CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

Climate Action Team Report to Governor Schwarzenegger and the Legislature

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In addition to setting targets for the state, the EO placed Cal/EPA in the lead to coordinate efforts to meet these targets among the following agencies: Business, Transportation and Housing Agency (BT&H), Department of Food and Agriculture (CDFA), Energy Commission (CEC), Resources Agency, and Public Utilities Commission (PUC). A coordinated effort is essential to success in climate change emission reduction strategies. Programmatic, incentive-based, or market-based strategies will require the efforts of agencies whose purview stretches across all sectors of the economy, from transportation to energy to agriculture to waste management.

Finally, the EO directed Cal/EPA to lead an evaluation of the impacts of climate change in California, mitigation strategies to reduce emissions, and adaptation measures that can be taken by the state to best respond to the adverse impacts of climate change. This effort is built upon the work of the CEC under the Public Interest Energy Research plan.

The CEC is currently about half way through a five-year plan that responds to many of the same directives included in the EO. Cal/EPA worked with CEC and other agencies to incorporate a broader scope and provide the Governor and Legislature with a mid-point estimate of what California can expect as a result of climate change and how the state can best respond to the adverse consequences.

3.3 Climate Action Team

In response to the EO, the Secretary of Cal/EPA created the Climate Action Team (CAT). The CAT includes knowledgeable representatives from Air Resources Board; Business, Transportation, & Housing; Department of Food and Agriculture; Energy Commission; California Integrated Waste Management Board (CIWMB), Resources Agency, and Public Utilities Commission (PUC). The CAT has prepared a recommended list of strategies for the state to pursue to reduce climate change emissions in the state. This list in described in detail in Section 0. The CAT has also contributed to and reviewed the scenario analysis described in Section 4.

There are two subgroups of the CAT, the market-based options subgroup and the scenario analysis subgroup. Both subgroups are made up of representatives appointed by the CAT and experts as appropriate. The market-based options subgroup was created by the Secretary of Cal/EPA because of the cross-cutting nature of a market-based program for the state. The scenario analysis subgroup addressed the directive in the EO to evaluate the impacts of climate change on the state and adaptation measures that can be taken by the state to best prepare for the adverse consequences of climate change.

4 SCENARIO ANALYSIS

In California and throughout western North America, signs of a changing climate are evident. Over the last 50 years, observations reveal trends toward warmer winter and spring temperatures, a smaller fraction of precipitation falling as snow instead of rain, a decrease in the amount of spring snow accumulation in lower and middle elevation mountain zones, an advance in snowmelt of 5 to 30 days earlier in the spring, and a similar shift in the timing of spring flower blooms.

These changes are consistent with much broader scale global measures. From 1900 through 1970, the average global temperature rose by about 0.1°F (0.06 °C) per decade, but since then the rate of warming has increased markedly, to about 0.5°F (0.3°C) per decade. During the last 1,000 years, available observations suggest that the 10 warmest years all occurred after 1990. Much of the warming during the last four decades is attributable to the increasing atmospheric concentrations of climate change emissions due to human activities.[1]

It is now evident that even if actions could be taken to immediately curtail climate change emissions, the potency of emissions that have already built up, their long atmospheric lifetimes, and the inertia of the Earth's climate system could produce as much as 1.1°F (0.6°C) of additional warming.[2] As a result, some impacts from climate change are now unavoidable.

For example, studies show that some unique ecosystems, such as coral reefs, and those in artic and alpine regions, have been or will be severely damaged or lost as a result of climate changes already underway.[3] However, depending on the amount of climate change emissions emitted over the next few decades, an opportunity remains to avoid the most severe impacts that are expected with greater rises in temperature.

The scientific community is striving to determine how vulnerable human society and the earth systems on which it depends are to future climate changes. Although no consensus has been reached as to what constitutes "dangerous" climate change, there has been increasing warning about the impacts of global average temperatures rising over 3.6°F (2°C). These include a rapid increase in global hunger, health risks, and water shortages[1]. Temperature rises above

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[1] Hare, W.: 2003, 'Assessment of Knowledge on Impacts of Climate Change – Contribution to the Specification of Art. 2 of the UNFCCC'. Potsdam, Berlin, WBGU - German Advisory Council on Global Change. http://www.wbgu.de/wbgu_sn2003_ex01.pdf

3.6°F (2°C) also increase the risk of abrupt climatic changes such as rapid sea level rise from continental ice including the disintegration of the West Antarctic Ice Sheet.[4]

Linking specific temperature changes—such as the proposed 3.6°F (2°C) dangerous threshold—with particular levels of global warming emissions in the atmosphere, is complicated. Although all climate models project increased temperatures to result from higher concentrations of climate change pollutants, these models vary in their sensitivity of the global and regional temperatures and other climate measures to changes in climate change pollutant concentrations.

For example, temperature rises between 2.7°–8.1°F (1.5°–4.5°C) have been projected for a doubling of the atmospheric CO_2 concentration above pre-industrial levels. This wide range of temperature rise projections is the result of differences in the way the models represent key processes within the climate system, particularly in characterizing clouds which can lead to either damping or reinforcing of global warming.

Society can neither control nor precisely determine the sensitivity of the earth's climate system to rising climate change emission concentrations. As a result, it is critical to carefully consider implications of a range of climate sensitivities when evaluating the risks of climate change and devising policies to manage the one factor we can control: our own climate change emissions.

For example, the United Kingdom (UK) adopted a target to limit the maximum atmospheric CO_2 concentration to 550 parts per million (ppm) and determined that reaching this target would require the industrialized world to decrease emissions by approximately 60 percent by the year 2050.

However, because of the uncertainty in climate model sensitivity, it is unclear if this 550 ppm target will keep global temperatures below a 3.6°F (2°C) dangerous threshold. Although the Intergovernmental Panel on Climate Change (IPCC) suggests that the UK concentration target is consistent with several recent climate model simulations, the 3.6°F upper warming limit under the 550 ppm threshold holds up under the lower- but is exceeded under the higher-climate

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Arctic Climate Impacts Assessment (ACIA) 2004, Impacts of a Warming Arctic - Arctic Climate Impact Assessment, Cambridge University Press, Cambridge, UK sensitivity models. This suggests that a lower concentration target, and therefore greater emission reductions, could be needed.

This chapter summarizes findings of recent analyses that explore the implications of various climate change scenarios for California. The studies focus on comparing the implications of different scenarios of climate change emissions given a range of climate sensitivities. The projections reported are driven by three climate change emission scenarios—a lower emissions, medium-high emissions, and higher emissions scenario.

