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Preparing California for a Changing Climate

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SUMMARY

California's ambitious efforts to reduce greenhouse gas emissions have made the state a leader in the domestic and international fight against global warming. But even if these efforts are successful, mounting evidence shows that some impacts of warming are inevitable, including higher air and water temperatures, accelerating sea level rise, increasing coastal storm surges, and more frequent extreme events, such as heat waves, floods, drought, and wildfires. These impacts are anticipated to affect many aspects of California's society, economy, and natural environment.

To reduce the state's vulnerability, we need a strategy to prepare for—and adapt to—a changing climate. Some adaptation measures will need to be made by individuals—for instance, taking out insurance to protect against increased flood risk, or installing air conditioning to better cope with hotter summers. But institutions, particularly government agencies and public and private utilities, must play a central role in the adaptation process. Such institutions are responsible for providing services, investing in infrastructure, and setting the regulatory contexts in which individuals and businesses will make adaptation decisions.

In this study, we review adaptation challenges in six particularly susceptible areas—water resources, electricity, coastal resources, air quality, public health, and ecosystem resources—focusing on how well California's institutions are prepared for the challenge. We find grounds for hope alongside grounds for concern. In some areas, such as water and electricity supply, tools already exist to help California adapt to the changing climate, and institutions have

begun planning for change. But in other areas—notably coastal management, flood control, and habitat protection—climate change will exacerbate already difficult tradeoffs.

To develop a comprehensive statewide adaptation strategy, six actions are key:

- Improve the basic science on climate impacts, particularly at the regional and local levels.
- Help frontline actors, such as city and county governments, interpret the science and determine which levels of climate risks to plan for, over which time frames.
- Determine where early actions are needed—when a failure to act now will result in much greater cost or reduce future flexibility. These areas currently include infrastructure investment and habitat protection.
- Refine existing adaptation tools and experiment with new ones.
- Strengthen the incentives for coordinated action at the regional level and seek federal cooperation.
- Make legal and regulatory adjustments to facilitate adaptation.

To be most effective, California policymakers should develop an integrated climate policy, one that considers efforts to reduce greenhouse gas emissions and strategies for climate change adaptation in tandem. This means recognizing that some emission reduction policies can actually weaken our ability to adapt to climate change. This also means capitalizing on the significant support for emission reductions to heighten awareness of adaptation needs and tools. California is already a leader in efforts to reduce the effects of global warming. We now have the opportunity to become a leader in developing tools and approaches to limit the harm caused by the warming that we are unable to prevent.

To be most effective, California policymakers should develop an integrated climate policy.

Please visit the report's publication page
http://www.ppic.org/main/publication.asp?i=755
to find related resources.

Introduction

> "... danger is never so near as when you are unprepared for it."
>
> —Francis Parkman (1849), *The Oregon Trail*

By setting ambitious targets for reducing greenhouse gas (GHG) emissions, California has become a leader in domestic and international efforts to combat global warming. However, even if these efforts are highly successful, significant climate change is inevitable. Anticipated impacts include higher air and water temperatures, accelerated sea level rise, and an increase in extreme weather events, such as storms and heat waves.

Many aspects of California's society, economy, and natural environment are vulnerable to these changes. Warmer winters spell more rainfall and less snowfall, dramatically reducing the mountain snowpack on which water managers rely to store water for the dry summer months. California's coastal areas, home to many recreational and tourist destinations, valuable infrastructure, and unique ecosystems, could be threatened by rising sea levels. Higher summer temperatures will threaten the reliability of electricity generation and increase risks to public health. Rising water and air temperatures will alter the fragile balance in which California's native species now exist, putting many of them at risk of extinction. Thus, although reducing emissions to minimize these impacts is crucial, it is also important to consider how Californians can best manage and adapt to inevitable changes in the climate.

This report provides some early answers to this question by assessing California's current level of preparedness and highlighting the steps needed to improve responsiveness to changing conditions. We focus on the readiness of

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An El Nino–powered storm pounds the pilings of homes in Malibu.

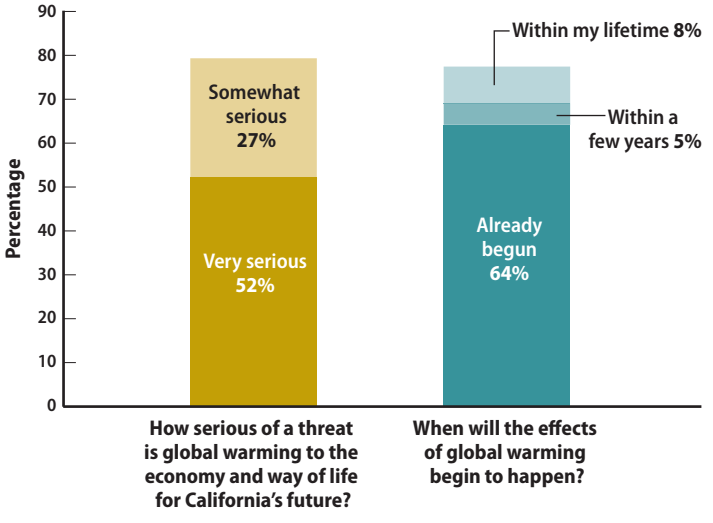
California's institutions—particularly government agencies and public and private utilities—because they are responsible for providing services, making infrastructure investments, setting the regulatory contexts, and shaping the incentive structures in which individuals and businesses will make their own adaptation decisions.

A strong majority of Californians are convinced that climate change poses a serious threat to the state's economy and quality of life, and many believe that the effects are already occurring (Figure 1). The key policy question is whether California's institutions have the information, tools, and resources to craft responses that encourage individuals and society as a whole to adjust and adapt to these changes. If our institutions fail at this task, the potential consequences include stranded public and private investments, loss of sensitive habitat, a decline in public services, and increased health risks for many Californians.

We explore California's institutional readiness by looking at six particularly susceptible areas: water resources,

Climate change has the potential to profoundly alter the conditions facing the state's residents and the natural environment.

Figure 1. Californians' views on the seriousness and timing of climate change impacts



Source: Baldassare et al. (2008).

electricity, coastal resources, air quality, public health, and ecosystems. Climate change has the potential to profoundly alter the conditions facing the state's residents and the natural environment in each of these areas. As we will see, California's institutions are better poised to handle these changes in some areas than in others. But in all areas, more actions are needed now to improve California's ability to cope with future conditions.

The report begins with a brief discussion of adaptation: What does it mean in practice, and how does it fit into the state's overall climate policy? We then look at how California's climate is likely to change over this century, including key uncertainties. We next present the adaptation challenges in the six areas of focus: How does climate change add to existing management challenges, and to what extent are managers aware of these new complications? We then look at various adaptation strategies—the technologies and management solutions available to address changing climate conditions—and outline the steps that California needs to take to improve institutional readiness. A concluding section highlights ways to better integrate adaptation into climate policy at the state and local levels.

The findings presented here draw on a set of more detailed studies, all available for download at www.ppic.org. Readers seeking more information on adaptation issues in a particular area are encouraged to refer to these studies. See the sidebar below for a Web link to these detailed studies.

Adaptation—A Key Piece of a Comprehensive Climate Policy

To date, much of California's climate policy has focused on *mitigating* the impacts of climate change, or reducing emissions that contribute to global warming. In June 2005, Governor Arnold Schwarzenegger issued an executive order establishing near- and long-term greenhouse gas emission reduction goals for the state. The near-term goal was codified into law through the Global Warming Solutions Act of 2006 (Assembly Bill [AB] 32), which calls for a reduction of GHG emissions statewide to 1990 levels by 2020. The long-term target is to reduce emissions 80 percent below 1990 levels by 2050. This level of reductions is considered necessary to help stabilize the world's climate.

Related studies

http://www.ppic.org/main/publication.asp?i=755

Climate Change in California: Scenarios for Adaptation
Amy Luers and Michael Mastrandrea

Adapting California's Water Management to Climate Change
Ellen Hanak and Jay Lund

Adaptation of California's Electricity Sector to Climate Change
Edward Vine

California Coastal Management with a Changing Climate
Ellen Hanak and Georgina Moreno

Air Quality Planning and California's Changing Climate
Louise Bedsworth

Climate Change and California's Public Health Institutions
Louise Bedsworth

Conservation and Management of Ecological Systems in a Changing California
Elisa Barbour and Lara Kueppers

The California Air Resources Board, along with a wide range of state agencies that form the "Climate Action Team," has been developing a comprehensive set of proposals to meet the 2020 goal. The measures are likely to touch all Californians, with efforts to improve energy efficiency in buildings, to increase the use of renewable energy sources, to use more fuel-efficient vehicles, and to make a host of other changes that reduce the state's carbon footprint.[1]

The success of California's mitigation policies depends on the state's ability to serve as a catalyst for other actors, because the efforts of any one state or country will be meaningless without global cooperation to reduce emissions. Reducing worldwide emissions is considered important—indeed, urgent—to avoid the potentially devastating effects of global warming under a business-as-usual emissions scenario. But mounting evidence also shows that it is too late to avoid all of the effects of global warming, even if the world is successful in meeting sharp emission reduction targets. Therefore, *adaptation* will also be a key component of managing the risks of climate change, even in the best-case scenarios. The less successful we are in meeting mitigation goals, the greater the need for adaptation.

