INDICATORS OF CLIMATE CHANGE IN CALIFORNIA:

ENVIRONMENTAL JUSTICE IMPACTS

December 2010

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EXECUTIVE SUMMARY

In 2009, the California Environmental Protection Agency's (Cal/EPA) Office of the Secretary requested the Office of Environmental Health Hazard Assessment (OEHHA) to develop indicators describing the disproportionate impacts of climate change on environmental justice communities. These indicators will help Cal/EPA examine potential environmental justice concerns associated with climate change.

Evidence is emerging that some of the projected impacts of climate change on human health and well-being are already occurring. Some of these impacts may disproportionately affect those who are socially or economically disadvantaged, and hence represent environmental justice concerns.

This report presents four indicators that help track trends relating to the disproportionate impacts of climate change on these communities. The indicators chosen were selected based on evidence that: (1) the impacts of climate change are already occurring (rather than projected to occur based on future climate scenarios); and (2) disparities exist among socioeconomic or racial groups in either the degree of exposure to a hazard, or the capacity to take action to reduce exposures or minimize adverse outcomes. The indicators are summarized in the text box below.

THE INDICATORS

Air conditioner ownership and cost
Low-income individuals and families are less likely to live in homes with air conditioning. Moreover, electricity costs for cooling are a greater proportion of their household income compared to more affluent households.

Farm worker exposure to extreme heat
Farm workers are a low-income, predominantly Hispanic population. They experience disproportionately greater exposures to extreme heat. Summertime extreme heat in certain agricultural stations declined from 1950 to the mid-1980s, but appears to be trending upward.

Exposure to urban heat
Low-income residents and people of color are more likely to live in urban neighborhoods with large impervious areas and with minimal tree canopy—conditions that intensify summertime heat. Indicators to track these conditions need to be developed.

Vulnerability to wildfires
The rural poor living at the wildland-urban interface may have less capacity and resources to take measures to prevent and fight wildfires and to recover following a fire. Indicators that integrate information about fire threat and about community capacity will help track vulnerability to wildfires.

The lack of California-specific data—in particular, community-level data—needed to examine disparities among income or racial groups precluded the development of more indicators. The present work also does not address projected impacts where the influence of climate change cannot be distinguished from the effects of other factors. Lastly, potential disparities resulting from climate change mitigation policies, strategies or regulations are beyond the scope of this report.

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INTRODUCTION

Purpose of Report

In 2009, the California Environmental Protection Agency's (Cal/EPA) Office of the Secretary requested the Office of Environmental Health Hazard Assessment (OEHHA) to develop indicators describing the disproportionate impacts of climate change on certain California communities. These indicators will help Cal/EPA examine potential environmental justice concerns associated with climate change. California law defines **environmental justice** as the "fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws and policies" (Government Code section 65040.12).

This report presents indicators that can track how certain socioeconomic or racial groups in California may be experiencing disproportionately greater impacts on their health or well-being than others as a result of climate change. These impacts are already occurring; impacts that are projected for the future (e.g., inundation of low-lying residential areas from sea level rise) are not addressed by the current effort. However, issues relating to potential disparities resulting from climate change mitigation policies, strategies or regulations are beyond the scope of this report.

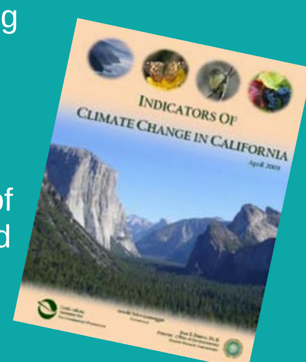
Indicators of Climate Change

Changes in California's climate represent serious threats to the health, environment, and economy of the state and its residents. Climate change refers to variations in temperature, precipitation, wind and other measurable properties of the climate system that persist over an extended period of time, typically decades or longer. Most of this warming can be attributed to increased greenhouse gas emissions from human activities (IPCC, 2007a).

Climate change trends in California are largely consistent with those occurring globally. These changes have been associated with a wide range of impacts on the state's physical and biological systems. Indicators for some of these impacts are presented in a recent Cal/EPA report, *Indicators of Climate Change in California* (OEHHA, 2009). (See text box.)

Some indicators describing climate change trends in California:

- spring snowmelt volumes are declining
- glaciers in the Sierra Nevada are decreasing in size
- sea level is rising
- large wildfires are becoming more frequent
- habitat ranges of certain plant and animal species are shifting



Environmental indicators are measurements that present scientific information on the status of, and trends in, environmental conditions. Indicators draw upon data collection, monitoring and studies by state and federal agencies, universities, and research institutions, and convey complex environmental information in an easily understood format. Indicators can be used to help track progress toward addressing possible impacts of climate change on our communities.

Environmental Justice and Climate Change

Research shows that future climate scenarios will disproportionately affect those who are socially and economically disadvantaged (IPCC, 2007b) (Morello-Frosch, 2009). These groups include the urban poor, the elderly and children, traditional societies, agricultural workers and rural populations.

The fact that some communities are more vulnerable to climate change impacts is well recognized. Vulnerability in this context is defined as the propensity of human and ecological systems to suffer harm and their ability to respond to stresses imposed by climate change (IPCC, 2007b). From a public health perspective, vulnerability results from the summation of all risk and protective factors that ultimately determine whether an individual or subpopulation experiences adverse health outcomes. Socioeconomic factors (such as income level and occupation) play a critical role in altering vulnerability by influencing the likelihood of exposure to harmful environmental conditions. Biological factors (such as age, genetic predisposition and nutritional status) also determine health outcomes and the ability to adapt (CCSP, 2008). A California study of mortality due to extreme heat found coastal areas to experience greater numbers of heat-related deaths with each 10 degree Fahrenheit increase in mean daily apparent temperature than inland areas. The researchers suggested that people living inland—where temperatures tend to be higher—have developed some biological adaptation to heat exposure (Basu and Ostro, 2008).

While all societies have inherent abilities to adapt, the capacity to do so is unevenly distributed both across countries and within societies (IPCC, 2007b). "Adaptive capacity" is defined as the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities or to cope with the consequences. The related concept of "resilience" is defined as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization and the capacity to adapt to stress and change. Population characteristics that might influence adaptive capacity and resilience include income, educational level, social isolation, and health status.

OEHHA recently released an August 2010 public review draft report (*Cumulative Impacts: Building a Scientific Foundation*) that summarizes research on how population characteristics affect vulnerability to disease and other impacts of pollution. It lays out a proposed screening methodology for analyzing cumulative impacts that takes into account population characteristics.

Identifying Relevant Issues

Climate-related environmental justice issues are those impacts of climate change that disproportionately affect certain socioeconomic groups more than others. The indicators discussed in OEHHA's initial climate change indicators report served as the starting point for identifying such issues in California (OEHHA, 2009). Of these indicators—which mostly reflect physical and ecological impacts—only a few directly affect human health and well-being: air temperature; extreme heat events; sea level rise; mosquito-borne diseases; and heat-related mortality and morbidity.

There is extensive scientific literature examining the potential impacts of climate change on human health and well-being globally. Based on its review of several key reports (CNRA, 2009; Shonkoff et al., 2009; Dreschsler, 2009; CCSP, 2008; CDPH, 2007; IPCC, 2007b), OEHHA identified the following recurring issues:

- *Altered distribution of some disease vectors and increased infectious diseases*

  Climate change could affect the range, incidence and spread of infectious diseases, and their vectors. Fewer freezing spells associated with increasing temperatures might lead to increased incidence of disease as vectors and pathogens do not die off. There is already some evidence of climate change-related shifts in the distribution of tick vectors, some non-malarial mosquito vectors and in bird pathogen reservoirs in certain regions of the world.

- *Altered seasonal distribution of some allergenic pollen species*

  Climate change has caused an earlier onset of the spring pollen season in the Northern Hemisphere. Changes in the spatial distribution of natural vegetation can introduce new airborne allergens into an area and increase sensitization. Hence, allergenic diseases caused by pollen may be increasing.

- *Decreased food quality and security, increased malnutrition and consequent health effects*

  Crop yields are expected to decline with climate change as a result of effect on water supply and reduced winter chill. Changes in ocean conditions may substantially change the distribution and abundance of major fish stocks. High temperatures have been associated with common forms of food poisoning (such as salmonellosis). The reduced availability and quality of food is expected to impact public health, particularly in low-income communities.

- *Increased death, disease and injury from heat waves, floods, storms, and fires*

  Extreme events, including heat waves, floods, storms, and fires are projected to occur more frequently and with greater intensity and duration due to climate change. These events are expected to result in adverse effects on health, as well as damage or loss of property.

- *Physical injury, loss of property and infrastructure damage from sea level rise*

  Sea level rise will exacerbate flood risk and accelerate erosion in coastal areas, causing physical injury to populations in these areas and damage to homes and critical infrastructure.

- *Increased morbidity and mortality associated with air pollution*

  Climate change influences on atmospheric processes are expected to promote the formation of pollutants, such as ozone and particulate matter. Such airborne pollutants may increase the incidence of cardiovascular, pulmonary and other diseases, especially in highly impacted urban areas.

- *Increased food- and water-borne diseases, including diarrheal disease*

  Climate change-related alterations in rainfall, surface water availability and water quality could increase the incidence of water-related diseases such as diarrhea. In the United States, extreme precipitation events have been associated with drinking water contamination. Runoff from rainfall has been associated with coastal contamination and subsequent contamination of shellfish. Thus, increased exposure to water-borne chemical contaminants and pathogens is likely to be associated with water-related problems due to climate change.

- *Reduced water availability and quality*

  Climate change is projected to reduce freshwater supplies. As surface water supplies are reduced, groundwater pumping is expected to increase, resulting in potentially lower water tables and adverse impacts on water quality. Drought conditions may lead to increased concentrations of contaminants in drinking water supplies. Further, sea level rise can increase the likelihood of saline intrusion into drinking water sources.

Selecting Issues for Indicator Development

Some of these impacts listed above have been specifically identified as environmental justice concerns. For example, low-income and minority communities have a greater prevalence of chronic health conditions that increase their susceptibility to heat-related illness. Another issue, sea level rise, is projected to disproportionately affect large numbers of low-income people and communities of color (Heberger, et al., 2009). Also, cities projected to experience the highest increases in ambient ozone levels also have the highest densities of people of color and low-income residents.

In selecting the issues to be addressed by indicators, OEHHA was constrained by the following:

(1) Many of the impacts reflect future projections for which the influence of climate change is not yet distinguishable from other factors. For example, ambient concentrations of ozone are affected by emission sources and geographic, temporal and other patterns, in addition to weather conditions; at present, the influence of climate change on current trends is difficult to discern.

(2) The impacts of climate change on physical and biological systems will generally affect all California residents, regardless of race or income. However, there are clearly certain subpopulations that will experience greater exposure to hazards—such as agricultural workers exposed to summertime temperatures, and residents living in “urban heat islands,” where heat-reflecting surfaces have been shown to intensify heat. Additionally, certain groups do not have the resources or the ability to cope with climate change induced impacts due to socioeconomic or inherent biological factors. A comprehensive identification of these community types has not yet been done.

(3) The lack of California-specific data—in particular, community-level data—needed to examine disparities among income or racial groups precluded the development of more indicators than are presented in this report.

Given the above considerations, OEHHA selected issues for indicator development based on evidence that:

- The impact is already occurring, rather than projected to occur based on future climate scenarios.

- Disparities exist among socioeconomic or racial groups in
  (1) the degree of exposure to the hazard; or
  (2) capacity to take adaptation measures in order to reduce exposures or minimize adverse outcomes.

The Indicators: Climate-Change Related Impacts on Environmental Justice

The following indicators are discussed in this report. The indicators are classified based on availability of data as Type I, II or III, as described in the text box below.

Air conditioner ownership and cost
(Type I indicator)
Low-income individuals and families are less likely to live in homes with air conditioning. Moreover, for those low-income households with air conditioning, electricity costs may represent a greater proportion of their annual income compared to more affluent households.

Farm worker exposure to extreme heat
(Type I indicator)
Farm workers are a low-income, predominantly Hispanic population. Their occupation involves exposure to extreme heat during the summer months, compared to the general population. Trends in extreme heat using data from selected climate stations located in agricultural areas are presented.

Exposure to urban heat
(Type III indicator)
Summertime heat can be intensified in urban areas by the presence of paved surfaces (impervious surfaces) and buildings and the lack of vegetative cover. Studies indicate that low-income residents and people of color are more likely to live in urban areas with large impervious areas and with minimal tree canopy.

Vulnerability to wildfires
(Type III indicator)
The rural poor living at the wildland-urban interface have less capacity to take measures to prevent wildfires and to recover from a fire. In addition, some low-income rural communities may not have the infrastructure and public services to prevent or fight wildfires.

Classification of indicators based on data availability

Type I: Adequate data are available and can be used to support the development of the indicator. These data are generated by ongoing, systematic monitoring or data collection efforts.

Type II: Full or partial data generated by ongoing, systematic monitoring and/or collection are available, but either a complete cycle of data has not been collected, or further data analysis or management is needed in order to present a status or trend.

