CLIMATE AND HEALTH PROFILE REPORT

MARIN COUNTY

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PREFACE

Through legislation and Governors' Executive Orders, the State of California has mobilized to meet the challenge of climate change. The overall strategy is embodied in reducing carbon emissions, promoting readiness for climate impacts, and conducting research to provide the best available science to guide our actions. In the course of this work, technical documents, strategies, and planning guidance have been produced by state agencies, including the California Department of Public Health (CDPH). This *Climate and Health Profile Report* represents a synthesis of information on climate change and health for California communities based on recently published reports of state agencies and other public data. We have compiled and edited this wealth of information from technical documents, and created a streamlined report accessible to public health professionals and their partners in state, regional, and local government, the private sector, and community-based organizations. We also highlight the public health dimensions of climate change along with its environmental impacts.

The content of this report was guided in part by a cooperative agreement between CDPH and the federal Centers for Disease Control and Prevention (CDC): *Building Resilience Against Climate Effects* or BRACE. The goals of BRACE are to assist state health departments to build capacity and further climate and health adaptation planning. This includes using the best available climate science to project likely climate impacts, identifying climate-related health risks and populations vulnerable to these impacts, assessing the added burden of disease and injury that climate change may cause, identifying appropriate interventions, planning more resilient communities, and evaluating and improving the planning effort. The CDPH Office of Health Equity brings an awareness that disadvantaged communities are likely to bear disproportional health impacts of climate change. We hope you find this material informative and empowering as we work together to protect and enhance our communities' health and well-being.

Disclaimers

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CLIMATE AND HEALTH PROFILE REPORT, MARIN COUNTY

BACKGROUND: WHAT IS THE LINK BETWEEN CLIMATE CHANGE AND HEALTH?

What is global warming?

Modern life has been made possible by the burning of coal, natural gas, petroleum and other fossil fuels in our power plants, factories, businesses, farms, homes, and cars. Key by-products of energy production and consumption are carbon dioxide, methane, and other pollutants. These gases are called greenhouse or heat trapping gases because, as they mix in the atmosphere, they create a barrier for solar radiation and heat produced by sun to escape the Earth's surface. Over the last 150 years, and especially in the last few decades, measurements taken around the world show that on average the temperature of the atmosphere and oceans is gradually increasing. The average carbon dioxide concentration in the atmosphere topped 400 parts per million (ppm) in 2013, which far exceeds the range experienced over the last 650,000 years.[1, 2 p.435] An overwhelming consensus of scientists now warn that this warming is due to human activities and that if we do not curb our current carbon emissions, the increase in the planet's temperature will cause significant harm to natural systems and threaten our health and very existence.[2] Efforts to reduce carbon emissions, called mitigation, are imperative. Because carbon dioxide takes centuries to dissipate in the atmosphere, the increased levels already present will cause a certain amount of global warming and climate change in the immediate future that cannot be reversed. Adaptation is the term used to describe the measures we take to prepare and respond to these inevitable climate changes.

How does global warming impact climate and weather?

Changes in atmospheric and ocean temperatures affect how Earth's water behaves, and, as the atmosphere warms, it holds more water vapor. Along with temperature, the timing, amount, and the manner in which the water circulates (the hydrologic cycle) or covers the Earth are part of what defines our climate and weather. Weather can be thought of the short term variability of local daily temperature, precipitation (rain, snow), wind, and events like storms (hurricanes, tornados, etc.) throughout a year. Climate can be thought of the general pattern on a larger geographic area and time scale usually in decades. California is unique in the United States and has Mediterranean type of climate with a distinct dry season (May to October) and wet season (November to April), which is modified by proximity to the coast or mountains or variable elevation.

How are future changes in climate predicted?

Scientists use historical weather data and mathematical models to describe historical trends and to predict the impacts of global warming.[3] Historical data show that on average sea levels are already rising, primarily from the

expansion of water. Historical data also show that in the past century average temperatures are increasing, polar ice and glaciers are melting at increased rates, and snow pack in mountains is diminishing compared to time periods in which human-generated carbon emissions were relatively small.[2]

Climate models are a 3-D computer simulation over time of the Earth's atmosphere and oceans taking into account solar radiation, surface reflection, circulating air masses and wind, heat stored in oceans, sea ice, evaporation from land surfaces and green plants, cloud cover, and other factors. A key input to climate projection models is the current and projected amount of carbon dioxide and other greenhouse gases emitted into the atmosphere.

The future amount of carbon emitted into the Earth's atmosphere has two broad drivers: 1) the dependence of economic growth on fossil fuels, and 2) the growth of the world's population. Based on the different combinations of economic development strategies and population growth, scientists have constructed formal scenarios[4] of future carbon emissions during the 21st century and predicted their associated climate impacts compared to a 1990 baseline. Average global temperature is predicted to increase by 1.8°C (3.2° F) for an optimistic scenario called B2 in which world economies become much less dependent on fossil fuels and the world population levels off after 2050. In a pessimistic scenario called A2, climate models predict a 3.4° C (6.1° F) increase, based on the assumption that the world continues its path of fossil fuel intensive economic development and that the world population increases during the 21st century.

On the backdrop of gradually increasing temperatures and sea levels, the climate models also predict an increase in the frequency and intensity of extreme weather events such as hurricanes, floods and droughts. Using these global climate models as a starting point, the Scripps Institute at the University of California, San Diego has further refined climate impacts in California to 12 km grids (7 by 7 miles).[5] This allows California communities to have local data to inform their adaptation planning.

