

X. TRANSPORTATION AND ENERGY INFRASTRUCTURE

Introduction

California's economy and population relies on one of the most extensive and costly infrastructure systems in the world. This includes thousands of miles of roads, highways and railroads, nearly 200 large water reservoirs of varying capacity, miles of canals, the second largest hydropower production in the United States, over 12 of the nation's largest oil reservoirs, hundreds of airports, thousands of bridges, and sea ports that deal in over \$200 billion in trade a year. Without this infrastructure, the state would not function as the eighth largest economy in the world.

California's infrastructure was developed to accommodate its highly variable climatic conditions, but it is frequently disrupted by natural disasters such as earthquakes, storms, and floods. Future climate change can directly and indirectly exacerbate these disasters, and add new ones, to California's infrastructure resulting in increased maintenance and repair expenditures, disrupting economic activity, interrupting critical lifelines, and ultimately reducing the overall quality of life for Californians.

To date, there are very few studies providing thorough, comprehensive economic or physical assessments of where California is most vulnerable from future climate change when, and from what specific climate change impacts. More are needed. However, several recent studies shine light on the potential scale of the economic and social impacts from climate change. One recent study from the Pacific Institute estimates that a 1.4 meter sea-level rise over the next century will "put 480,000 people at risk of [what is considered today] a 100 year flood" which would become a common event and cost \$100 billion to replace flooded property assuming current levels of development. Another study by researchers at UC Merced and RAND Corporation estimated that by the next 15 to 20 years the cost of wildfires to residential properties could escalate to more than two billion dollars a year and to more than \$10 billion a year by the end of this century.¹ Finally, a study by Next10 and U.C. Berkeley estimates that over \$2.5 trillion of the state's real estate assets (of \$4 trillion) are "at risk from extreme weather events, sea-level rise, and wildfires, with a projected annual price tag of \$300 million to \$3.9 billion."

In this chapter, *infrastructure* refers largely to transportation and energy-related infrastructure. Other chapters address water and coastal infrastructure strategies and impacts. Future climate adaptation strategy efforts will require a broader look at all infrastructure across California including the private sector and federal and local jurisdictions.

Future Climate Change Impacts to Infrastructure

The most significant climate impacts to California's infrastructure are predicted to be from higher temperatures and extreme weather events across the state, reduced and shifting precipitation patterns in Northern California, and sea-level rise. Higher air temperatures are expected to increase the demand for electricity in the Central Valley and Southern California, especially during hotter summer months, reducing energy production and transmission efficiency while increasing the risk of outages. Potential reductions on precipitation levels could significantly reduce hydropower production which currently accounts for up to 20 percent of the state's electricity supply. Heavy precipitation and increased runoff during winter months are likely to increase the incidence of floods damaging housing, transportation, wastewater, and energy infrastructure. The largest projected damages will come from sea-level rise threatening large portions of California's coastal transportation, housing, and energy-related infrastructure.

A. Increased Temperature and Extreme Events

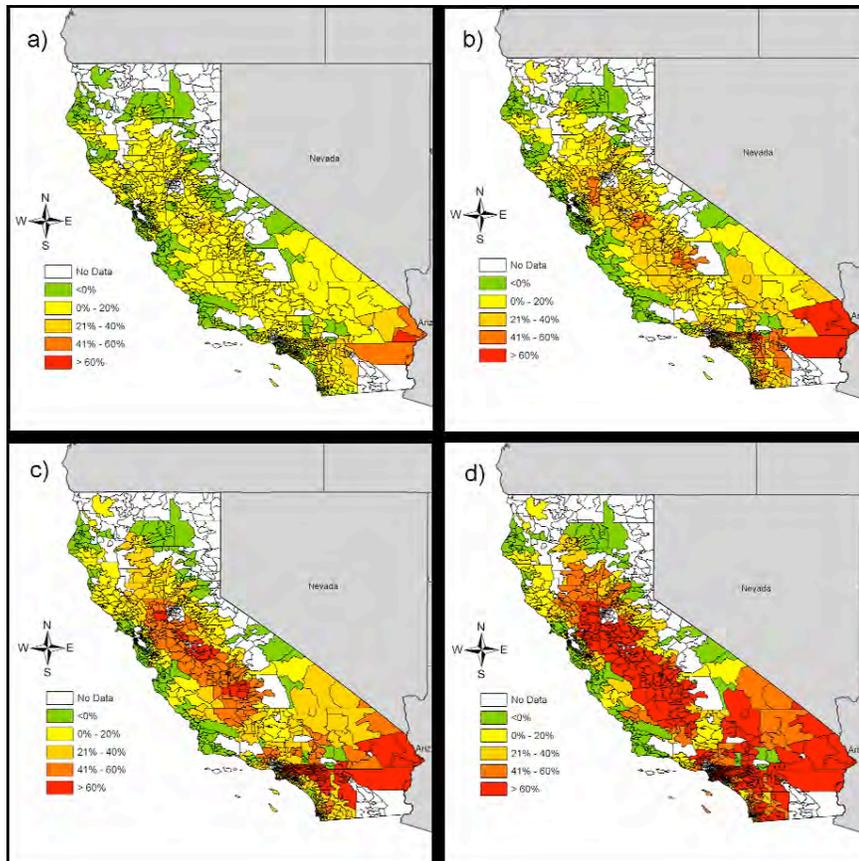
Temperature changes will have direct impacts on energy production, use and distribution and on transportation infrastructure. Average temperature changes are expected to increase energy demands in summer and decrease them in winter. However, with temperatures expected to increase more in summer than in winter in California, wintertime heating demand reduction is likely to be far outweighed by summertime demand increases.² Over the past few decades, California's per capita electricity consumption has remained relatively steady due in large part to cost-effective building and appliance efficiency standards and other energy efficiency programs.³ The *total* consumption, however, has increased substantially along with California's rapidly growing population.