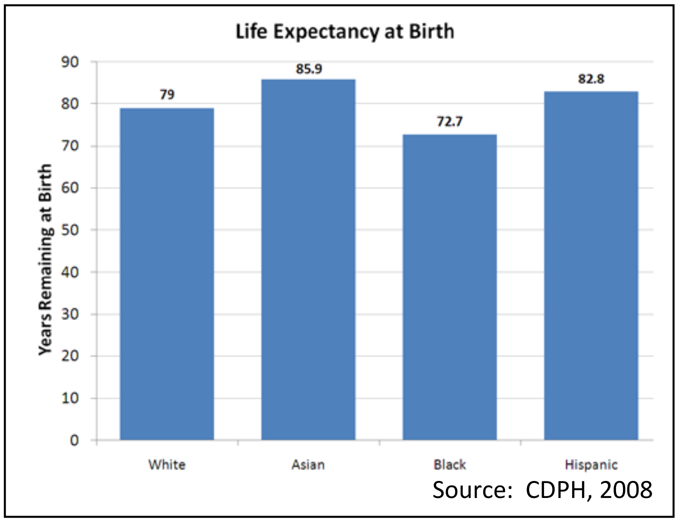
Type III: No ongoing monitoring or data collection is in place to provide data. These indicators are conceptual or have not been developed beyond one-time studies that provide only a snapshot in time.

CHAPTER 1.
BACKGROUND INDICATORS

Several indicators are presented below to provide background information on socioeconomic and racial differences in health status, the prevalence of certain health conditions, and health insurance coverage. These indicators provide context for understanding how these disparities might influence a population's response to climate change. It should be noted, however, that many other interrelated factors play a role in how a community is affected by, or adapts to, climate change.

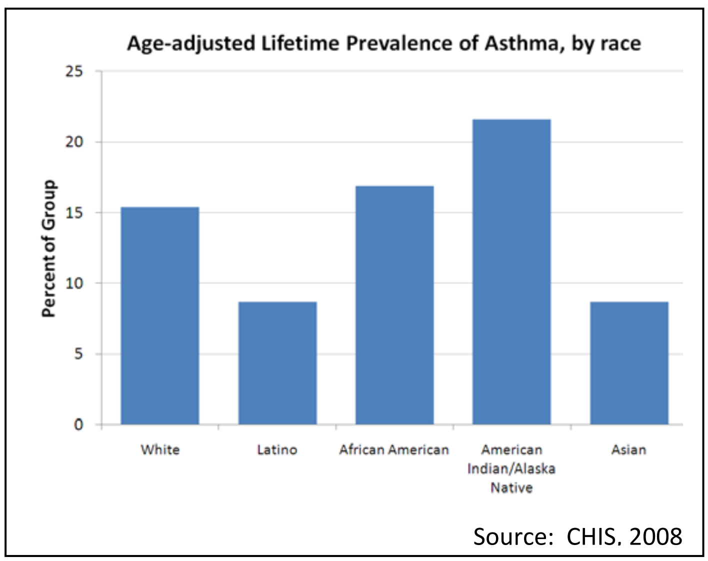
Life expectancy

Life expectancy is a key indicator of overall health. It represents the average number of years at birth a person could expect to live. It reflects the ability to control and prevent serious diseases or other potentially life-threatening conditions. The graph on the right shows life expectancies by race in California. For comparison, overall life expectancy for all races is 78.5 years for males and 83.3 years for females (CDPH, 2008).



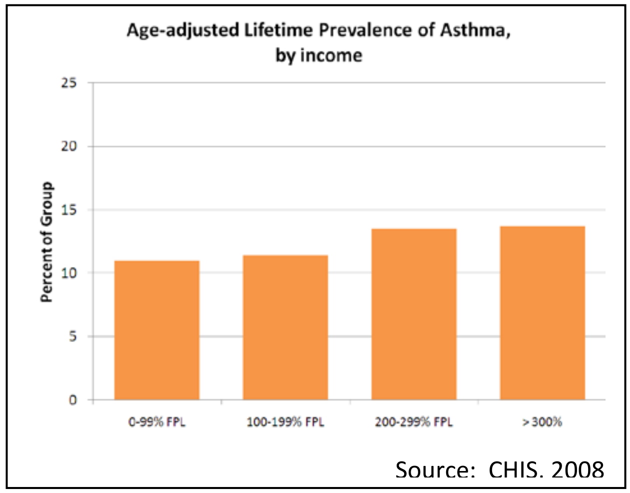
Asthma prevalence among adults

The prevalence of asthma in adults varies among racial and ethnic groups in California (CHIS, 2008*). In a 2005 statewide survey, American Indian/Alaska Natives (21.6 percent) and African-Americans (16.9 percent) had the highest prevalence of lifetime asthma. Hispanics (8.7 percent) and Asians (8.7 percent) had the lowest lifetime asthma prevalence. However, the Hispanic and Asian groups include many diverse subgroups that vary in asthma prevalence rates.



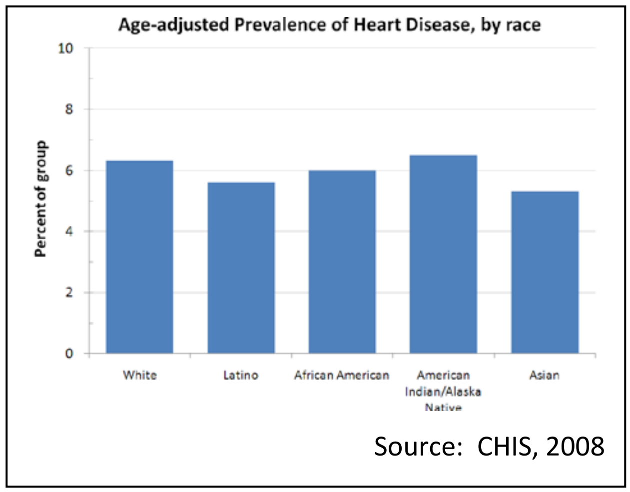
* The California Health Interview Survey (CHIS), the largest population-based state health survey in the United States, is a random-digit-dial telephone survey of over 45,000 households. The data presented here are from a summary report published in 2008 using data from a survey conducted in 2005.

Adults living in households at or above 200 percent the Federal Poverty Level (FPL) were more likely to have been diagnosed with asthma than those households below 200 percent FPL.

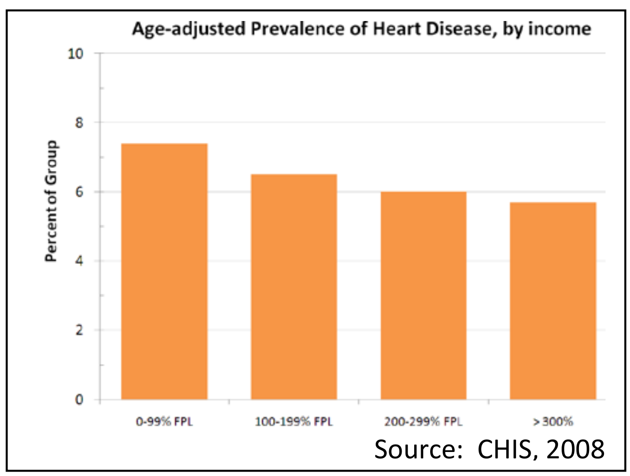


Heart disease prevalence among adults

About six percent of adults (6.1 percent) had ever been diagnosed with heart disease. American Indians/Alaska natives (6.5 percent) and Whites (6.3 percent) had the highest prevalence of heart disease, while Asians (5.6 percent) had the lowest.

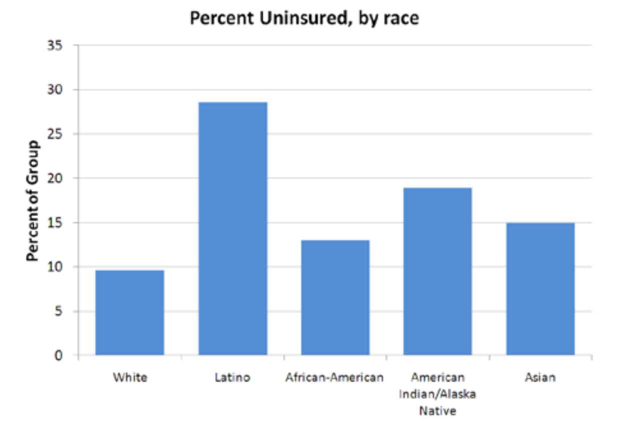


Adults with incomes at or above 300 percent FPL were less likely than those under 100 percent FPL to have been diagnosed with heart disease.



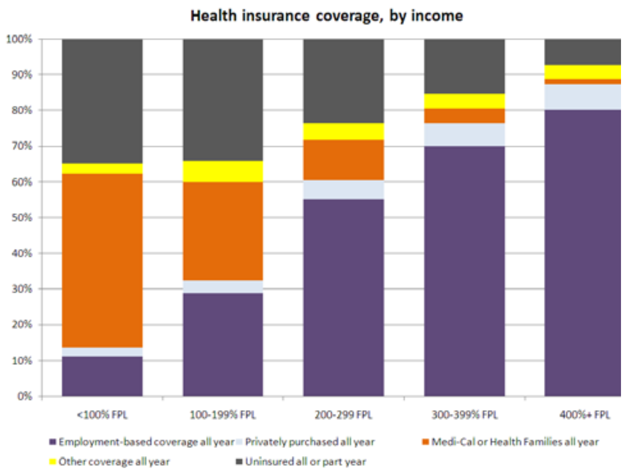
Health insurance coverage

Overall, 16 percent of adults surveyed were uninsured. Whites are more likely to have health insurance coverage than all other racial and ethnic groups in California. The likelihood of not carrying health insurance is highest among Latinos (28.6 percent); foreign-born Latinos (36.1 percent) are more likely to be uninsured than U.S.-born Latinos (14.3 percent).



Source: CHIS, 2008

The proportion of non-elderly individuals without health insurance decreases with increasing income. Lower income households are more likely to have insurance coverage through Media-Cal or Health Families, while higher income households are more likely to be covered by employment-based insurance.



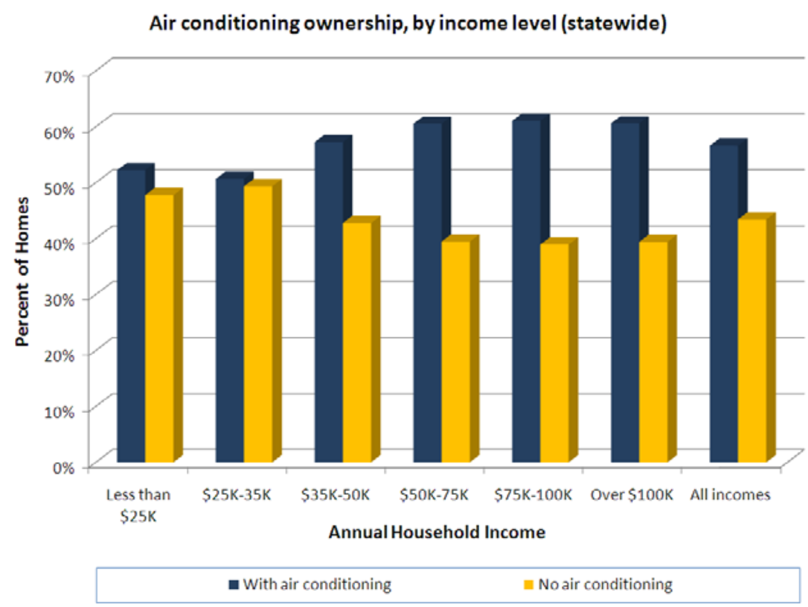
Source: Brown et al., 2009

The graphs generally demonstrate that there are disparities in life expectancy, prevalence of asthma and heart disease, and health insurance coverage among racial and income groups.

CHAPTER 2.
AIR CONDITIONER OWNERSHIP AND COST

(Type I Indicator)

Disparities in the ability to adapt to summertime heat exist among different income levels. Statewide, a greater proportion of households in lower income groups do not have air conditioning. Additionally, summertime electricity costs may be prohibitive for lower income households since these costs represent a greater proportion of their annual income.

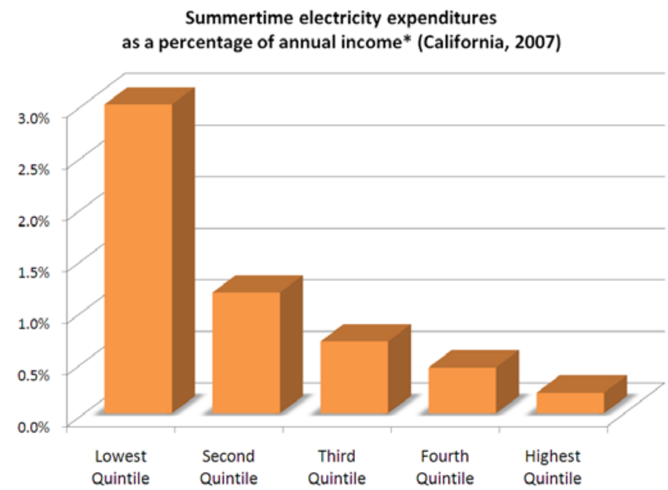


Source: KEMA-XENERGY, 2006

What is the indicator showing?

The indicator reflects the capacity of households at different income levels to cope with summertime heat. The graph above shows that in California, a greater percentage of lower income homes are without air conditioning ("air conditioning" includes central air conditioning, central evaporative coolers, and room air conditioners).