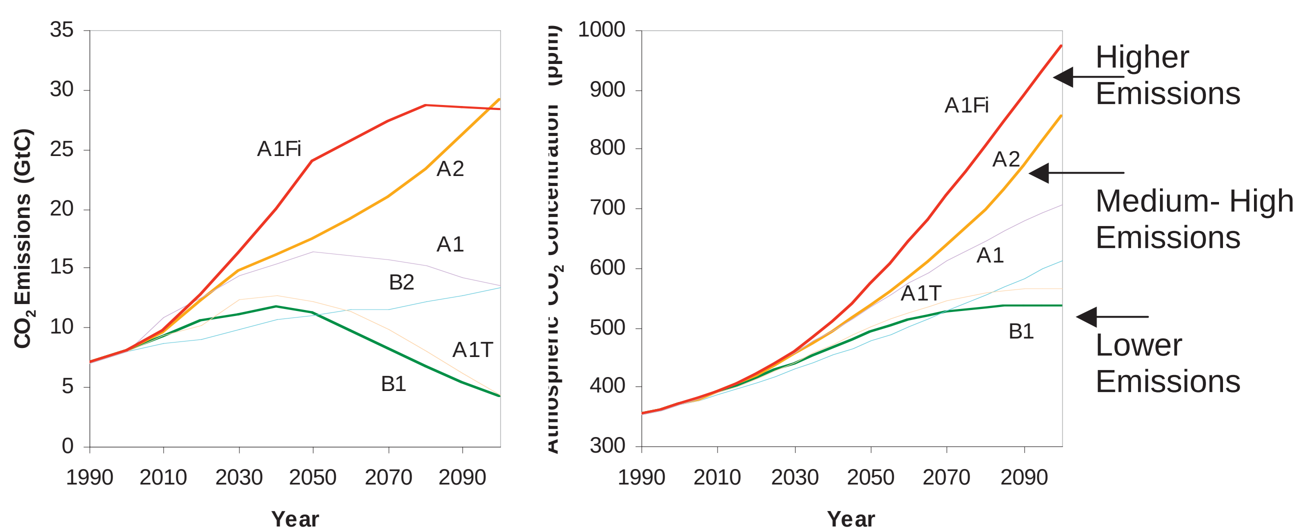
The sensitivity of the climate system to increasing atmospheric concentrations of climate change pollutants is explored by comparing the projected temperature rise from three different global climate models, each containing somewhat different representations of some crucial physical processes that result in levels of climate sensitivity.

The following section describes the global warming emission scenarios and climate projections reported in this chapter. Other sections report on the projected impacts of the specific climate projections across six sectors—coasts, water resources, agriculture, forests/fire, public health, and electricity. The chapter concludes with a discussion of the implications of these projections for mitigation and adaptation.

4.1 Climate Change Scenarios [5]

The Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES) developed a set of possible future emissions scenarios based on different assumptions about global development paths (Figure 4-1). This section relies upon the results from recent analysis for California of three SRES emission scenarios—a higher emissions scenario (A1Fi), a medium-high emission scenario (A2), and lower emission scenarios (B1).

Figure 4-1. Special Report on Emissions Scenarios



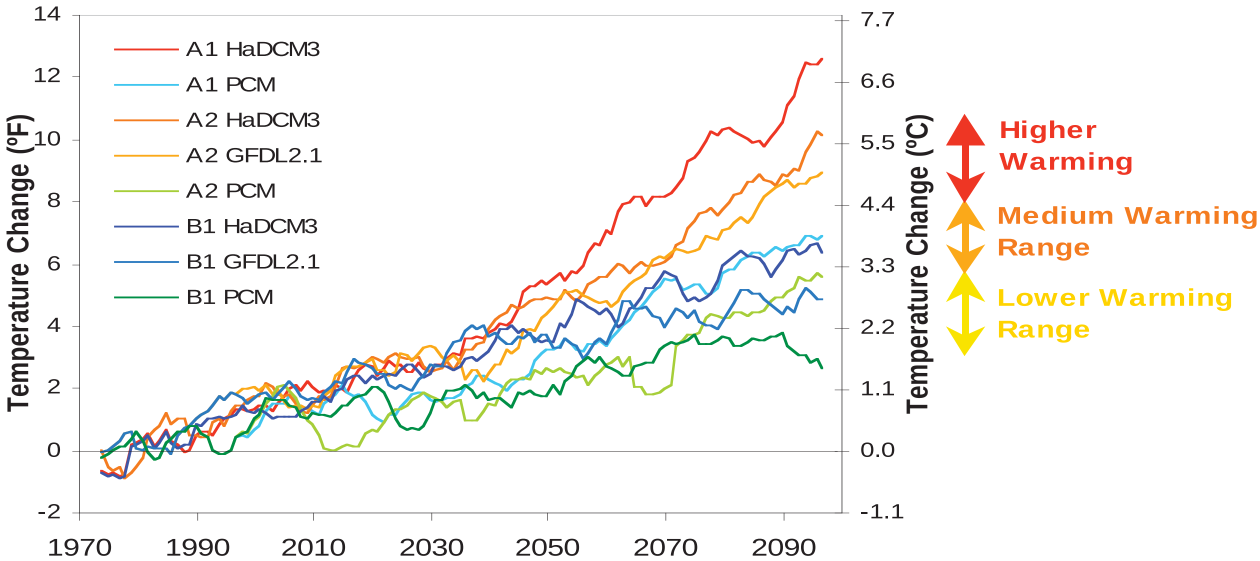
The higher emissions scenario (A1fi) represents a world of rapid fossil-fuel-intensive economic growth, global population that peaks mid-century then declines, and the introduction of new and more efficient technologies toward the end of the century. Global warming emissions grow rapidly, reaching about 25 gigatonnes per year (Gt/yr), more than 3 times the present rate of emissions, by 2050.

The medium-high emissions scenario (A2) projects continuous population growth with slower economic growth and technological change than in the other scenarios. In contrast, the lower emissions scenario (B1) characterizes a world with population growth similar to the highest emissions scenarios, but with rapid changes towards a service and information economy and with the introduction of clean and resource-efficient technologies. The B1 scenario has CO_2 emissions peaking just below 10 Gt/yr in mid-century before dropping below the current-day level of 7 Gt/yr by 2100. Under the B1 scenario, the CO_2 concentration would double, relative to its pre-industrial level, by the end of this century.[6] For the range of climate sensitivities reported on here, the B1 scenario leads to global temperature rises between 1.8-3.1 °C, capturing yet mostly rising above the "dangerous" threshold of 2°C described above. Importantly, in the B1 scenario simulations, while the upward trend of temperature tends to level off or slow down during the last few decades of the 21st Century, in the A2 and A1fi simulations the rising trend in temperature continues at a high rate, indicating that more warming would occur under these higher scenarios before an equilibrium is reached.