Coupled with future population growth, the projected rise in ambient temperatures will increase energy demand for cooling, especially in the Central Valley

POTENTIAL INFRASTRUCTURE IMPACTS DUE TO WARMING

- Higher Average Temperatures Affect Energy Production, Transmission and Demand
 - Increase in Cooling Demands
 - Decrease in Water Availability for Hydropower Generation
 - Risk of Increased Brown-Outs and Black-Outs
 - Transmission Efficiencies are Impacted in Hot Weather
- Temperature Extremes
 - Increase of Road and Railroad Track Buckling
 - Decrease in Transportation Safety and Higher Costs

Figure 20: Projected increase in household electricity consumption (from 1980–1999 simulated consumption)
 (a) 2020–2039, (b) 2040–2059, (c) 2060–2079, and (d) 2080–2099
 (Source: Aroonruengsawat and Auffhammer, 2009)



region where temperatures are predicted to significantly increase.⁴ A 2003 study analyzed data for several California cities and found that although previous studies indicate a response rate of two to four percent in electricity use for each degree Celsius increase in ambient temperatures, “long-term climate change will also impact electricity consumption through corresponding increases in the market saturation of air conditioning”.⁵ A more recent study showed that while California's total domestic electricity demand in the residential sector will most likely increase by a few percent in the next three decades, it could increase more than 60 percent by the end of the 21st century in certain areas, depending upon emissions scenarios.⁶ These increases are beyond what is expected from population growth alone.

In a nationwide review of the available research literature, researchers examined how climate change might affect energy consumption in the United States. Their answer is consistent with California Energy Commission projections and other regional

research relevant to California: “The research evidence is relatively clear that climate warming will mean reductions in total U.S. heating requirements and increases in total cooling requirements for buildings. These changes will vary by region and by season, but they will affect household and business energy costs and their demands on energy supply institutions. In general, the changes imply increased demands for electricity, which supplies virtually all cooling energy services but only some heating services”.⁷

Higher temperatures also decrease the efficiency of fossil fuel-burning power plants and energy transmission lines, thus requiring either increased production or improvements in the efficiency of power generation and transmission.⁸

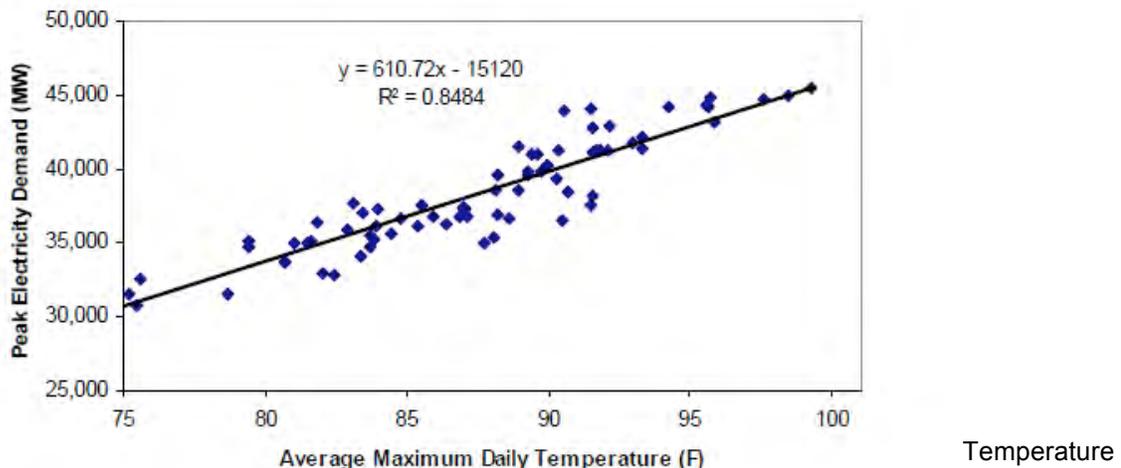
Extreme heat events could cause significant impacts to the energy and transportation sectors. A recent study on extreme heat events and energy demand in California concluded that by 2070-2099 extreme heat events under the IPCC’s highest emissions scenario (A1fi) are 20 to 30 percent higher than under the lower scenario (B1) due to temperature differences. The study concluded extreme heat days could double in inland cities like Sacramento and quadruple in coastal cities such as San Diego. Regarding energy supplies, the researchers found California has a 17 percent probability of facing electricity deficits during high-temperature (top 10 percent of historic temperatures) summer electricity demand periods, assuming constant technology and population growth.⁹ However, this negative effect could be averted or at least minimized adding more electricity generating units.