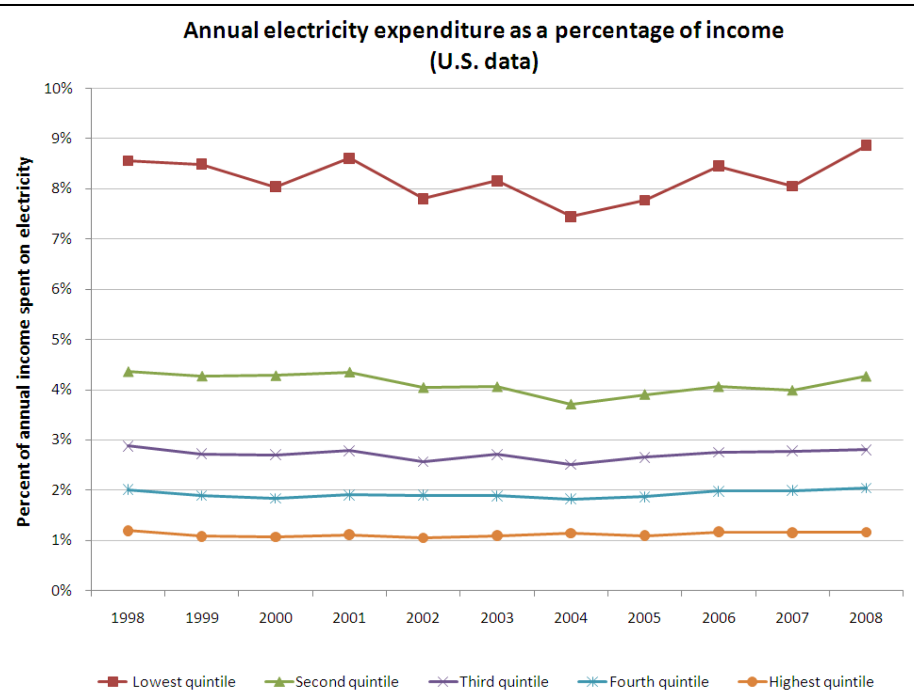
The second graph (next page) shows that the average amount spent on electricity in 2007 represented a greater percentage of the income of households with the lowest earnings. Electricity costs accounted for almost 3 percent of the annual income of households in the lowest income quintile, and only about 1 percent of the annual income of the second lowest quintile. This percentage decreases with increasing income. These results can be compared to findings from a 2003 assessment of the energy-related needs of California's low-income population (KEMA, Inc., 2007). This assessment found that low-income households in California typically spend about 4 percent of their total household income on energy (that is, $950 out of a household income of $23,000). This percentage ranged from 2.8 to 5.3 percent, depending upon the type of energy (electric, gas or a combination) and the utility providing the service.



Note: [1] The percentages are based on an estimate of statewide average cost per household (not actual expenditures) and do not account for, among other things, financial assistance to lower income households. [2] Mean income values for each quintile, from lowest to highest, are as follows: $13,905; $35,548; $59,760; $93,541; $206,941

Source: EIA, 2010; US Census Bureau, 2010

For comparison, national data on consumer expenditures on electricity by households at different income levels are presented in the graph below. While the numeric values are different, a similar pattern is seen nationally: electricity expenditures account for a greater percentage of income for households in the lowest income quintile.



Source: BLS, 2010

Why is this indicator important?

Temperatures have been warming over the past century (see *Annual Air Temperature* and *Air Temperature by County Population* for further information (OEHHA, 2009)). Summertime temperature extremes, in particular, are on the rise especially at night (see *Extreme Heat* Events (OEHHA, 2009)). California's climate is projected to continue to warm by up to 2 degrees Fahrenheit (^{o}F) in the next few decades, along with an increase in the number of days with extreme heat.

A broad spectrum of health impacts has been associated with exposures to heat, ranging from mild heat cramps to severe, life-threatening heat stroke. Children and the elderly, socially isolated populations, outdoor workers, the poor, the chronically ill and the medically underserved are more vulnerable to the effects of heat than the general population (CDPH, 2007). An assessment of a community's vulnerability can help in planning and allocating public resources to prevent heat-related illnesses and deaths. At present, heat-related mortality and morbidity trends associated with a community's vulnerability are not routinely tracked in California (OEHHA, 2009).

Air conditioning is a factor that affects an individual's ability to reduce exposures to heat. Studies of heat waves have identified the lack of access to air conditioning as one of the significant risk factors for heat-related mortality. Concern about the affordability of utility bills was found to influence individuals to limit air conditioning use during the 1995 heat wave in Chicago (CCSP, 2009).

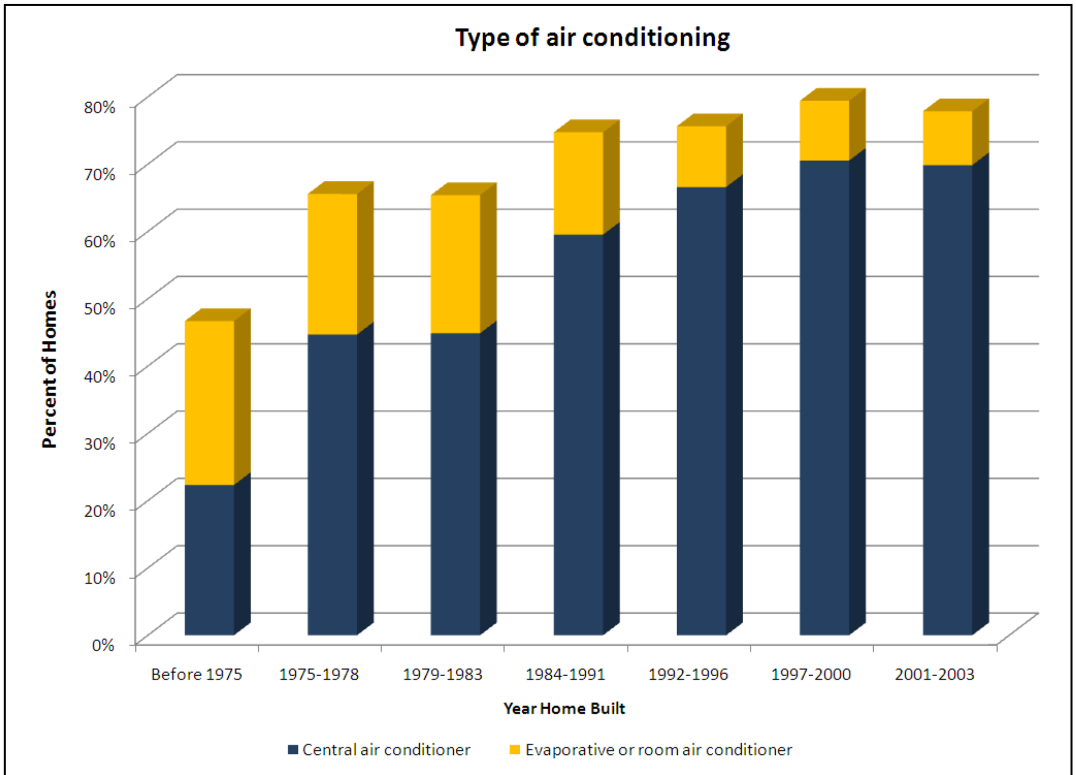
Air conditioning ownership and affordability of use need to be considered by state and local government agencies and other entities in developing and implementing strategies to protect against the adverse health impacts of heat. Such strategies include establishing and providing transportation to cooling centers for persons without access to air conditioning, public service announcements, and education and outreach regarding personal actions to prevent heat-related illness. While air conditioning is an important means of protecting public health in the near term, it should be noted that more comprehensive long-term planning recognizes that heightened electricity demand during heat waves can overload the grid and contribute to outages, and that electricity use is a source of greenhouse gas emissions.

State and local efforts directed at protecting public health during extreme heat events are at various stages of planning and implementation. For example, the California Department of Public Health has conducted an assessment to identify locations and/or populations with high risk for heat-related illness (CDPH, 2007). *A Contingency Plan for Excessive Heat Emergencies* describes state operations during heat-related emergencies and provides guidance for state and local government and non-governmental organizations in the preparation of heat emergency response plans and other related activities (OES, 2008).

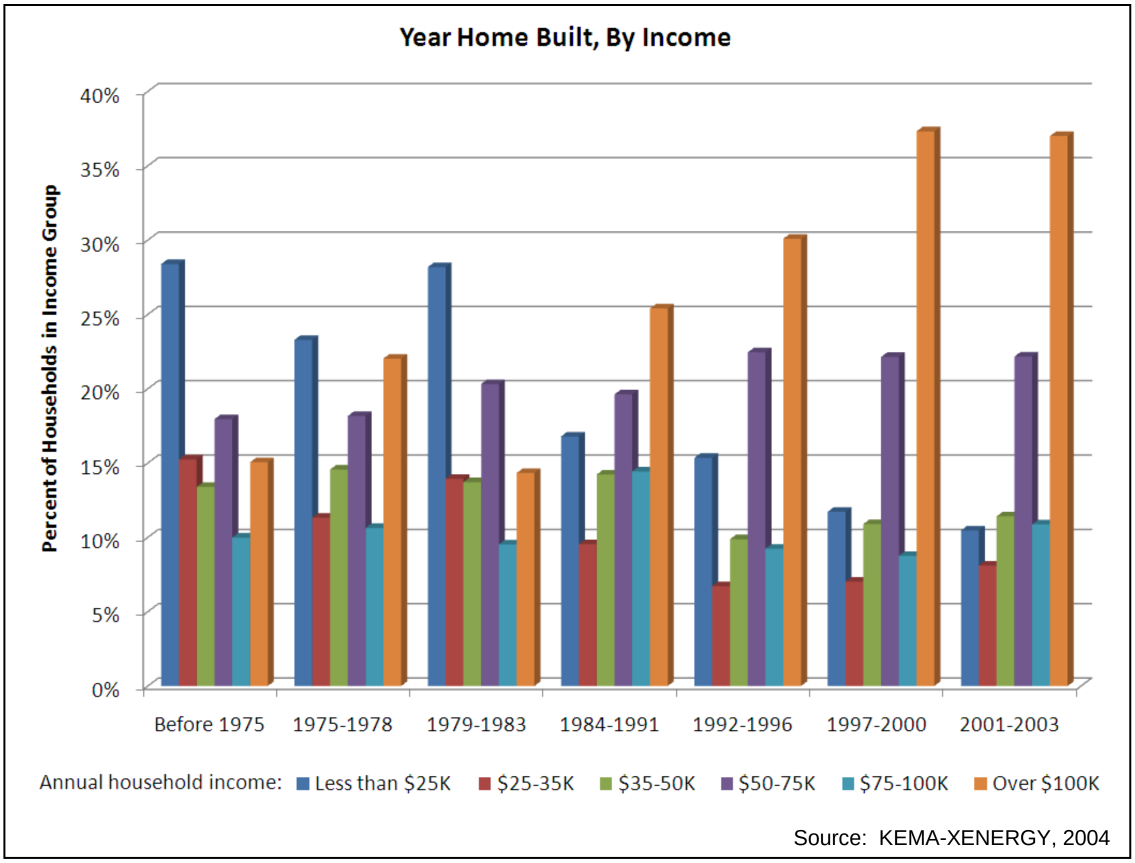
In addition, ongoing financial assistance is available to low-income households through the *California Alternate Rates for Energy Program*, administered by the California Public Utilities Commission. Under this program, eligible customers of investor owned energy utilities who request to participate receive a 20 percent discount on their electric and natural gas bills.

What factors influence this indicator?

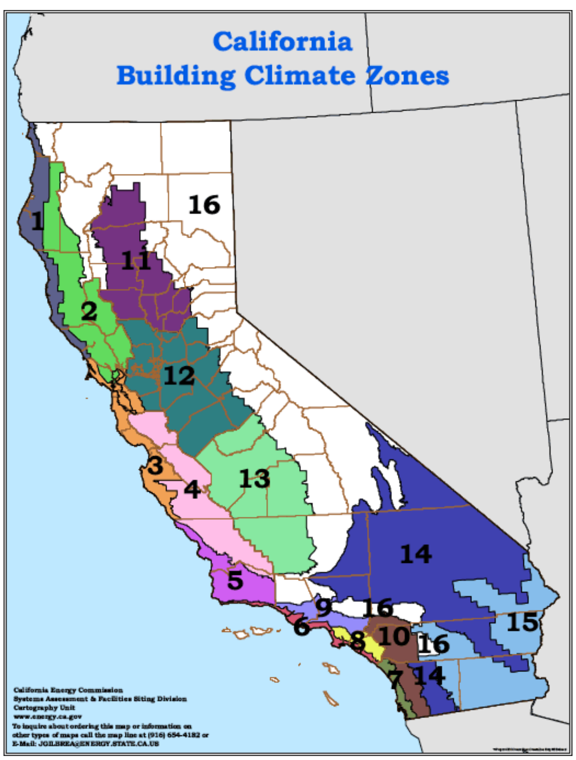
Less than half of surveyed homes built before 1975 have air conditioning; those that do are less likely to have a central air conditioning system compared to more recently built homes (see *Type of air conditioning* graph, below). The same survey showed that evaporative cooling systems and room air conditioners are more common in homes occupied by households earning less than $35,000 per year (KEMA-XENERGY, 2004). These are not as effective in reducing temperature as central air conditioning, especially in high humidity. Further, households earning less than $25,000 per year make up the largest income group in pre-1975 housing, while those earning over $100,000 per year comprise the largest group in homes built in 2001-2003 (see *Year home built, by income*, next page).



Source: KEMA-XENERGY, 2004



Air conditioner ownership is heavily influenced by climate. California is divided into sixteen climate zones, each of which is defined by certain climatic conditions that form the basis for minimum energy efficiency building standards (see map on the left). A representative city for each climate zone is listed in the table on the next page. Homes in climate zones that experience higher maximum temperatures are more likely to have air conditioning (see table, next page). As shown on the map on the next page, air conditioner ownership is high (that is, more than 65 percent of the population have air conditioning) in the Central Valley and the eastern Inland Empire and desert counties (San Bernardino, Riverside and Imperial) (CDPH, 2007). These are areas of the state that experience hotter temperatures (WRCC, 2009).



