4.4 Climate Change in California

4.4.1 Introduction

This section briefly describes the environmental setting for climate change across California. It provides a short summary of the sources of greenhouse gas emissions, reviews potential environmental impacts that are predicted from climate change models, and discusses the regulatory framework in California to address potential impacts from climate change.

Climate change is affecting California and the globe. The National Research Council (2001) states there is broad scientific agreement that: 1) significant global climate change is occurring, largely leading to warmer overall temperatures and more frequent extreme weather events; and 2) the observed and projected changes are likely being induced by human activities such as air pollution, in particular CO_2 from the burning of fossil fuels, and other greenhouse gases.

Given current social and economic patterns, the concentration of CO_2 in the atmosphere will continue to increase at an exponential rate for several decades. While programs for mitigating CO_2, including carbon sequestration, are important and moving forward in California (see below), such efforts are unlikely to significantly curb the upward trend for the foreseeable future. In addition, the mean residence time of CO_2 emitted into the atmosphere is estimated to be on order of a hundred years. Thus it will likely take several decades before any improvements in mitigating CO_2 pollution will result in benefits through reducing atmospheric greenhouse gases and lowering temperatures. This underscores the need to develop adaptation strategies and to conduct risk assessments to determine areas of vulnerability.

For a clearer understanding of the impending effects of increasing CO_2, several scientific establishments have created general circulation computer models (GCMs) that project future climatic conditions. Three of the most advanced models were compared in a recent review of climate change in California.

Near future climatic trends projected for the California region by these models showed: 1) warmer overall temperatures, due primarily to increased concentrations of CO_2 and other “greenhouse” gases, with the magnitude of the warming dependent on the amount of CO_2 emitted in future years; 2) uncertain but slight changes likely in precipitation amount and seasonal distribution; 3) increased frequency of extreme weather and climatic events, including more storms, higher winds, and more severe droughts.

4.4.2 Sources of CO_2 Emissions in California

Recent reports on the causes and effects of climatic change in California examine the state’s role in increasing overall atmospheric CO_2 levels (CAT, 2006; CEC, 2005). The state is the tenth largest greenhouse gas emitter in the world (Figure 4.4.1). Figure 4.4.2 shows the relative contribution of each economic sector in the state to its total greenhouse emissions (units are CO_2 equivalence). As shown in Figure 4.4.3, only about 2.3 percent of pollutant greenhouse gases in the state are contributed from non-fossil fuels, including the burning of wildland vegetation.

Currently, forests in California are thought to operate as a net sink for CO_2. However, estimates of carbon sequestration rates have varied substantially. As part of the Global Warming Solutions Act

(AB32) the Air Resources Board has reported forests to operate as -5 MMT CO_2 equivalent. More recent reports by CAL FIRE and USFS estimate carbon sequestration on forest lands to be on the order of -25 to -30 MMT CO_2 equivalent. There is limited information on grass and range land ecosystems, but similar to forests these ecosystems can operate as both a sink and source for carbon (Contant, 2010). The size of the carbon sink in grassland is influenced by the soil organic content as well as land management practices (Frank and Karn, 2005; Contant, 2010). Ma et al., (2007) found substantial inter-annual variability in oak/grass savanna and open grassland. Over the study period (2001 – 2006) oak/grass savanna operated as a slight carbon sink in all years; while open grassland was a source for all but one year. The amount of seasonal precipitation was noted to have a strong influence on whether open grassland was a sink or source.

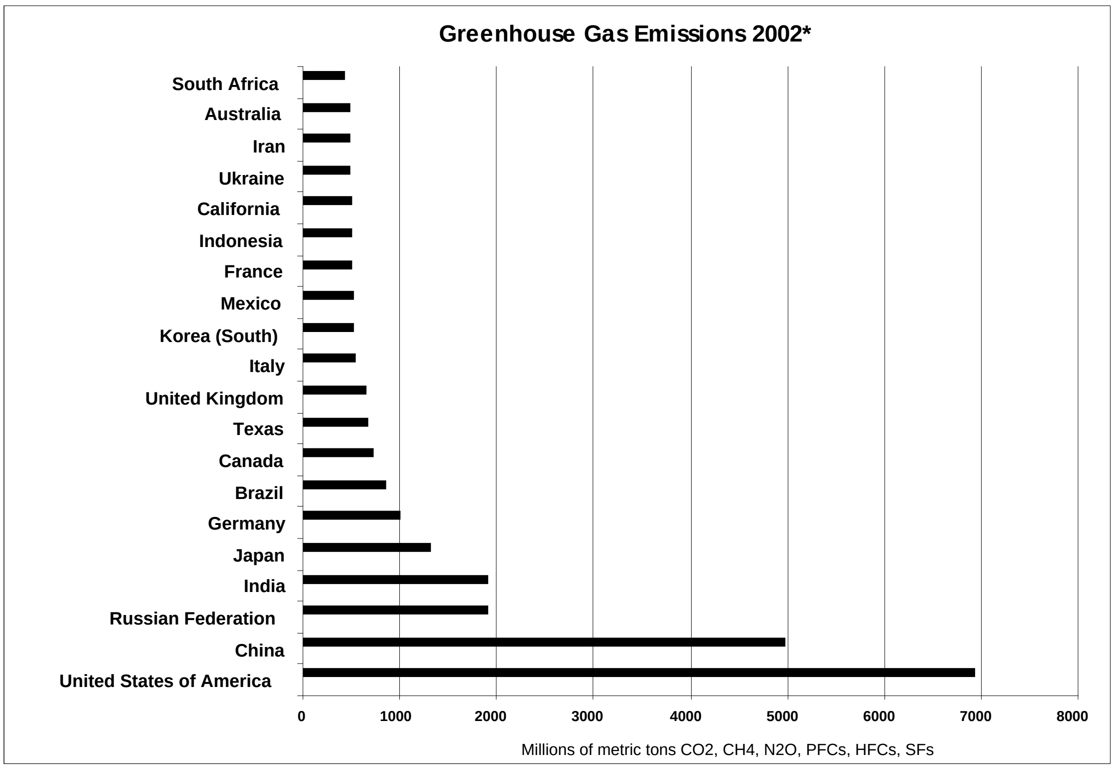

Figure 4.4.1 Greenhouse Gas Emissions (source: Sacramento Bee, December 2006)

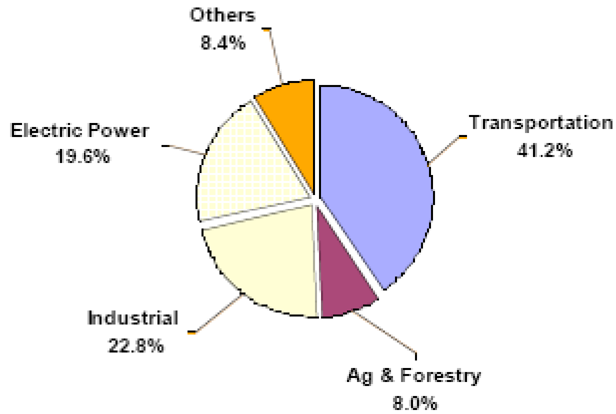

Figure 4.4.2 Economic sector contributions to greenhouse gases in California (CO_2 equivalents)

