Choosing Our Future
Climate Change in California

Rising Heat and Risks to Human Health

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On summer days, Californians may stroll through cool fog on the San Francisco waterfront, enjoy balmy breezes on a Los Angeles beach, or retreat from stifling heat on the waters of the Sacramento Delta. The wide range of climate zones in California is a product of the state's size, varied terrain, and proximity to the Pacific Ocean. As Earth warms, rising temperatures in California's growing urban centers will affect residents' lives in ways both simple (hotter summer days) and profound (increased health risks).

The latest climate projections for California suggest that temperatures will increase considerably during this century, and the rate of increase will depend on the amount and timing of further emissions of heat-trapping gases. Building on previous studies, the projections described here use two state-of-the-art climate models and two contrasting scenarios of future heat-trapping emissions. By the end of the century, statewide average annual temperatures are projected to increase about four to six degrees Fahrenheit under the lower-emissions scenario and 7 to 10.5°F under the higher-emissions scenario.

Statewide, average summer temperatures are projected to increase more rapidly than previously expected, accompanied by more common and severe extreme-heat conditions, such as heat waves and very high temperatures. The most severe and persistent heat is projected for locations that are already hot, such as Fresno and Sacramento. However, the impact of increasing heat on human health could be most serious in coastal locations that are relatively cool today, such as Los Angeles and San Francisco.

People living in urban centers, especially children, the elderly, and the poor, are most vulnerable to the physical dangers of increasing heat, and estimates of heat-related deaths for five major metropolitan areas show that the numbers are likely to increase substantially for most locations unless preventive measures are taken.

Climate Change and Human Health

Climate change is likely to affect human health in numerous ways, including increased heat stress and related deaths, changes in the incidence of infectious disease, and a higher risk of respiratory and other problems caused by deteriorating air quality. This study focuses on mortality associated with increased heat, which can cause death through dehydration, heat stroke/exhaustion, heart attack, stroke, and respiratory distress—especially in people who are already ill. While warmer winter temperatures are expected to reduce cold-related deaths in some regions, the increased health risks associated with summer heat are expected to far outweigh any positive effects of warmer winters in California.

The climatic conditions that contribute to heat-related mortality include sustained high daytime temperatures with little relief at night, high humidity, and intense sun. Extended heat waves and extremely high temperatures that occur early in the spring and summer, before people have had a chance to adjust to hot temperatures, can be particularly dangerous. The most vulnerable members of the population include people who are already ill, children, the elderly, and the poor (who are less likely to have access to air conditioning and other means of coping with heat).

Climate Projections

The most recent climate projections for California show that the state will likely become considerably warmer during this century, and the amount of warming will depend on the rate at which our use of fossil fuels and other actions continue to release heat-trapping gases into the atmosphere. These projections improve upon earlier projections of warming in the state by using two of the latest-generation global climate models, and lower- and higher-emissions scenarios instead of a single mid-range scenario. The higher-emissions scenario assumes continued, intensive reliance on fossil fuels, causing emissions of heat-trapping gases to grow rapidly throughout the century. In contrast, the lower-emissions scenario envisions a transition to clean energy technologies, causing emissions to peak by mid-century and then decline below current levels by 2100.

As summer temperatures rise, heat waves and extreme temperatures will likely become more common and severe.

The lower-emissions scenario is not the lowest possible pathway; actual emissions could be lower if early and aggressive steps are taken to limit the release of heat-trapping gases. Acting soon is important because most heat-trapping gases remain in the atmosphere for a long time and climate changes occur over the course of decades. In other words, the climate our children and grandchildren experience later in this century depends strongly on our emissions during the next few decades.

The projections of climate change described here provide the best available estimate of the direction and relative magnitude of changes that are likely to occur. Because climate models differ somewhat in their projections of future climate, two state-of-the-art climate models were used to provide a range of plausible outcomes for a particular scenario.