WHAT ARE THE GENERAL PATHWAYS THAT CLIMATE CHANGE IMPACTS HEALTH?

Researchers have examined the pathways in which increased temperatures and hydrologic extremes can impact health and generally recognize three main pathways: direct exposures, indirect exposures, and socioeconomic disruption (Figure 1-2). Based on the review of weather-related natural disasters and historical patterns[6,7] and scientific judgment, public health researchers have suggested the nature and direction of health harms or benefits.[8,9] The health risks associated with the following climatic factors in California stand out:

- Heat
- Wildfires
- Hydrologic extremes (sea level rise, storms and flooding, drought)
- Social/economic stress or disruption

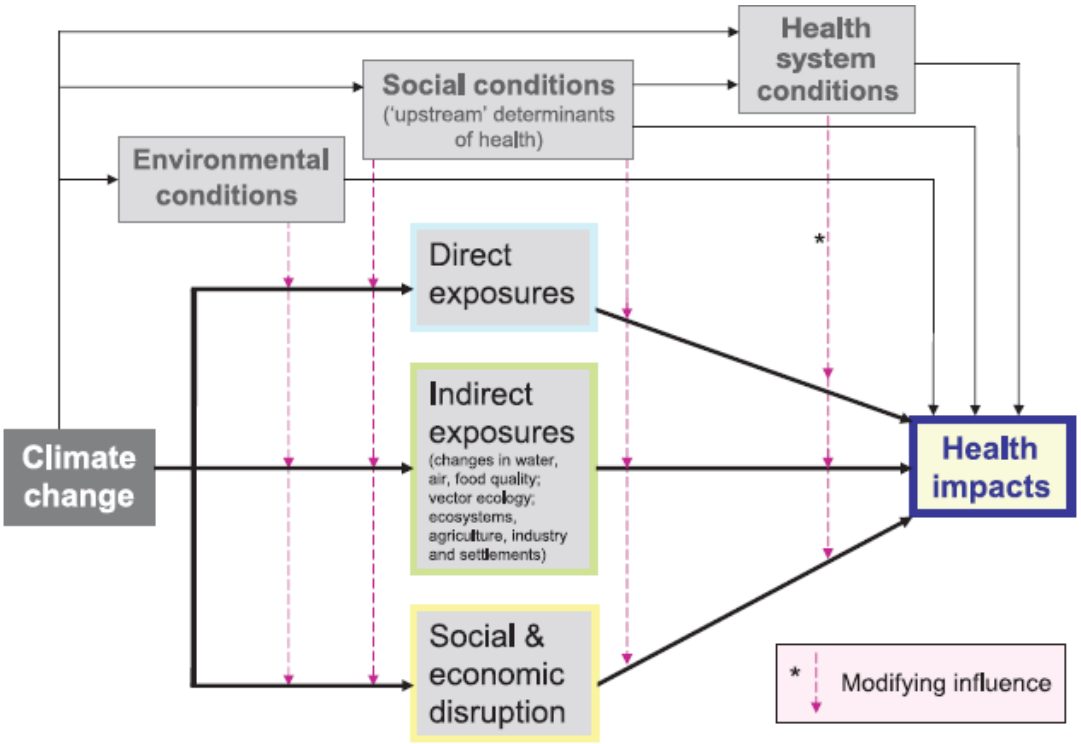


Figure 1. Climate Change and General Categories of Health Impacts

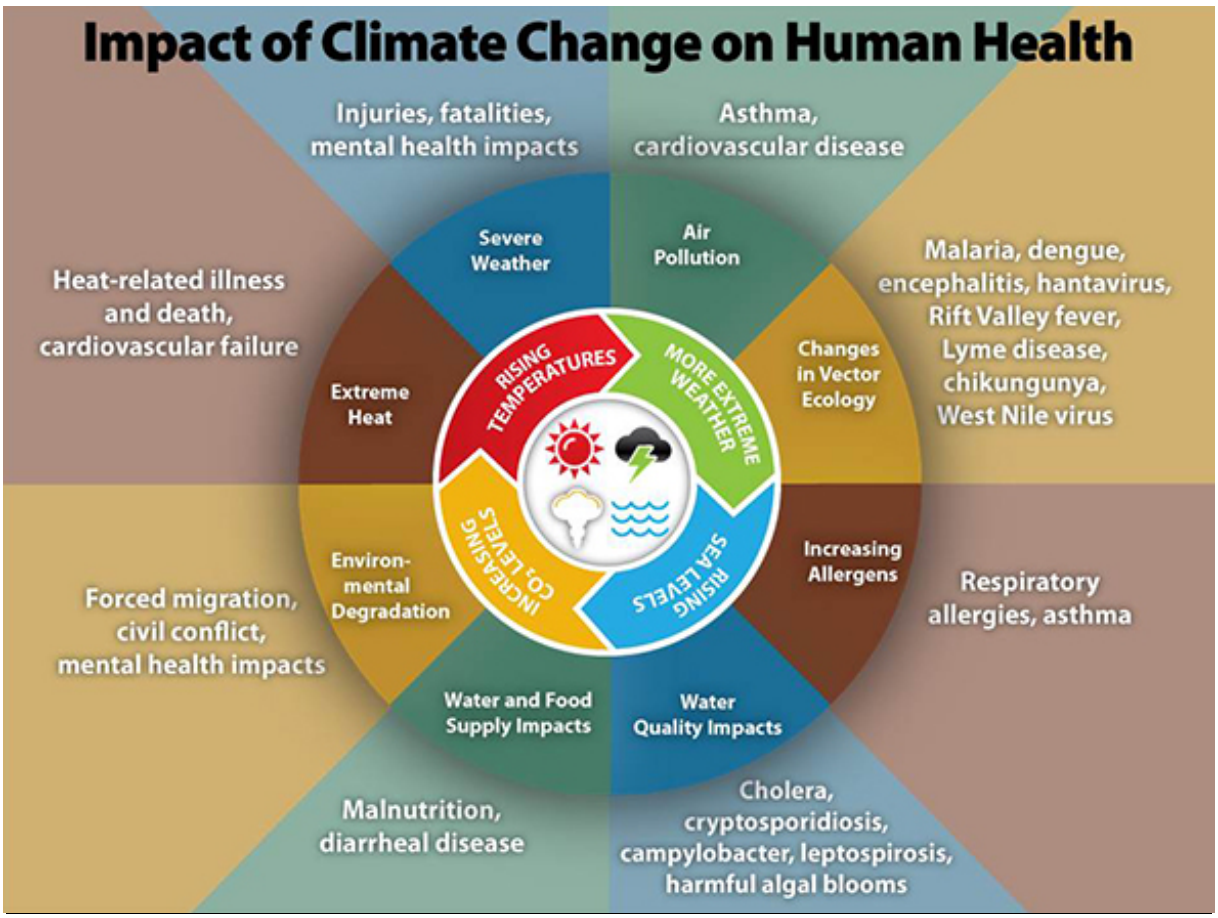


Figure 2. Impact of Climate Change on Human Health (Source: Centers for Disease Control)

Extreme Weather-Related Injury, Mental Health and Displacement

Extreme weather events (storms, flooding) cause fatal and nonfatal injuries from drowning, being struck by objects, fire, explosions, electrocution, or exposure to toxic materials. A widespread weather-related natural disaster may destroy or ruin housing, schools and businesses and cause temporary or permanent displacement. Individuals and families may experience post-traumatic stress, depression, and increased risk of suicide.[10,11]

Direct and Indirect Health Impacts of Heat

Increased temperatures manifested as heat waves and sustained high heat days directly harm human health through heat-related illnesses (mild heat stress to fatal heat stroke) and the exacerbation of pre-existing conditions in the medically fragile, chronically ill, and vulnerable.[12,13] Increased heat also intensifies the photochemical reactions that produce smog and ground level ozone and fine particulates (PM2.5), which contribute to and exacerbate respiratory disease in children and adults. Increased heat and carbon dioxide enhance the growth of plants that produce pollen, which are associated with allergies. Increased temperatures add to the heat load of buildings in urban areas and exacerbate existing urban heat islands adding to the risk of high ambient temperatures.

Direct and Indirect Health Impacts of Hydrologic Extremes and Heat

Lack of moisture, already at a severe level in California due to a current multi-year drought and decades of fuel accumulation from historical forestry and fire suppression practices, increases the risk of wildfires.[14] Devastating wildfires like the Rim Fire of 2013 impact watersheds and increase the risk of land- or mudslides, and sediment in run-off that reduce water quality. In addition to fire-related injuries, local and regional transport of smoke, ash, and fine particles increases respiratory and cardiovascular risks.