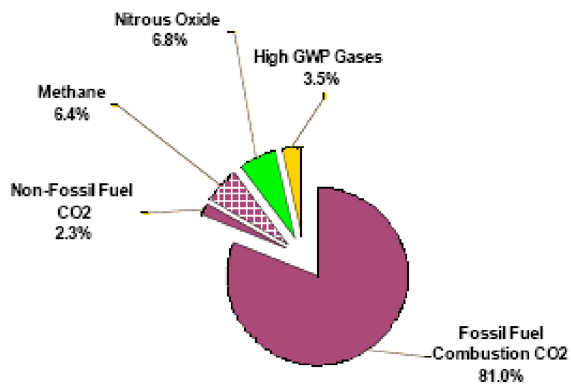

Figure 4.4.3 Composition of climate change pollutants in California (CO_2 equivalents)

4.4.3 Environmental Effects from Climate Change

Climate can greatly influence the dynamics of forest and rangeland ecosystems. Climate influences the type, mix and productivity of species. Future climate change scenarios predict increases in temperature, increases in atmospheric CO_2 concentrations and changes in the amount and distribution of precipitation (Cayan et al., 2006). Altering these fundamental drivers of climate can result in changes in tree growth, changes in the range and distribution of species, and alteration to disturbance regimes (e.g., wildfires, outbreaks of pests, invasive species).

While disturbances occur regularly in nature, large or rapid changes in the patterns of disturbance could make forests less resilient. Vegetation types with restricted ranges may be more vulnerable than others, as well as areas that are already under stress from land use (e.g., expansion of wildland urban interface) and management (Foster, 2003). The following section summarizes some of the expected climate change impacts on forest ecosystems (Table 4.4.1).

Table 4.4.1 Climate Change Impacts in the Forest Sector	
Factor	**Description**
Hydrologic	Changes in temperature, precipitation, and hydrologic processes (e.g., decreased snowpack, earlier spring runoff, lower summer baseflow).
Fire	Changes in the extent and frequency of disturbances from wildfires, pests, and disease outbreaks.
Biologic	Conditions may favor the spread of invasive species.
Biologic	Tree species expected to move northward or to higher altitudes.
Biologic	Changes in reforestation and regeneration success.
Biologic	Changes in forest productivity affecting growth and carbon storage. The effect of additional CO_2 on forest productivity is uncertain.
Economic	Economic impacts from increased fire damage and suppression costs, increased cost from forest health, and loss in productivity.

Data Source: modified from PEW Center on Global Climate Change, 2008

Temperature

All General Circulation Models (GCM) used for climate change research forecast significant increases in temperature for California. The range of temperature increase by the end of the century varies depending on the model from 1.7 ^{0}C to 5.8 ^{0}C (Figure 4.4.4). The range in predicted temperature increases is dependent upon low, medium, and high emission scenarios. Most of these models predict warmer summer months which could lead to more extreme drought conditions and have implications for ecosystem processes related to snowpack, water availability and governing fuel moisture conditions.

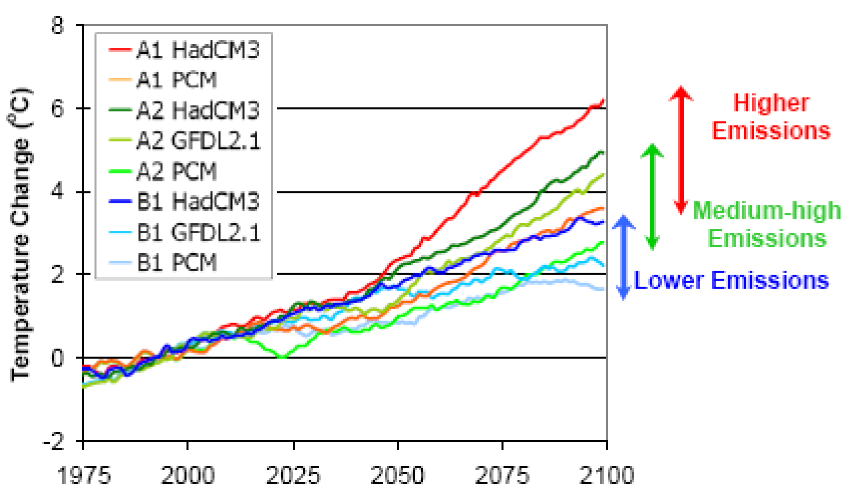

Figure 4.4.4 Predicted change in California annual mean temperature (Cayan et al., 2005)

Precipitation

GCM simulations for California are inconsistent in predicting long-term changes to precipitation patterns. Using more than 20 GCM simulations model estimates range from a 56 percent increase to a 10 percent decrease in winter precipitation, and no change in summer precipitation (Leniham, 2006). With warmer temperatures, models predict less precipitation falling as snow, resulting in a decrease in the size of mountain snow packs and earlier spring snowmelt (Cayan et al., 2006a). This has implications for moisture content in vegetation. An earlier spring melt will likely result in a longer dry season with decreased moisture content in vegetation. The drying of vegetation and fuels could result in an earlier and longer fire season.

Hydrology and Sea Level Rise

Lund et al., (2003) used CALVIN, a water management model, to simulate the effects of climate change on water resources. Under the drier Parallel Climate Model PCM climate scenario runoff was reduced by up to 26 percent, while under wetter scenarios (HadCM2) runoff increased by 77 percent. Predicted runoff from all other climate scenarios fell within this range. Even under wetter scenarios where runoff may increase substantially in winter months there are likely to be significant reductions in spring and summer months, due to diminished snowpacks (Roos, 2003).

Most models predict a substantial rise in sea level that has already been detected in the San Francisco Bay. Historical trends established from tidal gages suggest that present sea level rise is approximately two mm/yr (Cayan et al., 2005). The data does not suggest that sea level is rising at an accelerated rate, but many climate change models expect sea level to rise more dramatically by the end of the century. Recent studies suggest that by 2050 sea level rise is expected to increase from 30cm to 45cm relative to sea level in 2000 (Cayan et al., 2009). This has implication for increased coastal flooding and may place additional stress on Delta levees. In addition, a rise in sea level might also reduce the amount of freshwater habitat available in the bay-delta ecosystem and coastal estuaries.