To capture a range of uncertainty among climate models, this chapter reports on projections from three state-of-the-art global climate models (GCMs)—a low-sensitivity model, the Parallel Climate Model (PCM1)[7] from the National Center for Atmospheric Research (NCAR) and the Department of Energy (DOE) groups; a medium-sensitivity model, the Geophysical Fluids Dynamic Laboratory (GFDL) CM2.1 (NOAA Geophysical Dynamics Laboratory, Princeton NJ)[8] model; and the slightly higher-sensitivity U.K. Met Office Hadley Centre Climate Model, version 3 (HadCM3)[9].

Temperatures are projected to rise significantly over the 21st century. The magnitude of projected warming varies between models and the emission scenarios. The temperature rise (2000 to 2100) projections are from approximately 1.7°C to 3.0°C (3.0°F-5.4°F) in the lower range of projected warming, 3.1°C-4.3°C (5.5°F-7.8°F) in the medium range, and 4.4°C to 5.8°C (8.0°F-10.4°F) in the higher range. To comprehend the magnitude of these projected temperature changes, over the next century, the lower range of projected temperature rise is slightly larger than the difference in annual mean temperature between Monterey and Salinas, and the upper range of project warming is greater than the temperature difference between San Francisco and San Jose, respectively (Figure 4-2). There is no clear trend in precipitation projections for California over the next century. However the consensus of the recent IPCC model projections, including several models that were not selected for the present study, is for relatively little change in total precipitation, with a tendency toward a slightly greater winter and lower spring precipitation.

Figure 4-2. Change in California Annual Average Daily Mean Temperature Relative to 1961-1990



Change in California annual mean temperature (°F and °C) by year from 1961 to 2100 relative to 1961–1990 average—7-year running mean.

HadCM3 = Hadley Climate Model version 3

PCM = Parallel Climate Model

GFDL2.1 = Geophysical Fluid Dynamics Laboratory model 2.1

A1, A2, and B1 refer to global emission scenarios explained in Section 4. They are higher (A1), medium-high (A2), and lower (B1) emission scenarios.

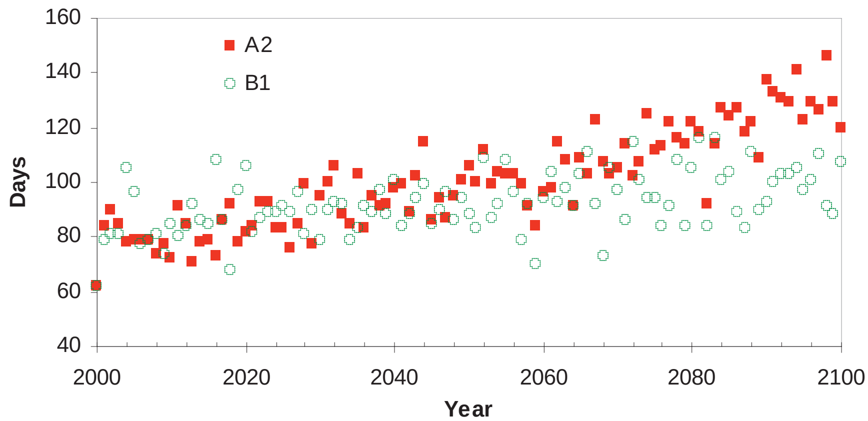
4.2 Public Health Impacts[10]

Climate change will affect the health of Californians due to increases in the frequency, duration, and intensity of conditions conducive to air pollution formation, oppressive heat, and wildfires. The primary concern is not the change in average climate, but rather the projected increase in extreme conditions that are responsible for the most serious health consequences.

Californians experience the worst air quality in the nation, with annual health and economic impacts estimated at 9,000 deaths and $60 billion per year. Ozone and particulate matter (PM) are the pollutants of greatest concern, and the current control programs for motor vehicles and industrial sources cost about $10 billion per year.

Maximum ozone levels are about double the current air quality standards. Climate change will slow progress toward attainment and increase control costs by boosting emissions, accelerating chemical processes, and raising inversion temperatures during summertime stagnation episodes. Results from statistical analyses indicate that the number of days meteorologically conducive to pollution formation may rise by 75 to 85 percent in the high ozone areas of Los Angeles (Riverside) and the San Joaquin Valley (Visalia) by the end of the century if temperatures rise to the higher projected warming range, and by 25 to 35 percent if temperature increases stay within the lower warming range.

Figure 4-3. Projected Days at Riverside Meteorologically Conducive to Exceedances of the 1-Hour California Ambient Air Quality Standard for Ozone of 0.09 Parts Per Million (ppm)



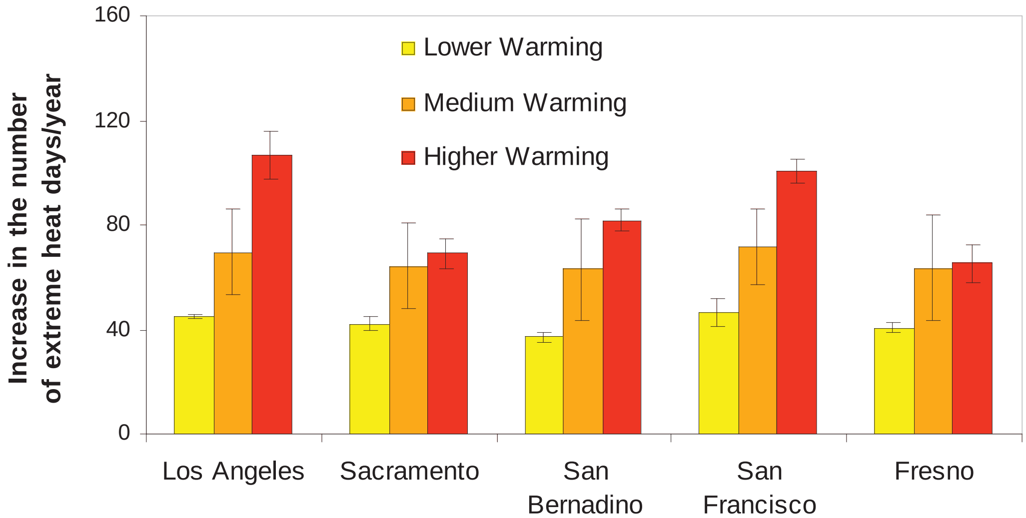
Geophysical Fluid Dynamics Laboratory (GFDL). Source: Kleeman and Cayan, 2006

In addition, global background ozone (primarily formed from methane and nitrogen oxides from fuel combustion) is projected to increase by 4 to 10 percent (lower emissions scenario) to 25 percent (higher emissions scenario) by 2100. If background ozone increases by the amount projected for the higher scenario, the ozone targets would be impossible to attain in much of California, even with near-zero local emissions.