Although the cause of the current California drought is under scientific investigation, climate scientists agree that increasing temperatures will exacerbate drought conditions. Drought decreases the availability and quality of water for humans. This includes reduced water levels to fight wildfires. Drought increases physiologic stress and decreases productivity of animals raised for food. Climatic changes alter the range, biogeography, and growth of microbes and the vectors of food, water, and vector-borne illnesses. This includes the changes in aquatic environments that decrease sea food production or that favor toxins that accumulate in seafood and fresh and salt water algal blooms.

Drought decreases crop yields and increases crop failures in California and elsewhere in the world. This causes both food shortages and price increases, which makes food less affordable and increases food insecurity, obesity, and malnutrition in economically constrained households. Through sea level rise, salt water may intrude into coastal aquifers thus reducing quality and quantity of water supply. Coastal erosion can contribute to the loss of recreational venues and pose a variety of hazards to infrastructure and public safety.

Socioeconomic Disruption

Widespread social and economic disruption includes damage to the infrastructure for the delivery of health services and for general economic well-being. Health care facilities, water treatment plants, and roads for emergency responders and transportation for health care personnel can be damaged in climate-related extreme weather events. Increased burden of disease and injury will test the surge capacity of health care facilities. Economic disruption can increase income loss and income insecurity, food insecurity, housing insecurity, and mental health problems, which in turn may increase substance abuse, family instability, suicide and other health problems.

Energy production and distribution are also threatened by heat and wildfires (loss of efficiency, generating capacity, and fires disrupting transmission lines). California's ports that provide the gateway to goods for California, national, and international markets are at risk from sea level rise and coastal storms.

WHICH POPULATION SUBGROUPS ARE PARTICULARLY VULNERABLE?

All Californians are vulnerable to the health impacts of climate change. Even if one is fortunate to live, work, study, or play in a place without direct contact with wildfires, flooding, or sea level rise, no one can entirely avoid excessive heat or the indirect effects of extreme weather events. Based on medical reviews of individuals who died during heat waves and other extreme weather events, it appears that the very old and very young, individuals who have chronic medical conditions and psychiatric illness, people taking multiple medications, those without means for evacuation (no access to public transit or private cars), the medically fragile or those living in institutions or socially isolated are particularly vulnerable to the direct effects of climate change.[12] Acclimatization to heat may help reduce risks from heat waves in the healthy general population, but may not be sufficient to protect those with underlying medical conditions.