Regional Climate Trends

A climate threat index was developed by CAL FIRE to better understand regional variations in projections from Global Climate Models (GCMs) (CAL FIRE, 2010). The data was provided by the California Energy Commission and was originally collected as part of the Climate Scenario's Project which was directed by the California Climate Change Center (Cayan et al., 2006; Cayan et al., 2008). This index was used to identify the deviation of future climate conditions from historic conditions for each climate variable for the following time periods: T1 (1970 – 1999), T2 (2010 – 2039), T3 (2040 – 2069), T4 (2070 – 2099). The Climate Threat Index was calculated for a regularly spaced grid of points that were further stratified among the major ecological units for California (Figure 4.4.5). The results of the Climate Threat Index are provided by ecological unit in Table 4.4.2.

Figure 4.4.5 Ecological units for California (Source: CAL FIRE, 2010; Bailey et al., 1981)

For all ecological units (Figure 4.4.5) average annual temperatures are expected to increase within the range of 0.8 degrees Celsius in 2039 to 2.41 degrees Celsius in 2099. Further, maximum daily temperatures during summer months showed the greatest increase in interior ecosections including: Northwestern Basin and Range, Modoc Plateau, Mojave/Sonora/Colorado deserts, Sierra and the Sierra foothill ecosections. Depending on moisture availability, temperature increases combined with decreases in precipitation could lead to dramatic shifts in forest composition and wildlife habitat in later decades. In addition, the expected increases in temperature alone are likely to result in declining snowpack over time, which will affect water resources and related environmental services. See Table 4.4.2 for a comprehensive listing of the predicted changes in climate variables by ecological units.

Table 4.4.2
Climate Threat Index: Deviation of Climate Variables by Ecological Unit

Ecosection Name	Central California Coast	Southern California Coast	Great Valley	Northern California Coast	Mojave/ Sonoran/ Colorado Deserts	Mono, Southeastern Great Basin	North-western Basin and Range	Klamath Mtns., No. California Coast and Interior Coast Ranges	Southern Cascades	Sierra Nevada	Sierra Nevada Foothills	Modoc Plateau	Central California Coast Ranges	So. California Valleys
Zone	261A	261B	262A	263A	322ABC	341DF	342B	M261ABC	M261D	M261E	M261F	M261G	M262A	M262B
TEMP DEG2039	0.55	0.59	0.67	0.53	0.83	0.83	0.87	0.62	0.75	0.71	0.67	0.84	0.67	0.79
TEMP DEG2069	1.20	1.34	1.44	1.11	1.94	1.88	1.91	1.31	1.62	1.64	1.50	1.82	1.46	1.81
TEMP DEG2099	2.88	3.11	3.21	2.60	3.85	3.75	3.80	2.84	3.34	3.40	3.22	3.65	3.27	3.70
SUM TEMP DEG2039	0.74	0.83	0.89	0.72	1.05	1.03	1.26	0.89	1.12	1.02	0.98	1.26	0.93	1.15
SUM TEMP DEG2069	1.71	2.02	1.93	1.67	2.41	2.28	2.90	1.92	2.47	2.23	2.09	2.84	2.07	2.56
SUM TEMP DEG2099	3.80	4.19	3.98	3.61	4.28	4.12	5.31	3.86	4.66	4.26	4.13	5.19	4.20	4.70
WIN TEMP DEG2039	0.47	0.48	0.53	0.38	0.68	0.72	0.71	0.47	0.57	0.53	0.50	0.69	0.56	0.58
WIN TEMP DEG2069	0.65	0.74	0.80	0.43	1.26	1.22	0.85	0.62	0.70	0.91	0.81	0.78	0.87	1.10
WIN TEMP DEG2099	2.07	2.22	2.35	1.57	3.06	3.02	2.61	1.87	2.14	2.48	2.27	2.46	2.46	2.82
PRECIP MM2039	101.79	63.16	51.11	157.05	14.05	32.91	59.34	147.50	114.66	146.57	115.39	96.82	70.74	52.36
PRECIP MM2069	-105.25	-76.25	-53.86	-78.26	-26.58	-50.22	-16.74	-62.88	-60.44	-131.11	-102.79	-11.27	-80.33	-78.10
PRECIP MM2099	-42.08	-30.95	-20.66	41.10	8.87	7.42	33.63	33.62	50.00	-5.18	-21.04	56.99	-47.68	-26.14
SWE MM2039	0.00	0.00	0.00	-0.51	-0.03	6.86	-2.23	-1.66	-7.27	33.77	-0.07	3.49	0.00	-0.60
SWE MM2069	0.03	0.00	0.00	-0.84	-0.04	-15.67	-17.65	-23.60	-44.89	-52.76	-0.10	-26.81	0.00	-1.72
SWE MM2099	0.00	0.00	0.00	-1.69	-0.04	-25.27	-34.54	-46.84	-81.38	-69.29	-0.13	-55.41	-0.01	-2.15

Vegetation and Ecosystems

Projected climatic changes and increases in CO_2 are expected to likely have several major impacts on the wildland vegetation and ecosystems of California, some direct and others indirect. Overall increases in temperature and the lengthening of summer drought could shift local climatic conditions enough to push species and communities to higher elevations. Grasslands and mixed evergreen forest types are predicted to expand in total area, whereas alpine and subalpine vegetation types will shrink (Figure 4.4.6). While one study shows mid-elevation conifer forests diminishing, this is less certain, and such changes may be dominated more by resulting local scale water balance. Climate change models also predict that under a wetter climate forests would expand in northern California and grasslands would expand in southern California, while under a drier climate grasslands would expand across the entire state (Lenihan et al., 2003).

Studies are inconclusive as to whether warming temperatures will result in increased plant growth. Although plants, in theory, benefit from increasing atmospheric CO_2 due to higher water use efficiency, these gains may be offset by other limiting factors (i.e. lack of water, soil nutrients, etc.). Battles et al., (2006) estimated that conifer tree growth and yield would be reduced under all climate model scenarios. In the most extreme case, productivity of mature stands was reduced by 18 percent by the end of the century, and up to 31 percent for pine plantations. Under medium levels of predicted warming, productivity in mature mixed-stands decreased by 20 percent by the end of the century. Other indirect effects in conifer forests include an increased vulnerability to attack and death from insect pests, due both to higher insect over winter survival rates and higher probability of drought and moisture stress in forested areas.

For a select number of forest species CAL FIRE used a Species Distribution Model (SDM) to predict the range or niche that a species might occupy under future climatic conditions (Table 4.4.3). The SDM assumes a species range or niche is primarily determined by environmental conditions and that by incorporating predictions from global climate models the shifts in future species range can be predicted (Aitken et al., 2007). As such, the representation of species distribution does not include the constraints from disturbance, competition or dispersal. The results summarize the expected increases and decreases in indicator species range when comparing current range extent to the predicted range in 2080. The species range was developed for two global climate models: the Community Climate System Model (CCSM) developed by National Center for Atmospheric Research and the Hadley Centre Model (HAD) under the higher emissions A2 scenario. For many species there was strong agreement in the predicted species shift from both models. However, in other cases the model results are quite different.