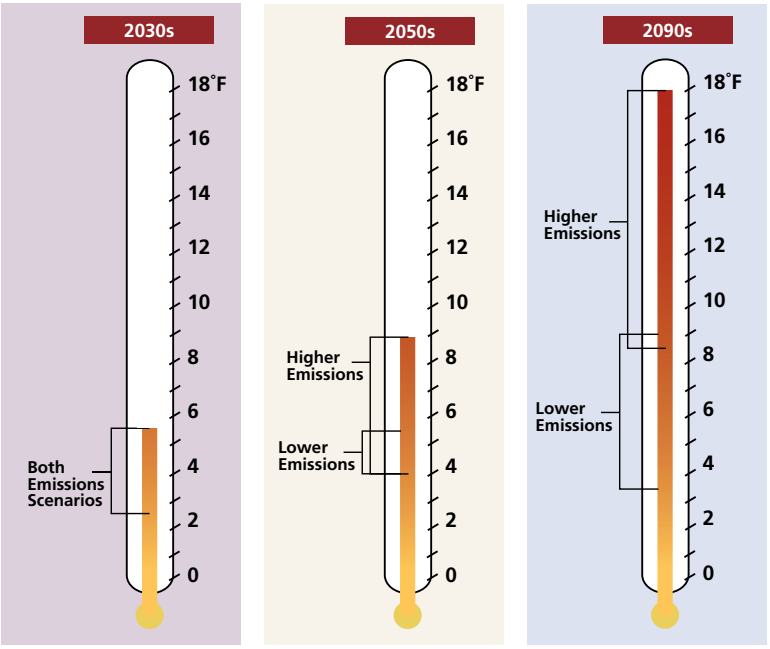
Temperatures are projected to increase substantially under both the lower- and higher-emissions scenarios, with differences between the scenarios emerging by mid-century. Before the century ends, temperature increases associated with the higher-emissions scenario are nearly double those of the lower-emissions scenario. Increases in summer temperatures are higher than previously projected using earlier models and emissions scenarios.

- Statewide, average summer temperatures are projected to rise about 2.5 to 5.5°F by the 2030s, while winter temperatures rise about two to three degrees Fahrenheit depending on the climate model used.
- Differences between emissions scenarios emerge by the 2050s, with average summer temperatures projected to rise about 4 to 5.5°F under the lower-emissions scenario and four to nine degrees Fahrenheit under the higher-emissions scenario. Average winter temperatures are projected to rise about 3.5 to 4°F under both emissions scenarios.
- By the 2090s, average summer temperatures are projected to rise about 3.5 to 9°F under the lower-emissions scenario and 8.5 to 18°F under the higher-emissions scenario. Average winter temperatures are projected to rise about 3.5 to 4.5°F under the lower-emissions scenario and 6.5 to 7.5°F under the higher-emissions scenario.

Extreme Heat

As average temperatures rise, extreme-heat conditions such as heat waves and very high temperatures are projected to become more common and severe. Differences between emissions scenarios emerge by 2050 and become more pronounced over the second half of the century, with the most persistent and severe high-temperature conditions projected for inland locations that are already hot. However, the impact on human health could be greatest in cooler coastal cities where extreme-heat conditions have historically been relatively rare. Projections for five major metropolitan areas (Los Angeles, Riverside/San Bernardino, San Francisco, Sacramento, and Fresno) show that:

- Heat waves[1] will likely occur more frequently and last longer. For example, heat waves that could be expected to occur about three times per year historically are projected to roughly double in frequency by the 2050s and become two to five times more common by the 2090s. The average heat wave could increase in length from about two to five days during the 1990s to about 5 to 12 days by the 2050s and 6 to 19 days by the 2090s.
- Heat waves will likely become more intense, with higher temperatures sustained over a longer period of time. In Fresno and Riverside, extreme heat waves[2] could account for about 25 to 50 percent of all heat waves by the end of the century under the lower-emissions scenario and about 60 to 80 percent of heat waves under the higher-emissions scenario. By comparison, extreme heat waves accounted for less than 15 percent of all heat waves in these locations during the 1990s.
- The heat wave season will likely grow considerably longer, particularly in the coastal and more southern locations. In Los Angeles, for example, the heat wave season is projected to increase from about 14 weeks during the 1990s to about 19 to 25 weeks by the 2090s under the lower-emissions scenario and 31 to 37 weeks—a total of nearly eight to nine months—