Climate Zone	Representative City	Average summertime maximum temperature of representative city	% of Homes with cooling system
1	Arcata	62	2
2	Santa Rosa	82	41
3	Oakland	73	11
4	Sunnyvale	83	46
5	Santa Maria	73	18
6	Los Angeles	77	32
7	San Diego	73	29
8	El Toro	83	48
9	Pasadena	87	71
10	Riverside	92	88
11	Red Bluff (Tehema County)	94	93
12	Sacramento	90	86
13	Fresno	94	95
14	China Lake (Kern County)	95	94
15	El Centro (Imperial County)	104	99
16	Mt. Shasta	80	68

Source: WRCC, 2009; KEMA-XENERGY, 2004

Source: CDPH, 2007
(based on data from the California Energy Commission)

Technical Considerations:

Data Characteristics

Data on air conditioning ownership, including data relating the age of dwelling with type of cooling system and with household income, are based on the California Energy Commission's 2003-2004 Statewide Residential Appliance Saturation Study (RASS). KEMA-XENERGY was the primary consultant for the study, with the following investor owned utilities as project sponsors: Pacific Gas and Electric; San Diego Gas and Electric; Southern California Edison; Southern California Gas Company; and Los Angeles Department of Water and Power. The study included results from a survey of 21,920 residential consumers for data on energy use, appliances and equipment (weighted to the population represented by the sponsoring utilities).

Data on electricity costs during the summertime months are from the Energy Information Administration (EIA). EIA compiles data on retail sales of electricity and associated revenue each month, as reported by a statistically chosen sample of electric utilities in the United States.

National data on electricity expenditures are from the U.S. Department of Labor, Bureau of Labor Statistics' (BLS) Consumer Expenditure Survey. The survey consists of two separate components, each with its own questionnaire and sample: a quarterly interview survey of large or recurring expenses and a diary survey of expenses for two consecutive one-week periods. Data for both survey components is collected by the U.S. Census Bureau under contract with BLS.

Strengths and Limitations of the Data

RASS was statistically designed to provide both statewide and utility-specific results and to allow comparisons across utility service territories, climate zones and other variables of interest (such as dwelling type, dwelling age and income). The study employed four different data collection methods: a mail survey (two rounds); non-respondent follow-up using a third mail survey with an incentive; a telephone interview, or an in-person interview; and collection of hourly electric load data in a small (180) subset of homes. RASS served as a reliable source of statewide information for air conditioning ownership and related parameters. The data, however, were collected in 2003 and may not reflect current information. In addition, certain areas of the state not served by the participating utilities may not be adequately captured by the study.

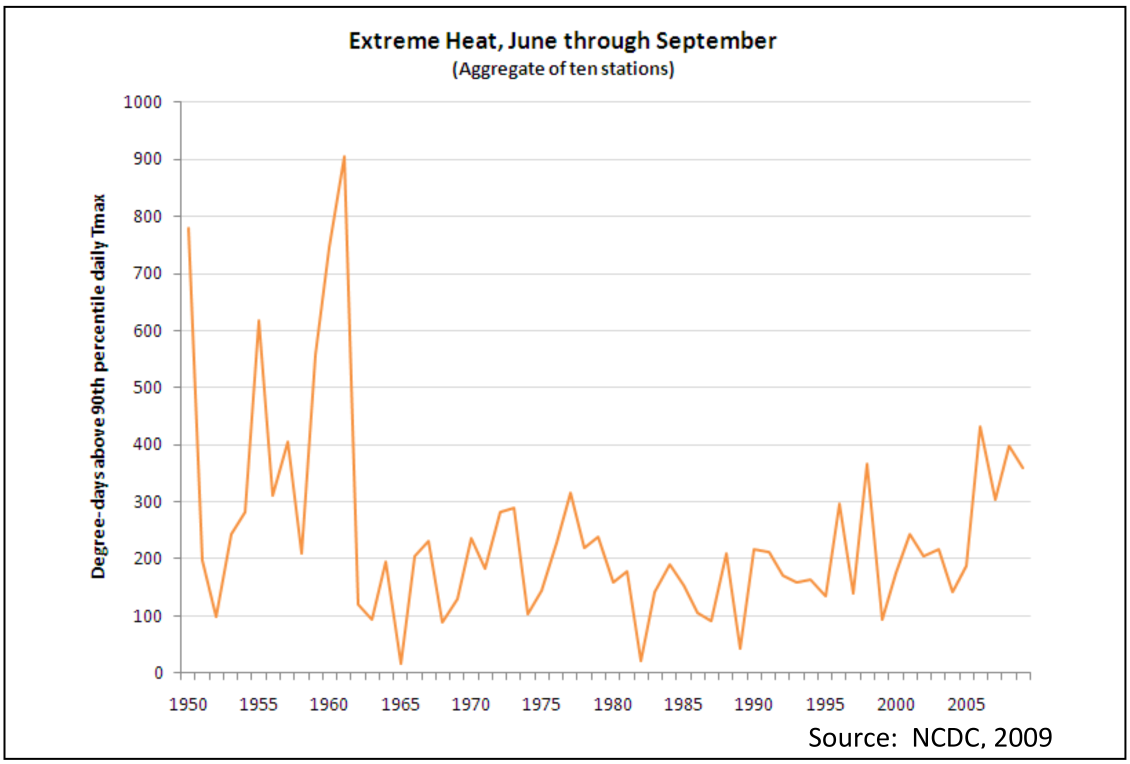
Electricity expenditures (used for the graph, *Summertime electricity expenditures as a percentage of annual income*) represent a statewide average amount per household. Hence, the value may not reflect differences in actual expenditures among different income groups (including financial assistance to low-income households) in different areas of the state. The income data used are from the 2000 Census and may likewise not be representative of current information.

CHAPTER 3.
FARM WORKER EXPOSURE TO EXTREME HEAT

(Type I Indicator)

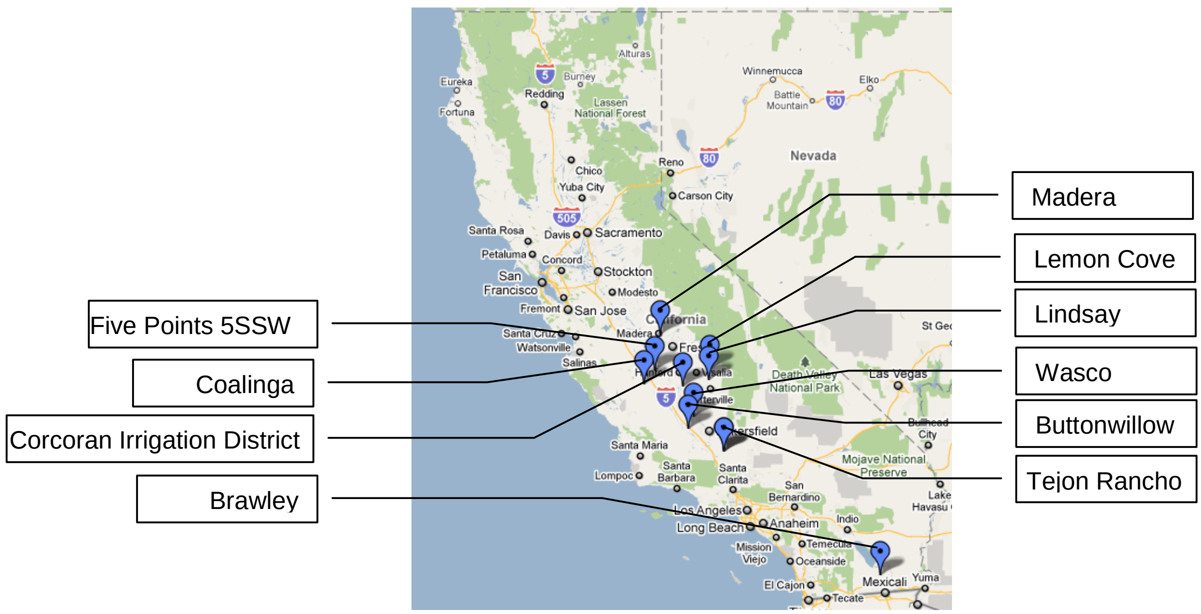
California's farm workers are a low-income, predominantly Hispanic population that experience disproportionately greater exposures to extreme heat. From 1950 to the mid-1980s, extreme heat[1] in the Central Valley and the Imperial Valley declined. Since the mid-1980s, however, extreme heat appears to be trending upward.

Photo: Clark, 1992



[1] Extreme heat is measured as "degree-days above the 90th percentile daily Tmax" aggregated from ten climate stations. For each climate station, the 90th percentile of daily maximum temperature readings (Tmax) for each month from June through September is determined. Daily Tmax exceedances of the 90th percentile value for each month at each station are summed for each year, then aggregated to derive each yearly value.

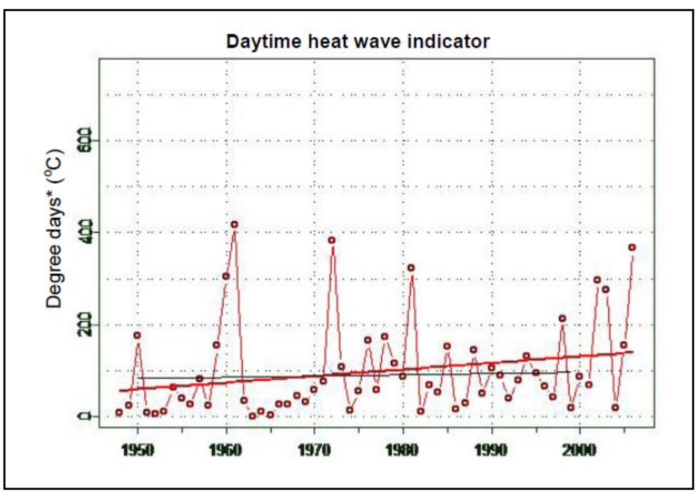
What is the indicator showing?
The indicator tracks extreme heat using a metric that incorporates both the magnitude and frequency of days from June through September when the maximum temperature was above the 90th percentile of readings at each climate station. In order to reflect farm worker exposures to extreme heat, measurements included ten climate stations in California counties that are among the highest in terms of number of farm workers and value of crops: Fresno, Kern, Tulare, Madera, Kings and Imperial counties (CDFA, 2009a). The locations of these stations are shown on the map below.



Source: Google Maps

The graph shows that from 1950 to the mid-1980s, the magnitude and frequency of extreme heat events aggregated across the selected locations had been declining, particularly following relatively intense heat activity from 1950 to 1961. Beginning around the mid-1980s, however, extreme heat appears to be trending upward. Most of the climate stations follow the same general trends (individual graphs for each station are presented on pages 22-26).

Information from these ten agricultural climate stations could be misinterpreted as showing that high summertime temperatures in California peaked in the 1950s and have generally been in decline since that time. In fact, data from 95 stations in California and Nevada clearly show a steady increase in extreme temperatures over the past 60 years (see graph, right, from *Extreme Heat Events* indicator (OEHHA, 2009)). One plausible



explanation for the post-1960 decrease in extreme temperatures at the agricultural stations is the influence of irrigation in those areas. This is discussed below (see *What factors influence this indicator?)*

Why is this indicator important?

As with other workers engaged in outdoor occupations, farm workers are at risk of heat-related illnesses, especially when performing physically demanding tasks. Some labor-intensive crops are produced in the hottest counties in California. For example, tomatoes and melons are grown in Imperial and Fresno Counties, where the average maximum temperatures in July are 107.6^{o}F and 99.3^{o}F, respectively (CDFA, 2009b; WRCC, 2009). In the past ten years, hiring of agricultural workers peaked during the months of June through September (EDD, 2006), the same months when daily maximum temperatures tend to be at their highest.

It is particularly important to track this indicator because in the last several years, extreme heat has been showing an upward trend which could adversely affect low-income farm workers.

Exposures to extreme heat can potentially impact a large population consisting of low income, largely Hispanic members. In 2008, California's agricultural work force totaled almost 375,000 persons (EDD, 2008). Nearly all (99 percent) of the state's farm workers are Hispanic, over 90 percent come from Mexico and 22 percent earned incomes below the federal poverty level ($9,573 for an individual and $14,680 for a family of three in 2003). These workers have limited English language skills, and about 70 percent have no health insurance (Aguirre International, 2005).

Farm labor entails physically demanding tasks, such as tilling soil, manually planting or transplanting crops, hoeing, harvesting, sorting, field packing and grading (Aguirre International, 2005). In cases where their pay depends on "piece work" (that is, a rate based on weight or number of crops picked) rather than a fixed, time-based salary, farm workers may be reluctant to slow down or rest despite fatigue or heat exhaustion. Heat-related illness results from a combination of factors including environmental temperature and humidity, direct radiant heat from the sun or other sources, and wind speed. Extra clothing or personal protective equipment used by farm workers to protect against pesticide exposures may increase farm workers' risk of heat-related illness (CDC, 2008). A broad spectrum of health impacts has been associated with exposures to heat, ranging from mild heat cramps to severe, life-threatening heat stroke (CDPH, 2007). Personal factors, such as age, weight, level of fitness, medical condition, use of medications and alcohol, and acclimatization affect how well the body copes with excess heat (UC Berkeley and DIR, 2006).

During 1992-2006, 68 heat-related deaths occurred among over 17 million crop workers in the United States, a rate (0.39 per 100,000 workers) nearly 20 times greater than for all civilian workers. During the same time period, 20 deaths occurred in California out of 404,100 crop workers (a death rate of 0.49 per 100,000) (CDC, 2008). An increased likelihood of more intense, longer lasting and more frequent heat waves is projected for the future (CCSP, 2008). This underscores the importance of taking vigilant steps to prevent heat-related illnesses and deaths.