The future trend for PM is not as clear, as increasing temperatures reduce some particle types while others show no change or increase slightly. In general, increased temperatures tend to reduce atmospheric nitrate, an important contributor to levels of PM2.5 (particles less than 2.5 microns) in California. However, a preliminary study by Kleeman and Cayan (2006) suggests that if global background ozone levels double, there would be an increase in PM2.5 levels despite the corresponding increase in temperature. Rainy days, wildfires, global dust storms, humidity, and other factors also affect PM and are the subject of ongoing study.

Analyses of various climate change scenarios project that the future will have a greater number of extremely hot days and fewer extremely cold days, with large increases in heat-related deaths predicted for the five cities studied.

Figure 4-4. Projected increase in extreme heat days relative to 1961–1990. "Extreme heat" defined as by the average temperature which is exceeded less than 10% of the days during the historical period (1961-1990), or approximately 36 days a year.



Source: Drechsler et al., 2006

For the higher warming range, the number of days with temperatures above 90°F in Los Angeles and higher than 95°F in Sacramento will increase to about 100 days by the end of the century, almost twice the increase projected if the temperatures stay within the lower warming range. Individuals likely to be the most affected include the elderly, already ill, and poor. On peak demand summer days in 2100, California would need at least 10 percent more electricity, compared to total generation capacity today, for air conditioning alone. Ongoing studies are investigating the relative contribution of air pollution to heat-related death, and refining the air conditioning demand estimates.

Climate change could affect asthma prevalence and attacks, but this is difficult to predict for several reasons. The most common asthma triggers are dust mites and molds, both of which are higher indoors than outdoors and require a relatively humid environment for survival. Consequently, if the climate becomes drier, these triggers will become less important, but they respond to higher humidity with increased growth. Many asthmatics are allergic to various plant pollens. Plants and trees typically have pollination seasons that last a few weeks per year. To the extent that pollen seasons lengthen or become more intense in response to climate change, increased asthma exacerbation could result.

Climate change has the potential to influence the incidence of infectious disease spread by mosquitoes, ticks, fleas, rodents, and food. More study is needed as research to date has focused on short-term changes in weather patterns (primarily in ambient temperature and rainfall), rather than long-term trends.

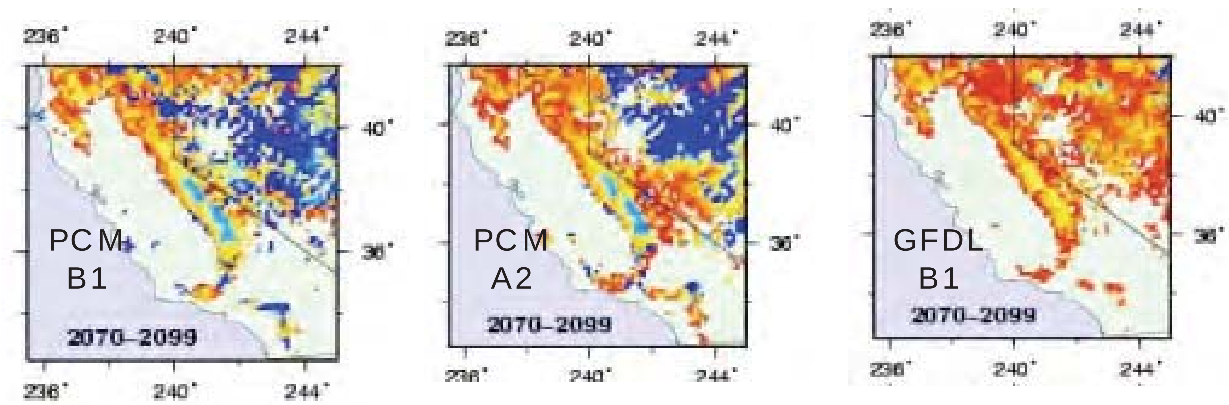
4.3 Water Resources Impacts[11]

Although precipitation is projected to change only modestly over this century, rising temperatures are expected to diminish snow accumulation in the Sierra Nevada and other mountain catchments in California. Higher temperatures will result in more precipitation as rain instead of snow and earlier melt of the snow that does fall. Reductions in snow accumulation and earlier snowmelt will have cascading affects on water supplies, natural ecosystems, and winter recreation.

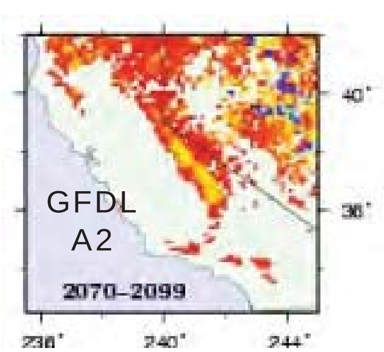
<u>Snowpack</u>

The projected losses in snowpack increase with temperature. Each of the simulations shows losses of spring snow accumulation, largely over the Sierra Nevada, to become progressively larger during the 21st century. By the 2035–2064 period, snowpack in the Sierra Nevada could decrease 10 to 40 percent depending on the amount of warming and precipitation patterns. By the end of century, snowpack could decrease by as much as 90 percent if temperatures rise to the higher warming range, almost double the loss is expected if temperature rises stay within the lower warming range.

Figure 4-5. April 1 Snow water equivalent 2070-2099 fraction of 1961–1990



Low Temperature



Source: Cayan et al., 2006

Medium Temperature

<u>Water Supply</u>

Declining snowpack will aggravate the already overstretched water resources in California. The snowpack in the Sierra Nevada provides natural water storage equal to about half the storage capacity in California's major man-made reservoirs. The snowpack holds the winter precipitation in the form of snow and, historically, has released it in the spring and early summer as the snow melts. This loss in storage could mean more water shortages in the future. However, the full effect of this storage loss will depend in part on whether reservoirs can be managed to capture the earlier snowmelt while loosing flood control capacity.

Under most scenarios stream flows are projected to decrease slightly by mid-century with more dramatic changes by the end of the century. Flows into the major Sierra Nevada reservoirs could decline between 25 to 30 percent if temperatures rise to the medium warming range and precipitation decreases by approximately 20%. This is almost double the decrease projected if temperatures are confined to within the lower warming range. However, in one model run, projections suggest a slight increase in precipitation and a corresponding rise in projected stream flows.

After mid-century, the change in the volume and timing of runoff reduces the ability of the major projects to deliver water to agricultural users south of the Delta. The projected changes in water supply may be further exacerbated by increasing demand. By the end of century, increasing temperatures are expected to increase the crop demand for water between 2 and 13 percent in the lower and medium warming ranges, respectively.