Summer temperatures are projected to increase more dramatically than previously expected. This figure shows projected increases in statewide average summer temperatures. Ranges for each emissions scenario are results from two climate models.

Extreme Heat and Heat-Related Mortality in California

SACRAMENTO: Stifling Temperatures
- In the 2090s, high-temperature extremes could soar above 109 to 111°F in the higher-emissions scenario.
- Currently facing ~18 days hotter than 98°F, Sacramento could see such temperatures on 50–60 days per year in a lower-emissions scenario and a staggering 90–110 days per year in the higher-emissions scenario at century's end.

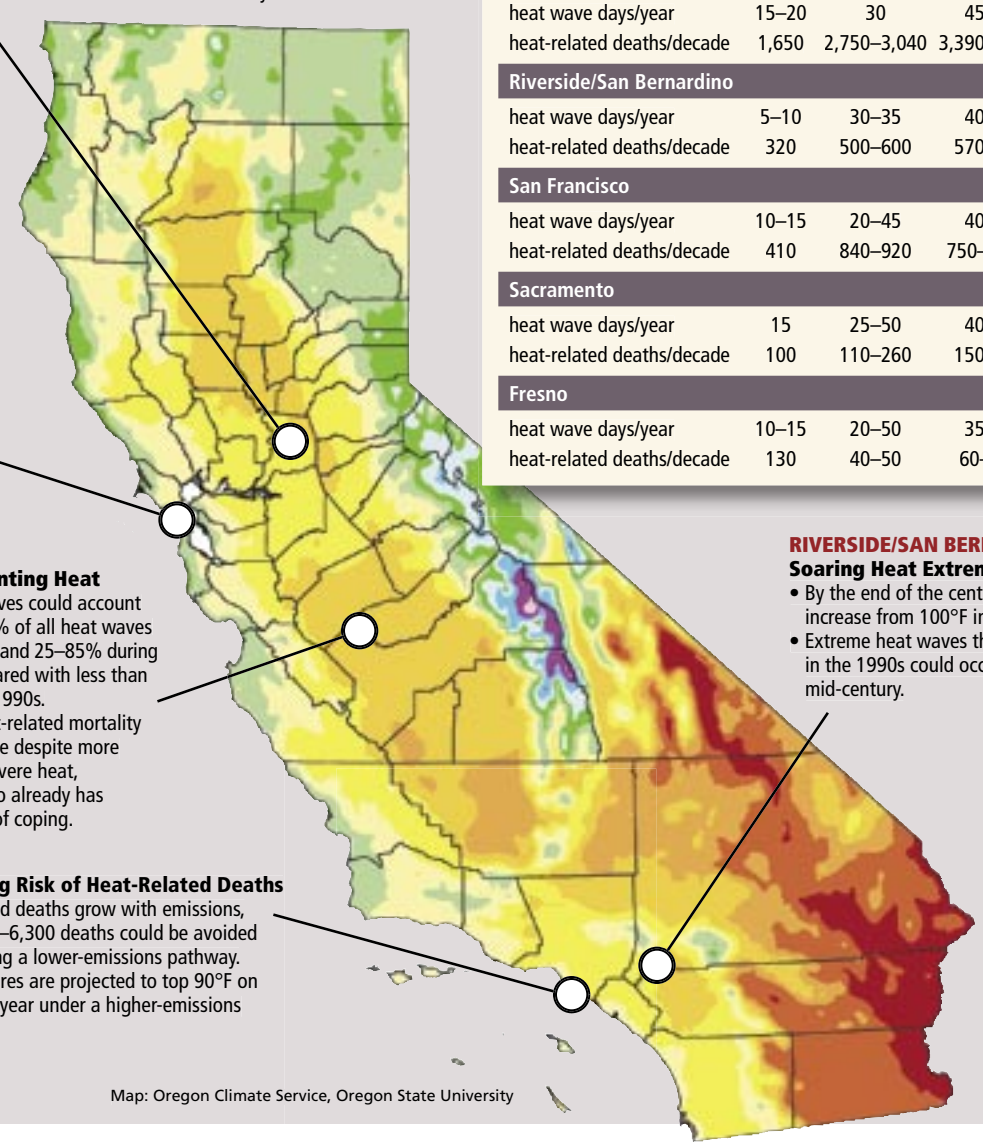
	1990s	2050s		2090s	
		Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions
Los Angeles					
heat wave days/year	15–20	30	45–50	45–65	80–120
heat-related deaths/decade	1,650	2,750–3,040	3,390–7,190	3,190–5,510	7,900–11,820
Riverside/San Bernardino					
heat wave days/year	5–10	30–35	40–45	35–55	70–100
heat-related deaths/decade	320	500–600	570–730	820–830	1,040–1,290
San Francisco					
heat wave days/year	10–15	20–45	40–55	35–65	90–135
heat-related deaths/decade	410	840–920	750–1,460	1,340–1,530	2,710–4,470
Sacramento					
heat wave days/year	15	25–50	40–55	45–65	85–110
heat-related deaths/decade	100	110–260	150–250	170–310	520–890
Fresno					
heat wave days/year	10–15	20–50	35–55	40–60	80–110
heat-related deaths/decade	130	40–50	60–100	50–70	170–180