The State of California recognizes the risk of heat illness from high temperatures as one of the most serious challenges to the health and safety of farm workers. Employers must comply with California's Heat Illness Prevention Standard (Title 8, Section 3395), which is enforced by Cal/OSHA. Employers are required to train employees and supervisors about heat illness prevention; provide enough fresh water and encourage employees to drink at least 1 quart per hour; provide access to shade for at least 5 minutes of rest when an employee believes he or she needs a preventative recovery period; and develop and implement written procedures for complying with the Cal/OSHA Heat Illness Prevention Standard (Cal/OSHA, 2010).

What factors influence this indicator?

Air temperature varies according to the time of day, the season of the year and geographic location. Daytime and nighttime temperatures have been warming in California over the past century, with nighttime temperatures increasing at a faster rate (see *Annual Air Temperature* indicator (OEHHA, 2009)). Summertime temperature extremes have also been increasing, especially at night (*Extreme Heat Events* indicator (OEHHA, 2009)). The 2006 heat wave in California, the largest heat wave on record since 1948, has been linked to a warming of the ocean especially west of Baja California (Moser et al., 2009). The decrease in extreme heat since 1950 for the ten climate stations is not consistent with the trend observed for 95 stations in California and Nevada (discussed in the *Extreme Heat Events* indicator).

Although assessments of its impacts on climate have produced conflicting results, irrigation may be a factor influencing summertime high temperatures in agricultural areas, such as the areas in which the ten stations analyzed are located. Two large water storage and delivery projects facilitated irrigated agriculture in California: the Central Valley Project, which began delivering water in the 1940s (USBR, 2010), and the State Water Project, which completed construction of its initial facilities in the mid-1960s (DWR, 2010). One study found that a doubling of irrigated area in the Central Valley from 1915 to 1979 was associated with a significant cooling relative to a modestly irrigated reference region. The study further found that during periods with little change in irrigation cover (1959-1969 and 1978-1982), the differences in temperature trends between the two areas were small, and during a period of recession of irrigation in 1982-1987, temperature in the Central Valley trended upward. Changes in irrigation cover were also found to closely correspond to summertime (June through August) maximum temperature in the areas of intensively irrigated land but not in a reference area (Bonfils and Lobell, 2007).

Technical Considerations:

Data Characteristics

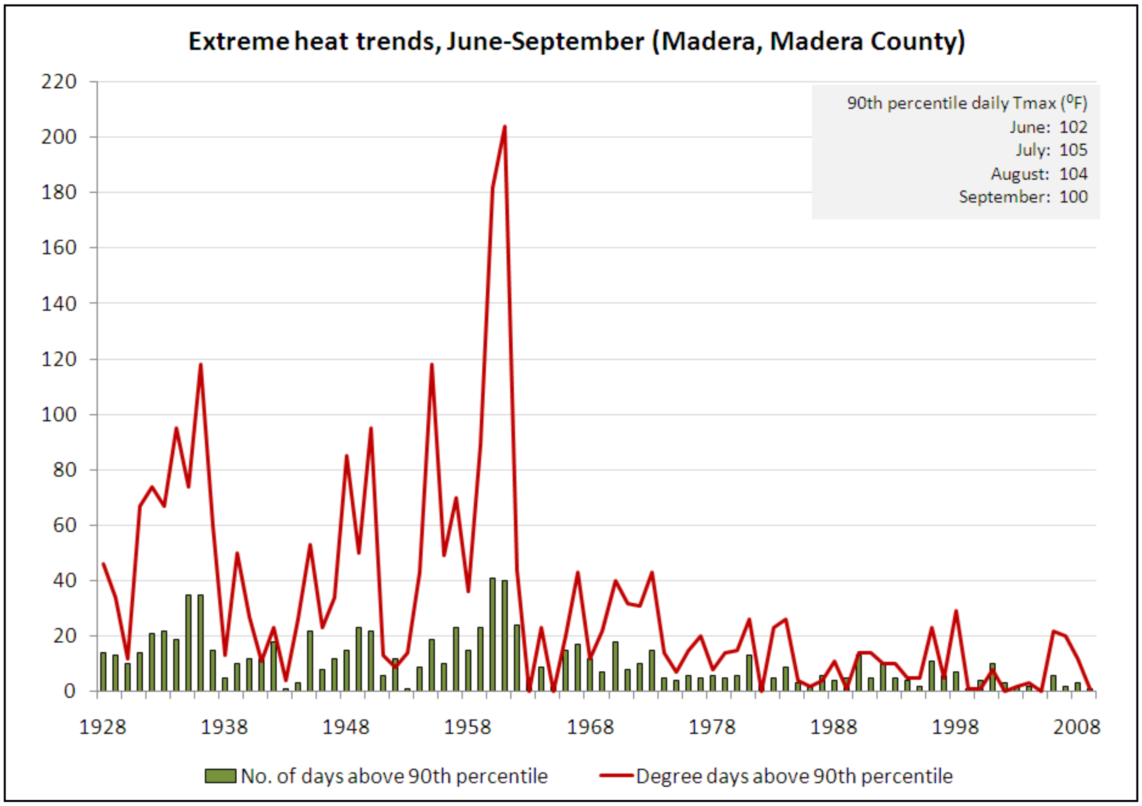
Temperature data were obtained from the National Climatic Data Center (http://www.ncdc.noaa.gov/oa/climate/stationlocator.html). Selection of climate stations considered the following factors: number of farm workers employed and value of crops produced by the county; location in an agricultural area; and availability of daily maximum air temperature data from approximately 1950 to at least up to 2006.

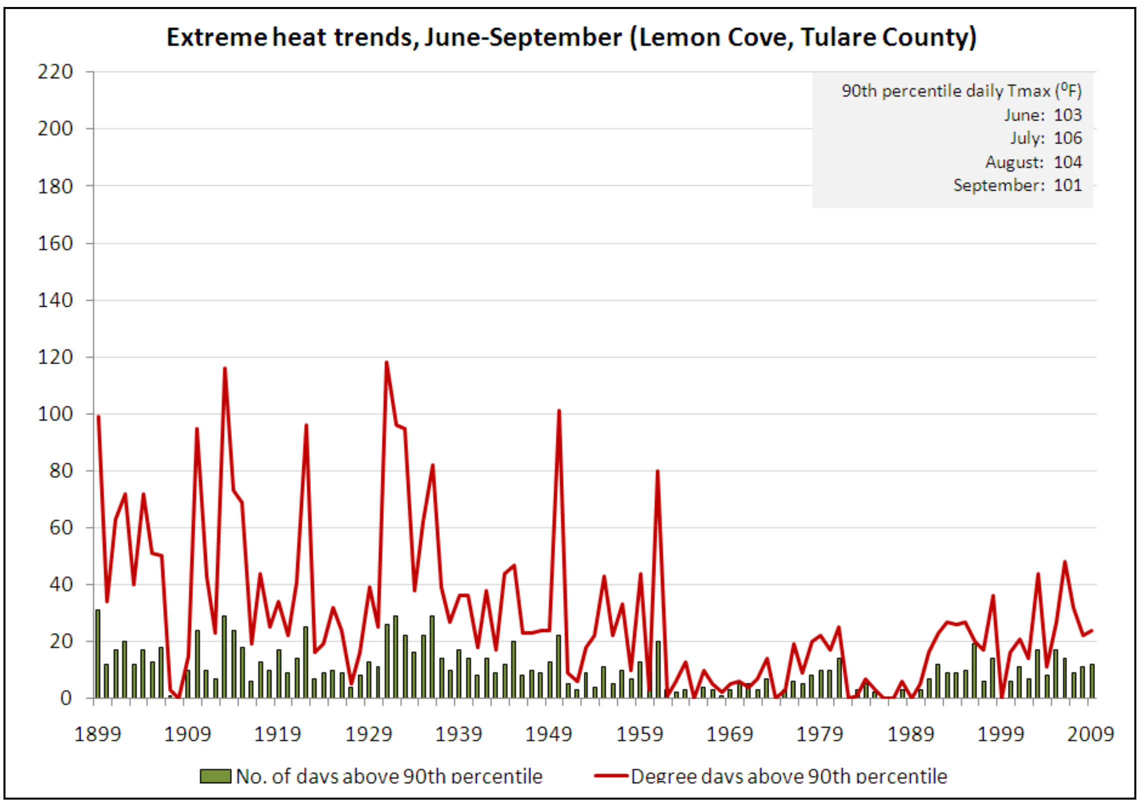
Calculation of the metric for extreme heat adopted the approach presented in the *Extreme Heat Events* indicator (OEHHA, 2009 based on analysis by Gershunov, 2008). The 90th percentile of the daily maximum temperature values for each month from June through September was determined for each climate station; the sum of each daily exceedance of the 90th percentile value from June through September was calculated for each year for each climate station. Graphs presenting the data for each climate station are presented in the appendix. The annual values from each of the ten selected climate stations were then added to derive the aggregate value shown on the indicator graph.

Strengths and Limitations of the Data

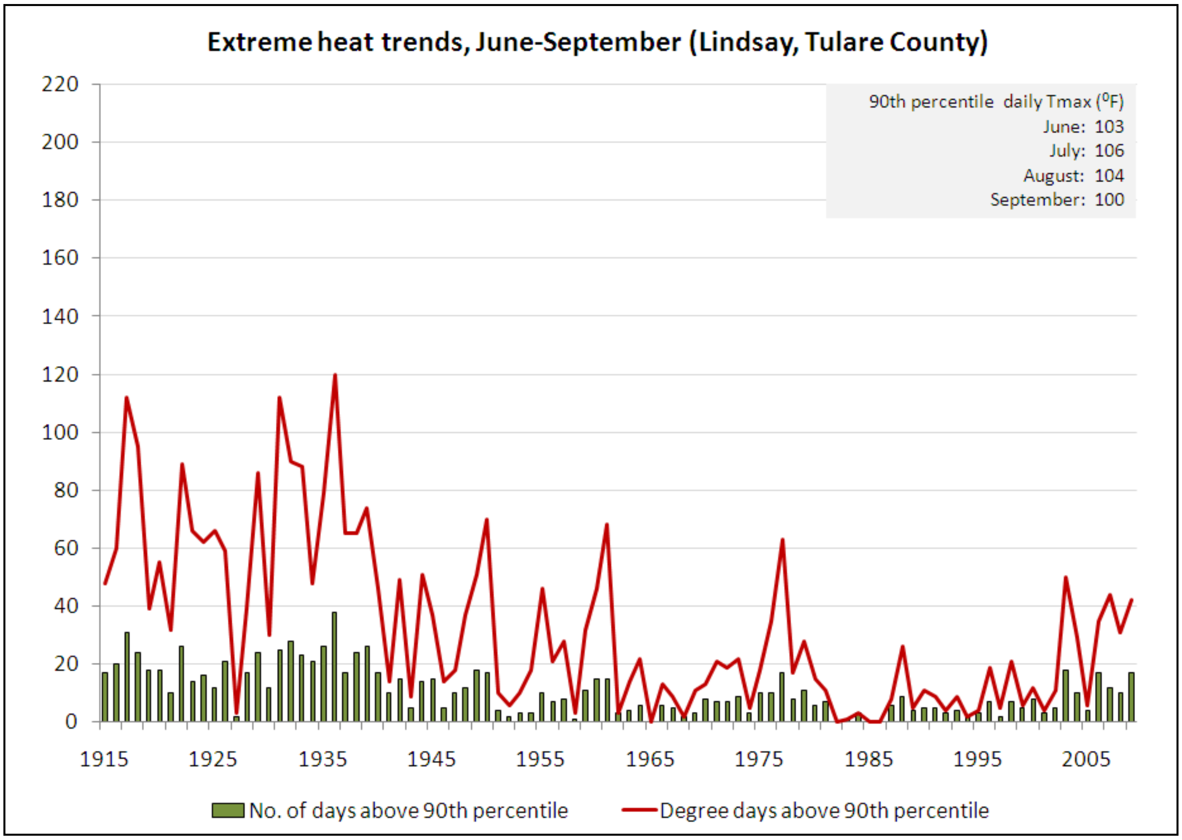
The datasets used in this work (WRCC, 2010) were subjected to quality control procedures to account for potentially incorrect data reported by the observer, missing data, and to remove inconsistencies such as station relocation or instrument change (Abatzoglou et al., 2009).