Winter Recreation

Declines in Sierra snowpack will also have widespread implications for winter tourism. Toward the end of the century, in lower temperature scenarios the ski season could shorten by as much as a month while projected climatic changes under the higher temperature scenario suggest that the minimum snow conditions for ski resort operation might be eliminated entirely. Many resorts would be forced to rely on snowmaking or move their operations.

4.4 Agriculture Impacts[12]

Agriculture, along with forestry, is the sector of the California economy that is most likely to be affected by a change in climate. California agriculture is a $68 billion industry.[13] California is the largest agricultural producer in the nation and accounts for 13 percent of all U.S. agricultural sales, including half of the nation's total fruits and vegetables.

Regional analyses of climate trends in agricultural regions of California suggest that climate change is already in motion. During the period 1951 to 2000, the growing season has lengthened by about a day per decade, and warming temperatures have resulted in an increase of 30 to 70 growing degree days per decade, with much of the increase occurring in the spring. Climate change affects agriculture directly through increasing temperatures and rising CO_2 concentrations and indirectly through changes in water availability and pests.

The agriculture sector is likely to bear a disproportionate share of any water scarcity due to any reduced water availability from climate change. A preliminary analysis suggests that a drier climate would impose significant costs on agricultural production in the Central Valley.

Temperature

Temperature influences crop growth through its impact on photosynthesis and respiration, as well as growing season length and water use. Temperature also serves as a controlling factor for developmental processes, such as flowering and fruit maturation, which may be threatened if lengthening of the growing season introduces asynchrony between the timing of flowering and the life cycle of important insect pollinators.

In general, a warming from a low to a higher temperature raises yield at first but then becomes harmful. Possible effects of excessively high temperature include decreased fruit size and quality for stone fruits, premature ripening and possible quality reduction for grapes, reduced fruit yield for tomatoes, increased incidence of tip burn for lettuce, and similar forms of burn for other crops.

As temperatures rise toward the medium warming range, by the end of this century, the local winter climate is expected to approach critical chill-hour thresholds for many species of fruit trees. (Chill hour is the number of hours below a critical temperature.)

Carbon Dioxide (CO_2)

From a variety of studies in the literature, photosynthesis increases when a plant is exposed to a doubling of CO_2. However, whether this translates into increased yield of economically valuable plant product is uncertain and highly variable. Also, elevated CO_2 levels are associated with decreased concentrations of mineral nutrients in plant tissues, especially a decrease in plant nitrogen, which plays a central role in plant metabolism.

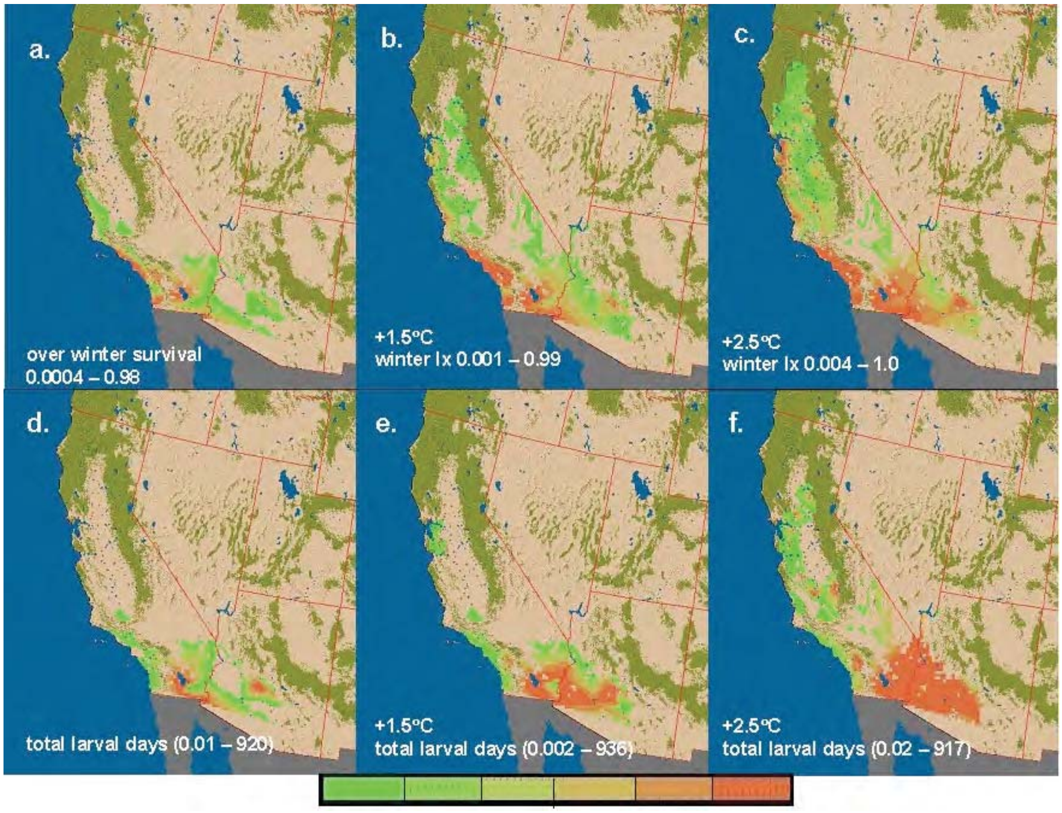
Some crops may benefit in quality from an increase in CO_2; for example, the fruit flavor of strawberries improves. Some crops are harmed by an increase in CO_2; for example grain protein in crops decreases and, in the case of wheat, bread-making quality decreases.

Pests and Weeds[14]

Growth rates of weeds, insect pests, and pathogens are also likely to increase with elevated temperatures, and their ranges may expand. A relatively new area of research involves the use of physiologically-based dynamic models to fully understand the effects of weather (e.g., temperature, rainfall, solar radiation, etc.) on species dynamics.

One of these models was used to estimate the potential impacts of a pest (pink bollworm, or PBW) on cotton cultivation in the state. At the present time this pest is of importance only in the southern desert valleys (e.g., Imperial and Coachella Valleys) because winter frost restricts the invasion of PBW to the million acres of cotton grown in the San Joaquin Valley. However, if winter temperatures rise by 3.6°–4.5°F (2°–2.5°C), the range of PBW of this pest would likely expand northward.

