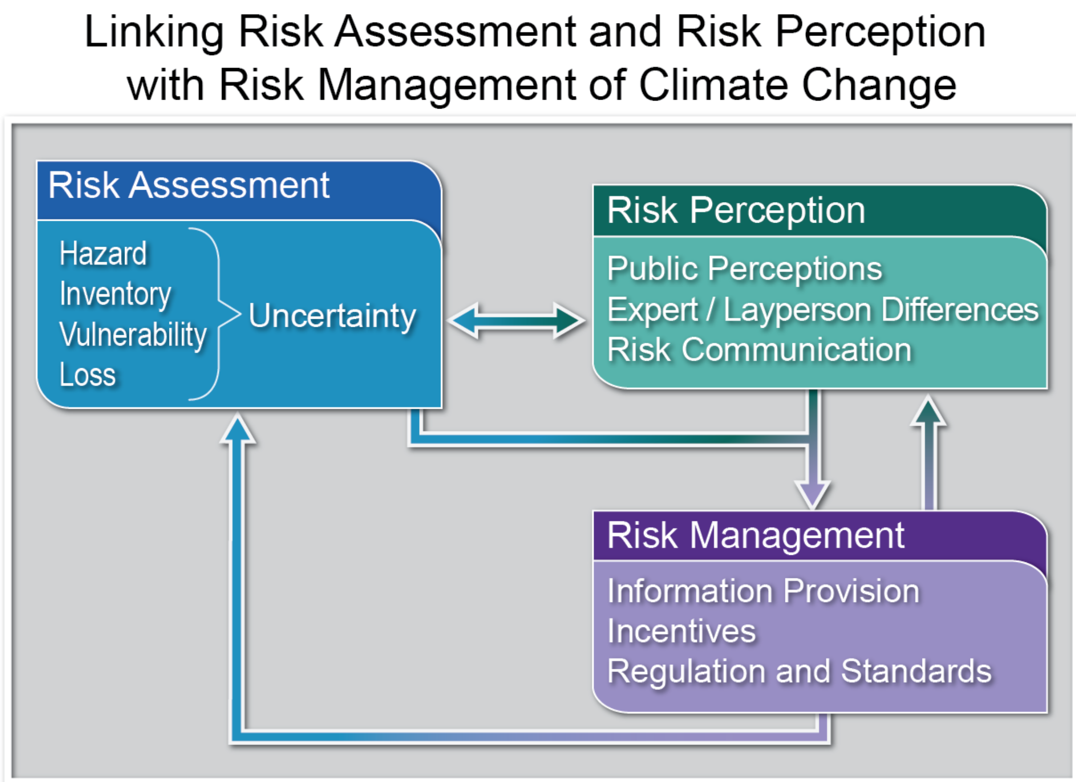

Figure 26.4: Linking Risk Assessment and Risk Perception with Risk Management of Climate Change

Caption: This figure highlights the importance of incorporating both experts' *assessment* of the climate change risk and general public *perceptions* of this risk in developing risk management strategies for reducing the negative impacts of climate change. As indicated by the arrows, how the public perceives risk should be considered when experts communicate data on the risks associated with climate change so the public refines its understanding of these risks. As the arrows indicate, the general public's views must also be considered in addition to experts' judgments when developing risk management strategies that achieve decision-makers' desired objectives. Climate change policies that are implemented will, in turn, affect both expert assessment and public perception of this risk in the future, as indicated by the feedback loop from risk management to these two boxes.

Risk Assessment

Risk assessment includes studies that estimate the likelihood of specific sets of events occurring and/or their potential consequences.[50] Experts often provide quantitative information regarding the nature of the climate change risk and the degree of uncertainty surrounding their estimates. Risk assessment focuses on the likelihood of negative consequences but does not exclude the possibility that there may also be beneficial consequences.

There are four basic elements for assessing risk – hazard, inventory, vulnerability, and loss.[51] This generalized approach to risk assessment is useful for a variety of types of decisions. The first element focuses on the risk of a *hazard* as a function of climate change, including interactions of climate effects with other factors. In the context of the coastal community example, the community is concerned with the likelihood of future hurricanes and the impacts that sea level rise may have on damage to the residential development from future hurricanes. There is likely to be considerable uncertainty about maximum storm surge and sea level from hurricanes during the next 50 to 70 years. The second element identifies the *inventory* of properties, people, and the environment at risk. To inventory structures, for instance, requires evaluating their location, physical dimensions, and construction quality.