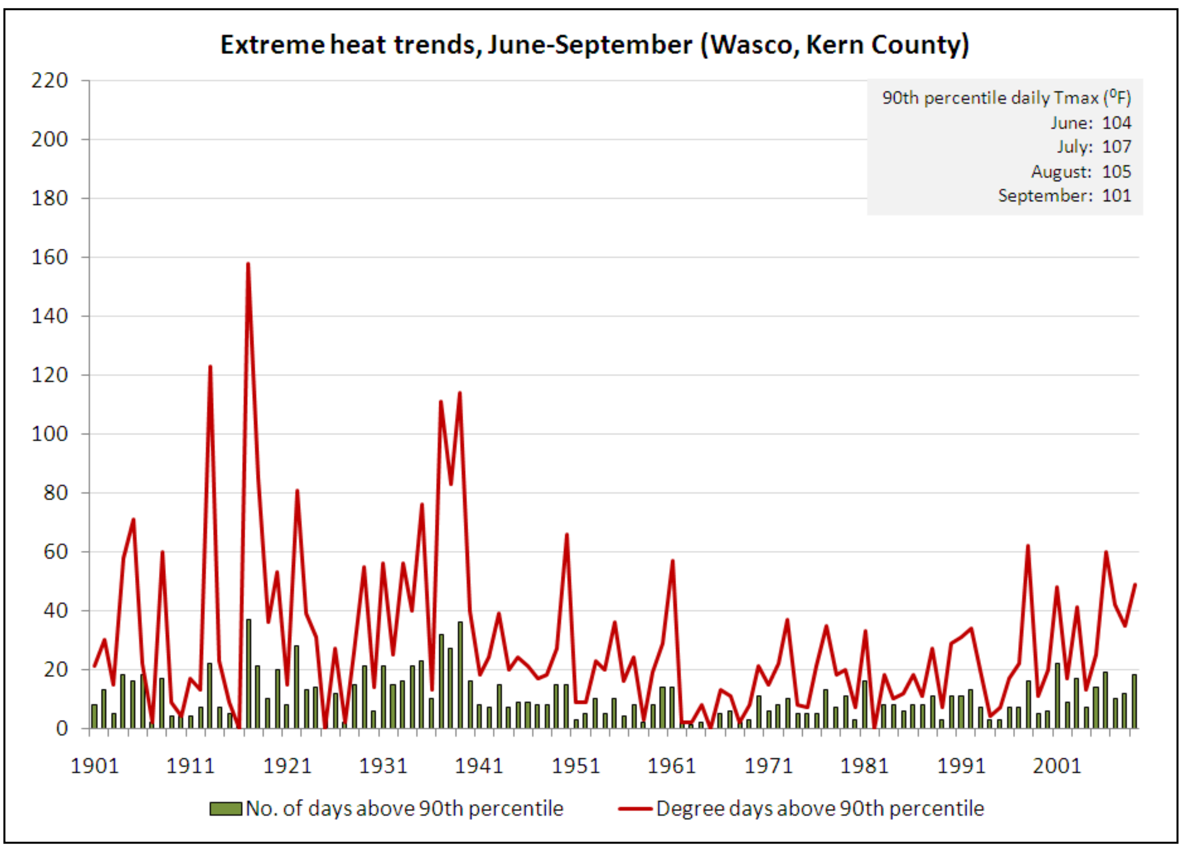
Extreme heat at selected climate stations: June through September*

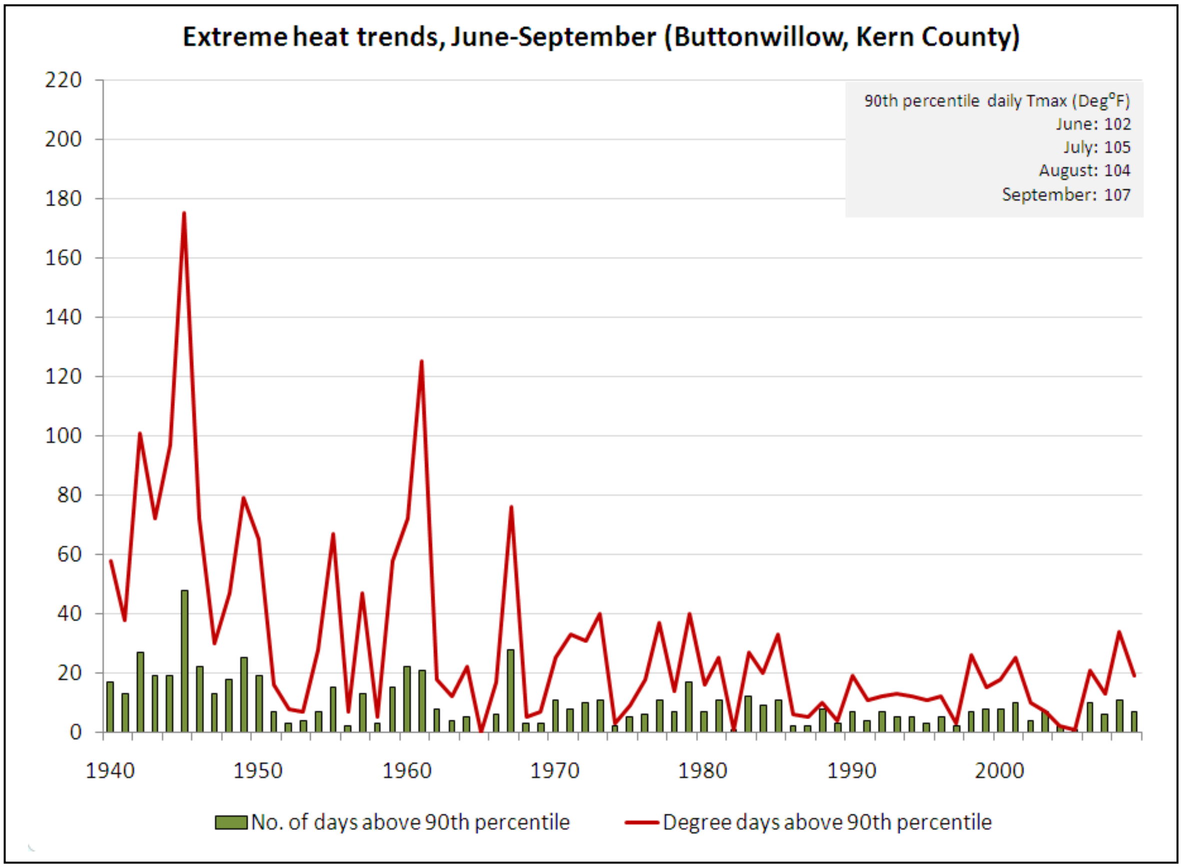


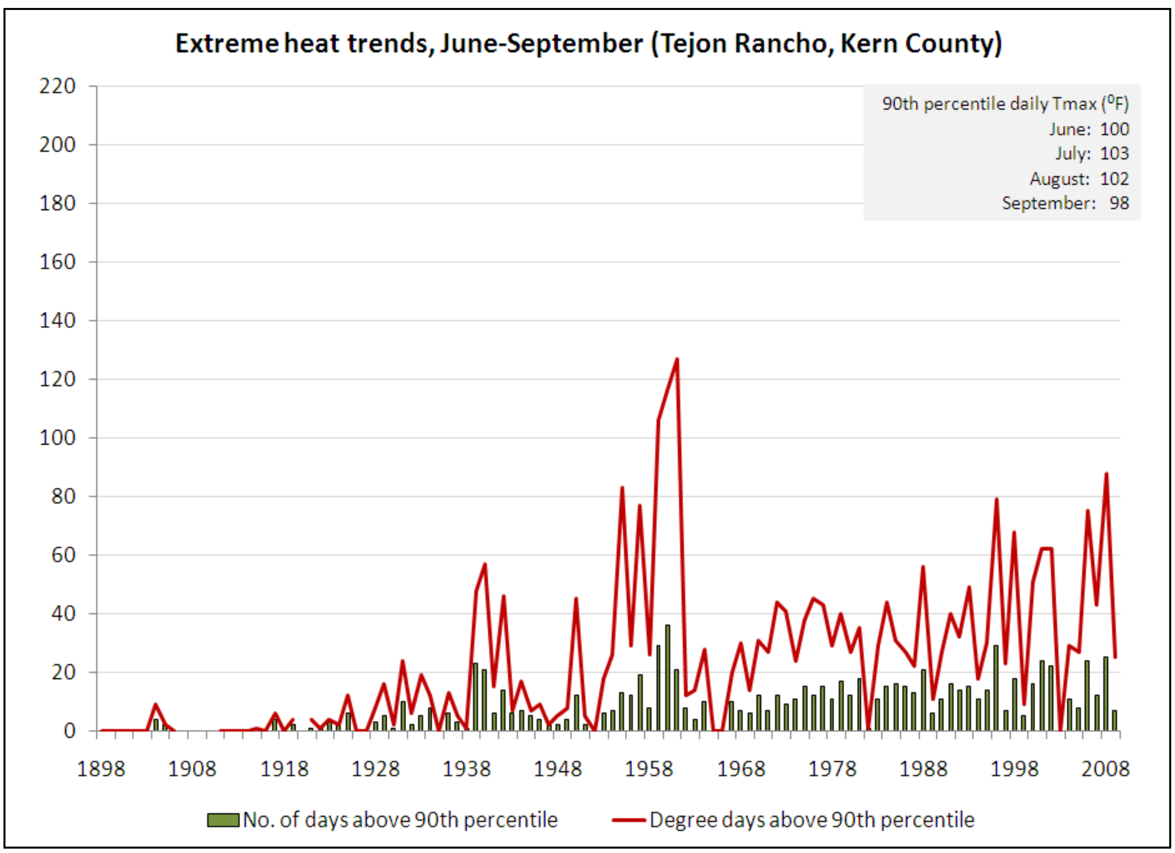


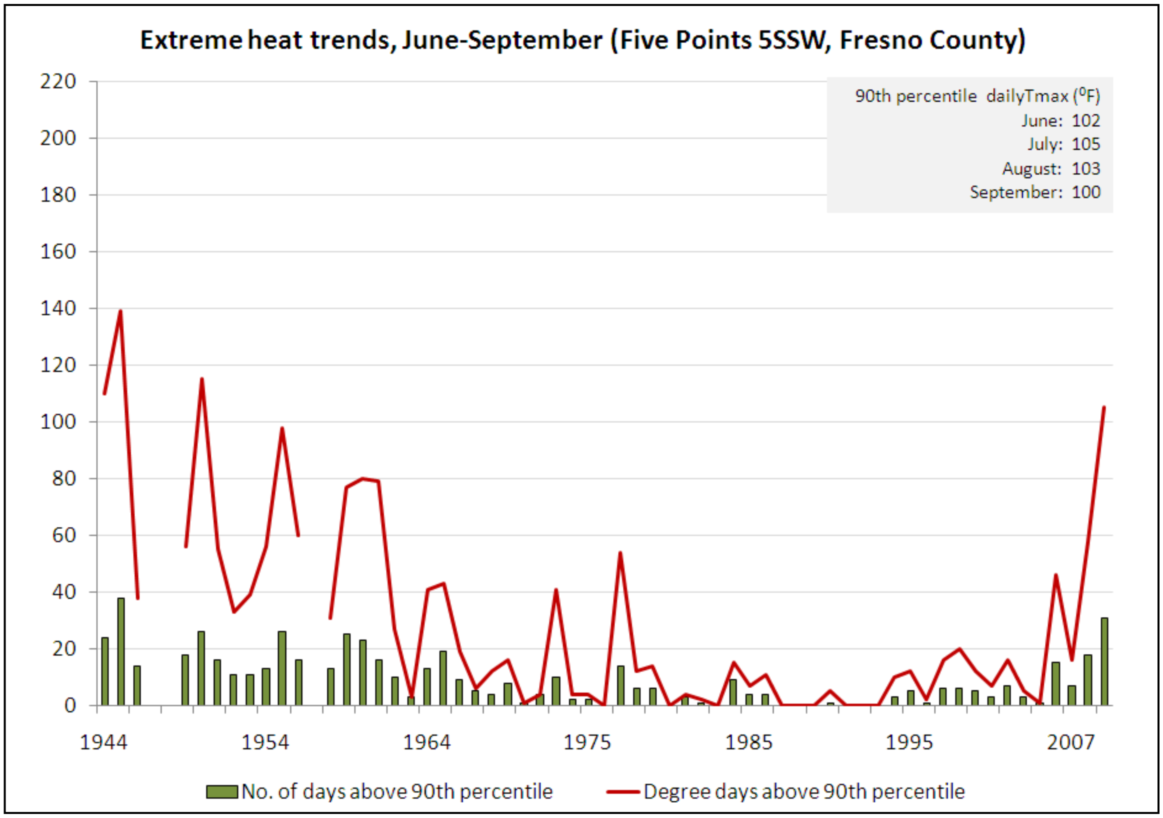
* Data source: National Climatic Data Center, http://www.ncdc.noaa.gov/oa/climate/stationlocator.html

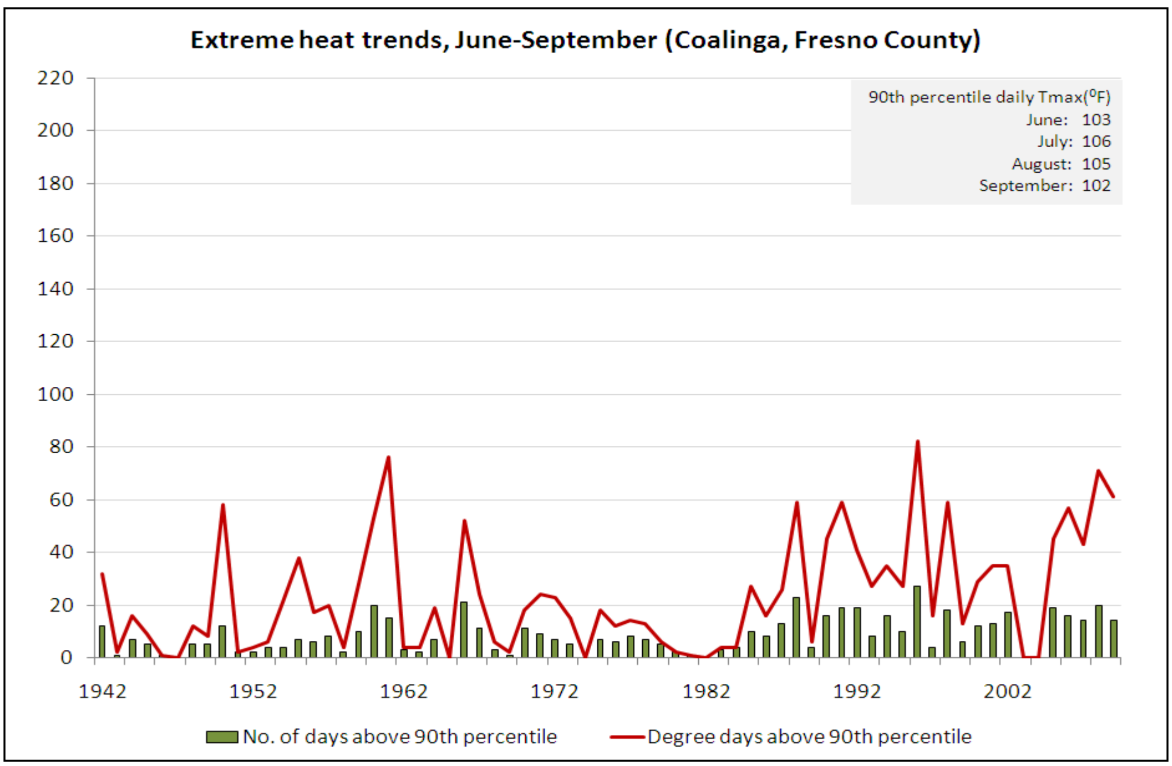

Extreme heat trends, June-September (Lindsay, Tulare County)
90th percentile daily Tmax (⁰F)
June: 103
July: 106
August: 104
September: 100
220
200
180
160
140
120
100
80
60
40
20
0
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
No. of days above 90th percentile
Degree days above 90th percentile