Key definitions

Adaptation: Adjustments that improve a social or natural system's capacity to cope with the effects of the changing climate; such adjustments will generally reduce vulnerability to potential loss or damage or help increase resiliency (Luers and Moser, 2006).

Emissions scenarios: Scenarios representing alternative rates of global GHG emissions growth, which are dependent on rates of economic growth, the success of emission reduction strategies, and rates of clean technology development and diffusion, among other factors.

Mitigation: A set of policies and programs designed to reduce emissions of greenhouse gases.

Resilience: A system's ability to absorb and rebound from changes in the climate, including extreme events.

Vulnerability: Susceptibility to sustained damage from weather extremes and climate variability and change.

Adaptation strategies can work in two ways: by reducing *vulnerability* (or susceptibility) to changing conditions or by increasing *resiliency* (or the ability to bounce back once the changes are felt). Adaptation to climate change is often thought of in terms of responses by individuals. For example, as temperature rises, people may adjust by installing air conditioning. Similarly, in response to sea level rise, they may choose to relocate to less vulnerable areas. To help protect against increased flood risk, they may take out insurance. But institutions must play a central role in the adaptation process, for two important reasons. For one, they have the ability to provide the right set of incentives to individuals to make adaptation decisions. As an example, individuals may not receive the appropriate warning signal about coastal flood risk unless regulations for coastal development are adjusted to take sea level rise into account. Likewise, vulnerable populations may improve their preparedness for heat waves if power utilities and public health services take the initiative to improve information and access to tools for staying cool and hydrated.

Equally important, institutions are significant investors and resource managers in their own right. How well they spend our collective dollars on new infrastructure, on open space protection, and on services to protect public health depends in part on the extent to which they are prepared for the consequences of climate change.

To date, the state's main effort on the adaptation side of the equation has been to generate information on the nature of climate-related risks facing California. The following section provides highlights from this work. As discussed below, state efforts are just beginning to address the implications of these findings for adaptation policy.

California's Changing Climate

Although California began assessing the impacts of climate change two decades ago, these efforts have gained in prominence in the past few years with the launching of a biennial statewide assessment of climate impacts.[2]

The statewide assessment is coordinated by the California Energy Commission's Public Interest Energy Research (PIER) program, which has been funding climate change research since 2003.[3] The first biennial assessment, which brought together a large team of scientists from universities, research institutes, and state agencies, was completed in 2006, and a second assessment is due to be completed in early 2009.[4] Much of the attention to date has focused on understanding how conditions may change in California under different emissions scenarios.

The findings underscore the very real threats posed by global warming to life as we know it in the state (Cayan et al., 2008). Here, we summarize some of the key ways in which California's climate is expected to change over the coming century, along with some of the key uncertainties.[5] Some of these changes, such as rising air and water temperatures, are already taking place, affecting water supplies, growing seasons, wildfires, and the range of viable habitat for California's native species.

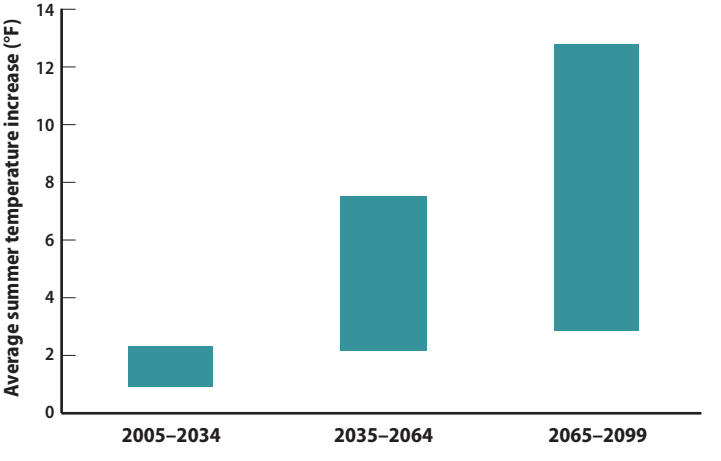
It is worth stressing that these changes in the climate will be occurring against a backdrop of continued population growth in California. By 2050, the state is expected to add another 21 million residents, to reach a total of nearly 60 million (Department of Finance, 2007). Much of this growth is expected to occur in the hotter inland counties of the Central Valley and the Inland Empire. Such growth would pose significant challenges even if the climate were stable; climate warming complicates the picture considerably.

Temperature

Under all emissions scenarios, temperatures are projected to increase rather steadily over the course of the 21st century. The rate of increase is similar for all emissions scenarios until about mid-century, when the average annual temperature in California is projected to rise by roughly 2 to 4°F (Cayan et al., 2008). By the end of the century, a medium- to high-emissions pathway is expected to increase temperatures by 4.5 to 10.5°F, whereas a lower emissions rate would hold the projected warming to 3 to 5.6°F.

Changes in temperature are not expected to be uniform over the year or across the state. Summer temperatures are expected to rise more rapidly than winter temperatures, and inland areas—already the warmest areas in the state—are projected to experience greater warming than coastal areas (Cayan et al., 2008). Figure 2 shows the range of projected temperature increases for the summer months, which are even higher than the average projections noted earlier.

Figure 2. Projected ranges of summer temperature increases for California



Sources: Hayhoe et al. (2004); Cayan et al. (2008).
Note: Projections for 2005–2034 do not include estimates for the highest-emissions scenario, which are included in the projections for the other time periods. Projections relative to 1961–1990.

Precipitation

Overall precipitation changes for California are uncertain, with most models showing little change in average levels. California is expected to maintain its highly seasonal pattern of precipitation, with most precipitation falling between November and April (Cayan et al., 2008). However, warming is projected to decrease the share of precipitation falling as snow and to increase the share falling as rain. This shift will significantly reduce the size of the Sierra Nevada snowpack, which will also melt earlier.

By mid-century, the amount of water stored as snow on April 1 is projected to decrease by 12 to 42 percent at all elevations.

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Warm temperatures threaten to melt the Sierra snowpack, a main watershed for the state.

By mid-century, the amount of water stored as snow on April 1 is projected to decrease by 12 to 42 percent at all elevations. By the end of the century, the average decrease could be as much as 32 to 79 percent. The largest reductions are projected at lower elevations and will particularly affect snowpack in the wetter, northern half of the state.

Sea Level Rise

Although sea level rise has been occurring since the end of the last Ice Age, its pace is expected to accelerate significantly as a result of global warming. Two factors are at work: the expansion of warming water and the melting of continental ice sheets and glaciers. Accounting for both factors, sea level is projected to rise by 8 to 16 inches by mid-century and by 20 to 55 inches by the end of the century (Figure 3).[6] There is significant uncertainty in the upper bound because of uncertainty in the rate and amount of ice sheet melting, which has accelerated in recent years. Sustained warming could destabilize the Greenland ice sheet, resulting in 6.6 to 23 feet of sea level rise, although complete melting could take many centuries (Meehl et al., 2007).

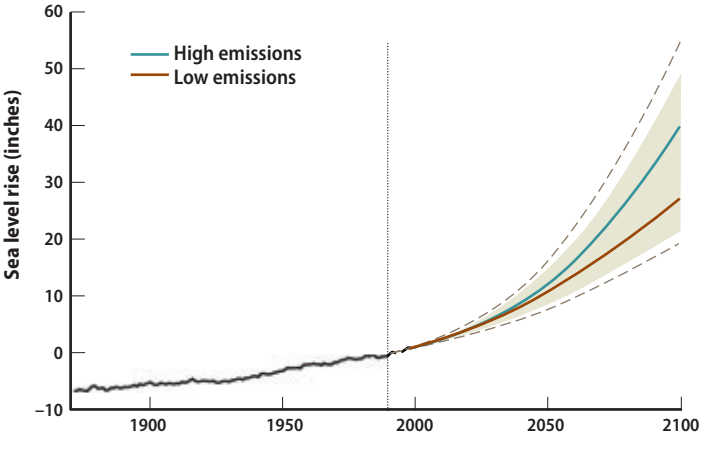
. . . sea level is projected to rise by 8 to 16 inches by mid-century and by 20 to 55 inches by the end of the century.

Extreme Events

Although many of the above changes will likely occur gradually, the frequency and intensity of extreme events can change substantially, with even small average changes. The potential for increases in events such as heat waves, droughts, wildfires, storm surges, and floods is perhaps the most immediate climate challenge facing California.

Parts of the California coast are already experiencing increasing occurrences of extremes in sea level. For

Figure 3. Historic and projected sea level rise



Source: Modified from Rahmstorf (2007).
Note: High emissions scenario is A1fi; low emissions scenario is B1.

example, in San Francisco, the occurrence of extremes has increased twentyfold since 1915, and in La Jolla, thirtyfold since 1933 (Cayan et al., 2006). In recent years, the state has experienced several severe wildfire seasons as well as summers of extreme heat (e.g., the 2006 heat wave). These increases cannot be attributed to climate change directly, but they could be a harbinger of changes to come.

Six Areas of Concern

The anticipated changes in California's climate will have profound implications for the way we manage a host of sectors and activities. In this section, we highlight some of the central challenges in six particularly vulnerable areas: water resources, electricity, coastal resources, air quality, public health, and ecosystem resources. Awareness of climate-related risks differs considerably across institutions and management areas.