A much larger part of the population is vulnerable to intermediate factors and social/economic disruption through preexisting physical and mental health conditions, cultural or physical isolation, occupations involving outside or high risk work, a precarious socioeconomic status, or lack of social cohesion, and collective efficacy. The latter includes lack of effective governmental action to plan and coordinate the preparation, response, and recovery to climate threats.[15]

A large percentage of our underlying burden of disease and injury is accounted for by the social determinants of health[16], which considers the health impact of one's living and working conditions (such as the distribution of income, wealth, influence, and power), rather than individual factors (such as behavior or genetics).

Community resilience refers to actions taken by individuals, neighborhoods, organizations, and multiple sectors of government to resist and overcome obstacles, and promptly recover from climate threats. In the short run, this may include traditional elements of public health preparedness and community development. However, in the long term,

this may include actions that broadly promote population health and decrease the number of those with physical and mental conditions that are avoidable, unfair, and rooted in the social determinants of health.

Health inequities based on race/ethnicity, income, geography (urban/rural) are widespread today in California.[17] Even without climate change, demographic changes already underway will increase the size of vulnerable populations in California in the coming decades. The population is aging and the share of individuals aged 65 or more years will increase from 13 percent in 2010 to 19 percent in 2050.[18] In many California communities, racial and ethnic minorities constitute the majority of residents.

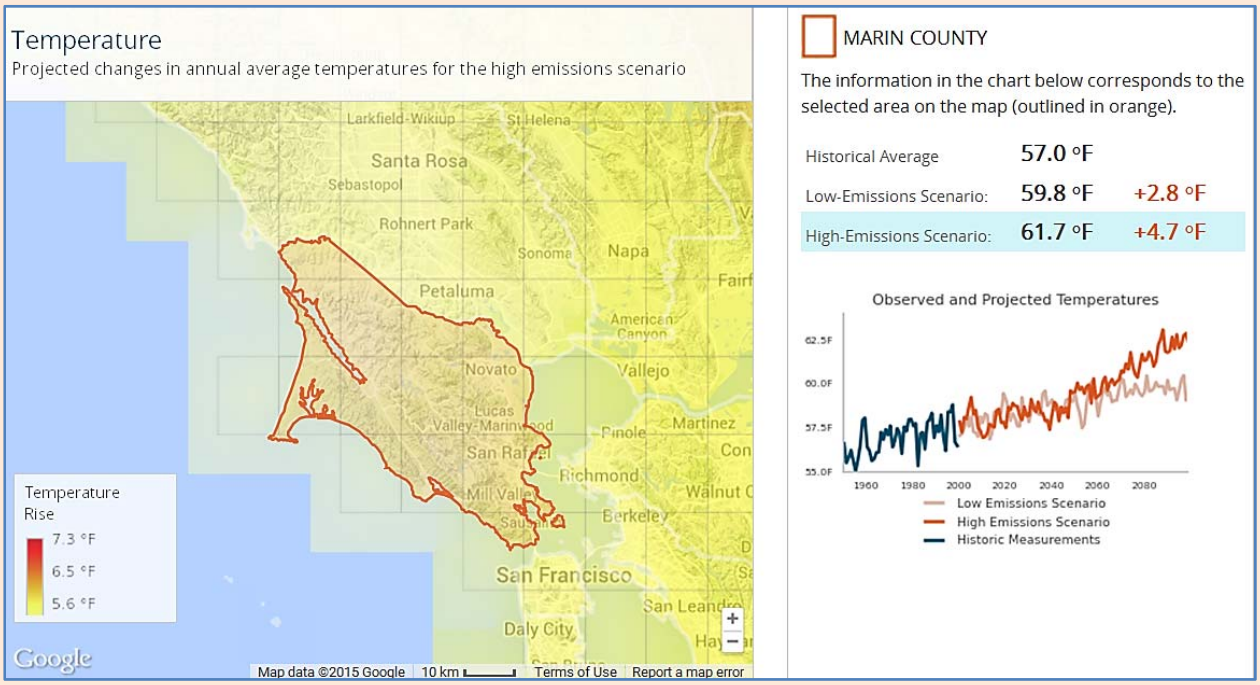
WHAT ARE THE CLIMATE PROJECTIONS FOR MARIN COUNTY AT 2050 AND 2099?

Figure 3. Summary of Cal-Adapt Climate Projections for the Bay Area Region

EFFECT	RANGES
Temperature Change, 1990-2100	
Precipitation	Precipitation varies widely in this region, with annual totals over 40 inches in northern Sonoma County to roughly 15 inches in the eastern portions of Solano and Contra Costa counties. A moderate decline in annual rainfall, 1 to 3 inches by 2050 and 4 to 5 inches by 2090, is projected throughout the region. (CCSM3 climate model; high carbon emissions scenario)
Sea Level Rise	By 2100, sea levels may rise up to 55 inches, posing considerable threats to coastal areas and particularly to low-lying areas adjacent to San Francisco bay. The number of acres vulnerable to flooding is expected to increase 20 to 30 percent in most parts of the Bay Area, with some areas projected for increases over 40 percent. Coastal areas are estimated to experience an increase of approximately 15 percent in the acreage vulnerable to flooding.
Heat Wave	Along the coast, particularly to the south, heat wave is defined as five days over 72°F to 77°F; in other areas the threshold is in the mid- to upper 90s. Over most of the region, a limited increase in the number of heat waves is expected by 2050, with only the eastern areas expecting more than one or two more per year. By 2100, between six and 10 more heat waves can be expected per year.
Fire Risk	There is little change in projected fire risk in this region, save for the slight increases expected in western Marin County. (GFDL climate model; high carbon emissions scenario)