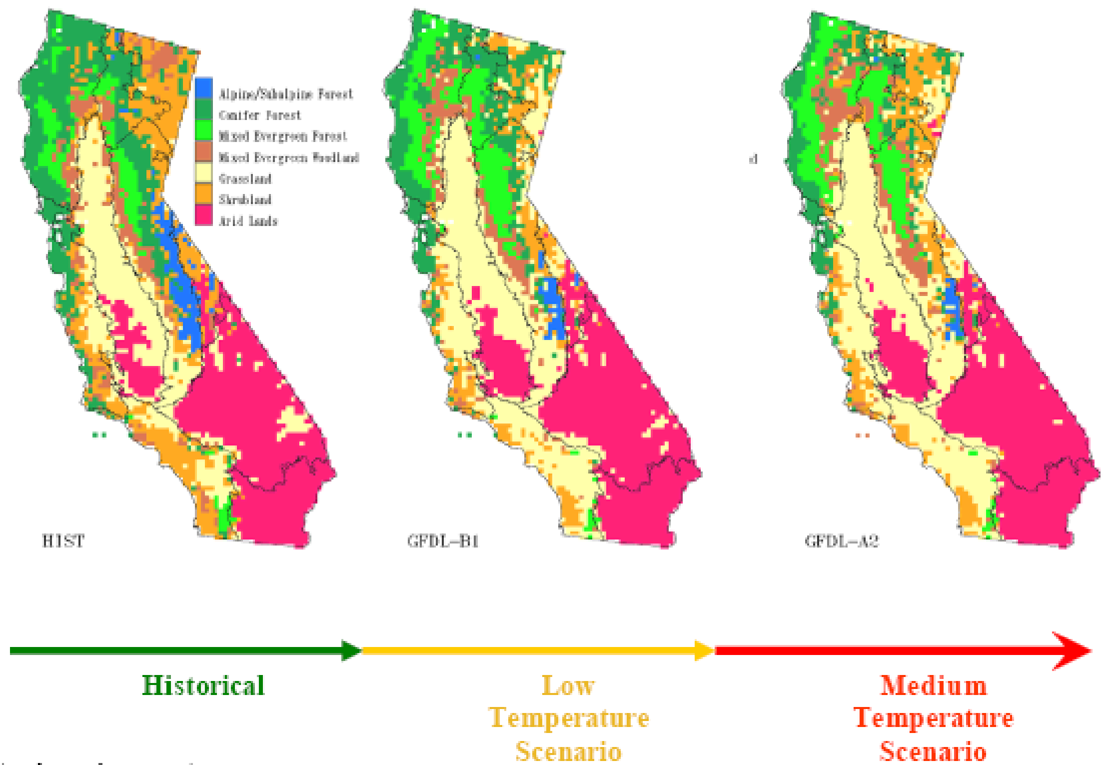

Figure 4.4.6 Vegetation distribution under current conditions and under two different climate change scenarios (Source: Lenihan et al., 2003)

Table 4.4.3
Summary of Percentage Change in Species Range for Two Global Climate Models
(CCM - Community Climate Model, HAD – Hadley; 2010 - 2080)

ABMA - CCM	Description	Acres	Percent Change	ABMA - HAD	Description	Acres	Percent Change
Abies Magnifica	Gained	53,127	1		Gained	494	0
	Lost	4,911,854	77		Lost	6,340,092	100
	Stable	1,432,933	23		Stable	4,695	0
	Present	6,344,787			Present	6,344,787	
PILA – CCM	Description	Acres	Percent Change	PILA – HAD	Description	Acres	Percent Change
Pinus Lambertiana	Gained	6,753,243	61		Gained	2,189,059	20
	Lost	383,993	3		Lost	3,727,256	34
	Stable	10,709,067	97		Stable	7,365,804	66
	Present	11,093,060			Past	11,093,060	
PICO – CCM	Description	Acres	Percent Change	PICO – HAD	Description	Acres	Percent Change
Pinus Coulteri	Gained	1,089,958	15		Gained	241,664	3
	Lost	5,346,009	75		Lost	6,008,978	84
	Stable	1,804,324	25		Stable	1,141,355	16
	Present	7,150,333			Present	7,150,333	
PSMA – CCM	Description	Acres	Percent Change	PSMA – HAD	Description	Acres	Percent Change
Pseudotsuga Macrocarpa	Gained	3,715,396	63		Gained	1,961,233	33
	Lost	1,812,479	31		Lost	2,016,089	34
	Stable	4,060,100	69		Stable	3,856,490	66
	Present	5,872,579			Present	5,872,579	
QUDO - CCM	Description	Acres	Percent Change	QUDO - HAD	Description	Acres	Percent Change
Quercus Douglasii	Gained	975,057	4		Gained	4,336,852	16
	Lost	10,008,538	37		Lost	7,053,222	26
	Stable	16,965,886	63		Stable	19,921,202	74
	Present	26,974,424			Present	26,974,424	
QUEN - CCM	Description	Acres	Percent Change	QUDO - HAD	Description	Acres	Percent Change
Quercus Engelmannii	Gained	1,220,180	38		Gained	2,607,399	82
	Lost	633,317	20		Lost	1,160,876	36
	Stable	2,551,802	80		Stable	2,024,243	64
	Present	3,185,119			Present	3,185,119	

Carbon and Biomass

In a report for the California Energy Commission, Lenihan et al., (2003) used a vegetation model (MC1), which estimates both the distribution and productivity of terrestrial ecosystems in California. Under both wetter and drier climate scenarios the model runs resulted in increases in carbon stocks between 3% and 6%. Wetter conditions lead to an expansion of forest area and an increase in above ground biomass, while drier conditions corresponded with an increase in grasslands. Historically, the highest carbon density is found in forested regions in the state. Shaw et al., (2008), found the MC1 model predicted substantial changes in vegetation composition by 2100. The most pronounced change was the dramatic increase in hardwood forests and a corresponding decline in conifer forests. The magnitude of the vegetation shift varied with the climate model and emission scenario (Figure 4.4.7). Estimated carbon stocks varied from a 12% increase under model scenarios that assume a warm and wet future climate, to a 30% decline in carbon stocks under model scenarios that assume a future climate that is hot and dry.