1. Water Resources

Management Challenges

Water management in California faces several major challenges: (1) meeting the water demands of a growing population while facing limited potential to expand supplies, (2) improving water quality and availability for fish and aquatic wildlife, and (3) reducing the risk to the state's residents and infrastructure of devastating floods. Flood risk is particularly high in some fast-growing areas of the Central Valley.

Climate Complications

California's water managers are accustomed to dealing with considerable year-to-year variability in precipitation. But with the shift in timing of mountain runoff, water agencies will need to adjust to the loss of "free" water storage in the Sierra snowpack; by late in this century, this storage could be cut in half relative to the 1995–2005 average (Figure 4). This shift also means that flood managers will need to cope with higher peak flows during the winter and early spring flood season. Sea level rise will increase the risk of catastrophic levee failure in the Sacramento–San Joaquin Delta, cutting off important supplies to the Bay Area, the San Joaquin Valley, and Southern California. Higher water temperatures will make it harder to meet the needs of some endangered species, such as salmon. One big uncertainty is whether average precipitation levels will change: With a dryer climate, flood risks could diminish but water shortages could increase. As yet, very little is known about the effects of warming on water quality for environmental and human uses.

Climate Change Awareness

Water providers are highly aware of the potential climate impacts on supplies. Climate change has begun to be considered in environmental water management. There is as yet little discussion of these issues in flood management circles.

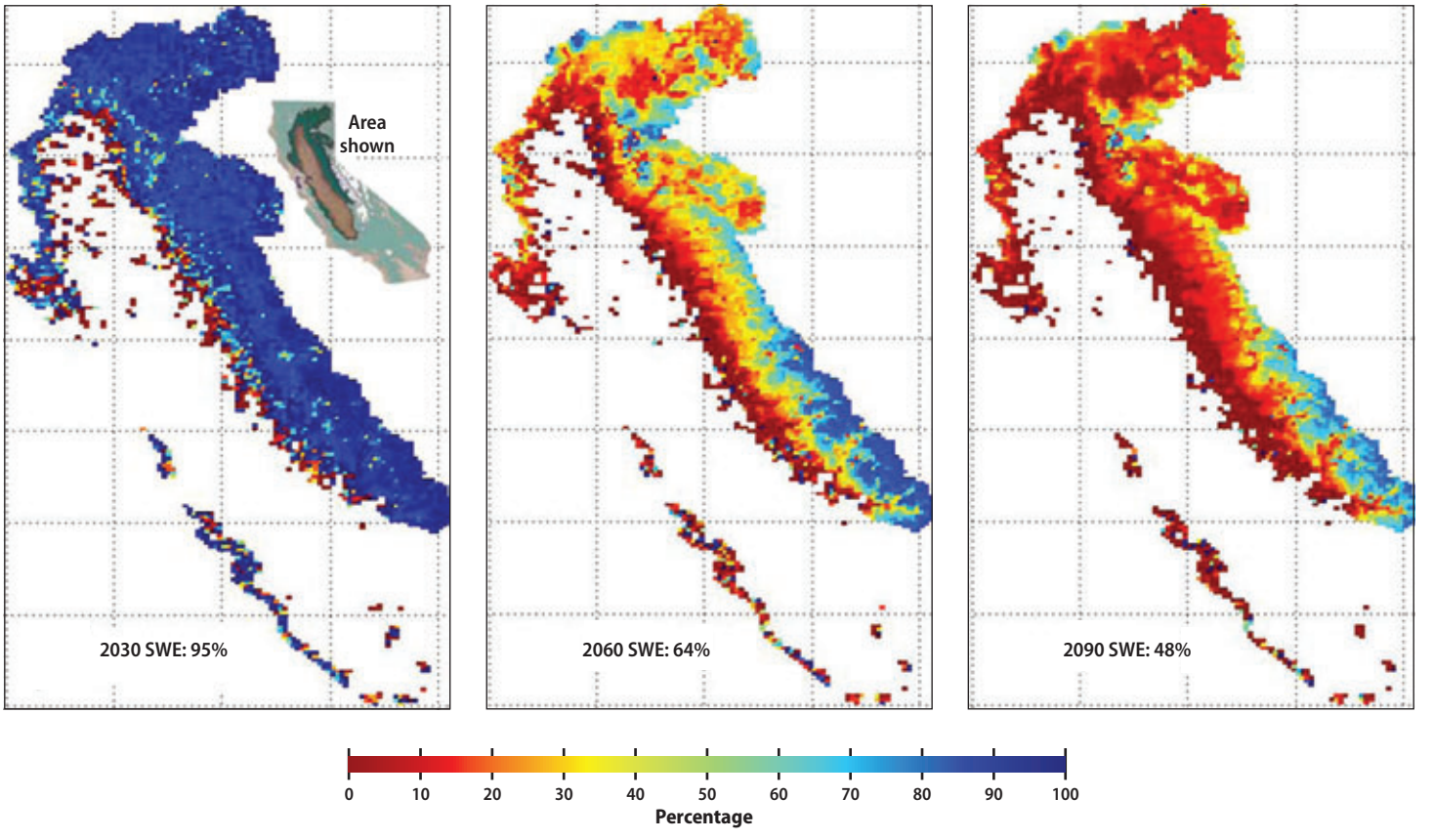
2. Electricity

Management Challenges

California's electricity providers have been significantly adjusting their service delivery in the wake of the 2001 energy crisis, adding measures to improve service reliability, increase demand responsiveness in peak periods, and raise the share of renewable sources in their overall portfolio (Pechman, 2007). These changes are occurring in the context of continued demand growth, including peak demand for cooling in the summer months.

Intense summer heat will increase the electricity system's vulnerability to peak-period power outages, as air conditioning use increases.

Figure 4. April snow water equivalent under projected temperature increases

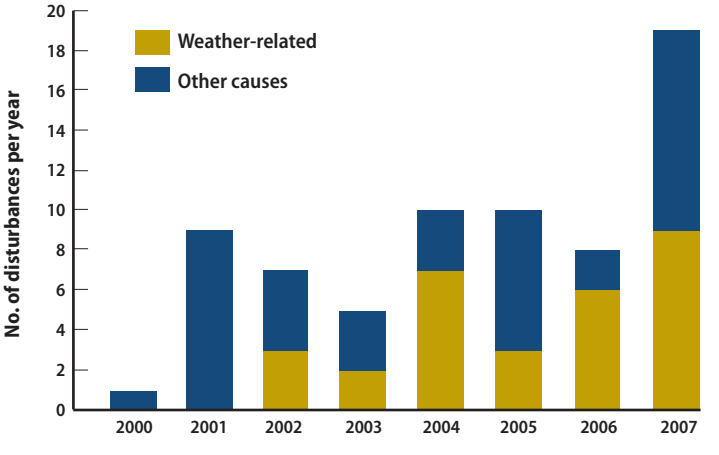


Source: Knowles and Cayan (2002).
Notes: Projected temperature increases: 0.6°C (2020–2039), 1.6°C (2050–2069), and 2.1°C (2080–2099), expressed as a percentage of estimated present conditions (1995–2005). SWE is snow water equivalent.

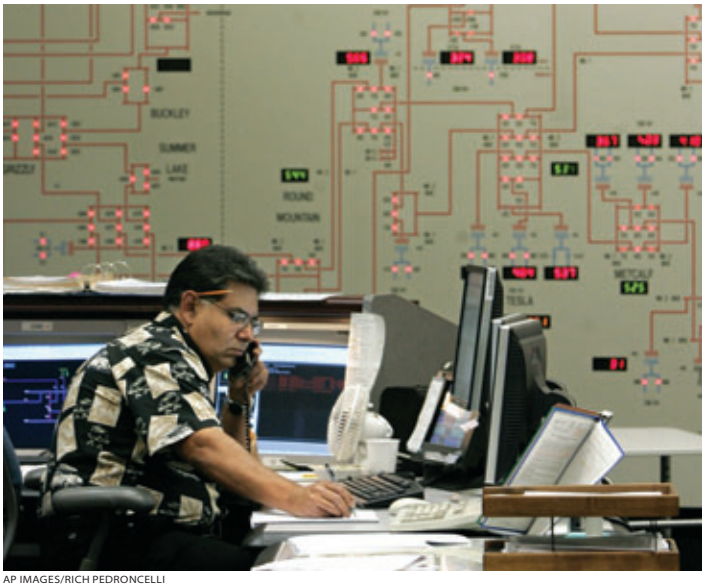
Climate Complications

Although higher winter temperatures will lessen the demand for heating, the largest effects will be felt during the summer. Intense summer heat will increase the electricity system's vulnerability to peak-period power outages, as air conditioning use increases. Meanwhile, the declining snowpack could reduce the availability of hydroelectric power, a preferred source of peak-period electricity. More extreme weather events and an increased incidence of wildfires may also increase risks to the transmission and distribution system. Weather-related disturbances to the electrical grid are already a significant problem—such as the Southern California fires in 2007 (Figure 5).