Evaluating both the hazard and its impacts on the inventory often requires an appropriate treatment of uncertainty. In some cases a probabilistic treatment may prove sufficient. For instance, in the coastal community example, decision-makers may have sufficient confidence in estimates of the return frequency of extreme storms (for example, that the once-in-a-hundred-years storm is and will remain a once-in-a-hundred-years storm) to base their choices largely on these estimates. If such probabilistic estimates are not available, or if decision-makers lack sufficient confidence in those that are available, they may find it useful to consider a range of scenarios and seek risk management strategies robust across these ranges of estimates.[49,52,53]

Together, the hazard and inventory elements enable calculation of the damage *vulnerability* of the structures, people, and environment at risk. The vulnerability component enables estimation of the human, property, and environmental *losses* from different climate change scenarios by integrating biophysical information on climate change and other stressors with socioeconomic and environmental information.[54] These assessments typically involve evaluation of exposure, sensitivity, and adaptive capacity for current and projected conditions. Quantitative indicators are increasingly used to diagnose potential vulnerabilities under different scenarios of socioeconomic and environmental change[55] and to identify priorities and readiness for adaptation investments.[56] In the case of a coastal residential development, the design of the facility will influence its ability to reduce damage from hurricanes and injuries or fatalities from hurricane storm surge and sea level rise. Decisions may involve determining whether to elevate the facility so it is above ten feet, how much this adaptation measure will cost, and the reduction in the impact of future hurricanes on damage to the facility and on the residents in the building, as a function of different climate change scenarios.

Risk Perception in Climate Change Decision-Making

The concept of risk perception refers to individual, group, and public views and attitudes toward risks, where risks are understood as threats to life, health and safety, the environment, economic well-being, and other things of value. Risk perception encompasses perspectives on various dimensions of risks, including their severity, scope, incidence, timing, controllability, and origins or causes. The knowledge base regarding risk perception includes research in psychology, social psychology, sociology, decision science, and health-related disciplines (see “Factors affecting attitudes toward risk” box)

Box 26.3: Factors affecting attitudes towards risk

Extensive literature indicates that a range of factors shape risk perceptions. For example, psychological risk dimensions have been shown to influence people's perceptions of health and safety risks across numerous studies in multiple countries.[57] People also often use common "mental shortcuts," such as availability and representativeness, to organize a wide range of experiences and information.[58] How risks are framed is also important – for example, as numbers versus percentages and worst-case formulations versus more probable events.[59] Recent research has emphasized the role of emotions in the perception of risk.[60,61]

Other factors explored in the literature center on perceived characteristics of specific risks, such as whether the risks are familiar or unfamiliar; prosaic or perceived as catastrophic ("dread" risks); reversible or irreversible; and voluntarily assumed or imposed.[62] Risk perception is also influenced by the social characteristics of individuals and groups, including gender, race, and socioeconomic status.[61,63] Experiences with specific risks are also important, such as being affected by a hazard (for discussions, see [64,65,66]) and experiencing near misses or false alarms.[67]

Risk perceptions do not exist as isolated perceptions, but are linked to other individual and group perceptions and beliefs and to psychosocial factors, such as fatalism, locus of control (the degree to which people feel they have control over their own lives and outcomes), and religiosity,[65,66] as well as to more general worldviews. Research has also focused on people's mental models regarding the causality and effects of different risks.[68]

Still other research focuses on how risk information is mediated through organizations and institutions and how mediation processes influence individual and group risk perceptions. For example, the "social amplification of risk" framework stresses the importance of the media and other institutions in shaping risk perceptions, such as by making risks seem more or less threatening.[69] Perceptions are also related to people's trust in the institutions that manage risk; loss of trust can lead to feelings of disloyalty regarding organizations that produce risks and institutions charged with managing them, which can in turn amplify individual and public concerns.[70] Additionally, perceptions are linked to individual and group attitudes concerning sources of risk information, including official and media sources. These factors include the perceived legitimacy, credibility, believability, and consistency of information sources.[71]

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As noted in the box "Factors affecting attitudes towards risk", many factors influence risk. Social scientists and psychologists have studied people's concerns about climate change risks and found that many individuals view hazards for which they have little personal knowledge and experience as highly risky.[72] On the other hand, seeing climate change as a simple and gradual change from current to future values on variables such as average temperatures and precipitation may make it seem controllable.[73]

The effects of risk perception on decision-making have also been studied extensively and support a number of conclusions that need to be considered in decision support processes. The decision process of non-experts with respect to low-probability, high-consequence events differs from that of experts.[74] Non-experts tend to focus on short time horizons, seeking to recoup investments over a short period of time, in which case future impacts from climate change are not given much weight in actions taken today. This is a principal reason why there is a lack of interest in undertaking adaptation measures with upfront investments costs where the benefits accrue over a long period of time.[75] In the context of the coastal residential development, elevating the structure will reduce expected damages from hurricanes, resulting in smaller annual insurance premiums. Long-term loans that spread the costs of this action over time can make the option financially attractive, if the savings on the insurance premiums outweigh the costs of the loan payments.

There is also a tendency for decision-makers to treat a low-probability event as if it had no chance of occurring because it is below their threshold level of concern (such as a 1 in 100 chance of a damaging disaster occurring next year). As shown by empirical research, stretching the time horizon over which information is communicated can make a difference in risk perception.[76] In the case of the coastal residential development, community leaders may pay more attention to the need for adaptation measures if the likelihood of inundation by a future hurricane is presented over a 25 year or 50 year horizon (for example, the facility may flood 5 times in 25 years) rather than as a risk on annual basis (for example, there is a 20% chance of flooding in any given year).