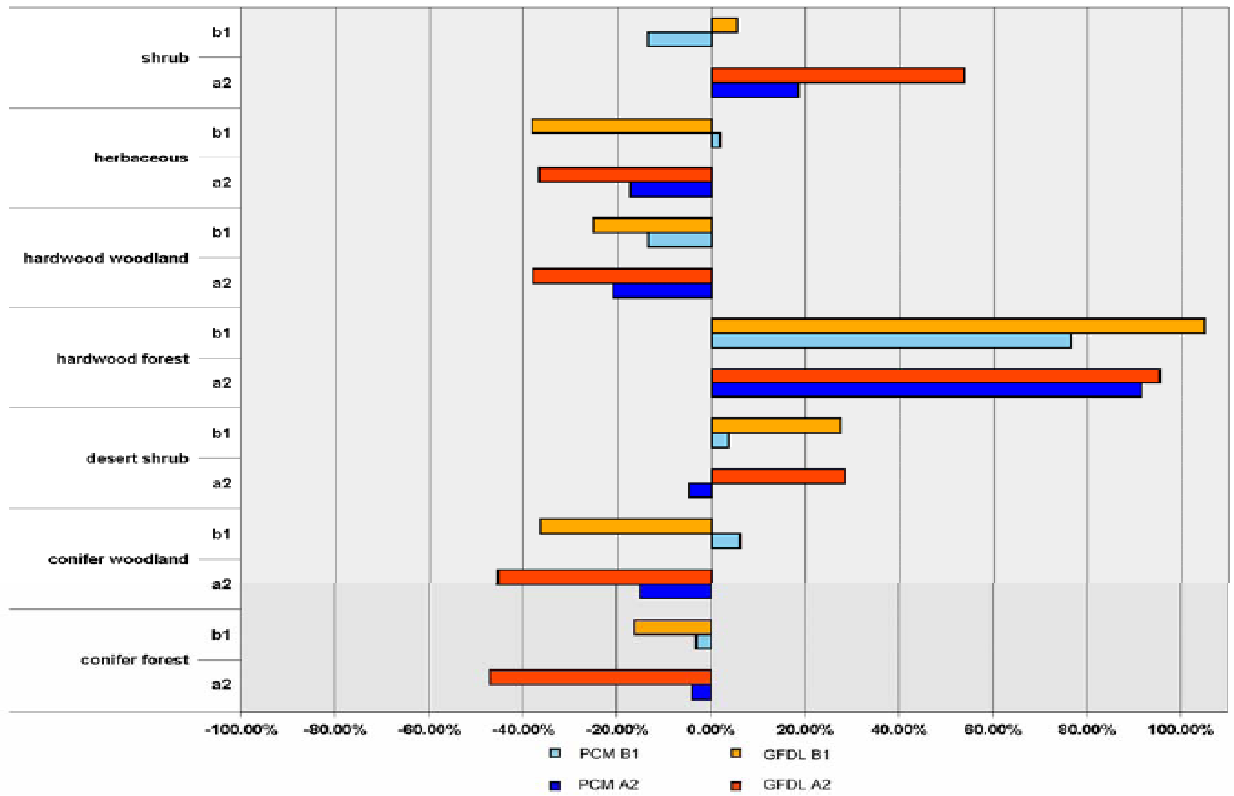

Figure 4.4.7 Change in areal extent of major vegetation types projected by 2070–2099. The chart shows the difference between the areal extent of vegetation types in 2070–2099 as compared to the base scenario for that time period**.** The X axis represents the percent change in vegetation extent between current conditions and 2099 (Source: Shaw et al., 2008.)

In a more recent study, estimates of aboveground carbon stocks were derived by CAL FIRE using the USFS Forest Inventory Analysis (FIA) data. The FIA data was collected between 2001 and 2007 and used to make 10-year projections based on forest growth simulations (CAL FIRE, 2010). Estimates were made across both public and private forest lands. The study estimated an average annual sequestration rate for all forestlands of approximately -30 MMT CO_2eq (Table 4.4.4). This estimate incorporates substantial losses from wildfire and other forms of tree mortality. The estimate of aboveground live tree carbon from this study was 31.1 tonnes C per acre. This compares favorably with the results from a previous study conducted by USFS that estimated aboveground tree carbon at 30.6 tonnes per acre using FIA data from 2001 - 2005 (Christensen et al., 2008).

Table 4.4.4
Results for all California Forestlands (32,114,317 acres)
Harvest Emissions were reduced by 22.8% to avoid double counting with mortality and fire emissions.

Source	Type	C (tonnes)	CO2e (tonnes)
Growth	Storage	-16,367,285	-60,067,936
Model Mortality	Emission	5,455,351	20,021,137
Wildfire	Emission	1,719,915	6,312,087
Harvest (merch)	Emission	565,315	2,074,706
Harvest (non-merch)	Emission	791,776	2,905,819
WP (in-use)	Pool	-389,436	-1,429,231
WP (landfill)	Pool	-48,796	-179,081
Net		**-8,273,161**	**-30,362,499**

In addition to the amount of carbon sequestered in forestlands the trend or likelihood of future storage must also be considered. The Scoping Plan for implementing The Global Warming Solutions Act estimated that forests were currently sequestering approximately -5 MMT CO_2eq, but that the sequestration rate was declining and would become negligible by 2020 (CARB, 2008). A USFS study estimated that national forests in California were currently operating as a substantial sink, but that over the next several decades there were great risks to carbon storage depending on disturbance and management regimes (Goines and Nechodom, 2009). Using the MC1 vegetation model CAL FIRE estimated that carbon stocks were relatively stable through 2050, but then declines would occur through 2100 (CAL FIRE, 2010). In addition, there were substantial acres of forestland, with high carbon storage, that are at risk from wildfire and mortality from forest pests (Table 4.4.5; Figure 4.4.8).

Table 4.4.5
Summary of the Acres of Medium and High Priority Landscape by Bioregion.
Acreage in Medium and High Priority Represents Areas with Forest Carbon that are At Risk From Wildfire Threats and Forest Pest Outbreaks.
These estimates are based on results from the MC1 vegetation dynamics model.