Figure 5. Disturbances in California's electrical grid, 2000–2007



Source: U.S. Department of Energy (http://www.eia.doe.gov/cneaf/electricity/page/disturb_events.html).
Note: Weather-related disturbances include storms, wildfires, and heat events.



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Authorities assess the effects of heat waves on the state's power supply.

Climate Change Awareness

Electricity providers and state regulatory agencies are leaders in assessing climate-related risks. This sector is also at the forefront of the state's GHG mitigation efforts (notably efforts to increase energy efficiency and renewable sources).

3. Coastal Resources

Management Challenges

In 2000, three-quarters of a million people lived in the census block groups closest to the ocean and the San Francisco Bay; some 4,600 miles of roadway lie within one-quarter mile of these coastlines.[7] The coast is also a valuable environmental and recreational resource. Coastal management seeks to balance the sometimes competing goals of economic development, public access and recreation, and protection of the ecosystem. Continued coastal erosion from sea level rise and storm surges threatens all three goals, and management solutions often pose difficult tradeoffs among them.

Climate Complications

Accelerating sea level rise and increasing storm surges will put many more coastal areas at risk of inundation, particularly in the San Francisco Bay Area (Figure 6). These forces will also create drainage problems for many coastal wastewater and stormwater systems. Coastal habitat will suffer if it is not given space to migrate inland, and buildings and infrastructure will be lost without an increase in protective barriers.

Climate Change Awareness

The state's two regional authorities for coastal oversight—the Coastal Commission and the San Francisco Bay

Figure 6. Projected Central and South San Francisco Bay sea level rise

Source: San Francisco Bay Conservation and Development Commission, using elevation data from the U.S. Geological Survey and imagery data from the National Agriculture Imagery Program.
Note: The map is illustrative and depicts a potential inundation scenario with one meter (3.3 feet) of sea level rise.

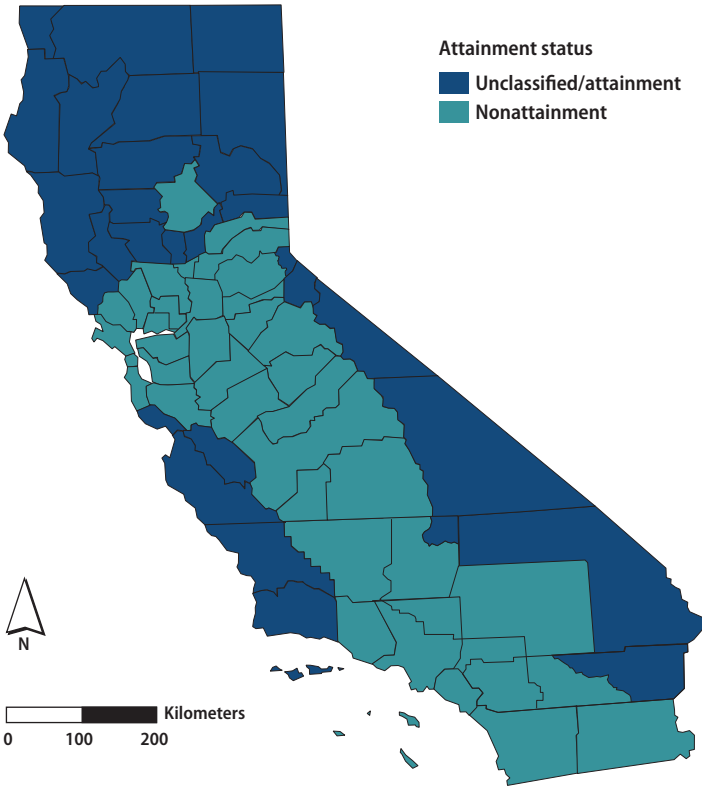
Conservation and Development Commission (BCDC)—are both actively assessing climate risks and informing local communities. Awareness at the local level and among infrastructure providers appears uneven.

4. Air Quality

Management Challenges

Air quality in California poses a major public health threat, linked to high rates of asthma, other respiratory ailments, and cardiovascular disease. Over 90 percent of the state's population live in areas that fail to meet at least one of the federal air quality standards (Figure 7). The San Joaquin Valley and the South Coast have the highest rates of ozone in the nation, and all of the state's major metropolitan areas are in violation of the federal fine particulate matter standard. California's state and regional air quality planning agencies design and implement emission reduction programs for industry, transportation, and other sectors to meet state and federal air quality standards—a difficult task under current conditions and even more challenging with continued population growth.

Figure 7. California areas out of attainment with the federal eight-hour ozone standard



Source: U.S. Environmental Protection Agency (2008).
Note: Figure shows attainment status under the 1997 standard. This standard was updated in 2008.

Climate Complications

Higher temperatures will increase the frequency and severity of ozone air pollution episodes, making it difficult to meet air quality standards without larger emission reductions. These additional emission reductions and the cost that they entail are called the "climate penalty." Increased demands for electricity during extreme heat events could add to emission levels, compounding the difficulty of meeting standards. Other extreme events, such as more frequent wildfires, could also negatively affect air quality.

Higher temperatures will increase the frequency and severity of ozone air pollution episodes, making it difficult to meet air quality standards without larger emission reductions.

Climate Change Awareness

The California Air Resources Board is the lead agency for the state's climate activities. However, climate change receives limited attention at the regional level: Meeting air quality standards in the near term is the primary focus of most air quality planning agencies. Some air districts have undertaken climate-related programs, but this is the exception.

5. Public Health

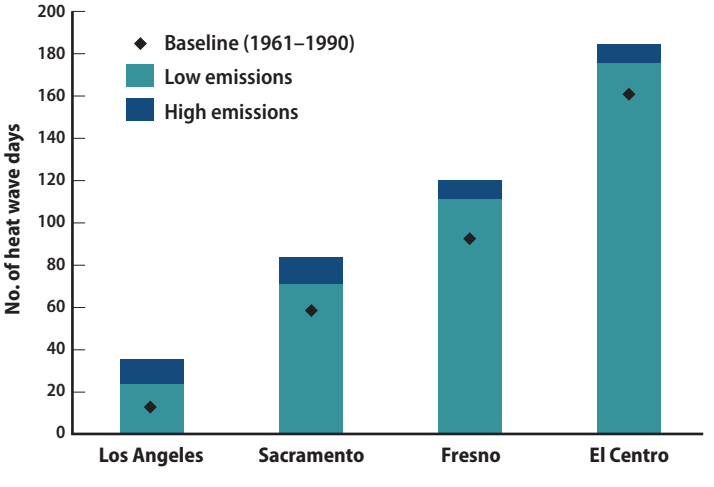
Management Challenges

California is home to over 35 million people, including many (for example, the elderly and those living in poverty) who are especially vulnerable to public health risks. Public health agencies in California are responsible for protecting and enhancing human health through outreach, education, and direct services. Each county in California, as well as three cities, has its own local health agency. The California Department of Public Health was recently created to focus public health activities at the state level.

Climate Complications

Higher temperatures will increase the number of extreme heat events and associated heat-related morbidity and mortality, straining the emergency medical response functions of public health agencies and requiring additional outreach and resources for vulnerable populations (Figure 8). An increase in wildfires and floods will pose additional challenges. Climate change could also contribute to shifts in the ranges and prevalence of vector-borne diseases as well as the emergence of new diseases.

Figure 8. Projected increase in the number of heat wave days by the middle of the 21st century compared to historic levels



Source: Hayhoe et al. (2004).
Note: Heat wave conditions are defined as three or more days with temperatures greater than 90°F (32°C).

Climate Change Awareness

Over 90 percent of local health officers surveyed in 2007 believe that climate change poses a very or somewhat serious threat to public health, but over 60 percent feel that they lack adequate resources or information to respond. The California Department of Public Health has an internal working group on climate change issues, but is not very involved in the state's broader climate activities.

6. Ecosystem Resources

Management Challenges

California's rich natural heritage is already heavily compromised by 150 years of economic development: More than 30 percent of the state's native plants and 15 percent of its native vertebrate wildlife (fishes, mammals, birds, reptiles, and amphibians) are at risk of extinction. Federal and state environmental laws established since the 1970s aim to protect endangered species by restricting development in sensitive areas, and Californians continue to invest heavily to protect open space and habitat.

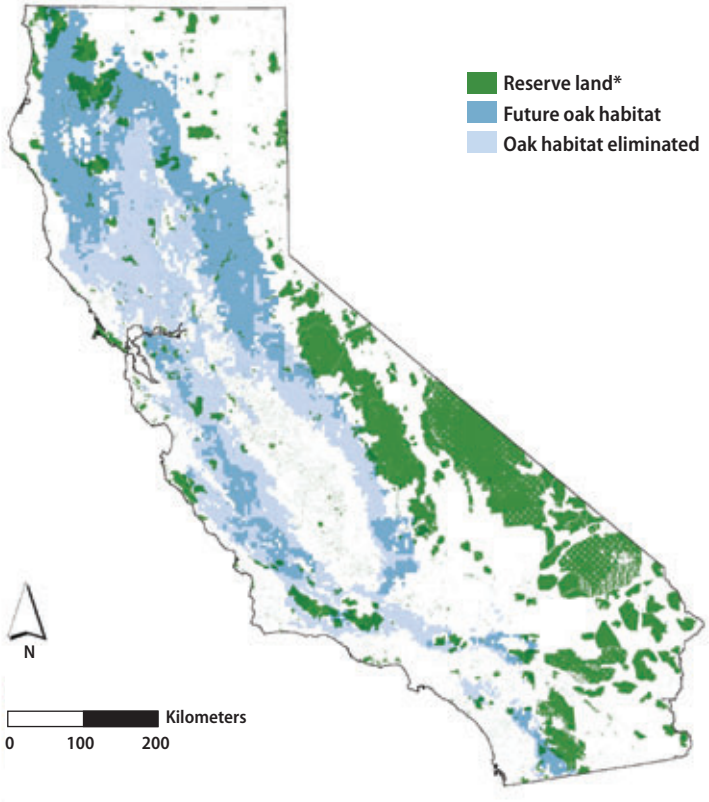
Rising air and water temperatures will alter the habitat conditions for many species, forcing terrestrial species to seek cooler temperatures at higher elevations or along the coast and forcing coastal aquatic species to migrate inland as the coastline erodes.