Risk Management Strategies

In general, an effective response to the current and future risks from climate variability and change will require a portfolio of different types of actions, ranging from those intended to manage, reduce, and transfer risk to those intended to provide additional information on risks and the effectiveness of various actions for addressing it (see "Value of Information" box). For instance, in the coastal community example, decision makers might better *manage* risk through changes in building codes intended to reduce the impact of flooding on structures, might *share* risk by appropriate adjustments in flood insurance rates, and might *reduce* risk via land use policies that shift development towards higher ground and via participating in and advocating for greenhouse gas emission reduction policies that may reduce future levels of sea level rise.

To facilitate these strategies given the uncertainty associated with the likelihood and consequences of climate change, "robust decision-making" may be a useful tool for evaluating alternative options and risk management strategies. One study reviews the application of a range of decision-making approaches to assessing options for mitigating or adapting to the impacts of climate change.[77] In the context of the coastal residential development, the choice of adaptation measures to reduce the likelihood of future water-related damage may require using such an approach. To illustrate, consider two adaptation measures, elevating a building and flood-proofing it, to reduce the chances of severe water damage from hurricane storm surge coupled with sea level rise. Measure 1 (elevation) may perform extremely well based on specific estimates of the likelihood of different climate change conditions that will affect storm surge and sea level rise, but it may perform poorly if those estimates turn out to be mistaken. Measure 2 (flood-proofing) may have a lower expected benefit than elevation but much less variance in its outcomes and thus be the preferred choice of the community.[49]

Turning to risk management strategies, public agencies, private firms, and individuals have incentives, information, and options available to adapt to emerging conditions due to climate change. These options may include ensuring continuity of service or fulfillment of agency responsibilities, addressing procurement or supply chain issues, preserving market share, or holding the line on agency or private-sector production costs. Commercially available mechanisms such as insurance can also play a role in providing protection against losses due to climate change.[78] However, insurers may be unwilling to provide coverage against such losses due to the uncertainty of the risks and lack of clarity on the liability issues associated with global climate change.[79] In these cases, public sector involvement through public education programs, economic incentives (subsidies and fines), and regulations and standards may be relevant options. Criteria for evaluating risk management strategies can include impacts on resource allocation, equity and distributional impacts, ease of implementation, and justification.

Box 26.4: Value of Information

A frequently asked question when making complex decisions is: "When does the addition of more information contribute to decision-making so that the benefit of obtaining this information exceeds the expense of collecting, processing, or waiting for it?" In a decision context, the value of information often is defined as the expected additional benefit from additional information, relative to what could be expected without that information.[80,81] Even though decision-makers often cite a lack of information as a rationale for not making timely decisions, delaying a decision to obtain more information doesn't always lead to different or better decisions.[82,83]

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Implementation, Continued Monitoring, and Evaluation of Decisions

The implementation phase of a well-structured decision process involves an ongoing cycle of setting goals, taking action, learning from experience, and monitoring to evaluate the consequences of undertaking specific actions, as shown on the left-hand side of Figure 26.3. This cycle offers the potential for policy and outcome improvement through time. Ongoing evaluation can focus on how the system responds to the decision, leading to better future decisions, as well as on how different stakeholders respond, resulting in improvements in future decision-making processes. The need for social and technical learning to inform decision-making is likely to increase in the face of pressures on social and resource systems from climate change. However, the relative effectiveness of monitoring and assessment in producing social and technical learning depends on the nature of the problem, the amount and kind of uncertainty and risk associated with climate change, and the design of the monitoring and evaluation efforts.

Examples of Decision Support Tools and Methods

While decision frameworks vary in their details, they generally incorporate most or all of the steps outlined above. To support decision-making across these steps, various technical tools and methods, developed in both the public and private sectors, can assist stakeholders and decision-makers in meeting their objectives and clarify where there are value differences or varying tolerances for risk and uncertainty. Many of these tools and methods are applicable throughout the decision-making process, from framing through assessment of options through evaluation of outcomes. Several of the tools and methods – data management systems and scientific assessments – help to expand the relevant information and provide a means of managing large amounts of data. Three other tools described below – comparative trade-off methods, scenario planning, and integrated assessment models – are particularly useful in assisting stakeholders and decision-makers in identifying and evaluating different options for managing risks associated with climate change. The following discussion describes these approaches; examples are provided in the "Example decision support tools" box.

Box 26.5: Example decision support tools

Many decision support tools apply climate science and other information to specific decisions and issues; several online clearinghouses describe these tools and provide case studies of their use (for example,[39,84,85]). Typically, these applications integrate observed or modeled data on climate and a resource or system to enable users to evaluate the potential consequences of options for management, investment, and other decisions. These tools apply to many types of decisions; examples of decisions and references for further information are provided in Table 26.2.