Priority Rank	**2010**		**2020**		**2050**	
	Medium	**High**	**Medium**	**High**	**Medium**	**High**
Bay Area/Delta	2,016,788	2,263,489	1,979,036	2,104,163	2,026,876	1,933,870
Central Coast	3,343,717	3,477,329	3,343,717	3,477,329	3,565,984	2,651,494
Colorado Desert	604,994	16,839	604,994	16,839	418,396	51,289
North Coast/Klamath	3,688,012	9,863,887	3,688,012	9,863,887	3,342,963	10,261,090
Modoc	3,041,900	3,978,349	3,041,900	3,978,349	2,858,730	3,974,886
Mojave	1,875,220	52,655	1,875,220	52,655	1,316,526	190,115
Sacramento Valley	1,170,792	507,695	1,170,792	507,695	1,108,082	312,430
San Joaquin Valley	896,541	142,498	896,541	142,498	644,205	89,033
Sierra	7,868,253	5,962,034	7,868,253	5,962,034	6,337,216	6,351,938
South Coast	3,192,306	2,454,319	3,192,306	2,454,319	2,816,817	2,202,495

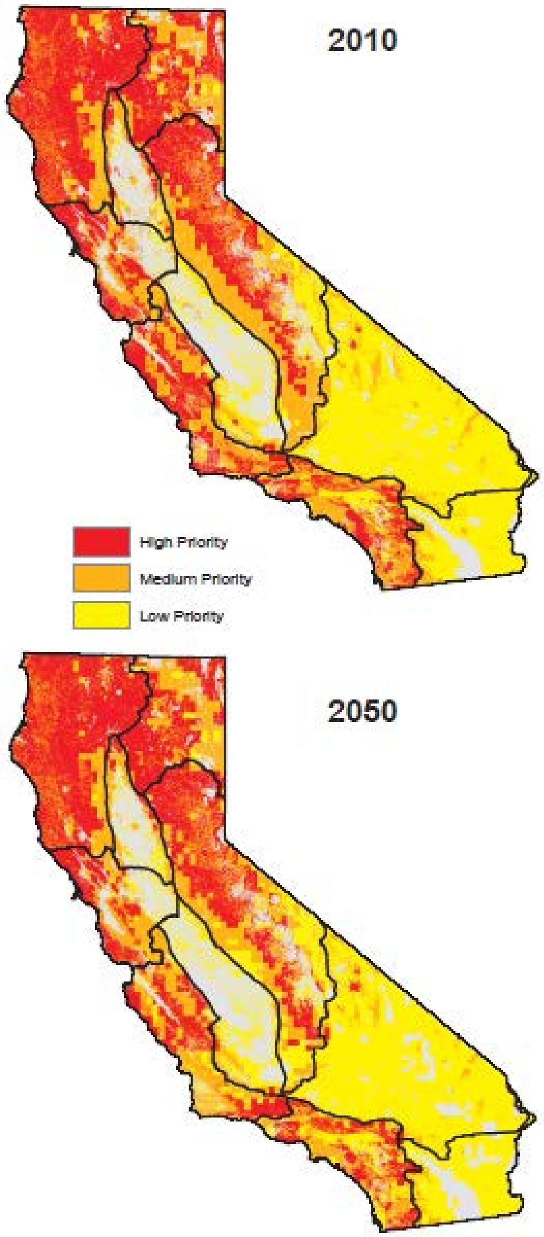

Figure 4.4.8 Priority landscape maps depicting ecosystem threats to forest carbon

Data Source: MC1 Dynamic Global Vegetation Model, USFS / Oregon State University / The Nature Conservancy (2009); Forest Pest Risk, USFS FHP (2006 v1); Statewide Land Use / Land Cover Mosaic, CAL FIRE (2006); California Fire Regime Condition Class, CAL FIRE (2003)

The data inputs to the priority landscape were derived from the MC1 vegetation dynamics model and are based on climate data from the GFDL GCM under the A2 emissions scenario. Under this projected climate scenario the priority landscape areas remain relatively stable through 2050.

Wildfire

Indirect effects of the trend in climatic change include an increase in the frequency and intensity of wildfires in several vegetation types, which is likely to play a role in the expansion of grasslands. A warmer, drier climate will likely increase the number of days of severe fire danger. The fire season in California and elsewhere seems to be starting sooner and lasting longer, with climate change being suspected as a key mechanism in this trend (Flannigan et al., 2000; Westerling et al., 2006). The rolling five year average for acres burned by wildfires on all jurisdictions increased in the past two decades from 250,000 to 350,000 acres (1987–1996) to 400,000 to 600,000 acres (1997–2006) (2006, California Wildfire Activity Statistics). In addition, the three largest fire years since 1950 have occurred this decade, with both 2007 and 2008 exceeding the previous five-year average.

Wildfire risk will continue to be highly variable across the state. Research suggests that large fires and burned acreage will increase throughout the century (Westerling and Bryant, 2006; Lenihan et al., 2008), with some declines after mid-century due to vegetation type conversions. Recent research estimates that the wildfire area burned is expected to increase by at least 100 percent in the forests of Northern California (Westerling et al., 2009). This estimate was consistent for the three GCMs that were used in the analysis. This is likely to have adverse effects on air quality, especially during summer and fall months. Another study used data from three CAL FIRE ranger units (Santa Clara, Amador, and Humboldt) to model potential effects to vegetation and wildfire under differing climate change scenarios (Fried et al., 2004). When interpolated to most of northern California's wildlands, these results translate to an average annual increase of 5,000 hectares (12,355 acres) burned by contained fires. Fire suppression was simulated using California Fire Economics Simulator (CFES). Across all SRA lands in northern California the model predicted 114 additional escapes per year. This is roughly a doubling of the number of escapes under current conditions.

Wildlife

Under warmer and wetter climate scenarios forecast a slight increase in biodiversity; while a drier climate is expected to lead to long-term reductions in biodiversity. Coastal Sage Scrub in Southern California was identified as one habitat type that is likely to be further impacted by both climate change and increasing urbanization associated with population growth.

Under a wetter climate scenario increased runoff in winter months could benefit waterfowl in the San Francisco Bay Area and Central Valley by increasing foraging and resting habitats (Inkley, 2004). This assumes that land use patterns are similar with an abundance of rice fields in the central and northern portions of the Central Valley. However, more intense winter flooding could also erode riparian habitat and cause greater sedimentation in wetland habitats (CDFG, 2005). Drier summers will increase the water needs and lower seasonal river flows and water availability to wildlife, especially in these drier lowland regions. In north coastal watersheds, flow reductions will also adversely impact survival rates of anadromous salmonids (e.g. coho and Chinook) that depend on adequate summer stream volumes. In upland habitats across the state, and particularly in mountainous bioregions, reduced spring snow packs and drier summer conditions will exacerbate the impacts on habitat from more frequent and severe uncharacteristic wildfires.

Sea level rise has the potential to impact coastal habitat through coastal inundation, increased coastal erosion, and a direct loss of coastal habitat. Sea level rise is also expected to create more salt water intrusion and thus reduce the amount of freshwater habitat in the Bay Delta and increase the amount of shallow near shore habitat.

Overall, wildlife in upland habitats will be disrupted by climate change and either adapt, move or experience local and regional population declines. Shrinkage and increased levels of disturbance in available habitats (e.g. upslope) may make successful relocation of species a difficult challenge. Moreover, little research exists and much uncertainty remains on the impacts of climate change on species at risk throughout the state (CDFG, 2005).