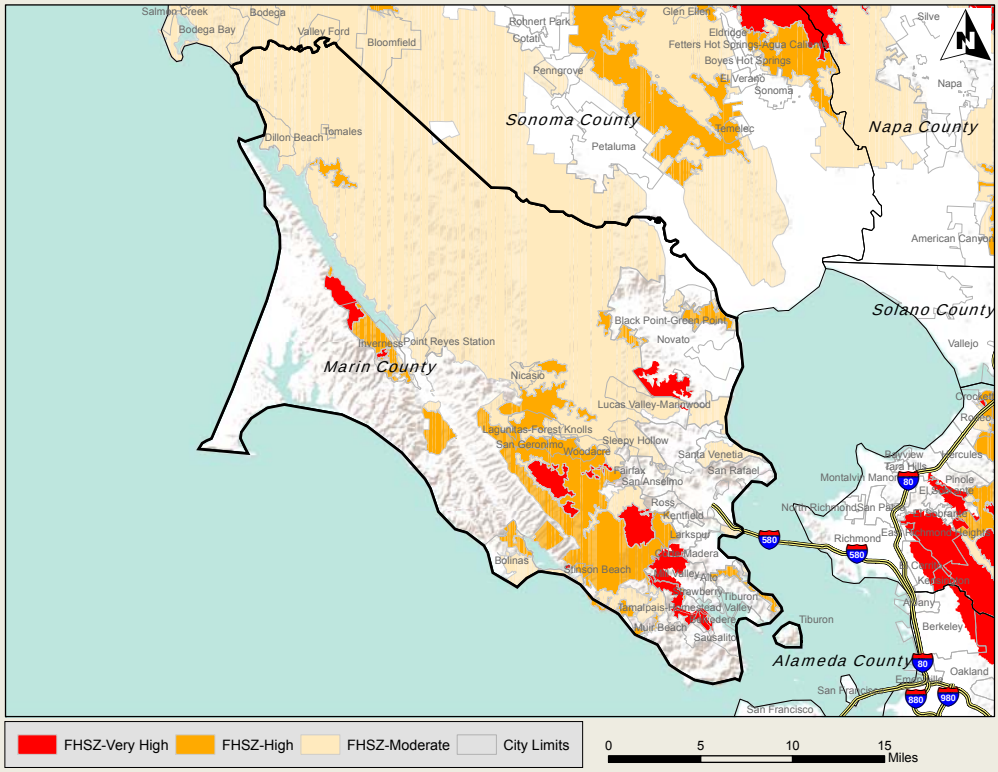
Public Interest Energy Research, 2011. Cal-Adapt (http://cal-adapt.org)

Figure 4. Projected Annual Average Temperature in Future Carbon Emissions Scenarios, Marin County, 2099



Overall temperatures are expected to rise substantially throughout this century. During the next few decades, scenarios project average temperature to rise between 1 and 2.3°F. The projected temperature increases begin to diverge at mid-century so that, by the end of the century, the temperature increases projected in the higher emissions scenario (A2) are approximately twice as high as those projected in the lower emissions scenario (B1). These projections also depend on the time of year and the type of measurement (highs vs. lows), all of which have different potential effects to public health and the state's ecosystem health, agricultural production, water use and availability and energy demand.

Figure 5. Current Fire Hazard Severity Zones (FHSZ), Marin County, 2007



Fire Hazard is a way to measure physical fire behavior to predict the damage a fire is likely to cause. The factors are taken into account. **Vegetation** - "Fuel" to a wildfire. **Topography** - Fire burns faster on steep slopes. **Weather** - Fire burns faster and with more intensity when air temperature is high, relative humidity is low, and winds are strong. **Crown fire potential** - Under extreme conditions, fires burn up into trees and tall brush. **Ember production and movement** - Fire brands are blown ahead of the main fire, spreading the fire and getting into buildings and igniting.