Table 26.2 Examples of decisions and tools used

Topic	**Example Decision(s)**	**Further Information and Case Studies**
Water resources	Making water supply decisions in the context of changes in precipitation, increased temperatures, and changes in water quality, quantity, and water use	Means et al. 2010;[86] International Upper Great Lakes Study 2012;[24]; State of Washington 2012;[87] "Denver Water case study" box; Ch. 3: Water
Infrastructure	Designing and locating energy or transportation facilities in the coastal zone to limit the impacts of sea level rise	Ch. 11: Urban; Ch. 10: Energy, Water, and Land
Ecosystems and biodiversity	Managing carbon capture and storage, fire, invasive species, ecosystems, and ecosystem services	Byrd et al. 2011;[88] Labiosa et al. 2009;[89] USGS 2012a, 2012b, 2012c;[90,91] Figure 26.5
Human health	Providing public health warnings in response to ecosystem changes or degradation, air quality, or temperature issues	Ch. 9: Human Health
Regional climate change response planning	Develop plans to reduce emissions of greenhouse gases in multiple economic sectors within a state	"Washington State's Climate Action Team" box

Many available and widely applied decision-making tools can be used to support management in response to climate extremes or seasonal fluctuations. Development of decision support resources focused on decadal or multi-decadal investment decisions is in a relatively early stage but is evolving rapidly and shared through the types of clearinghouses discussed above.

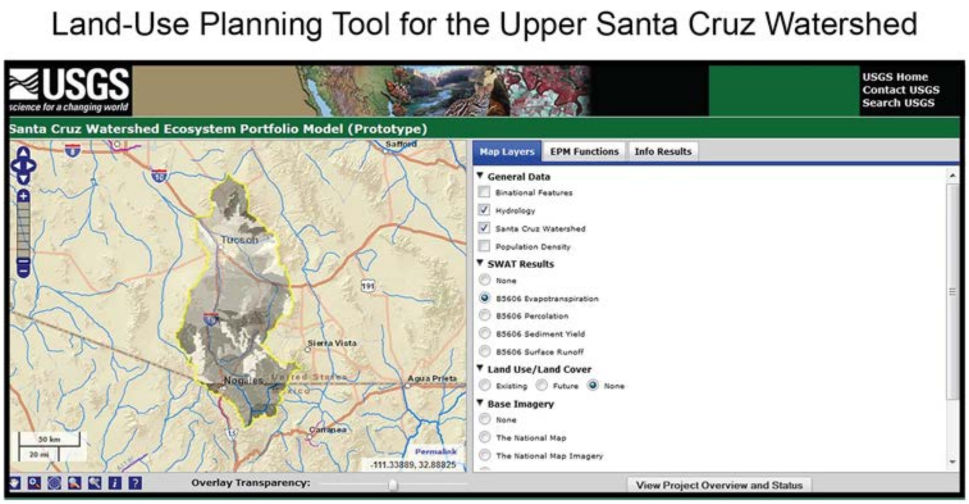

Figure 26.5: Land use planning tool for the Upper Santa Cruz Watershed.

Caption: The Santa Cruz Watershed Ecosystem Portfolio Model is a regional land-use planning tool that integrates ecological, economic, and social information and values relevant to decision-makers and stakeholders. The tool is a map-based set of evaluation tools for planners and stakeholders, and is meant to help in balancing disparate interests within a regional context. Projections for climate change can be added to tools such as this one and used to simulate impacts of climate change and generate scenarios of climate change sensitivity; such an application is under development for this tool (Figure source: USGS 2012[90]).

--end box—

Valuing the Effects of Different Decisions

Understanding costs and benefits of different decisions requires understanding people's preferences and developing ways to measure outcomes of those decisions relative to preferences. This "valuation" process is used to help rank alternative actions, illuminate trade-offs, and enlighten public discourse.[31] In the context of climate change, the process of measuring the economic values or non-monetary benefits of different outcomes involves managers, scientists, and stakeholders and a set of methods to help decision-makers evaluate the consequences of climate change decisions.[92] Although values are defined differently by different individuals and groups and can involve different metrics – for example, monetary values and non-monetary benefit measures[93] – in all cases, valuation is used to assess the relative importance to the public or specific stakeholders of different impacts. Such valuation assessments can be used as inputs into iterative adaptive risk management assessments (which has advantages in a climate context because of its ability to address uncertainty) or more traditional cost benefit analyses, if appropriate.

Some impacts ultimately are reflected in changes in the value of activities within the marketplace and in dollars[94] – for example, the impacts of increased temperatures on commercial crop yields.[95] Other evaluations use non-monetary benefit measures such as biodiversity measures[96] or soil conservation and water services.[97]

Valuation methods can provide input to a range of decisions, including cost-benefit analysis of new or existing regulations[98] or government projects;[99] assessing the implications of land-use changes;[100] transportation investments and other planning efforts;[101,102] developing metrics for ecosystem services; and stakeholder and conflict resolution processes.[103]

Comparative Trade-off Methods

Once their consequences are valued or otherwise described, alternative options are often compared against the objectives or decision criteria. In such cases, approaches such as listing the pros and cons,[104] cost-benefit analysis,[105] multi-criteria methods,[80] or robust decision methods[106] can be useful. Multi-criteria methods provide a way to compare options by considering the positive and negative consequences for each of the objectives without having to choose a single valuation method for all the attributes important to decision-makers.[31] This approach allows for consequences to be evaluated using criteria most relevant for a given objective.[107] The options can then be compared directly by considering the relative importance of each objective for the particular decision.