Figure 4-6. Cotton/pink bollworm (PBW): Predicting areas favored by PBW



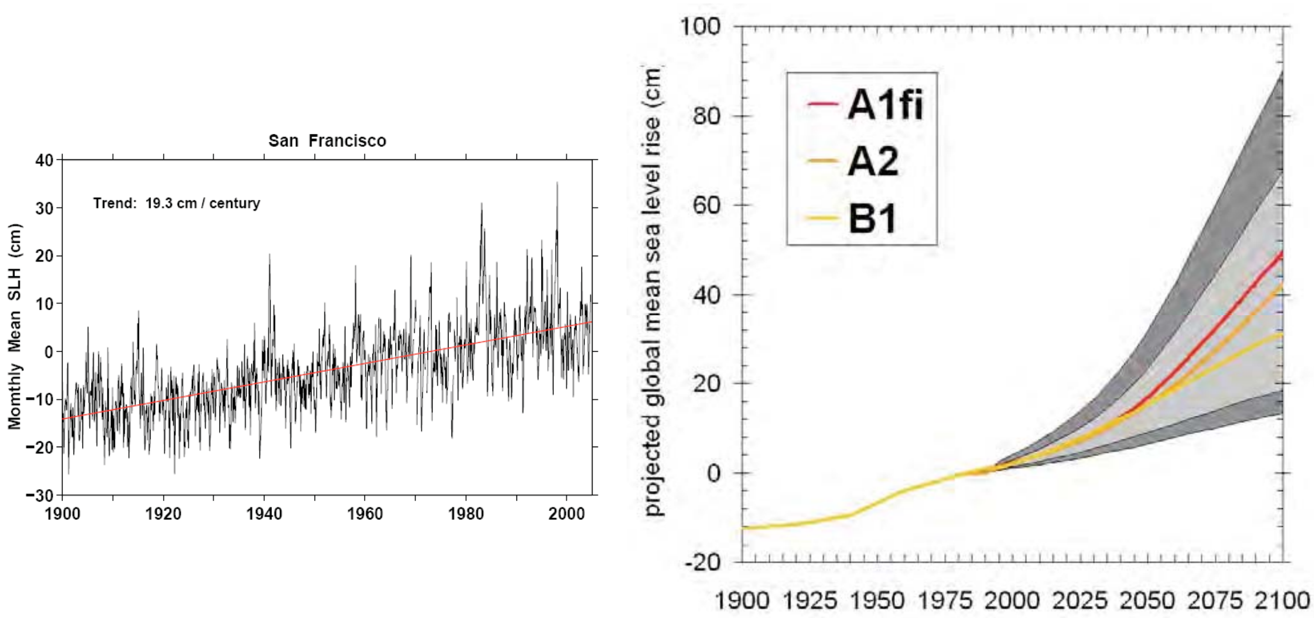
The effects on winter survival (a-c) and total seasonal pest PBW larval densities (larval days, d-e) under current weather (a,d) and with 1.5ºC (b,e) and 2.5ºC (c,f) increases in daily temperatures respectively (Gutierrez et al. in press).

4.5 Coastal Sea Level Impacts[15]

California's coastal observations and global model projections indicate that California's open coast and estuaries will experience increasing sea levels during the next century. These changes could amplify the sea level rise which has historically affected much of the coast of California, including the Southern California coast, the Central California open coast, and the San Francisco Bay and upper estuary. These trends, quantified from a small set of long-duration California tide gages, show rises of about 2 mm/year (Figure 4-6). They are very similar to trends estimated for global sea level.

In addition to long-term trends, sea levels along the California coast undergo shorter period variability above or below predicted tide levels. Highest sea levels have usually occurred when winter storms and Pacific climate disturbances such as El Niño[2] have coincided with high astronomical tides. So far, there is little evidence that the rate of global sea level rise has accelerated (the rate of rise at California tide gages has actually flattened during the last several years), but climate models suggest strongly that this may change.

Figure 4-7. Observed Change in Sea Level in San Francisco during the last century and Projections of Global Mean Sea Level during next century.



Source: Cayan et al., 2006

Global sea level rise is projected to range from 4 to 33 inches during the 2000 to 2100 period. This compares to a rate of approximately 7.6 inches (19 cm) per

[2] El Niño: A phenomenon in the equatorial Pacific Ocean characterized by a positive sea surface temperature departure from normal. Water in the eastern Pacific Ocean close to the equator gets warmer than normal, which results in changes in weather patterns. In some cases, El Niño results in significant increases in precipitation in California. For example the 1982-1983 El Niño event.)

century observed at San Francisco and San Diego during the last 100 years. Superimposed on these rising seal levels will be astronomically-driven tides, and fluctuations from weather, El Niño and other influences, so that, the occurrence of extreme events will increase as sea level rises.

The frequency that sea level exceeds a stationary threshold, as projected over future decades for locations such as the San Francisco tide gage, increases markedly as the mean sea level increases. Thus, historical coastal structure design criteria may be exceeded, the duration of events will increase, and these events will become increasingly frequent as sea level rise continues. On the open coast, impacts during these events will continue to be exacerbated by high surf from wind, waves, and, in the Sacramento/San Joaquin Delta of the San Francisco Bay estuary, by floods that may further jeopardize levees and other structures.

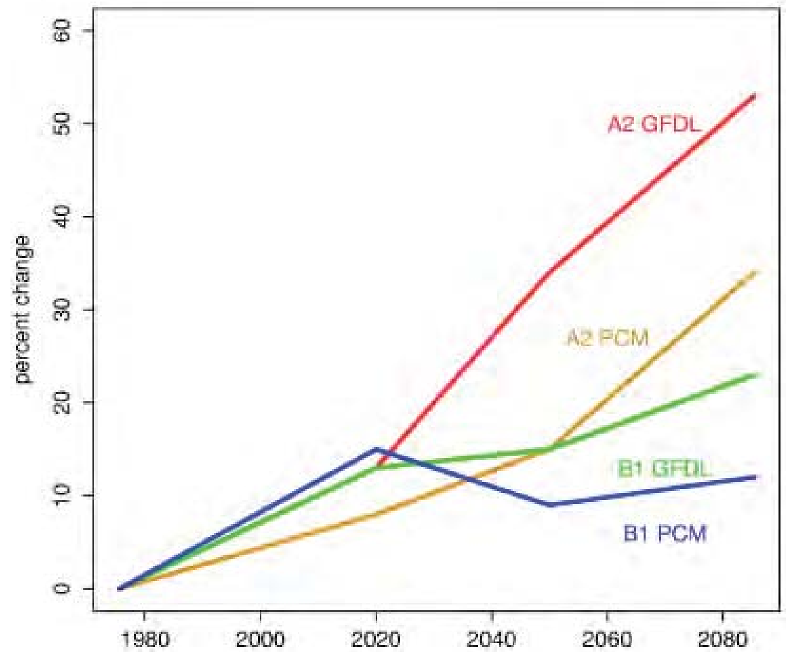
4.6 Forests and Natural Landscapes Impacts[16]

Climate changes and increased CO_2 concentrations are expected to alter the extent and character of forest and other ecosystems. The distribution of species is expected to shift, the risk of climate-related disturbance such as wildfires, disease, and drought is expected to rise, and forest productivity is projected to increase or decrease depending on species and region. The ecosystems most susceptible to temperature rise are the alpine and sub-alpine forest cover. In addition, changes in fire frequency are expected to lead to an increase in grasslands, largely at the expense of woodland and shrub-land ecosystems.