Severity Key

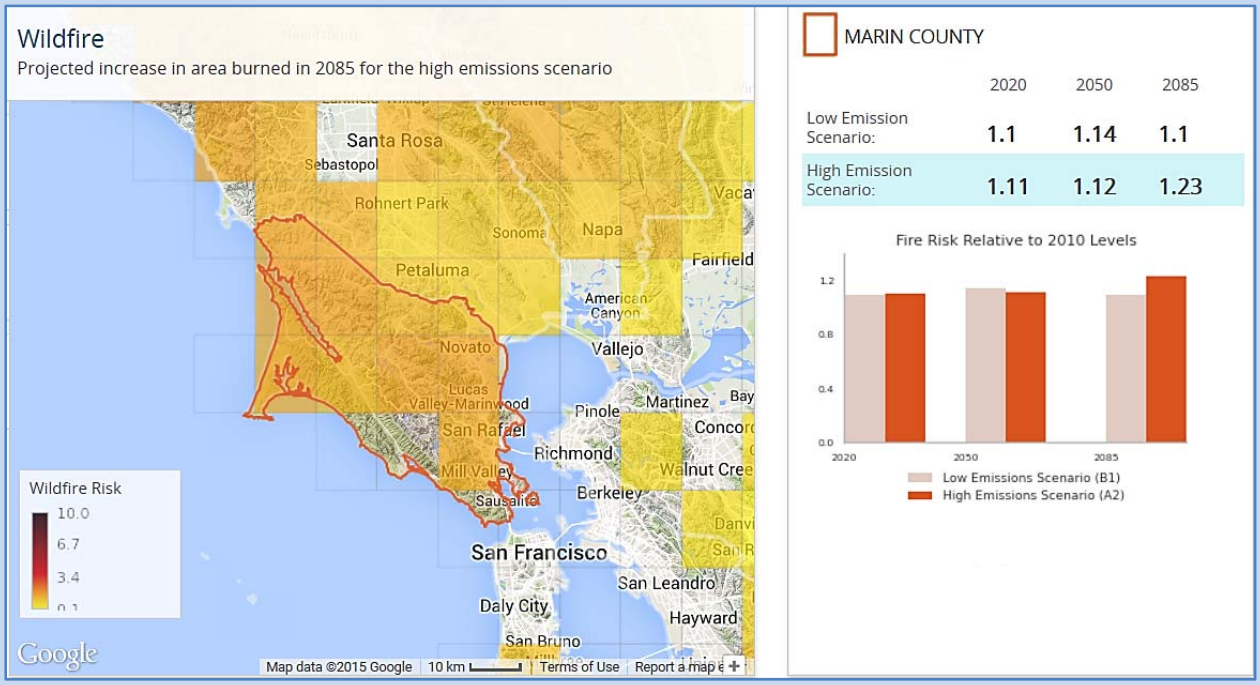
Moderate: Wildland areas supporting areas of typically low fire frequency and relatively modest fire behavior, OR developed/urbanized areas with a very high density of non-burnable surfaces including roadways, irrigated lawn/parks and low total vegetation cover (<30%) that is highly fragmented and low in flammability.

High: Wildland areas supporting medium- to high-hazard fire behavior and roughly average burn probabilities, OR developed/urbanized areas with moderate vegetation cover and more limited non-burnable cover. Vegetation cover typically ranges from 30-50% and is only partially fragmented.

Very High: Wildland areas supporting high to extreme fire behavior resulting from climax fuels typified by well-developed surface-fuel profiles (e.g., mature chaparral) or forested systems where crown fire is likely, OR developed/urban areas typically with high vegetation density (>70% cover) and associated high fuel continuity, allowing for frontal flame spread over much of the area to progress impeded by only isolated non-burnable fractions. The rating system is more completely described at http://frap.fire.ca.gov/projects/hazard/fhsz_review_instructionsv1_3b.pdf.

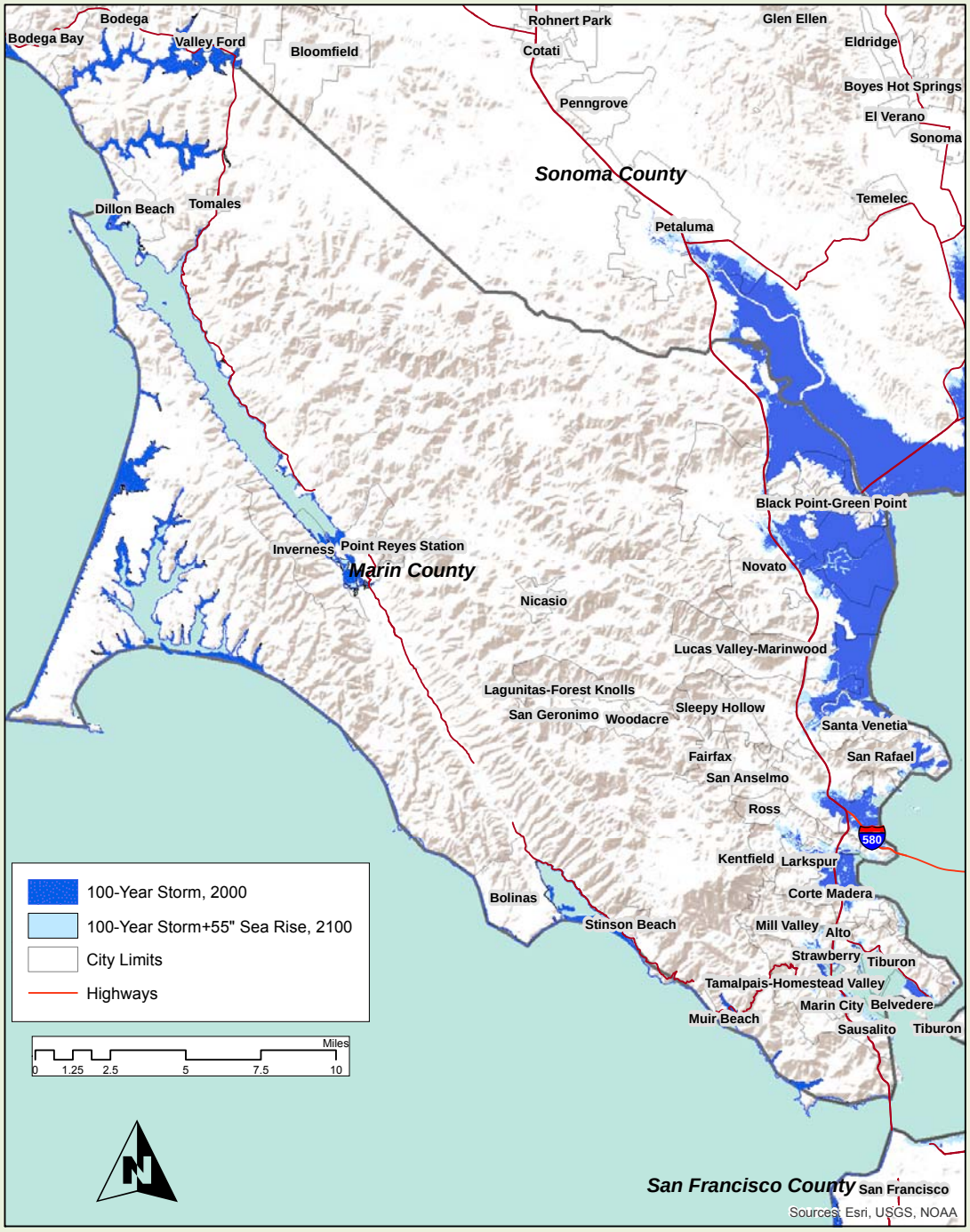
Note: Map includes only state and local responsibility areas.