Integrated Assessment Models

Integrated Assessment Models are tools for modeling interactions across climate, environmental, and socioeconomic systems.[108] In particular, integrated assessment models can be used to provide information that informs trade-offs analyses, often by simulating the potential consequences of alternative decisions. Integrated assessment models typically include representations of climate, economics, energy, and other technology systems, as well as demographic trends and other factors that can be used in scenario development and uncertainty quantification.[109] They are useful in national and global policy decisions about emissions targets, timetables, and the implications of different technologies for emissions management.[110] These models are now being extended to additional domains such as water resources and ecosystem services to inform a broader range of trade-off analyses and to finer resolutions to support regional decision-making.[111]

Scenarios and Scenario Planning

Scenarios are depictions of possible futures or plausible conditions given a set of assumptions; they are not predictions. Scenarios enable decision makers to consider uncertainties in future conditions and explore how alternate decisions could shape the futures or perform under uncertainty. One approach to building scenarios begins with identifying any changes over time that might occur in climate and socioeconomic factors (for example, population growth and changes in water availability), and then using these projections to help decision-makers rank the desirability of alternative decision options to respond to these changes.[112] This works well when decision-makers agree on the definition of the problem and scientific evidence.[53,113] A second approach is widely used in robust decision-making and decision-scaling approaches. It begins with a specific decision under consideration by a specific community of users and then poses questions relevant to these decisions (for example, "how can we build a vibrant economy in our community in light of uncertainty about population growth and water supply?") to organize information about future climate and socioeconomic conditions (for example,[114]).

Scenario planning often combines quantitative science-based scenarios with participatory "visioning" processes used by communities and organizations to explore desired futures.[115] It can also facilitate participatory learning and development of a common understanding of problems or decisions. There are many different approaches, from a single workshop that uses primarily qualitative approaches to more complex exercises that integrate qualitative and quantitative methods with visualization and/or simulation techniques over multiple workshops or meetings. Common elements include scoping and problem definition; group development of qualitative (and, optionally, quantitative) scenarios and analysis that explore interactions of key driving forces, uncertainties, and decision options.

Scenario planning has been useful for water managers such as Denver Water, which has also used "robust decision-making" to assess policies that perform well across a wide range of future conditions, in the face of uncertainty and unknown probabilities (see "Denver Water Case Study" box). Other examples of the use of scenario planning include:

- National Park Service, to consider potential climate change impacts and identify adaptation needs and priorities in several parks or regions[116]
- California State Coastal Conservancy, to plan tidal marsh restoration and planning in the San Francisco estuary in the face of climate change and sea level rise[117]
- Urban Ecology Research Lab at the University of Washington, for planning adaptation to preserve ecosystem services in the Snohomish Basin[118]
- A group of agencies and organizations considering the impacts of climate change on ecosystems in the Florida Everglades[119]

The National Climate Assessment has developed and used a number of different types of scenarios and approaches in preparation of this report (see Appendix 5: Scenarios).[120]

Box 26.6: Denver Water case study

Climate change is one of the biggest challenges facing the Denver Water system. Due to recent and anticipated effects of climate variability and change on water availability, Denver Water faces the challenge of weighing alternative response strategies and is looking at developing options to help meet more challenging future conditions.

Denver Water is using scenario planning in its long-range planning process (looking out to 2050) to consider a range of plausible future scenarios (Figure 26.6). This approach contrasts with its traditional approach of planning for a single future based on demand projections and should better prepare the utility and enhance its ability to adapt to changing and uncertain future conditions.

Denver Water is assessing multiple scenarios based on several potential water system challenges, including climate change, demographic and water use changes, and economic and regulatory changes. The scenario planning strategy includes "robust decision-making," which focuses on keeping as many future options open as possible while trying to ensure reliability of current supplies.

Scenario planning was chosen as a way to plan for multiple possible futures, given the degree of uncertainty associated with many variables, particularly demographic change and potential changes in precipitation. This method is easy to understand and has gained acceptance across the utility. It is a good complement to more technical, detailed analytical approaches.

The next step for Denver Water is to explore a more technical approach to test their existing plan and identified options against multiple climate change scenarios. Following a modified robust decision-making approach,[121] Denver Water will test and hedge its plan and options until those options demonstrate that they can sufficiently handle a range of projected climate conditions.