4.4.4 California's Regulatory Framework in Response to the Challenge of Climate Change

Assembly Bill (AB) 32, the Global Warming Solutions Act establishes a framework to reduce greenhouse gas emissions (GHG) in California. The bill requires the Air Resources Board to: 1) identify, monitor and track sources of emissions of greenhouse gases; and 2) develop regulatory and market based approaches to lessen GHG emissions. The Legislative findings in Health and Safety Code Section 38501 describe global warming as a threat in areas where CAL FIRE has jurisdiction, including water from the Sierra snowpack, and to industries such as forestry, agriculture and recreation.). California's leadership efforts in such areas as environmental stewardship, renewable energy standards, and natural resource conservation are also cited. Lastly, the Act states the intent that the Climate Action Team (CAT), established by the Governor, continues its role in coordinating overall climate policy.

Two recent Executive Orders, addressing biofuels and climate change, look to forest and wildland management to provide cost-effective alternatives for fossil fuels and increased carbon sequestration to help absorb excessive atmospheric carbon dioxide and in the longer term, reduce the effects of climate change.

Executive Order S-03-05 deals with climate change, stating that climate change impacts pose a significant threat to California and setting specific goals for reductions of GHG within the State. California Environmental Protection Agency (Cal EPA) was established as the coordinator of this effort and was directed to provide the Governor a report by January 2006, setting out recommendations on how to achieve the targets set in Executive Order S-03-05. The Climate Action Team (CAT) was established to coordinate planning efforts to achieve the goals in Executive Order S-03-05. The CAT team, involving a number of agencies, provided for necessary studies and issued the CAT Report in March 2006. The CAT report contained GHG emission reduction targets for California. The targets from that report have been institutionalized by including them in the language of AB 32. The greenhouse gases emission targets established by the Executive Order are shown in Figure 4.4.9. According to the report,

> "The 2010 and 2020 targets are based on an ambitious estimate of how much the state can reduce emissions with strong top-down leadership and a coordinated effort amongst various state agencies. Cal/EPA worked with the Air Resources Board (ARB), California Energy Commission (CEC) and Tellus, a technical contractor, to develop the targets in the 2010 and 2020 timeframes. The 2050 target is based on emission reductions the science indicates will be necessary from all developed nations to ensure protection of the planet in the 100-year time frame… Finally, the EO directed Cal/EPA to lead an evaluation of the impacts of climate change

in California, mitigation strategies to reduce emissions, and adaptation measures that can be taken by the state to best respond to the adverse impacts of climate change."

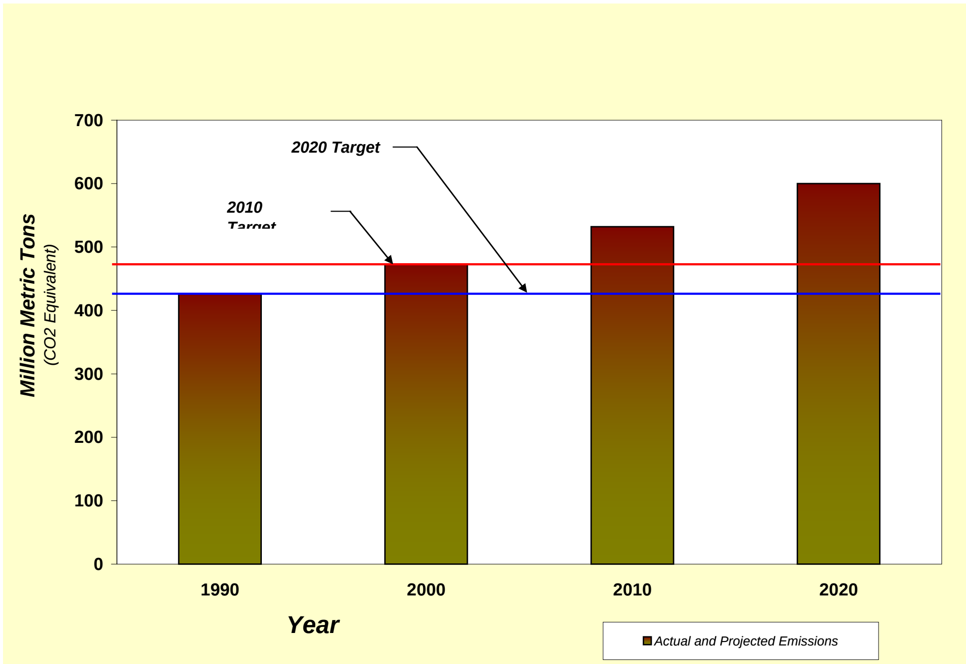

Figure 4.4.9 California's climate change emissions and targets

The reports authored by the Bio Energy and the Climate Action Team recognize the burning of fossil fuels as the major contributor to greenhouse gas emissions, which are the main pollutants forcing climate change and the associated societal impacts. Both reports identify California's forest resources (wildland and urban forests) as a significant contributor to proposed solutions. Other recent reports also list catastrophic wildfires in the western U.S., including California, as significant greenhouse gas contributors.

The CAT recommendations prescribe a series of possible actions that will require multiple agencies, including CAL FIRE, to implement a significant number of coordinated actions and individual projects. Of the strategies given to the Resources Agency, CAL FIRE is the primary agency in five approaches: forest management; forest conservation; fuels management/ biomass; urban forestry; and afforestation/reforestation. Agencies are to proceed with implementation through existing regulatory, public, and stakeholder processes for each of the strategies. Additional development and modifications of the strategies are anticipated over time. These five strategies have the objective of a 9MtC0_2 emissions reduction by 2010 and a total 33 MtC0_2 emissions reduction by 2020.

Table 4.4.6 lists all of the strategies that Resources Agency is in the process of implementing to reduce California's greenhouse gases emissions. The forest management efforts promise not only climate change emission reductions, but also serve to protect biological diversity, water quality and habitat diversity.

Table 4.4.6 Resources Agency Strategies to Reduce Greenhouse Gases Emissions		
Climate Change Emission Reductions (Million Metric Tons CO_2 Equivalent)	2010	2020
Department of Forestry		
Forest Management	1-2	2-4
Forest Conservation	4.2	8.4
Fuels Management/Biomass	3.4	6.8
Urban Forestry	0	3.5
Afforestation/Reforestation	0	12.5
Department of Water Resources		
Water Use Efficiency	0.4	1.2
Energy Commission		
Building Energy Efficiency Standards in Place	1	2
Appliance Energy Efficiency Standards in Place	3	5
Fuel-Efficient Replacement Tires & Inflation Programs	1.5	1.5
Building Energy Efficiency Standards in Progress	TBD	TBD
Appliance Energy Efficiency Standards in Progress	TBD	TBD
Cement Manufacturing	<1	<1
Municipal Utility Energy Efficiency Programs/ Demand Response	1	5.9
Municipal Utility Renewable Portfolio Standard	<1	3.2
Municipal Utility Combined Heat and Power	0	<1
Municipal Utility Electricity Sector Carbon Policy	3	9
Alternative Fuels: Non-Petroleum Fuels	TBD	TBD

[1] These estimates are based on best available current information and will be updated as needed.