Climate Complications

Rising air and water temperatures will alter the habitat conditions for many species, forcing terrestrial species to seek cooler temperatures at higher elevations or along the coast and forcing coastal aquatic species to migrate inland

as the coastline erodes. These changes will exacerbate other challenges facing native species, including competition with alien invasive species, effects from pollution, and fragmented habitat. If habitat conservation planning does not take these climate shifts into account, the wrong lands may be protected, with development allowed to occur in areas that would be most beneficial for species conservation (Figure 9).

Figure 9. Projected blue oak range shifts with climate change



Sources: Kueppers et al. (2005) (oak habitat); Department of Forestry and Fire Protection (land management status).

*Includes national and state parks, wilderness areas, private reserves, and other areas where conservation is a primary management objective.

Climate Change Awareness

Although awareness of the risks to species and ecosystems is growing in the scientific and environmental communities, the legal framework for species protection does not take climate change into account.

Adaptation Strategies: Tools and Timing

This review of the science suggests that climate change in California—at least over the next century—is likely to be experienced largely as an accentuation of problems we already face. Rising temperatures and more frequent extreme heat waves will likely increase several types of health risks, air quality violations may increase in frequency, more prolonged heat waves may put vulnerable populations at greater risk, and vectors of insect-borne diseases may spread. More intense summer heat will also increase the use of air conditioning and the electricity system's vulnerability to peak-period power outages. A reduced Sierra Nevada snowpack will heighten the existing management challenges from seasonal and interannual rainfall variability and increase seasonal flood risks. Sea level rise will accelerate coastal erosion, threaten Delta levees, and accentuate the existing tradeoffs between economic development and coastal ecosystem conservation. These same tradeoffs will become increasingly apparent across California, as rising air and water temperatures compound the already compromised state of many native species habitats.

However, familiarity with the problems should not foster complacency, because the changes California faces are real. Two questions are central to building an effective

LESTER LEFKOWITZ/CORBIS

California is home to some of the worst air quality in the nation.

adaptation strategy: What types of tools should be employed? And when is the best time to employ them? These are not always easy questions to answer, given the uncertainties in the size and timing of climate impacts. But the way society tackles them will affect both the costs of an adaptation strategy and its effectiveness in reducing risk.

Elements of the Toolkit

Adaptation tools generally fall into one of two categories: investments in infrastructure or technology ("physical" tools) and changes in management approaches or incentives ("behavioral" tools). Table 1 summarizes key elements of the adaptation toolkit for our six areas of concern, along with key implementation challenges. Because many potential climate impacts have required attention under current circumstances, California will not need to start from scratch. Over the past two decades, water supply planners have gained considerable experience with diversifying supply portfolios to cope with variable rainfall and meet the demands of a growing population. Likewise, electricity providers have been pursuing various strategies to reduce the threat of peak-period blackouts, including demand management and real-time pricing. Programs to monitor and control insect-borne vectors are well-established across most of California, and many local public health agencies have heat emergency plans. Although they are not systematically applied in the field, longstanding principles for conservation reserve management—including protection of consolidated stretches of habitat (or "habitat corridors")—are well-suited to the climate-related challenges facing many species, for whom migration will be necessary as conditions change.

Nevertheless, as the examples in Table 1 illustrate, barriers to adaptation also exist. Barriers can include lack of information on climate-related risks, lack of technical tools for incorporating this information, limitations of institutional authority, funding constraints, and legal and regulatory obstacles. Adaptation can also be made more difficult by the competing goals of interested parties, particularly when difficult tradeoffs are involved.

When to Act?

Ideally, adaptation should be timed to occur when the costs will be lowest.[8] In some cases, there may be straightforward "fixes" that can be put into place fairly quickly, making it unnecessary to undertake large anticipatory investments in the near term. For instance, it would likely take little time to fine-tune and expand heat emergency plan operations as heat waves become more prevalent. The important thing, from the standpoint of institutional readiness, is that public health agencies have set up a process for responding to emerging needs; this process can be scaled up as the climate evolves.

By contrast, some "fixes" are both costly and slow to implement. For example, some potential measures to help California adapt to changes in water conditions involve multibillion-dollar investments in new storage and conveyance facilities. From start to finish, such investments could take a minimum of a decade to build, probably a good deal longer. In such cases, there can be advantages to moving early, as an insurance against climate risk. On the other hand, it can make sense to postpone large investments as long as possible if there are ways to "get by" for an interim period. The water community is currently wrestling with these decisions regarding new surface storage, given the costs and the continued uncertainties regarding some climate impacts for this sector.

Early actions are also warranted to avoid economic and social losses that result from making long-term investments without considering future climate consequences. The longevity of many real estate and infrastructure

Early actions are also warranted to avoid economic and social losses that result from making long-term investments without considering future climate consequences.

Table 1. Elements of the adaptation toolkit

Area	Tools	Key Issues/Barriers
Water resources	**Physical tools:** *Water supply:* new surface storage, canal around Delta, conservation technologies; *Flooding:* levee and reservoir upgrades, stricter building codes, low-impact development **Behavioral tools:** *Water supply:* water marketing, pricing incentives, groundwater management, changing reservoir operations; *Flooding:* insurance mandates, restrictions on floodplain development, changing reservoir operations	New surface storage is costly and will be less useful if average precipitation falls, given existing capacity. Canal around Delta could benefit species and many water users, but not all Delta farmers. Federal standards on floodplain development and mandatory insurance requirements are low. Federal approval is required to change reservoir operations.
Electricity	**Physical tools:** stricter building codes, innovative energy-saving devices, distributed generation **Behavioral tools:** real-time pricing, incentives for installation of renewable energy (e.g., solar)	Some cost-effective efficiency technologies require large up-front investments by users. Local restrictions are common on renewable energy installations.
Coastal resources	**Physical tools:** coastal armoring (seawalls, levees, etc.), beach nourishment, stricter building and zoning codes, relocation of structures to allow inward migration of coastline, artificial drainage systems for low-lying areas **Behavioral tools:** setback requirements for new development, insurance mandates	Coastal armoring can protect structures but is detrimental to environment and public use. Relocation can be costly to property owners. Local governments do not have guidelines for setting stricter building and zoning codes.
Air quality	**Physical tools:** stricter emissions standards (overall and for peak episodes), new emission reduction programs **Behavioral tools:** public awareness campaigns (e.g., air quality alerts), regional climate change programs, estimating the climate penalty, adopting new approaches and methods for modeling	Focus is on meeting existing standards. Climate change impacts on air quality in specific regions are uncertain. GHG emission reductions measures could conflict with air quality/public health goals.
Public health	**Physical tools:** cooling centers, vector control programs **Behavioral tools:** emergency plans (heat, fire, etc.), disease vector monitoring, public awareness campaigns, assistance for vulnerable groups (e.g., air conditioning subsidies), disease prevention programs	Funding and other resources for adding climate change to portfolio are limited. Practical information on risks of climate change is lacking.
Ecosystem resources	**Physical tools:** habitat corridors, preemptive protection of areas to anticipate future species needs **Behavioral tools:** incentives for "smart growth" land use planning and regionwide multispecies conservation planning (forward-looking)	Habitat protection is often piecemeal. Federal/state regulations do not require climate-sensitive species protection plans. Few incentives are available for regional smart-growth approaches.

investments means that decisions we make today affect our options for many decades into the future. One case in point is locating costly new development and infrastructure in areas that will become increasingly prone to flood or fire risk as the climate changes. Another is failing to introduce building codes that will make these investments less vulnerable. A third is deciding which types of habitat and open space to protect, given that many native species will need to migrate to survive. There are real risks that development decisions will permanently harden coastal and inland landscapes that could serve as valuable habitat corridors. Questions of climate-sensitive development planning echo those arising in the discussions about how to "build greener" to reduce the state's carbon footprint. Not taking steps now spells missed opportunities.