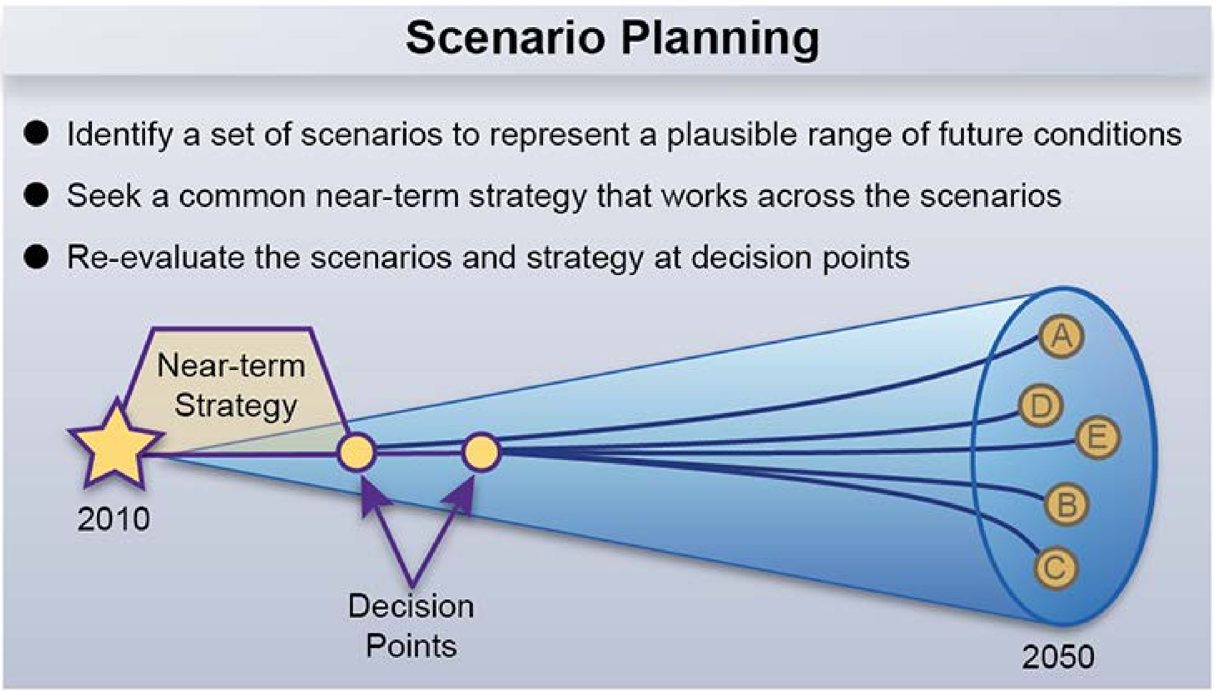

Figure 26.6: Scenario Planning

Caption: Scenario planning is an important component of decision-making. This "cone of uncertainty" is used to depict potential futures in Denver Water's scenario planning exercises. (Figure source: adapted from Waage 2010[122]).

-- end box –

Scientific Assessments
Ongoing assessments of the state of knowledge allow for iterative improvements in understanding over time and can provide opportunities to work directly with decision-makers to understand their needs for information.[123] A sustained assessment process (Ch. 30: Sustained Assessment)[40] can be designed to support the adaptation and mitigation information needs of

decision-makers, with ongoing improvements in data quality and utility over time. This report represents one such type of assessment. The Intergovernmental Panel on Climate Change (IPCC) has prepared assessments of the state of the science related to climate change, impacts and adaptation, and mitigation since the late 1980s. Numerous additional assessments have been prepared for a variety of national and international bodies focused on issues such as biodiversity, ecosystem services, global change impacts in the Arctic, and many others.

Box 26.7: Washington State's Climate Action Team: uses and limits to decision support

Between 2000 and 2007, pioneering work by the University of Washington's Climate Impacts Group (a NOAA RISA) tailored national climate models to the Pacific Northwest and produced, for the first time, specific information about likely adverse impacts to virtually every part of Washington's economy and environment if carbon dioxide concentrations in the atmosphere were not quickly stabilized.[124] The localized impacts predicted from these models were significant.

In February of 2007, Governor Christine Gregoire issued Executive Order 07-02, establishing the Climate Action Team (CAT).[125] Its charge was to develop a plan to achieve dramatic, climate-stabilizing reductions in emissions of greenhouse gases (GHGs) according to goals established in the Executive Order. The CAT was a 29-member team that included representatives of industry, utilities, environmental advocacy groups, Native American tribes, municipal governments and elected officials, both statewide and legislators.

The CAT met four to five times a year for two years. Between meetings, technical consultants, including boundary organizations such as the Climate Impacts Group, provided detailed analyses of the issues that were on the next CAT agenda. Technical experts were recruited to provide direct testimony to the CAT. Professional facilitators helped run the meetings, decipher the technical testimony, and keep the CAT on track to meet its obligations. All CAT meetings were open to the public, and public testimony was accepted. To assist in this effort, five subcommittees were created to develop proposals for achieving emissions reductions in the following parts of the economy: the built environment, agriculture, forestry, transportation, and energy generation. Similarly, adaptation groups were formed to develop recommendations for dealing with impacts that could not be avoided. These Preparation/Adaptation Working Groups focused on forest health, farmlands, human health, and coastal infrastructure and resources.

The CAT and the working groups were well supported with science and technical expertise. The CAT issued its first report, on reducing greenhouse gases, at the close of 2007.[126] It was well received by the legislature, and a significant number of its recommendations were implemented in the 2008 session.[127]

In 2008, the CAT continued its work. The focus shifted to whether Washington should join the Western Climate Initiative (WCI), a state and provincial organization that was developing a regional, economy-wide cap and trade system for carbon emissions. The same high-quality professional facilitation was provided at all meetings. Several highly qualified technical experts provided technical support.

With this support, the CAT produced another set of recommendations.[128] The centerpiece recommendation was that Washington join the WCI's regional cap and trade program. This time, the combination of a weakening economy and political dynamics trumped the CAT's findings, and resulted in a decision not to implement its recommendations.