An additional order, Executive Order S-06-06 sets out targets for the creation of biofuels and use of biomass (including forestry waste) to produce electricity and reduce consumption of fossil fuels. The resulting wildland fuels reduction will also contribute to lessening the risks associated with catastrophic fire. Order S-06-06 also mandates continuation of the Bioenergy Interagency Working Group (BEIWG) and charges the Resources Agency and Chair of the California Energy Commission with providing oversight of efforts made by state agencies to promote the use of biomass resources.

The State of California has also recognized the need to plan for adaptation needs to address climate impacts that are likely to occur regardless of mitigation efforts. In response to Governor Schwarzenegger's Executive Order S-13-2008 the California Natural Resources Agency led an effort to develop the 2009 California Climate Adaptation Strategy. The forestry chapter of the report makes recommendations that include the use of vegetation management to improve forest health and to promote resilience.

4.4.5 Carbon Sequestration, Forest Conservation and Restoration

Conservation projects can be designed to minimize/prevent the climate change emissions that are associated with the conversion of forestland to non-forest uses by adding incentives to maintain an undeveloped forested landscape.

California is losing forestland at increasing rates: 35,000 to 40,000 acres of private forestland is converted annually to non-forest uses (Stewart, 2005), which could contribute as much as 12 million tons of CO_2 emissions annually. Policies designed to minimize or prevent forestland conversion to non-forest uses could provide significant benefits by 1) preventing or minimizing climate change emissions that are associated with increasing forestland conversion in California and 2) maintaining the opportunity to increase forest carbon stocks on these lands through additional sequestration over time. Forest conservation can also enhance and protect biodiversity, water quality, and habitat resources that the state will increasingly seek to protect from the negative effects of climate change.

Reforestation projects focus on restoring native tree cover on lands that were previously forested and are now covered with other vegetative types. Recent studies have estimated that approximately 9 million acres of land in California could be reforested to increase carbon sequestration and provide other benefits. Each of these acres has the potential to store between 150 to 230 tons of carbon.

The Role of the VTP in Carbon Sequestration and in Reducing California's Greenhouse Gas Emissions

Forest and wildland vegetation management strategies are being developed to reduce CO_2 and other greenhouse gases emissions, and are intended to store additional carbon through a range of activities such as increasing the growth of individual trees, increasing the overall age of trees prior to harvest, or dedicating land to older aged trees. With roughly 33 million acres of forest land (45% private and 55% public) in California, changes in forest management can produce significant amounts of climate change emission reduction benefits for the state. Under AB32 the state is in the process of developing mitigation strategies for the forest sector (see http://www.arb.ca.gov/cc/scopingplan/document/draftscopingplan.htm). As part of the scoping process undertaken by the Air Resources Board and the Board of Forestry, five major strategies have been identified. The following description of the strategies is an excerpt from a Board of Forestry scoping report that was recently submitted to the Air Resources Board.

- **Reforestation and Afforestation**. The forest sector has strong emission reduction potential in both the near term and the long-term. Re- and Afforestation are great examples where investment in the near-term will provide enormous benefits in the 2050 timeframe from a combination of the CFIP program, state and federal re- and afforestation, mitigation and offsets. This strategy may provide more than 23 $MMTCO_2E$ per year by 2050. The GHG benefits of this strategy in the near-term, however, are small.
- **Fuels management**. The most significant potential near-term reductions come from using residual forest wood waste from thinning, harvesting and urban forestry practices to displace fossil fuel in energy generation. Annual savings by 2020 are calculated to be 4.2 $MMTCO_2E$. Reducing fuel loads where appropriate on state and federal lands and using that biomass for energy generation significantly reduces GHG emissions by reducing the risk of wildfire and displacing emissions from fossil fuels. This helps meet the growing demand for renewable energy sources and the state's bio-power objectives, including the Renewable Portfolio Standard. The removal of fire-hazardous fuels from forests has the dual benefit of reducing the frequency and magnitude of wildfire – when applied appropriately -- and the associated emissions. While the benefits of displaced fossil fuel use come from activities in the forest sector, the emission reductions are counted in the energy sector.
- **Urban forestry**. Trees planted in urban areas through state and voluntary programs not only sequester CO_2, but also provide energy savings through the cooling effects of shade, as well as providing multiple co-benefits.

- **<u>Conservation</u>.** Proposition 40, 50 and 84 funds have or will purchase conservation easements in forest lands to protect them from development. More proposition funds in the future would maintain these actions. Conservation approaches are the ONLY guaranteed reductions from the forest sector for 2020 as they are already underway. They total 1.4 MMT annually in 2020.
- **<u>Forest management</u>.** Incentivized by the carbon offset market, voluntary increases in riparian buffer areas and voluntary improvement to timber management techniques would increase sequestration potential in managed forest lands.

Inclusion of the forest and range sector in climate mitigation policy can lead to additional local environmental benefits that may help the state's resources adapt to potential negative effects of climate change (more resilience to drought, etc.). Overall changes in forest management can enhance and protect biological diversity, water quality, and habitat resources that the state will increasingly seek to protect in the advent of climate change.

Reducing the Contribution of California Wildfires to Atmospheric CO_2

Large, episodic, unnaturally hot fires are an increasing trend on California's wild lands because of decades of fire suppression activities, sustained drought, and increasing insect, disease, and invasive plant infestations. Actions taken to reduce wildfire severity through fuel reduction and biomass development are expected to reduce climate change emissions from wildfire. Due to the complex nature of wildfires it is currently difficult to quantify the direct benefits of fuel reduction projects on avoided emissions from wildfires. While there are many examples of fuel treatments successfully modifying fire behavior much research is still needed on this topic. See Sections 4.2, 4.6, 5.2 and 5.6 for additional information on wildfires, vegetation treatments, and air quality.

4.4.6 Summary

California will continue to be affected by climatic change, including the range and forest resource sectors of the economy. The future climate is expected to be warmer, but it is uncertain whether it will be wetter or drier. The prevailing climatic conditions will clearly dictate the extent, composition, and distribution of forest, shrub, and grasslands across the state. In this era of shifting climate, it is likely that catastrophic events such as stand-replacing wildfires will be the proximate triggers in changing natural vegetation distribution.

The state is moving forward on a variety of policies and strategies for reducing greenhouse gases. The VTP can play a role in helping to maintain sequestered carbon in the form of forests and other natural vegetation. It can do so by reducing the frequency and intensity of catastrophic wildfires, and potentially by improving tree growth. Wildfires put large amounts of CO_2 and other greenhouse gases into the atmosphere in a short period of time as well as destroy carbon stocks. Keeping carbon on the ground and out of the air will be a top priority in mitigating climatic changes due to greenhouse gases.