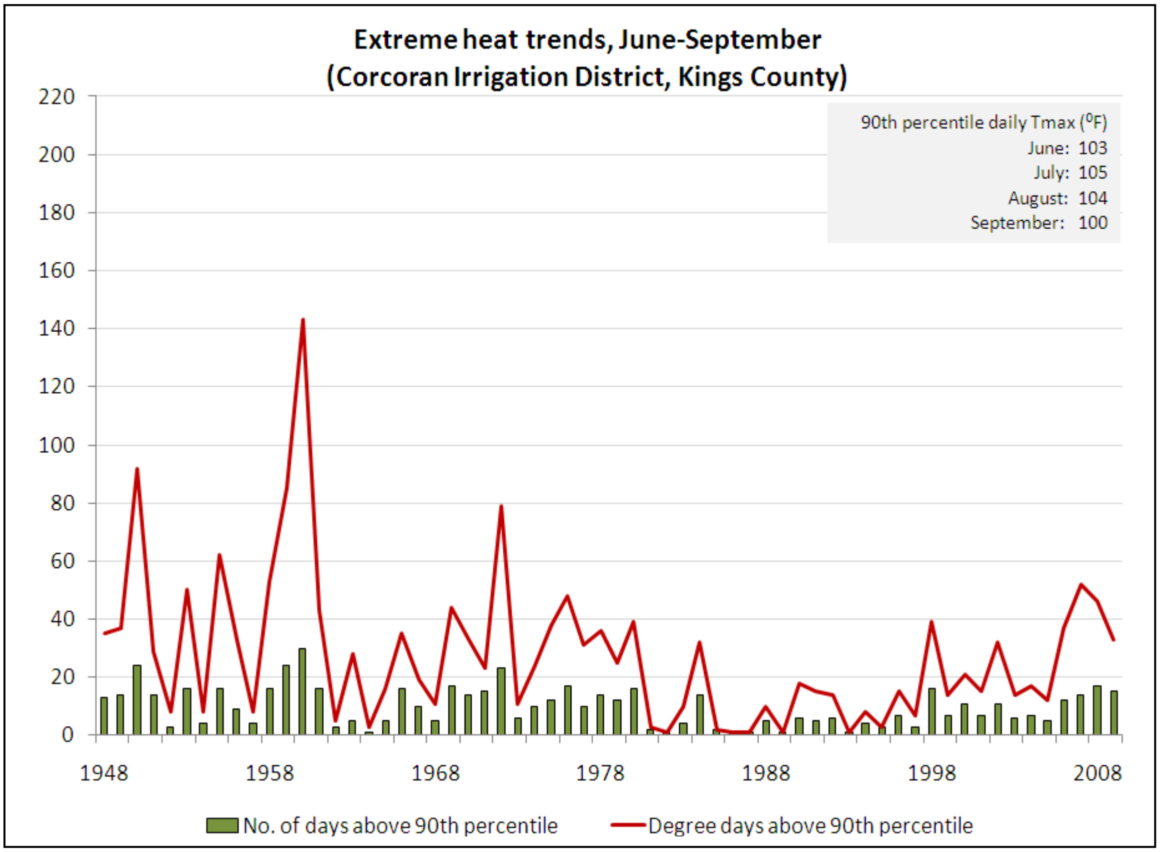

Extreme heat trends, June-September (Wasco, Kern County)
90th percentile daily Tmax (⁰F)
June: 104
July: 107
August: 105
September: 101
220
200
180
160
140
120
100
80
60
40
20
0
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
No. of days above 90th percentile
Degree days above 90th percentile

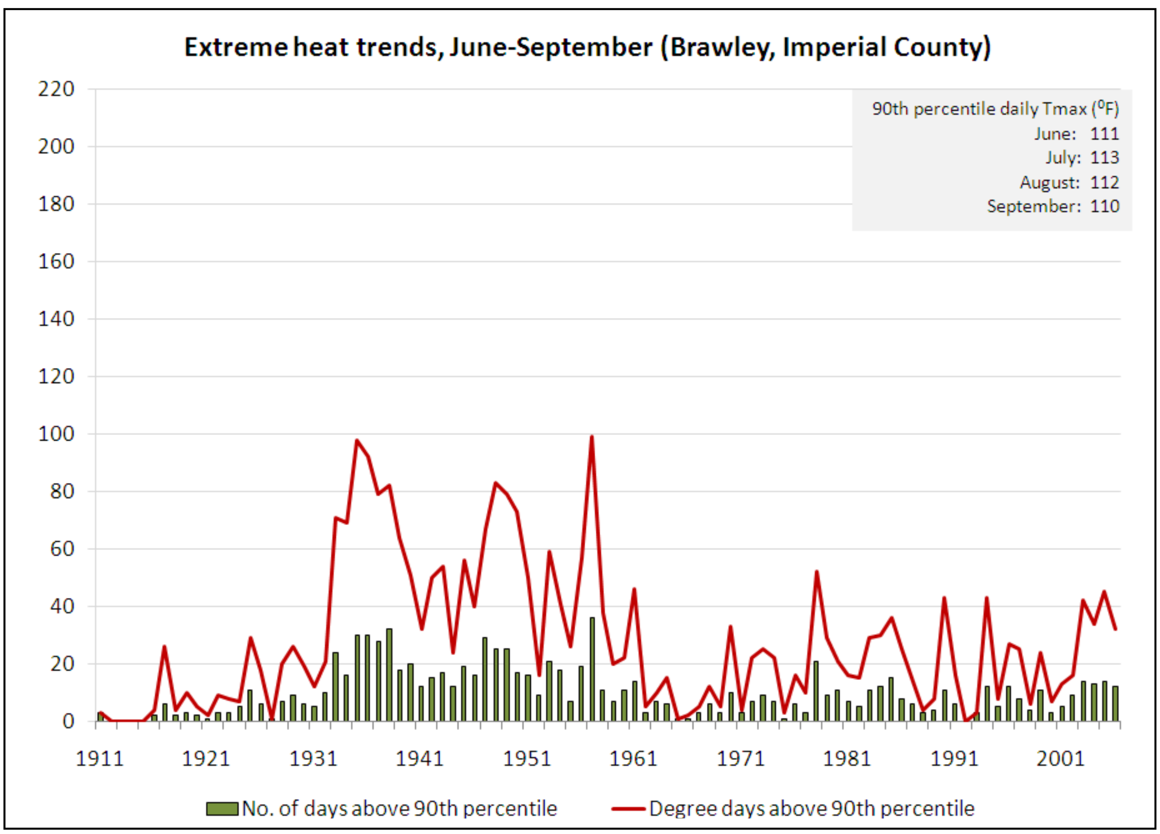

Extreme heat trends, June-September (Buttonwillow, Kern County)
90th percentile daily Tmax (Deg°F)
June: 102
July: 105
August: 104
September: 107
0
20
40
60
80
100
120
140
160
180
200
220
1940
1950
1960
1970
1980
1990
2000
No. of days above 90th percentile
Degree days above 90th percentile


Extreme heat trends, June-September (Tejon Rancho, Kern County)
90th percentile daily Tmax (°F)
June: 100
July: 103
August: 102
September: 98
0
20
40
60
80
100
120
140
160
180
200
220
1898
1908
1918
1928
1938
1948
1958
1968
1978
1988
1998
2008
No. of days above 90th percentile
Degree days above 90th percentile


Extreme heat trends, June-September (Five Points 5SSW, Fresno County)
90th percentile dailyTmax (^{0}F)
June: 102
July: 105
August: 103
September: 100
220
200
180
160
140
120
100
80
60
40
20
0
1944
1954
1964
1975
1985
1995
2007
No. of days above 90th percentile
Degree days above 90th percentile


Extreme heat trends, June-September (Coalinga, Fresno County)
90th percentile daily Tmax(^{0}F)
June: 103
July: 106
August: 105
September: 102
220
200
180
160
140
120
100
80
60
40
20
0
1942
1952
1962
1972
1982
1992
2002
No. of days above 90th percentile
Degree days above 90th percentile


Extreme heat trends, June-September
(Corcoran Irrigation District, Kings County)
90th percentile daily Tmax (⁰F)
June: 103
July: 105
August: 104
September: 100
220
200
180
160
140
120
100
80
60
40
20
0
1948
1958
1968
1978
1988
1998
2008
No. of days above 90th percentile
Degree days above 90th percentile


Extreme heat trends, June-September (Brawley, Imperial County)
90th percentile daily Tmax (⁰F)
June: 111
July: 113
August: 112
September: 110
220
200
180
160
140
120
100
80
60
40
20
0
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
No. of days above 90th percentile
Degree days above 90th percentile

CHAPTER 4.
EXPOSURE TO URBAN HEAT

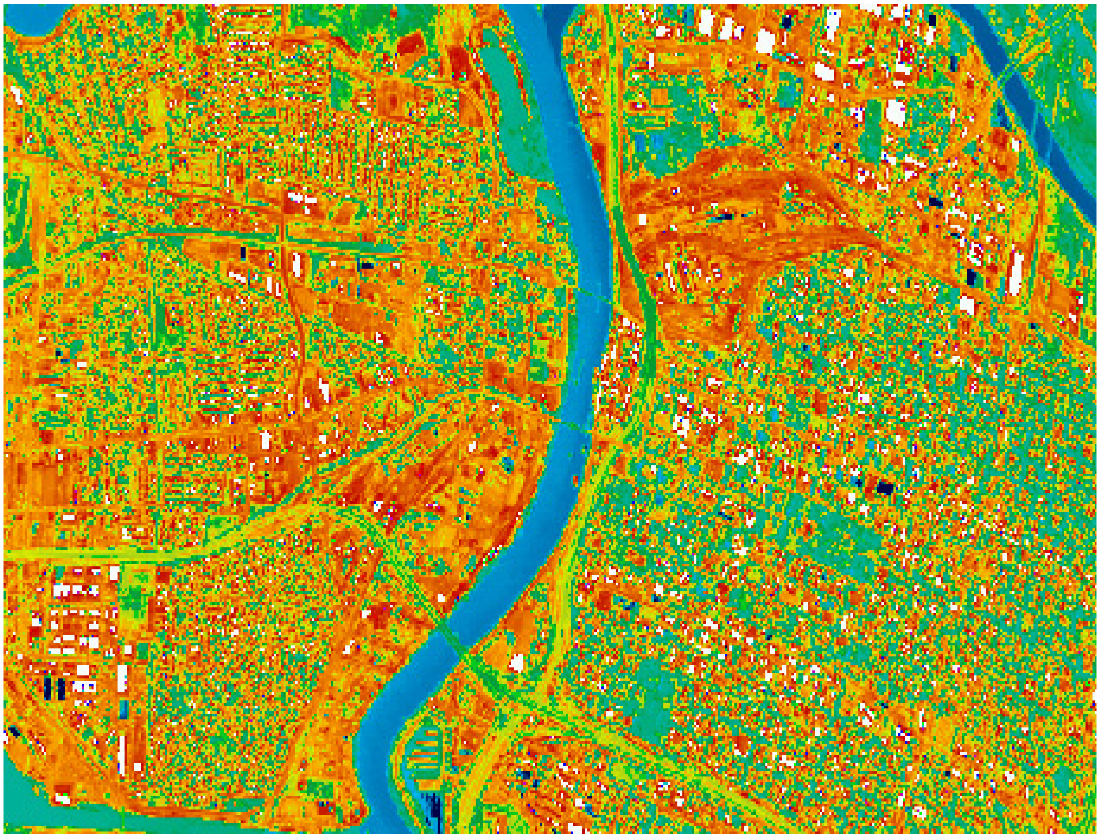
(Type III Indicator)

Absorption of heat by dark paved surfaces and buildings, lack of vegetation and trees, heat emitted from buildings, vehicles and air conditioners and reduced air flow around buildings can raise air temperatures in cities over the surrounding suburban and rural areas by 2 to 10^{o}F (CCSP, 2008). This is commonly referred to as the "urban heat island" effect. During heat waves, urban heat islands are especially dangerous because they are hotter during the day and do not cool down at night, increasing the risk of heat-related illness (CNRA, 2009).

Because low-income urban residents and communities of color are often segregated in the inner city, they are more likely to experience higher temperatures than suburban or rural residents. Analyses of neighborhoods in the Los Angeles, Sacramento, San Diego and San Francisco metropolitan areas found that increasingly greater proportions of households below the poverty line reside in neighborhoods with increasing impervious cover and decreasing tree canopy; the same relationships were found between the percentage of people of color in a neighborhood and both impervious cover and tree canopy (Morello-Frosch et al., 2009). In a California nine-county study from May through September of 1999-2003 (Basu and Ostro, 2008), heat-related mortality rates were reported to be elevated for African-Americans when compared to Hispanics and Whites. The authors suggested that the African-American populations studied may have been more vulnerable to extreme heat due to factors such as lack of access to air conditioning and pre-existing health conditions.