SAN FRANCISCO: Susceptibility to Extreme Heat
- Accustomed to cool summers, San Francisco could see 3–11 times as many heat-related deaths in the 2090s.
- Under the higher-emissions scenario, heat waves that now occur on only about 12 days per year could occur on a stunning 90–130 days per year in the 2090s—that's 50–70% of the days between May and October.

FRESNO: Unrelenting Heat
- Extreme heat waves could account for about 25–35% of all heat waves during the 2050s and 25–85% during the 2090s, compared with less than 15% during the 1990s.
- Estimates of heat-related mortality show little change despite more persistent and severe heat, suggesting Fresno already has effective means of coping.

LOS ANGELES: Growing Risk of Heat-Related Deaths
- Estimates of heat-related deaths grow with emissions, suggesting about 4,700–6,300 deaths could be avoided in the 2090s by following a lower-emissions pathway.
- In the 2090s, temperatures are projected to top 90°F on about 90–130 days per year under a higher-emissions scenario.

RIVERSIDE/SAN BERNARDINO: Soaring Heat Extremes
- By the end of the century, high-temperature extremes could increase from 100°F in the 1990s to about 106 to 115°F.
- Extreme heat waves that occurred only once per decade in the 1990s could occur 16–25 times per decade by mid-century.



Map: Oregon Climate Service, Oregon State University

under the higher-emissions scenario. Much of the increase is due to heat waves occurring earlier in the year, when people are more vulnerable to extreme-heat events.

- High-temperature extremes[3] will likely rise and occur more often. Under the higher-emissions scenario, for example, high temperatures that occurred on the 18 hottest days of the year during the 1990s are projected to occur on as many as 90 to 130 days each year during the 2090s. Under the lower-emissions scenario, such temperatures are projected to occur on about 40 to 65 days each year. Projected high-temperature extremes increase most rapidly in Riverside/San Bernardino and Sacramento, rising about 2.5 to 6°F by the 2050s and about 5.5 to 13.5°F by the 2090s.