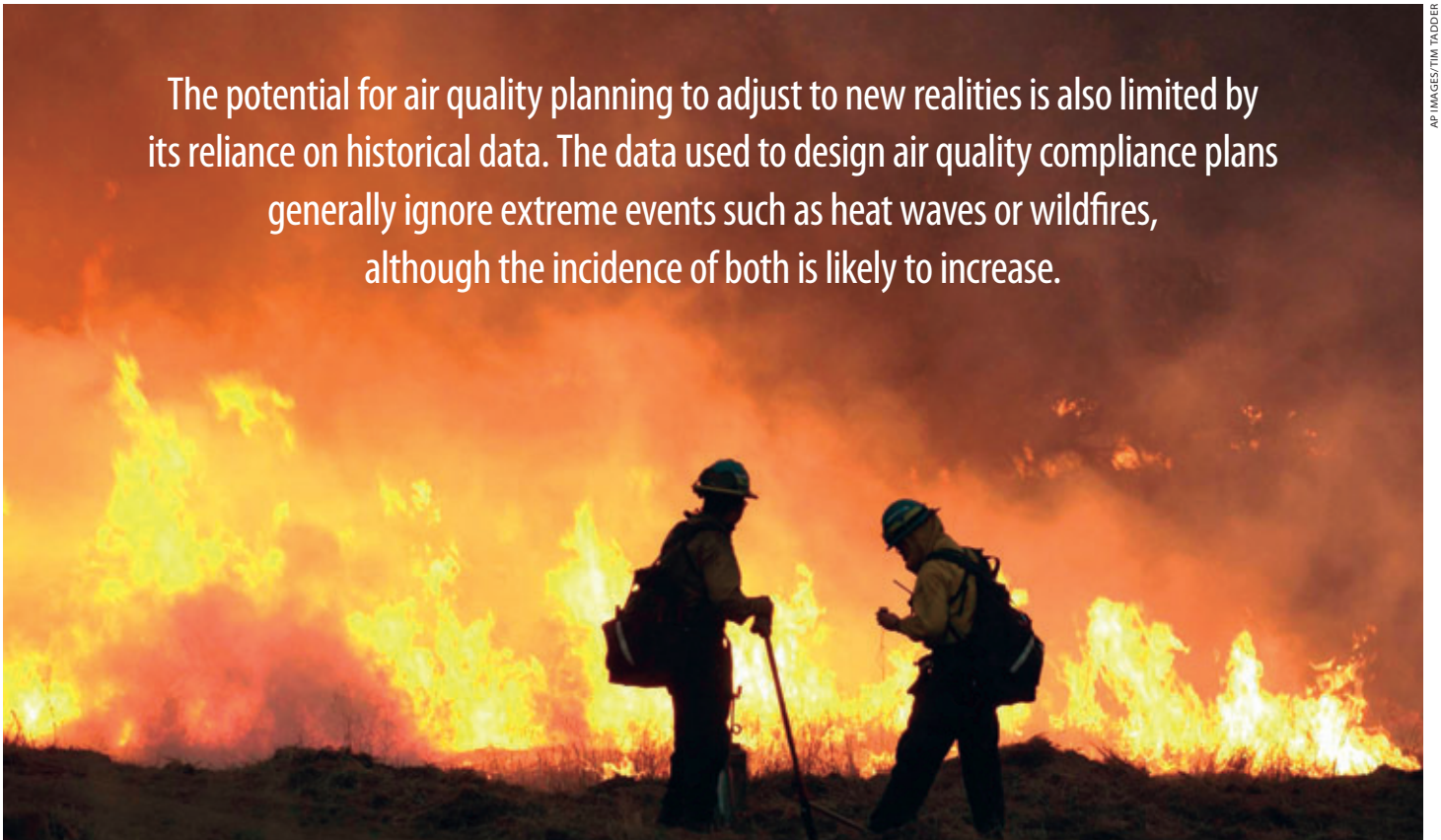
Is California Prepared for Climate Change?

Thanks to the state's initiatives on climate policy, California has a head start compared to many regions in assessing the broad impacts of climate change. Many institutions are already considering the implications of these impacts for their operations, and many tools exist to reduce risk. Yet important barriers remain. Our overall diagnosis can be summarized in terms of four themes:

- **Many institutions are on the right track.**
- **Some key tools and institutions fall short.**
- **Funding constraints compound other challenges.**
- **California's efforts may be constrained by federal policies.**

California's Institutions Are Often on the Right Track

Many institutions are already geared toward dealing with climate-related challenges, whether or not they are explicitly thinking in terms of climate responses. Water agencies and electricity utilities—both of which have direct service obligations to the public—are actively exploring how to increase their resiliency to climate impacts. Although the toolkits of public health agencies were not developed with climate change in mind, they are well suited to the coming challenges. Both regional bodies responsible for coastal oversight—the Coastal Commission and the San Francisco Bay Conservation and Development Commission—have been addressing the challenges of sea level rise.



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In Several Key Areas, Some Tools and Institutions Are Not Up to the Task

Among the areas examined in our study, four exhibit particular difficulties: coastal management, flood management, ecosystem conservation, and air quality planning. With regard to coastal management, there are unresolved constraints to tackling the central challenge: balancing property protection goals with those of habitat protection and public access. The main adaptation tools for protecting existing buildings and infrastructure from coastal erosion and flooding come in the form of coastal armoring (e.g., seawalls and levees). These tools conflict directly with the other public goals. In particular, they prevent the inward migration of coastal wetlands as they are swallowed by the ocean and bay. Coastal policy since the late 1980s has aimed to curb new armoring; but with sea level rise, future pressures to armor will be strong. Alternatives might include softer forms of coastal protection—sometimes called "living shorelines"—and policies that encourage some property owners to relocate. Neither has been well tested in California.

Although many tools are available to manage flood risk, the institutional framework for floodplain management places California in a difficult position. The federal guidelines for flood insurance rates, established by the Federal Emergency Management Agency, have also served as guidelines for where communities can build without restrictions. These standards have been very lax—already putting many homes at considerable risk—and they have been based on historical runoff patterns, which are likely to underestimate future risks. Local governments have had added incentives to build in the floodplains, because their liability for damages is very limited. In addition, the U.S. Army Corps of Engineers has been slow to examine the implications of changing runoff patterns for reservoir management—a key tool for managing risks to existing properties.

The potential for air quality planning to adjust to new realities is also limited by its reliance on historical data. The data used to design air quality compliance plans generally ignore extreme events such as heat waves or wildfires, although the incidence of both is likely to increase. Because an increase in air quality violations is often caused by such events, this modeling gap may lead to an underestimation of the severity of future air quality. It also may reduce the incentives to regional air districts to plan for such events, which are not included in the federal air quality planning process.

Ecosystem conservation may face the greatest challenges of any sector, despite the suitability of some core conservation planning tools.

Ecosystem conservation may face the greatest challenges of any sector, despite the suitability of some core conservation planning tools. Although the past decade has seen the rise of more regional approaches to habitat protection, there are still considerable problems with open space fragmentation—a serious barrier to species migration as natural conditions change. Perhaps an even greater problem is the lack of clear priorities for where to invest available resources for acquiring reserves in light of climate change. Most efforts to date, including those funded by several multibillion-dollar bonds over the past decade, have focused on the current needs of species and habitat without considering the changing conditions. Future investments will need to be more forward-looking, and this may involve making choices to favor habitats and species that have a better chance of prospering at the expense of some species that have limited chances of survival. These decisions could be constrained by the terms of the state and federal endangered species acts, which require attention and resources to be focused on species that are already endangered.

Funding Constraints Compound Other Challenges

The contrasts in institutional capacity and readiness extend to funding. The agencies with relatively healthy finances are in a better position to implement adaptation strategies. For instance, both water and electricity utilities have steady income streams from ratepayers, and their rates can be increased to accommodate needed programs. In contrast, local funding for flood and storm water management, where

climate change will also increase spending needs, cannot be augmented without direct voter approval, generally by a two-thirds majority. Ecosystem conservation programs are hampered by small ongoing budgets for reserve land management and planning activities. State funding needs for habitat acquisitions, largely financed through bonds, are likely to increase. A constrained fiscal environment at the state level has also made it difficult for such agencies as the Coastal Commission to fund climate planning activities.

California's Efforts May Be Constrained by Federal Policies

As the examples above suggest, federal agencies are key players in flood management, air quality planning, and species protection. In some of these areas, federal policies are particularly rigid and backward-looking, making it a challenge for California's institutions to reduce vulnerability to climate change. Recently, the state took the initiative to go beyond federal policies in flood management, with a legislative reform package that aims to impose stricter standards on floodplain development. There are questions about how far California can diverge from federal policies in other areas without changes at the federal level.

What Do We Need to Do Better?

California's state and local institutions can take a variety of steps to prepare for a changing climate. Our analysis has identified the following six areas for action.

- **Improve the basic science on climate impacts.** Although we possess relatively good general information, we need more specific information (e.g., regional or local climate impacts) to support prudent adaptation strategies.
- **Help frontline actors to interpret the science.** State direction can help local actors determine which levels of climate risks to plan for, over which time frames.
- **Determine where early actions are needed.** Early actions are particularly important when a failure to act now will result in much greater cost or reduced flexibility in the future.
- **Refine existing adaptation tools and experiment with new ones.** Enhancing the adaptation toolkit is an important early action, across the board.
- **Strengthen the incentives for coordinated actions.** Many adaptation measures require regional responses. Some require federal cooperation. The state can facilitate coordination.
- **Make legal and regulatory adjustments to facilitate adaptation.** Although much can be done within the existing framework, some changes will be needed.