-- end box –

Incorporating Recent Scientific Advances and Translating Science for Decision-Making

While decision support is not necessarily constrained by a lack of tools, a number of barriers restrict application of existing and emerging science and technology in adaptation and mitigation decisions.[3,8,129] In cases where tools exist, decision-makers may be 1) unaware of tools; 2) overwhelmed by the number of tools; 3) hesitant to use tools that are not appraised or updated and maintained with new information; or 4) require training in how to use tools.[8,130] Recent scientific developments could help address some of these barriers, but are not yet incorporated into decision support tools.[65] For example, individual climate models can provide very different projections of future climate conditions for a given region, and the divergence of these projections can make it seem impossible to reach a decision. But comparing different models and constructing climate model "ensembles" can highlight areas of agreement across large numbers of models and model runs, and can also be used to develop ranges and other forms of quantification of uncertainty (for further discussion, see Chapter 2: Our Changing Climate and Appendix 4: Climate Science). While results from these activities can prove difficult to present in formats that could help decision-makers,[131] new approaches to visualization and decision support can make such ensembles useful for decision making.[132]

There is also a need for "science translators" who can help decision-makers efficiently access and properly use data and tools that would be helpful in making more informed decisions in the context of climate change.[3,4,8,83,133] The culture of research in the U.S. often perpetuates a belief that basic and applied research need to be kept separate, though it has been demonstrated that research motivated by "considerations of use" can also make fundamental advances in scientific understanding and theory.[134] The U.S. climate research effort has been strongly encouraged to improve integration of social and ecological sciences and to develop the capacity for decision support to help address the need to effectively incorporate advances in climate science into decision-making.[135]

Research to Improve Decision Support

There are a number of areas where scientific knowledge needs to be expanded or tools further developed to take advantage of existing insight. The National Research Council (NRC) identifies a research agenda both *for* decision support (such as identifying specific information needs) and *on* decision support (such as improving tools for risk assessment and management).[3] A number of studies assess approaches and identify needed research and development (for example,[136]). A subset of the opportunities and needs identified by the NRC seem particularly relevant in the context of the National Climate Assessment, including:

- A comprehensive analysis of the state of decision support for adaptation and mitigation, including assessment of processes, tools, and applications, and development of a knowledge-sharing platform will facilitate wide public access to these resources.

- Comparisons of different adaptation and mitigation options will be improved by investments in understanding how the effects of climate change and response options can be valued and compared, especially for non-market ecosystem goods and services[101,137] and those impacts and decisions that have an effect over long time scales.

- Improvements in risk management require closing the gap between expert and public understanding of risk and building the institutions and processes needed for managing persistent risks over the long term.

- Probabilistic forecasts or other information regarding consequential climate extremes/events have the potential to be very useful for decision-makers, if used with improving information on the consequences of climate change and appropriate decision support tools.

- Better methods for assessing and communicating scientific confidence and uncertainty in the context of specific decisions would be very useful in supporting risk management strategies.

- Improvements in processes that effectively link scientists with decision-makers and the public in resource management settings and developing criteria to evaluate their effectiveness would enhance knowledge building and understanding.

Traceable Accounts

Chapter 26: Decision Support

Key Message Process: During March-June 2012, the author team engaged in multiple technical discussions via teleconference (6 telecons) and email, and in a day-long in-person meeting (April 27, 2012 in Washington, D.C.). Authors reviewed over 50 technical inputs provided by the public and a wide variety of technical and scholarly literature related to decision support, including reports from the National Research Council that provided recent syntheses of the field (America's Climate Choices series, especially the report *Informing an effective response to climate change*;[8] *Informing Decisions in a Changing Climate*[3]). During the in-person meeting, authors reflected on the body of work informing the chapter and drafted a number of candidate critical messages that could be derived from the literature. Following the meeting, authors ranked these messages and engaged in expert deliberation via teleconference and email discussions in order to agree on a small number of key messages for the chapter.

Key message #1/5	**Decisions about how to address climate change and adapt to its effects can be complex. Decision-makers—whether individuals, public officials, or others—may need help integrating scientific information into adaptation and mitigation decisions.**
Description of evidence base	The sensitivity of the climate system to human activities, the extent to which mitigation policies are implemented, and the effects of other demographic, social, ecological, and economic changes on vulnerability also contribute to uncertainty in decision-making. Uncertainties can make decision-making in the context of climate change especially challenging for several reasons, including the rapid pace of changes in physical and human systems, the lags between climate change and observed effects, the high economic and political stakes, the number and diversity of potentially affected stakeholders, the need to incorporate scientific information of varying confidence levels, and the values of stakeholders and decision-makers.[2,3] An iterative decision process that incorporates constantly improving scientific information and learning through periodic reviews of decisions over time is helpful in the context of rapid changes in environmental conditions.[3,4] The National Research Council has concluded that an "iterative adaptive risk management" framework, in which decisions are adjusted over time to reflect new scientific information and decision-makers learn from experience, is appropriate for decisions about adaptation and ways to reduce future climate change, especially given uncertainties and advances in scientific understanding.[8,26] Well-designed decision support processes, especially those in which there is a good match between the availability of scientific information and the capacity to use it, can result in more effective outcomes based on relevant information that is perceived as useful and applicable.[6]
New information and remaining uncertainties	N/A
Assessment of confidence based on evidence and agreement or, if defensible, estimates of the	N/A

likelihood of impact or consequence	

CONFIDENCE LEVEL			
Very High	**High**	**Medium**	**Low**
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

Key Message Process: See key message #1.