Figure 6. Relative Increase in Wildfire Acreage in Future Carbon Emission Scenarios, Marin County



Fire is an important ecosystem disturbance. It promotes vegetation and wildlife diversity, releases nutrients into the soil, and eliminates heavy accumulation of underbrush that can fuel catastrophic fires. The data in the map above display the projected increase or decrease in potential area burned based on projections of the Coupled Global Climate Model (version 3) for the high carbon emissions scenario in 2085. The bar graphs to the right illustrate the projected time trend over the 21st century for both the high and low emissions scenarios. Please note that these data are modeled solely on climate projections and do not take landscape and fuel sources into account. The projections of acreage burned is expressed in terms of the relative increase or decrease (greater or less than 1) from a 2010 baseline for fires that consume at least 490 acres. The 2010 baseline reflects historic data from 1980-1989 and trends through 2010. Data on the number of fires and the acreage burned are described later in the text.

Figure 7. Inundation Areas for a 100-Year Flood (2000) with an Additional 55 Inches of Sea Level Rise (2100), Marin County



Source: Pacific Institute and Cal-Adapt

California's coastline, which includes more than 2,000 miles of open coast and enclosed bays, is vulnerable to a range of natural hazards, including storms, extreme high tides and rising sea levels. Climate change models indicate that California may see up to a 55 inch (140 cm) rise in sea level within this century. The map above displays areas that may be in threat of inundation during an extreme flood event known as a 100-year flood. The 100-year flood is used as a standard for planning, insurance and environmental regulations. The dark blue color indicates areas already in threat today. The lighter shade of blue is the area projected to be in threat for a 55-inch sea level rise, which is consistent with a high carbon emissions scenario. The map does not take into account protective structures, such as levees, or the effects of wind and waves.

WHAT ARE THE CURRENT HEALTH STATUS, HEALTH INEQUITIES, AND POPULATION VULNERABILITIES IN MARIN COUNTY?

The age-adjusted death rate is a basic indicator of the health status of our communities. In 2010, the rate in Marin County was lower (better) than the state average (Figure 8). Within the county, the death rate of African-Americans is 70% higher than that of Latinos. Nearly 35% of adults (83,035) report one or more chronic health conditions like heart disease, diabetes, asthma, severe mental stress or high blood pressure. Obesity occurs in approximately 14% of adults, and nine percent of residents aged 5 years and older have a mental or physical disability. Annually, there is an average of 16 heat-related emergency room visits.

Among climate vulnerable groups are 13,932 children under the age of 5 years and 42,192 adults aged 65 years and older. Five percent of households (5,080) do not have a household member 14 years or older who speaks English proficiently. Approximately eight percent of adults aged 25 years and older have less than a high school education.

Financial hardship is experienced by seven percent of the population that lives below the federal poverty level and 22% of households pay 50% or more of their annual income on rent or a home mortgage. Approximately 16,000 (58%) of low-income residents report they do not have reliable access to a sufficient amount of affordable, nutritious food. Other vulnerable populations include the approximately 28,506 outdoor workers whose occupation increases their risk of heat illness. Social cohesion contributes to community resiliency. The county annually records 1.4 violent crimes per 1,000 residents. Seventy-six percent of registered voters voted in the 2010 general election. Among those with mobility limitations, there are approximately 9,044 people living in nursing homes, dormitories, and other group quarters, where institutional authorities may provide transportation in the event of emergencies. Approximately five percent of households do not own a vehicle, which could be used for evacuation. Roughly 55% of residents do not live close to frequent public transit.

Approximately 73% of households are estimated to lack air conditioning, a strategy to counter adverse effects of heat. Tree canopy, which provides shade and other environmental benefits, is present above 29% of the county's land area.

All Californians are at risk from extreme heat. Approximately 16% or 41,581 of the county's population live in fire hazard zones with a moderate to very high severity. From 1980 to 1989 (a pre-climate change baseline), 24 wildfires at least 490 acres in size consumed a total of 112,892 acres in the Bay Area.

Ten percent or approximately 25,335 of county residents live on coastal blocks that are at risk of inundation from a 100-year flood. Nearly 34% of the county's Latino residents live in such inundation areas. With an additional 55 inches of sea level rise, which is at the upper end of predictions for the year 2100, the inundation zone would potentially include 33,393 residents.