Wildfires[17]

The changing climate may modify the natural fire regimes in ways that could have social, economic and ecological consequences. The most recent analysis, which is a conservative estimate that does not include the effects of extreme fire weather, indicates that wildfire will increase, especially as warming intensifies. These projections suggest that the risk of large wildfires statewide may rise almost 35 percent by mid-century, 55 percent by the end of the century under a medium-high emissions scenario, and almost twice that expected under lower emissions scenarios.

Figure 4-8. Percent change in the expected minimum number of large fires per year in California



Source: Westerling et al., 2006

These increases in fire season severity could lead to more "bad air" days as well as increased damage costs of approximately 30 percent above current annual damage

Although society has developed a number of ways to adapt to wildfires, climate change, along with the multiplying impacts of other stresses such as population growth and land-use change, may be pushing California outside of its coping range.

However, in the short-term, California can take actions to improve its ability to live within the state's fire-prone landscapes while maintaining the functioning and structure of the ecosystems upon which its residents depend. These include[18]: 1) the adoption of a risk-based framework for fire management; 2) the reintroduction of fire to fire-prone ecosystems (managing natural fires in some regions rather than suppression); 3) creation of new and flexible policies that are able to differentiate between the diverse ecosystems in California; and 4) a re-evaluation of urban planning and building in the wildland-urban interface.

<u>Pests and Pathogens</u>[19]

Historically, pests and disease have caused significant damage to California forests. The changing climate may exacerbate these effects by expanding the range and frequency of pest outbreaks. For example, the introduced pathogen, pine pitch canker (Fusarium subglutinans f. sp. pini), once limited to coastal areas of California, has expanded to the El Dorado National Forest in the Sierra Nevada. Rising winter temperatures in the Sierra Nevada would make conditions more favorable for pitch canker and could result in increased disease severity and economic loss.

Forest Productivity[20]

Several studies have projected increases in forest productivity under future climate change. However, recent studies indicate that it is uncertain how trees will respond to elevated CO_2 concentrations, and that there will be increased risk and susceptibility to catastrophic loss. Thus, the implications for the forest productivity and the timber industry may be less optimistic.

The most recent assessment of the impact of climate change on the California forest sector used an industry standard planning tool to forecast 30-year tree growth and timber yields for forest stands in El Dorado County under a high and medium temperature scenario.

Conifer tree growth was reduced under all climate change scenarios. If temperatures rise to the projected medium warming range, productivity in mature stands is expected to decline by 20 percent toward the end of the century. The reductions in yield were more severe (30 percent) for pine plantations. Projections further indicate that the reduced growth rates could lead to substantial decrease in tree survival rates.

4.7 Electricity Sector Impacts[21]

Changes in temperature and other meteorological variables will affect both the generation of and demand for electricity. This section discusses the potential effects of climate change on hydropower production and electricity demand in California.

Energy Supply—Hydropower

Changes in precipitation levels, should they occur, and patterns and timing of snowmelt would alter the amount of electricity that hydroelectric facilities could generate. It would also affect seasonal availability, with less water available for hydroelectric generation in the late spring and summer months when demand is the highest.

In addition, there is a high likelihood that changes in precipitation and runoff patterns would lead to changes in broader water policies and end-use priorities, such as water supply and flood control, which could impose further limitations on hydroelectric production. Currently, hydropower generation contributes about 15 percent of the in-state electricity production, with a range from 9 to 30 percent due to variations in climatic conditions.

Past studies have suggested that annual hydropower generation will increase or decrease with increasing or decreasing precipitation levels in California. The most recent study using an economic-engineering optimization model of the state water system suggests that under a medium range of temperature increase and decreased precipitation levels, annual generation by the end of this century would decrease by about 30 percent and stream flows would decrease by 28 percent.

Another new study prepared by the Department of Water Resources (DWR) simulating the State Water and Central Valley Projects suggests reductions of approximately 7 percent in hydropower unit electricity generation for most scenarios by mid-century. However, one exception is the low temperature scenario in the less dry model, where electricity generation is projected to increase by approximately 4 percent.

It is important to emphasize that even relatively small changes in in-state hydropower generation results in substantial extra expenditures for energy generation, because losses in this “free” generation must be purchased from other sources.

For example, assuming a decrease of 10 percent from the current average in-state generation level from this renewable energy source, and assuming a price of about 10 cents per kilowatt-hour, this decrease would result in an additional $0.35 billion per year in net expenditures to purchase sufficient electricity to replace the electricity that otherwise would be generated using hydroelectric resources.

Electricity Demand

Electricity demand is projected to rise between 3 to 20 percent by the end of this century. These results are based on correlation functions relating electricity demand with temperatures in key areas in California and future climate projections assuming current socio-economic conditions, including no change in present day population. In the next 20 years electricity demand would increase from 1 to 3 percent from the baseline, and peak electricity demand would increase at a faster rate.

Since annual expenditures of electricity demand in California represent about $28 billion, even the relatively small increases in energy demand would result in substantial extra energy expenditures for energy services in the state. For example, assuming a linear increase in electricity expenditures from the historical period, a 3 percent increase in electricity demand by 2020 would translate to about $1.2 billion a year in extra electricity expenditures.

Potential Coping Strategies

There are several options to reduce the negative effect of climate change on the electricity system. The use of modern probabilistic hydrological forecasts for the management of water reservoirs in the state is a promising option being studied. Some options needed to reduce climate change emissions can be seen as coping strategies. They include, for example, enhanced energy efficiency programs, increased penetration of photovoltaic systems, and the implementation of measures designed to reduce the heat island effect.