Improve the Basic Science on Climate Impacts

California has already benefited from scientific efforts to assess the impacts of climate change, but more work is needed to provide actionable information to planners and decision-makers. Two broad types of efforts will be helpful. First, to the extent feasible, we need to reduce the uncertainties in estimates of the fundamental impacts of climate change in different parts of the state—air and water temperatures, precipitation patterns, sea level rise, and storm surges. Second, we need to develop more specific information about the implications of these changes for different sectors and regions.

There is already a solid framework for conducting this work, through the biennial Statewide Assessment and scientific efforts supported by the California Energy Commission. More input from sectoral and regional actors could help to identify important questions to be addressed. The Climate Action Team, whose membership includes many departments and agencies, can play a useful role in soliciting this input. To date, much of the focus of the Climate Action Team has been on mitigating greenhouse gas emissions. As the state's focus on climate policy expands to include adaptation to climate impacts, the Climate Action Team should be expanded to include agencies that do not have a role to play in mitigation efforts but that can play an important role on the adaptation side. In particular, the Department of Public Health and the Department of Fish and Game should become members of the Climate Action Team.[9] It would also be valuable to include university participants to bolster the scientific capabilities of the team. The sidebar lists some of the priority areas for research.

Priority areas for research on climate impacts

Improved climate projections

1. Develop more precise forecasts of changes in air and water temperature, precipitation patterns, sea level rise, and storm surges in different parts of the state.

Better sectoral and regional assessments of climate impacts

1. Assess the effects of increases in temperature on water quality for humans and aquatic species.
2. Analyze the implications of changes in precipitation runoff patterns for reservoir operations (flood management and water supply).
3. Analyze the implications of average temperature increases and extreme weather events for electricity system resiliency, with a supply-side focus on hydroelectricity, wind, and solar and a demand-side focus on short- and long-run patterns of electricity consumption.
4. Improve understanding of the effects of accelerated sea level rise and storm surges on coastal bluff erosion rates.
5. Quantify the "climate penalty" for air quality (i.e., the effects of increased temperatures on air pollutant concentrations).
6. Conduct more detailed local and regional analysis of the public health impacts of climate change.
7. Assess likely climate impacts on California species and ecosystems and identify key data gaps.

Institutional linkages

1. Use the Climate Action Team to generate scientific information needs from sectors and regions.
2. Incorporate the Department of Public Health and Department of Fish and Game, as well as university scientists, in the Climate Action Team.

Help Frontline Actors to Interpret the Science

In addition to working with local and regional agencies to help identify scientific information needs, state agencies can play an essential role in helping these frontline actors to interpret the science. What levels of sea level rise or temperature changes should local agencies and infrastructure providers plan for, over what time horizons? What steps should local agencies take to prepare for such changes? Although a few local agencies have taken the initiative to use specific forecasts, it is generally difficult for them to sort through the various projections to determine what it should mean for their activities.

By weighing in, the state can also provide necessary support to agencies when there may not be sufficient local public consensus on the importance of planning for climate change. Several agencies interviewed for this study highlighted this need: With guidelines from the state about planning for sea level rise, for instance, they will have some protection from lawsuits if they change codes to make new buildings less vulnerable to coastal flooding.

A new state law requiring that California Environmental Quality Act (CEQA) guidelines be updated to incorporate climate change issues by 2009 is a useful step in this direction.[10] However, the new guidelines are not likely to contain specific benchmarks or guidelines, but rather only general principles on what local agencies should address. Other state-level actors will need to step in with guidelines and benchmarks on the science itself. One recent move in this direction is the request by officials in the Resources Agency for guidance on sea level rise projections from an independent scientific advisory board (Mount, 2007). To carry more weight at the local level, state agencies should not only commission this type of analysis but also ensure that it is disseminated widely, ideally with explicit recommendations from the agency itself.

Determine Where Early Actions Are Needed

Because many anticipated effects of climate change will take some time to be felt, not all adaptation measures need to be taken now. However, it is important to act now to identify where early actions are needed. Early actions are particularly important when a failure to act now will greatly increase cost or reduce flexibility in the future. Our analysis highlights two important areas.

First, there is an urgent need to map out a strategy for protecting habitat to facilitate the adaptation of terrestrial and aquatic species to changing climatic conditions. This forward-looking strategy will likely result in some different decisions about which areas to protect, as compared to often-fragmented restoration efforts to date. In addition to helping devise these strategies, the state can orient available

bond funds for open space acquisition as part of this forward-looking strategy. This task is urgent because land development pressures will make it increasingly difficult, if not impossible, to safeguard these areas in the future, when they will be most needed.

Second, California must take steps now to avoid putting new long-term investments in harm's way. This issue has already arisen for investments in floodplains under current conditions, and it will become increasingly important as flood risks increase with changing winter runoff, sea level rise, and higher coastal storm surges. The dangers go beyond putting lives and property at risk; these investments will also generate political pressure to expand flood protection investments in ways that will conflict with coastal and riverine habitat protection and public access to the coast.

Because more than 4,600 miles of roadway lie within one-quarter mile of the coastline and several state highways cross the fragile Delta islands, Caltrans and regional and county transportation agencies should be particularly mindful of coastal flood risks when making investment decisions. To date, there has been no assessment of the extent of these risks and the implications for transportation investment plans. Caltrans should take the lead on this effort, in association with regional and local agencies.

Refine Existing Adaptation Tools and Experiment with New Ones

Across the board, now is also the time to take stock of existing adaptation tools, to refine them where necessary, and to experiment with new tools, so that they are ready when needed. The sidebar highlights some of the strategies that deserve attention in the six areas we have examined in this study. Often, the focus will need to be not only on the technical aspects but also on the behavioral aspects—overcoming institutional barriers to new approaches and increasing their acceptability to businesses and households.

Strengthen the Incentives for Coordinated Actions

As some of the examples above illustrate, information exchange is essential for developing and refining approaches to cope with the effects of climate change. In addition, more formal types of coordination will often be necessary. To be effective, many adaptation tools require regional approaches. Regional interconnections linking local water supply systems can build in resiliency to drought and other emergencies. Better management of the state's groundwater basins—a key resource in the face of changing conditions—requires effective coordination among different agencies overlying the basins. To build habitat corridors—a tool to facilitate species migrations—local governments and other agencies need to coordinate their habitat conservation planning efforts. To help chart

Priorities for refining and developing adaptation tools

1. **Water resources:** Experiment with long-term options for water transfers to manage shortages and with changes in reservoir operations to enhance water supply and flood management capabilities. Refine low-impact development techniques in different parts of the state to cope with more extreme precipitation events.
2. **Electricity:** Assess and refine strategies to enhance system resilience, including regional interconnections, distributed generation, and technologies and services for space cooling. Learn from local efforts to facilitate renewable energy and energy efficiency through regulatory reforms (e.g., ordinances, standards, permitting fees).
3. **Coastal resources:** Experiment with "rolling easements" to allow wetlands migration in areas of high ecological value. Experiment with living shoreline techniques as an alternative to coastal armoring in the San Francisco Bay.
4. **Air quality:** Develop modeling scenarios that incorporate extreme heat events and assess possible responses to increased air quality violations. Draw lessons from regional air district efforts to incorporate climate change.
5. **Public health:** Refine local heat emergency plans, drawing on experiences from within California and elsewhere. Identify priorities for health tracking with climate change.
6. **Ecosystem resources:** Develop adaptive management and monitoring plans for at-risk species and ecosystem health. Develop a toolbox for forest and rangeland managers to evaluate priorities in different areas (economic value, biodiversity).

Because more than 4,600 miles of roadway lie within one-quarter mile of the coastline and several state highways cross the fragile Delta islands, Caltrans and regional and county transportation agencies should be particularly mindful of coastal flood risks when making investment decisions.

the future of an expanded San Francisco Bay, a wide range of local governments, agencies, and stakeholders will need to participate in an assessment of opportunities and tradeoffs. In some sectors, such as electricity, there are already good lines of communication among different players. In others, notably habitat protection, much needs to be done to improve the lines of communication and to implement coordinated actions.

Coordination will also be valuable across sectors, given the important overlaps and the potential for complementarities or conflicts. Water supply and flood control are largely managed separately, but both activities would benefit greatly from modifying reservoir operations in response to changes in the snowpack. Collaboration between electricity providers and public health agencies could aid the development of programs to protect vulnerable populations during heat emergencies. So, too, would collaboration between electricity and water utilities, because water use is energy-intensive. Local land use decisions (zoning, building codes) have implications for adaptation needs across a wide spectrum: habitat, water and energy use, and susceptibility to floods and wildfires, to name a few.

Often, state agencies will need to be active participants in these efforts. In addition, the state can promote coordination among local and regional entities through financial and regulatory incentives. A very useful model is apparent in the water sector, where the state has directed bond funds toward collaborative planning and management efforts. Competition for these funds has been a powerful incentive for local agencies to coordinate their efforts. State leadership will also be needed to help bring federal agencies into adaptation efforts.