Key message #2/5	**To be effective, decision support processes need to take account of the values and goals of the key stakeholders, evolving scientific information, and the perceptions of risk.**
Description of evidence base	This message emphasizes that making a decision is more than picking the right tool and adopting its outcome. It is a process that should involve stakeholders, managers, and decision-makers to articulate and frame the decision, develop options, consider consequences (positive and negative), evaluate tradeoffs, make a decision, implement, evaluate, learn, and reassess.[1,8] Oftentimes having an inclusive, transparent decision process increases buy-in, regardless of whether a particular stakeholder's preferred option is chosen.[3] Decisions about investment in adaptation and mitigation measures occur in the context of uncertainty and high political and economic stakes, complicating the evaluation of information and its application in decision-making.[3,8] Decisions involve both scientific information and values—for example, how much risk is acceptable and what priorities and preferences are addressed.[2]
New information and remaining uncertainties	N/A
Assessment of confidence based on evidence	N/A

CONFIDENCE LEVEL			
Very High	**High**	**Medium**	**Low**
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

Key Message Process: See key message #1.

Key message #3/5	**Many decision support processes and tools are available. They can enable decision-makers to identify and assess response options, apply complex and uncertain information, clarify tradeoffs, strengthen transparency, and generate information on the costs and benefits of different choices.**
Description of evidence base	Many decision support tools have been developed to support adaptive management in specific sectors or for specific issues. These tools include: risk assessments; geographic information system (GIS-based analysis products; targeted projections for high consequence events such as fires, floods, or droughts; vulnerability assessments; integrated assessment models; decision calendars; scenarios and scenario planning; and others.[3,8,84] Many of these tools have been validated scientifically and evaluated from the perspective of users. They are described in the sector and regional chapters of this assessment. In addition, a variety of clearing houses and data management systems provide access to decision support information and tools (for example, [39,85]). There are many tools, some of which we discuss in the chapter, that are currently being used to make decisions that include a consideration of climate change and variability, or the impacts or vulnerabilities that would result from such changes. Also important is the creation of a well-structured and transparent decision process that involves affected parties in problem framing, establishing decision criteria, fact finding, deliberation, and reaching conclusions.[1,8,26] These aspects of decision-making are often overlooked by those who focus more on scientific inputs and tools, but given the high stakes and remaining uncertainties, they are crucial for effective decision-making on adaptation and mitigation.
New information and remaining uncertainties	N/A
Assessment of confidence based on evidence	N/A

CONFIDENCE LEVEL			
Very High	**High**	**Medium**	**Low**
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

1 # Chapter 26: Decision Support

2 **Key Message Process:** See key message #1.

Key message #4/5	**The sustained assessment process should incorporate ongoing evaluation of decision support tools, their accessibility to decision-makers, and their application in decision processes in different sectors and regions.**
Description of evidence base	As part of a sustained assessment, it is critical to understand the state of decision support, including what is done well and where we need to improve. At this point in time, there is a lack of literature that provides a robust evidence base to allow us to conduct this type of national, sector-scale assessment. Developing an evidence base would allow for a movement from case studies to larger-scale assessment across decision support and would allow us to better understand how to better utilize what decision support is available and understand what needs to be improved to support adaptation and mitigation decisions in different sectors and regions.
New information and remaining uncertainties	N/A
Assessment of confidence based on evidence	N/A

3

CONFIDENCE LEVEL			
Very High	**High**	**Medium**	**Low**
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

4

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Key Message Process: See key message #1.

Key message #5/5	**Steps to improve collaborative decision processes include development of new decision support tools and building human capacity to bridge science and decision-making.**
Description of evidence base	There are many challenges in communicating complex scientific information to decision makers and the public,[11] and while "translation" of complex information is one issue, there are many others. Defining the scope and scale of the relevant climate change problem can raise both scientific and social questions. These questions require both scientific insights and consideration of values and social constructs, and require that participants engage in mutual learning and the co-production of relevant knowledge.[10] Boundary processes that are collaborative and iterative[18] among scientists, stakeholders, and decision-makers, such as joint fact finding and collaborative adaptive management, foster ongoing dialogue and increasing participants' understanding of policy problems and information and analysis necessary to evaluate decision options.[12,13] Analysis of the conditions that contribute to their effectiveness of boundary processes is an emerging area of study (McCreary et al. 2001).[13] A large body of literature notes that the ability of decision-makers to use data and tools has not kept pace with the rate at which new tools are developed, pointing to a need for "science translators" who can help decision-makers efficiently access and properly use data and tools that would be helpful in making more informed decisions in the context of climate change.[3,4,8,83,133] The U.S. climate research effort has been strongly encouraged to improve integration of social and ecological sciences and to develop the capacity for decision support to help address the need to effectively incorporate advances in climate science into decision making.[135]
New information and remaining uncertainties	N/A
Assessment of confidence based on evidence	N/A

CONFIDENCE LEVEL			
Very High	**High**	**Medium**	**Low**
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

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