4.8 Implications for Mitigation and Adaptation[22]

Continued climate change would have widespread impacts on California's economy, ecosystems, and the health of its citizens. However, analyses from the present study, summarized in Figure 17, suggest that many of the more severe impacts projected under the medium and higher warming ranges could be avoided by following the lower emissions pathway. It should be noted though, that, if the actual climate sensitivity to climate change emissions reaches the level of the more sensitive global climate models employed here, an even lower emissions path than the B1 scenario may be required to avoid the medium warming range. How much would climate change emissions have to be reduced to stay below the lower emissions pathway (B1) and insure against temperatures rising to the medium and higher warming ranges presented in this study? The Governor's Executive Order #S-3-05, calls for an 80% reduction in CLIMATE CHANGE emissions, relative to 1990 levels, by 2050. If the industrialized world were to follow California's lead and the industrializing nations transitioned to a lower emissions energy system as characterized by the B1 pathway, global emissions would remain below the lower emissions scenario (B1),[3] increasing the likelihood that California and the world would be on track to avoid the more severe impacts by preventing temperatures from rising to the medium warming ranging.[4] This estimate of the impact of an 80% reduction by the industrialized world on global emissions depends crucially on the development patterns of the Industrializing Nations. The SRES B1 scenario assumes development proceeds with a "high level of environmental and social consciousness" with a transition to "alternative energy systems" (Nakicenovic et al. 2000). Emission reductions targets such as the one set by the Governor's Executive Order could spur the innovation necessary to lead the World to a transition to alternative energy systems.

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[3]This was calculated as follows: 1) OECD population and total emissions were based on SRES B1 IMAGINE runs (Nakicenovic et al. 2000). OECD total emission in 1990 were 2.83 GtC; 2) 80% below this value is 566MtC; 3) Total global emissions was calculated by adding the 566 MtC to the total emissions for non-OECD countries, as projected by SRES B1. This value is approximately 10GtC; 4) This 10 GtC/yr was compared to the global emission projected in the B1 scenario (approximately 11 GtC/yr).

[4] As illustrated in figure 1,beyond 2050 global emissions will need to decrease substantially below 10 GtC/yr to stay on the B1 pathway out to the end of the century. The SRES B1 pathway assumes Global emissions decrease to 4.23 GtC/yr by 2100. However, stabilizing atmospheric concentrations will require even lower emissions as natural uptake is estimated between 0.7-2.9 GtC/yr (IPCC 2001).

Figure 4-9. Projected Impacts End of Century

Emissions Scenarios (End of century Atmospheric CO_2 Concentration)		Statewide Temperature Rise (ºC) 2070-2099
Higher Emissions A1fi (970 ppm)	90% loss in Sierra snow pack 55-75 cm (22-30 inches) of Sea level rise 3-4 times as many heatwave days in major urban centers[2] 2.5 times the number critically dry years[3] 20 % increase in electricity demand 4-10 times as many heat-related deaths projected for some urban centers[4] Increase in Forest yields not evaluated for this scenario[5] Increase in Fire risk not evaluated for this scenario[5] Increase in days meteorologically conducive to ozone formation[5]	4.4 – 5.8 ºC (8-10.4 ºF)
Medium-High Emissions A2 (830 ppm)	70- 80 % loss in Sierra snow pack 35-55 cm (14-22 inches) of Sea level rise 1-2 times as many heatwave days in major urban centers 2.5-5.5 times as many heat-related deaths projected for some urban centers[4] 75-85% increase in days meteorologically conducive to ozone[6] 2-2.5 times the number critically dry years[3] 11% increase in electricity demand 30% decrease in forest yields (Pine) 55% increase in the expected risk of large fires	3.1 -4.4 ºC (5.5-7.9 ºF)
Lower Emissions B1 (550 ppm)	30-60 % loss in Sierra snow pack 15-35 cm (6-14 inches) of Sea level rise 2-2.5 times as many heatwave days in major urban centers 2-4 times as many heat-related deaths projected for some urban centers[4] 25-35% increase in days meteorologically conducive to ozone formation [6] Upto 1-1.5 times the number critically dry years[3] 3- 6 % increase in electricity demand 7-14% decrease in forest yields (Pine) 10-35% increase in the risk of large fires	1.7 -3.0 ºC (3.0-5.4 ºF)

1. Impacts presented relative to 1961–1990.
2. Los Angeles, San Bernardino, San Francisco, Sacramento, and Fresno.
3. Measures for the San Joaquin and Sacramento basins.
4. For Los Angeles, Riverside, and Sacramento.
5. Impacts expected to be more severe as temperatures rise. However, higher temperature scenarios were not assessed for the project.
6. Formation in Los Angeles and the San Joaquin Valley.

Climate projections show little difference between the emissions scenarios prior to 2035 due to the inertia of the climate system, indicating that even under the lower emissions path some further impacts from climate change are inevitable. Consequently, although it is not the solution to global warming, it is becoming clear that adaptation is an essential complementary strategy to manage some of the projected impacts of climate change. While there are many opportunities for California to increase its capacity to cope with the projected changes, these are often costly.

Furthermore, there are limits to adaptation, especially in addressing the threats of abrupt climate changes or in dealing with those impacts on natural, unmanaged species and ecosystems. These species may not be able to keep up with the increasingly rapid and severe climate change expected in future decades. Finally, the ability to cope and adapt is differentiated across populations, economic sectors, and regions within the state. As a result, without appropriate actions climate change will likely aggravate existing equity issues within California and the rest of the U.S.

For example, the most vulnerable populations to the health impacts of climate change are children, elderly people, and residents of minority and low-income communities—the same groups that already face the greatest health and environmental risks.

The Department of Water Resources and other State agencies have already started to include climate change considerations in their long-range plans. However, no cities in California have a heat emergency action plan; such plans are especially crucial to assist the elderly, especially those living in housing without air conditioning, who may be the most at risk from heat waves.

Thus, the Department of Health Services should develop heat emergency action plans for California (with a focus on protecting the economically disadvantaged) before the need arises. Existing air pollution control programs do not consider the effect of climate change on vulnerable populations; children and the elderly (especially those with pre-existing heart disease) are among the groups most vulnerable to air pollution episodes. Those that live closer to freeways and other emission sources (disproportionately in low-income and minority communities) are exposed to higher levels of pollution.

The Air Resources Board should work with the U.S. Environmental Protection Agency to begin to build climate change considerations into efforts to attain and maintain the health-based air quality standards over the long term.

Better monitoring of California's climate and sensitive climate related sectors will be crucial to detecting and understanding a complex chain of impacts. Finally, the State should continue to generate public discussion and build awareness of the need to manage climate change, develop enabling (or eliminating constraining) adaptation policies, and foster the political will necessary to critically assess and ultimately realize the State's significant adaptive potential.

5 RECOMMENDATIONS FOR EMISSION REDUCTION STRATEGIES

The CAT evaluated a significant number of strategies that could be implemented in California to reduce climate change emissions. The strategies listed in the section represent the recommendations of the CAT regarding activities that should be undertaken in the state agencies to ensure the Governor's targets are met. Most of these strategies can be implemented with existing authority of the state agencies represented on the CAT.