Figure 8. Profile of Health Outcomes and Inequities, Social Vulnerabilities and Climate Risks, Marin County

Health Outcomes

	Number	Rate or Percent
2010 Age-Adjusted Death Rate/10,000*		
Total	1,834	52
Asian	48	36
Hispanic/Latino	57	34
White	1,690	54
African-American	30	57
California	233,143	64
Multiple Chronic Conditions in Adults (N,%), 2011-12		
Total	83,035	35%
California	12,394,876	44%
Ever-Diagnosed with Asthma (N,%) 2011-12		
Total	21,000	16%
California	5,143,000	14%
Annual heat-related ER visits/100,000, 2005-10	16	6
Adult obesity (N,%), 2011-12	27,000	14%
Living with a disability (N,%), 2008-12	21,216	9%

* Groups with less than 20 observations are not presented.

Figure 8. Profile of Health Outcomes and Inequities, Social Vulnerabilities and Climate Risks, Marin County

	Number	Rate or Percent
Social Vulnerabilities		
Living in rural areas	16,457	7%
Children aged 0-4 years	13,932	6%
Adults aged 65 years and older	42,192	17%
Linguistically isolated	5,080	5%
Adults educated less than high school	14,980	8%
Poverty rate, total	17,402	7%
Households rent/mortgage ≥50% of income	22,095	22%
Population within ½ mile of frequent transit	113,902	45%
Outdoor workers	28,806	5%
Households that do not own a car	5,264	5%
Food insecurity	16,000	58%
Violent crimes per 1,000	520	1
Voted in 2010 general election	115,192	76%
Nursing facilities, prisons, college dorms	9,044	4%
Households with air conditioning	36,690	27%
Census tract average area with tree canopy		29%
Climate Risks		
Population in 100-year flood area, 2000	25,335	10%
Population in 100-year flood area and 55" SLR*, 2100	33,393	14%
Population in a high-risk wildland fire area, 2010	41,581	16%

* SLR, sea level rise

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Table 1. WHAT ARE SOME OF THE PUBLIC HEALTH STRATEGIES AND ACTION STEPS FOR ADAPTING TO CLIMATE CHANGE?

STRATEGY	ACTION STEPS	
	NEAR-TERM	LONG-TERM
1. Promote community resilience to climate change to reduce vulnerability	• Promote healthy, built environments • Identify and reduce health vulnerabilities • Improve food security and quality	• Promote food sustainability • Reduce heat islands • Support social and community engagement • Promote increased access to health care
2. Educate, empower and engage California residents, organizations and businesses to reduce vulnerability through mitigation and adaptation	• Educational outreach campaign tying into existing efforts • Specific outreach to vulnerable populations	• Proactive social marketing campaign
3. Identify and promote mitigation and adaptation strategies with public health co-benefits	• Identify and prioritize strategies with co-benefits	
4. Establish, improve and maintain mechanisms for robust rapid surveillance of environmental conditions, climate-related illness, vulnerabilities, protective factors and adaptive capacities	• Monitor outcomes (state and local) • Develop existing environmental contaminant biomonitoring • Maintain and upgrade water accessibility information • Improve heat warning systems	• Convert to electronic surveillance systems to improve disease reporting, management and surveillance
5. Improve and sustain public health preparedness and emergency response	• CDPH and local health departments should refine existing preparedness plans and conduct exercises	
6. Work in multi-sectoral partnerships (local, regional, state and federal)	• Expand training and education to build collaborative capacity	
7. Conduct applied research to enable enhanced promotion and protection of human health	• Vulnerability assessments • Research collaboration • Assess local impacts on health	
8. Implement policy changes at local, regional and national levels	• Policy collaboration with stakeholders • Occupational safety standards	• Model policies & training • Public engagement
9. Identify, develop and maintain adequate funding for implementation of public health adaptation strategy	• Identify and develop funding mechanisms	• Develop funding mechanisms/AB32 for education and research

Source: California Natural Resources Agency (http://resources.ca.gov/climate_adaptation/docs/Statewide_Adaptation_Strategy.pdf)

SUMMARY AND RESOURCES

This report has brought together recently published, technical information from state-sponsored research and planning documents, such as:

- *California Climate Change Adaptation Planning Guide, 2012*
  http://resources.ca.gov/climate/safeguarding/adaptation_policy_guide/

- *Safeguarding California: Reducing Climate Risk, 2014*
  http://resources.ca.gov/docs/climate/Final_Safeguarding_CA_Plan_July_31_2014.pdf

- *California Climate Adaptation Strategy, 2009*
  http://resources.ca.gov/docs/climate/Statewide_Adaptation_Strategy.pdf

- *Cal-Adapt: Exploring California's Climate Change Research* (http://cal-adapt.org/)

The aim has been to provide a county-level summary of information on current and projected risks from climate change and potential health impacts.

This report is part of a suite of tools in a toolkit that is being developed by the California Department of Public Health to support local, regional and statewide efforts of the public health sector to build healthy, resilient and adaptive communities ready to meet the challenges of climate change. Coupled with state-sponsored guidance documents, such as *Preparing California for Extreme Heat: Guidance and Recommendations* (http://www.climatechange.ca.gov/climate_action_team/reports/Preparing_California_for_Extreme_Heat.pdf), this information will provide a knowledge base for taking informed action. BRACE will be partnering with local health departments and other community organizations to build local, regional and state capacity to meet the challenge of climate change.

For more information, visit the BRACE website:
http://www.cdph.ca.gov/programs/Pages/CalBRACE.aspx

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