Heat-Related Mortality

As extreme-temperature conditions become more common and severe, California's increasingly urban population will be at greater risk for heat-related death. Estimates for the five major metropolitan areas studied show that:

- The risk of heat-related mortality increases rapidly with continued warming. The annual number of heat-related deaths is projected to increase an average of about 60 to 180 percent by the 2050s and 130 to more than 500 percent by the end of the century in four of the five cities analyzed. In the fifth city (Fresno), the number of heat-related deaths changes only slightly, despite more frequent dangerous-heat conditions. This may be because Fresno already has effective means of coping with heat.

People living in urban areas, especially children, the elderly, and the poor, are most vulnerable to rising heat.

AP Photo/Franck Prevel

• The risk grows with increasing emissions of heat-trapping gases. On average, mortality estimates for the higher-emissions scenario are on the order of 10 to 100 percent higher than estimates for the lower-emissions scenario during the 2050s and about 100 to 150 percent higher during the 2090s. These findings suggest that, for the five cities combined, we could prevent somewhere between 500 and 5,000 heat-related deaths during the 2050s and more than 8,000 deaths during the 2090s by following a lower-emissions pathway.

• Of the five cities, San Francisco appears most susceptible to increasing heat, as the population—accustomed to relatively cool conditions—has limited ability to adjust to heat (see box, "Estimating heat-related mortality"). Fresno, which already experiences frequent extreme heat, appears to be the least susceptible to increasing heat.

Meeting the Challenges of Climate Change in California

California's population of 34 million is expected to grow to 59 million by 2040, and could reach 92 million by 2100. Much of this growth will occur in urban areas, where the risks of heat-related illness and death are greatest. Projected increases in extreme heat and heat-related deaths are greater under the higher-emissions scenario, suggesting we can reduce future health risks and adaptation costs by taking steps now to lower emissions of heat-trapping gases. California residents, public health officials, and policy makers can help reduce the potential impact of climate change on human health through three complementary strategies:

• ***Reducing emissions of heat-trapping gases*** is the most important step to curbing the rate and extent of climate change. California can accomplish this and build on its legacy of environmental leadership by continuing to increase industrial and building efficiency, switching to renewable energy sources such as wind and bioenergy, and introducing cleaner vehicles. These strategies not only reduce emissions of heat-trapping gases but also typically yield significant economic savings and other environmental benefits.

• ***Minimizing other pressures on human health*** by protecting and improving air and water quality and treating existing health conditions that make people more vulnerable to heat.

• ***Preparing for those consequences of climate change that cannot be avoided.*** One solution is creating effective public education and early warning systems; sophisticated heat and health warning systems are already operational in a number of large urban areas outside California, such as New Orleans, Philadelphia, and Phoenix. Other solutions include investing in public health resources, working with communities to develop intervention programs that protect the most vulnerable members of the community, providing residential air conditioning and public cooling-off centers, and emphasizing heat reduction in urban planning and building design.

Estimating heat-related mortality

The estimates of future heat-related deaths described here are based on statistical relationships between mortality rates and extreme-heat events in the past. These relationships were developed for each of the five metropolitan areas studied and are adjusted to account for potential *acclimatization*—the physiological and behavioral adjustments people make to cope with heat. Also, because the most vulnerable people may die soon after the initial onset of extreme heat, death rates can decline over the course of extended hot periods. These estimates do not account for population growth or other factors such as age and income distribution, or measures that California's cities may take to reduce the risk of heat-related deaths.

ENDNOTES

1 Heat waves are defined as three or more consecutive days with temperatures exceeding locally defined thresholds. The temperature thresholds for the five cities studied are: Los Angeles, 90°F; Sacramento, 99°F; Fresno, 102°F; Riverside/San Bernardino, 102°F; and San Francisco, 79°F.

2 Extreme heat waves are defined based on threshold temperature conditions that occurred during the one or two most severe heat waves of each decade during the 1961–1990 reference period.

3 High-temperature extremes are defined based on the average maximum temperatures for the hottest five percent (or roughly 18 hottest days) of the year during the 1990–1999 reference period.

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