Exposures to urban heat are important for public health and social services agencies to consider in planning and implementing responses to heat emergencies. Further, indicators that allow the identification of urban heat islands can inform the development of mitigation measures. Many of these measures can result in multiple benefits beyond urban heat reduction such as reducing energy demand for heating and cooling; reducing stormwater runoff; and improving aesthetic qualities and increasing property values. Examples of mitigation strategies include planting trees and other vegetation, and installing cool roofs and cool pavements.

The amount of impervious surface in urban areas can be used as an indicator of heat island potential in California. Identifying areas where heat-absorbing surfaces and buildings with little vegetation or tree canopy are concentrated can reveal neighborhoods where temperatures will likely be amplified during heat events. For example, the thermal infrared photograph of the downtown Sacramento area (see map, next page) shows red and yellow "hot spots" that generally correspond to concrete areas or rooftops; blue and green areas correspond to cooler vegetative areas or water. Once these hot spots are identified, the income and racial characteristics of these areas can be determined. This information can help guide planning, mitigation and response efforts.



Source: NASA, 1998

Source: Google Maps, 2010

The thermal infrared image (above) shows urban structures in Sacramento and West Sacramento as red and yellow, and vegetative cover and water as green and blue (U.S. EPA, 1998). A satellite view (left) is shown for reference.

An indicator for tracking disparities in urban heat exposures will need to integrate data for multiple components: impervious surfaces; vegetation cover or tree canopy;

temperature; and community demographics. Community-level temperature data can be derived from thermal infrared images or collected using climate monitors at appropriate locations. At present, infrared images of California cities are not routinely taken, and climate monitors are often located only at the airports, commercial buildings, and non-residential locations.

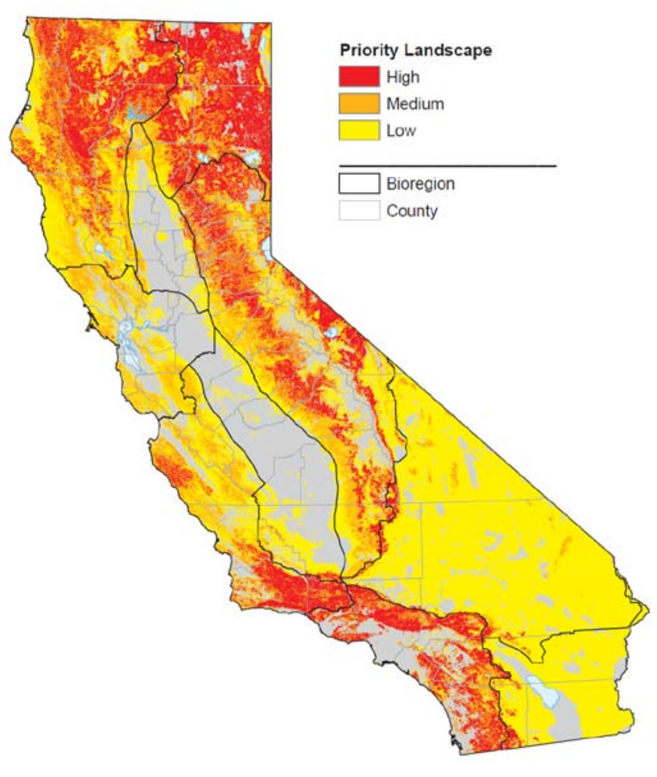
CHAPTER 5.
VULNERABILITY TO WILDFIRES

(Type III Indicator)

In the western United States large wildfires (1000 acres and greater) and fire season length are increasing in tandem with rising temperatures (see *Large Wildfires* indicator (OEHHA, 2009)). Wildfires are projected to increase in California with climate change (Cayan et al., 2006). Climate change can increase wildfire risks by elevating temperatures and by either increasing the vegetative fuel load (in wet years) or drying out vegetation (in dry years) (Westerling and Bryant, 2008). Certain communities may be less able to cope with this increasing danger.

Source: CAL FIRE (2010 a)

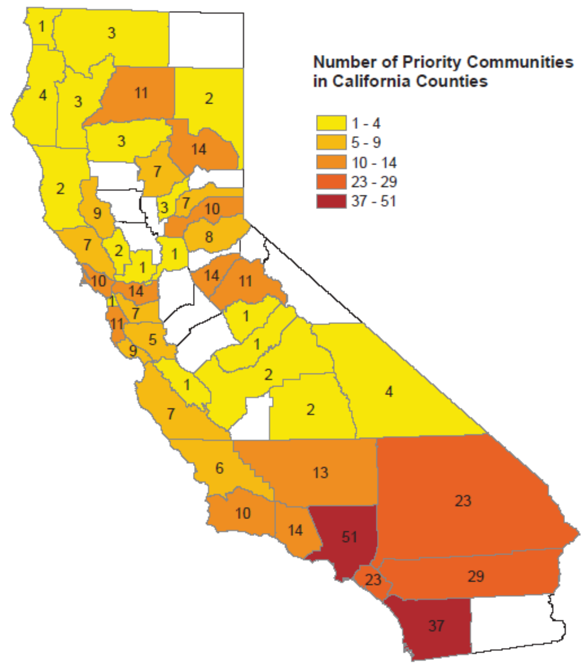
Ecological assets and wildfire threats are enumerated and combined to create “priority landscapes,” which assigns a rank to each area. Fuel conditions, observed fire frequency and expected fire weather conditions are considered in assessing the fire threat of damage. The rank is used to locate high value/high threat areas where action is needed in terms of protecting the land and creating a more desirable future landscape threat of damage. The rank is also used to locate high value/high threat areas where action is needed in terms of protecting the land and creating a more desirable future landscape condition (CAL FIRE, 2010b). Over 21 million acres statewide have been designated as “high priority landscapes.” Roughly half of this area is on public lands. Large concentrations of these areas are in the South Coast, Sierra and Modoc bioregions, and in the northern interior portions of the Klamath/North Coast bioregion (see map, left).



Source: CAL FIRE, 2010

As communities develop in the wildland/urban interface (WUI), wildfires pose increasing threats to people and their property (Lynn and Gerlitz, 2005). The WUI is the line, area or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuel. A higher percentage of low-income households live in wildland areas not considered part of the WUI; these areas may not be covered by fire prevention programs.

A separate assessment of wildfire threats to community safety designated 866,000 acres of high and 2.2 million acres of medium priority landscape scattered throughout the state (CAL FIRE, 2010). These are areas where high community wildfire threat and human infrastructure assets (such as housing, major roads and transmission lines) converge. The map on the right shows the number of communities (by county) with significant areas of high plus medium priority landscape (that is, communities having 500 people or 1,000 acres).



Communities (by county) in "high plus medium" priority landscapes

Source: CAL FIRE. 2010

It should be noted that many rural counties have significant numbers of communities and acreage in medium priority landscape—a result of extensive low density housing in high threat areas. These are the areas where individual homeowner vegetation management can make a large difference. California law (Public Resources Code section 4291-4299) requires persons to clear their property of vegetative fuels to at least 100 feet in high risk areas; failure to comply could result in fines or loss of insurance coverage. Without funding assistance, complying with the law may present a financial burden for low-income households and communities.

A community's vulnerability to wildfires is influenced by socioeconomic and institutional factors. While data on these factors are not readily available for California's communities at risk, there is evidence that rural, low-income households residing in these areas may have a much lower capacity to protect themselves from and recover from the impacts of a fire than more affluent households (Lynn, et al., 2006; Collins, et al., 2009; Niemi and Lee, 2001). Low-income households are less likely to live in homes that meet or exceed building codes, have non-flammable roofing or have a defensible space free of flammable material. They are more likely to lose more or all of their assets in a fire and are less likely to have adequate insurance to cover the cost of rebuilding or replacing personal property. Further, they may be more susceptible to the adverse health impacts of exposure to smoke because of poor health or limited access to health care. Finally, poor rural communities may not have the level of fire protection services available in urban areas (Niemi and Lee, 2001).

The National Fire Plan was created in 2001 and provides grant money to community Fire Safe Councils for fire prevention, education, and preparedness such as prescribed burns and mechanical fuel reduction. Disadvantaged persons locally may not know how to access these community grants or have the resources to provide matching funds which are sometimes required (Lynn and Gerlitz, 2005).

A 2003 study on natural disasters in the United States over the past 20 years found that social class plays a role in how people are affected by disaster on many levels, from preparation to emergency aid (Nachtigal, 2006). The social disparity is evident in many types of disasters (Morrow, 1999) including wildfire and wildfire risk management (Haque et al., 2007; Ojerio, 2008a). Affluent urbanites and retirees are migrating in increasing numbers to fire-prone environments of the United States that are already home to socially vulnerable groups such as indigenous peoples, extractive industry workers and, increasingly, Hispanic service workers (Collins, 2009). A survey of households in a WUI community in California found that cost was the most common barrier to taking steps to reduce their home's ignitability (Collins, 2005).

The Harvard School of Public Health published a study that found seven percent of African-Americans and ten percent of Latino-Americans indicated they needed help to evacuate before a disaster, compared to three percent for Caucasians (Harvard, 2006; Ballen, 2009). Recent immigrants may lack connections to the larger community and hesitate to seek assistance outside their immediate ethnic group for a variety of reasons. Indians and undocumented migrant laborers were "invisible" and neglected victims of the deadly 2007 Southern California wildfires (Davis, 2007; Kelly, 2007). In the WUI, low-income residents without insurance or bank accounts are more likely to lose all of their assets—buildings, possessions, livestock, and vehicles—when fire strikes (Niemi and Lee, 2001).

Effective planning to respond to a wildfire is important in protecting communities. Given the number of California fires and acreage burned annually, the number of persons involved in fire incidents is substantial. For example, in the 2007 fire season in Southern California there were 10 fatalities, 22,195 persons sheltered in 54 shelters and 592,500 people ordered to evacuate. There was minimal planning and preparedness for sheltering people with disabilities and special dietary needs, the elderly, minority groups, children, pregnant women and those without working vehicles. The telephone emergency notification system (reverse 911) did not address non-English speaking persons or the hearing impaired. Increasingly, emergency planners who develop wildfire strategies at the local, regional and national levels are recognizing that knowing exactly who is at risk and where they live is critical (Kailes, 2008).

Indicators that incorporate physical hazards (fuel, topography, weather) along with community characteristics that influence its capacity to take action to prevent, respond to and recover from wildfires could be used to track impacts in high fire threat communities. They could be particularly helpful in revealing those areas that have a disproportionate number of low-income households. Potential indicators could address two components, discussed below (adapted from Lynn and Gerlitz, 2006).

1. ***Fire threat***

   Assessments conducted by the Forest and Range Assessment Program (FRAP) identifies areas of the state where wildfires pose significant threats to both ecosystem and to community assets (CAL FIRE, 2010b). Possible indicators, such as a measure of fuel load, can be derived based on FRAP assessments. Another possible metric could be the number of homes complying with the clearing requirements per income level.

2. ***Community capacity***

   Community capacity is a community's ability to mitigate wildfire threats (such as by implementing risk-reduction strategies, including hazardous fuels reduction) and to respond to wildfires (American Forests, 2001). The involvement of rural WUI persons of low income in the initial fire protection planning process builds community cohesion and the capacity to protect large tracts of common land. Other considerations may include the presence of residents who may be economically disadvantaged or require special assistance during a fire due to health reasons or lack of access to transportation. Fire hazard ratings, used by both public and private sector organizations can be used as indicators of the capabilities of fire districts to protect their communities from wildfire (Lynn and Gerlitz, 2006).

   A number of demographic metrics—alone or in combination—may be used to characterize community capacity. Examples are census data; Housing and Urban Development (HUD) Income Limits; housing price-to-wage relationship; poverty level; number of residents who are elderly, sick or otherwise have special needs; educational level; unemployment; and language spoken (Ojerio, 2008b). In addition, economic metrics, such as estimates of property damage or replacement costs and insurance coverage, may be used to track financial capacity to deal with the threat of wildfires.

Wildfire protection in California relies on an integrated, multi-agency effort to maximize the use of firefighting resources. The effectiveness of the efforts of these agencies, particularly in less affluent communities, could be tracked in part using the indicators suggested above. For example, indicators can be used to track whether funds for National Fire Plan grants and fuels-reduction projects are being allocated to high-risk areas (Lynn and Gerlitz, 2006).

CONCLUSIONS

This report builds on the Office of Environmental Health Assessment's (OEHHA) earlier effort to develop indicators to track climate change, its drivers and impacts. It explores potential environmental justice concerns associated with climate change.

The impacts of climate change on physical and biological systems will generally affect all California residents, regardless of race or income. However, there are clearly certain subpopulations that will experience greater exposure to hazards—such as agricultural workers exposed to extreme summertime temperatures in the Central Valley and Imperial Valley, and residents living in "urban heat islands," where heat-reflecting surfaces have been shown to intensify heat.

Additionally, certain groups do not have the resources or the ability to cope with climate change induced impacts due to socioeconomic or inherent biological factors. For example, low-income households are less likely to live in homes with air conditioning, and the rural poor living at the wildland-urban interface may not have the resources to prevent, fight and recover from wildfires.

The diversity of California's geography and associated microclimates will experience a wide range of climate change related impacts. Examining the environmental justice concerns relating to these impacts requires community-level data both on the hazards and on the specific socioeconomic characteristics of the population.

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Introduction

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