Make Legal and Regulatory Adjustments to Facilitate Adaptation

To date, most of the state's legislative actions on climate policy have focused on mitigation efforts. However, there has been a recent uptick in legislative proposals to address adaptation. For instance, AB 1066 would have instructed local and regional agencies to address the implications of sea level rise for coastal resources, and AB 224 proposed similar measures for state and local water agencies. Likewise, the California Resources Agency has recently begun to develop an integrated climate adaptation strategy.[11] Going forward, the legislature and the administration should augment their focus on adaptation needs. Although much can be done within the existing framework, some legislative and regulatory changes will be needed at the state, federal, and local levels. The sidebar on the next page summarizes some key issues for the six areas examined in this study.

Toward an Integrated Climate Policy

Given the urgency of actions to limit global warming, California's initiatives to reduce greenhouse gas emissions have naturally been the top priority of the state's leaders. At the same time, California's institutions need to prepare for some amount of warming and its associated effects on air and water temperatures, precipitation, sea level rise, and extreme events. Policymakers should consider mitigation and adaptation issues in tandem.

Our analysis suggests that although these two policies are often complementary, this is not always so (Table 2).

Legal and regulatory changes to facilitate adaptation

1. **Water resources:** Conduct flood risk analysis with forward-looking hydrology (federal action may be required). Reconsider reservoir operation rules (federal action). Modify zoning and building ordinances to accommodate extreme precipitation (local action, state should encourage). Reform constitution to make it easier for local flood and stormwater agencies to raise revenues (state action).
2. **Electricity:** Modify building standards and codes for energy efficiency, facilitate use of renewable energy sources (local and state action).
3. **Coastal resources:** Expand the BCDC's authority beyond 100-feet of coastline to enable proactive steps on Bay expansion (state action). Require assessment of sea level rise by Caltrans (state action). Require that local governments update local coastal plans to account for accelerating sea level rise and coastal erosion (state action). Modify local building codes to take into account sea level rise (local action, state should encourage). Set guidelines on sea level rise projections for infrastructure and land use planning (state action). As in 1, reform rules on local flood and stormwater funding.
4. **Air quality:** Authorize local air districts to incorporate climate change into air quality plans (federal action may be required). Provide incentives to do it (federal and state action).
5. **Public health:** Tie the system into the state's climate planning by incorporating the Department of Public Health in the Climate Action Team (state action).
6. **Ecosystem resources:** Require habitat conservation plans to consider climate change effects on species and habitat (state action, federal action may be required). Require that regional transportation plans coordinate their actions with habitat conservation plans (state action). Establish a dedicated funding stream for ecosystem conservation (state action).

There are very positive overlaps in the energy sector, where efforts to reduce emissions simultaneously improve the system's resiliency during peak-demand periods. Although water use efficiency gains present similar benefits, some adaptation strategies in this sector, such as recycling and desalination, could increase the average profile of emissions by increasing energy use. Conversely, planting shade trees can lower home cooling needs, but this may come at the expense of higher water use. Similar water use issues can arise for biofuels production.

Habitat and reserve management presents both opportunities and challenges. The set of land use strategies commonly known as "smart growth"—with a focus on higher densities and transit-oriented development—can benefit habitat while reducing emissions from transportation and water use. Forestry provides significant opportunities for sequestering carbon, but this strategy needs to be mindful of biodiversity goals lest it harm, rather than help, California's native tree species. In sum, although it is desirable to find strategies that serve both mitigation and adaptation functions, it is important to be attentive to the potential conflicts. If the mitigation policies that California adopts are too rigid, we may limit our ability to adapt to the impacts of warming.

As Table 2 also shows, some well-entrenched policies are likely to be detrimental to both adaptation and mitigation efforts. The traditional pattern of suburban development generates higher water and electricity needs than more compact, transit-oriented development and results in higher emissions from vehicle use. Development in floodplains is not only risky for lives and property; it also increases energy loads for drainage systems. More generally, California's current growth trajectory, where at least half of all new growth over the coming decades is expected to occur in the hotter inland regions, raises challenges for adaptation and mitigation, because it generates higher energy and water demands. For this reason, some Bay Area leaders have recently called for a reassessment of the region's growth barriers, because denser development in coastal counties (at a safe distance from the coastline) could tackle both prongs of climate policy at once (King, 2008).

Mitigation: A Pathway to Local Adaptation Efforts?

California should also consider how to use the current focus on mitigation as a pathway to increasing local awareness of the need to prepare for a changing climate. In the

Table 2. Complementary and conflicting actions in adaptation and mitigation efforts

Favorable actions ⟷ Unfavorable actions

Favorable for adaptation and mitigation efforts	Favorable for mitigation, but unfavorable for adaptation efforts	Favorable for adaptation, but unfavorable for mitigation efforts	Unfavorable for adaptation and mitigation efforts
Energy demand management Energy efficient buildings Water conservation Biodiversity-oriented forestry "Smart growth" Development in cooler regions	Forestry with non-native species Urban forestry (shade trees) with high water demand Some biofuels production	Meeting peak energy demand with fossil fuels Wastewater recycling and desalination Groundwater banking Increased air conditioner use Use of drainage pumps in low-lying areas	Development in floodplains Traditional "sprawl" development Development in hotter regions

past few years, California's local governments have begun to invest considerably in implementing more climate-friendly policies, and these efforts are likely to increase as the implementation of AB 32 proceeds. As of this writing, roughly one-quarter of the state's cities have signed the U.S. Conference of Mayors' Climate Protection Agreement, and many have also signed on to the global climate protection program of ICLEI, an international nonprofit group that helps local governments adopt more environmentally sustainable programs.

Results of a recent PPIC survey of California's cities and counties point to a significant discrepancy between mitigation and adaptation efforts: Whereas roughly three-quarters of respondents reported climate change–related activities, fewer than half as many had begun consideration of potential climate impacts in their communities (Hanak et al., 2008).[12] These findings suggest that California's local governments are lagging behind the general population in concern about this issue. They also suggest that California may be able to tap the energy of local mitigation efforts to encourage adaptation planning. As local governments share experiences on how to reduce emissions, they can also begin to explore approaches to adapt to climate impacts. There are also potential benefits from regional climate planning efforts that look at both issues together. The state can encourage these efforts by providing regional grants for climate planning.

In the end, many policies that are adopted in the climate arena will aim to influence the actions of individual Californians. Ideally, the suite of mitigation policies that the state adopts will encourage California homes and businesses to reduce their emissions in the least costly way possible. By the same token, adaptation policies should aim to send the right signals to California residents about the need to make adjustments. Both regulatory measures (such as building codes) and financial tools (such as pricing) can help to get the incentives right for decisions about coastal development and armoring, water and energy conservation, floodplain development, and habitat protection. The challenge before California's institutions is twofold: to find the political wherewithal to take on this task and to arrive at workable solutions. Forward-looking approaches by California's policymakers have already made the state a leader in efforts to mitigate the effects of global warming. With similar attention to adaptation needs, California also has the opportunity to become a leader in developing tools and approaches to manage the risks posed by the warming that we are unable to prevent. ●

Notes

[1] For details on proposed measures, see the proposed "scoping plan" for the implementation of AB 32 (California Air Resources Board, 2008).

[2] The California Energy Commission completed the state's first assessment of climate change impacts in 1989 and conducted several assessments in subsequent years (Franco et al., 2008).

[3] A complete list of PIER climate change reports can be accessed at http://www.energy.ca.gov/publications/searchReports.php?pier1=Climate%20Change.

[4] For a summary of the first statewide assessment, see Cayan et al. (2006). Much of this research now appears in a special issue of the journal *Climatic Change* (Vol. 87, Supplement 1, March 2008). For information on the second statewide assessment, see http://www.climatechange.ca.gov/research/2008_assessment/index.html.

[5] Uncertainties in climate projections arise from several factors: (1) uncertainty about which emissions scenario will be adopted, (2) incomplete scientific understanding of how the climate system responds to a particular emissions scenario (or level of GHG concentration), and (3) complexities in translating the predictions of global climate models to the regional and local scales where impacts will be felt (Luers and Mastrandrea, 2008).

[6] These projections take into account the recent acceleration in global sea level. The projections of the 4th Intergovernmental Panel on Climate Change (Meehl et al., 2007) are somewhat lower but are based on models that are not able to account for this acceleration.

[7] In densely populated areas, coastal block groups extend roughly one-quarter mile inland. In less dense areas, they can extend more than 10 miles inland.

[8] See Schneider, Easterling, and Mearns (2000); Yohe (2000).

[9] Other agencies with important adaptation roles are already members, including Caltrans, the Air Resources Board, the Department of Parks and Recreation, the Department of Water Resources, the State Water Resources Control Board, the Department of Food and Agriculture, and the Department of Forestry and Fire Protection (http://www.climatechange.ca.gov/climate_action_team/members.html).

[10] This requirement was introduced under Senate Bill 97 in 2007. This law also requires the updating of CEQA guidelines to account for project impacts on GHG emissions.

[11] For information on this strategy, see http://www.climatechange.ca.gov/adaptation/.

[12] Similar results were in evidence in a recent survey by the Governor's Office of Planning and Research (2008). Thirty percent of respondents indicated that they require a CEQA analysis of the impacts of a project on global warming (a mitigation focus), whereas only half as many require an analysis to assess the impacts of global warming on the project (an adaptation focus). In almost all cases, communities with an adaptation policy also had a mitigation policy.

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