POTENTIAL INFRASTRUCTURE IMPACTS DUE TO PRECIPITATION CHANGES

- Climate Changes - Decrease of Hydropower Generation
- Shrinking Snowpack - Affects High Elevation Hydropower Systems with Less Storage Capacity
- Lower River Flows - Requires Increase Release of Water
 - Causing Spills and
 - Reducing Water in Dry Months
- Winter Storms and High Runoff Snowmelt - Results in Flooding and Damage to Transmission Lines
- Extreme Rainfall and Flooding - Causes Wastewater System Overload and Damage to Culverts, Canals and Treatment Facilities
- Increased Flood Damage of Transportation Infrastructure
- More Drought, Fires and Intense Rainfall - Results in Landslides and Disrupt Roadways and Rail Lines

Higher temperatures and heat waves will impact peak electricity demand in California. Figure 21 illustrates how peak temperatures correlate with state electricity load during a peak summer day¹⁰.

Figure 21: Peak electricity demand June- September 2004



extremes are also relevant to the transportation sector. It is expected less extreme cold days will reduce frost heave and road damage,¹¹ but extreme hot days (including prolonged periods of very hot days), are likely to become more frequent, increasing the risk of buckling of highways and railroad tracks and premature deterioration or failure of transportation infrastructure (Figure 22).¹²

Figure 22: Trains can derail due to extreme heat warping railroad tracks.



B. Precipitation Changes and Extreme Events

Fluctuations, and possible total reductions, in California's precipitation patterns will impact several key energy and transportation infrastructure components; primarily hydropower production and all manufacturing and processing operations requiring large volumes of readily available water. In addition, roads, tunnels, airport runways and railroad tracks are likely to be affected by changes in precipitation patterns.

In the energy sector, changes in hydrological patterns will affect the reliability of the region's hydropower generation, which accounts for 12 to 20 percent of the state's total annual electricity generation. A warmer and drier future climate could reduce hydroelectric generation by 19 percent, whereas a wetter future climate could increase hydroelectric generation by 5 percent.¹³ Of the 12 climate projections used in the 2008 California Climate Impacts Assessment, only one simulation produced slightly wetter conditions by 2050, and none did so for the end of the century (see Water chapter).

Hydropower production is a significant contributor of energy for electricity suppliers Pacific Gas and Electric Company (PG&E) and the Sacramento Municipal Utility District (SMUD) among many others. SMUD is particularly vulnerable, as hydropower can account for up to 50 percent of its annual power generation.¹⁴

The economic impact of climate change due to the loss in hydropower generation and the increase in electricity demand during late spring and summer is estimated to be approximately \$2.7 billion annually in a lower-warming scenario and \$6.3 billion annually in a high-warming scenario, with roughly \$21 billion in energy assets at risk.¹⁵

The extent to which climate change will actually affect hydropower generation in California depends both on how precipitation patterns and the amount of warming in different regions end up changing reservoir storage and the flexibility of the systems. Hydropower generation capacity in high-elevation systems peaks in the summer, whereas capacity in lower-elevation systems peaks in winter.¹⁶

A decreasing Sierra Nevada snowpack (due to a higher snowline and increased temperatures, making more precipitation fall as rain rather than as snow) will also reduce the amount of water available for hydropower generation during late spring and summer when energy demand is higher. The shrinking snowpack will particularly affect high-elevation hydropower systems (higher than 1,000 feet above sea level) that have less storage capacity. This type of system accounts for half of the state's hydropower generation and relies on melting snowpack for operations.¹⁷ In addition, more winter precipitation falling as rain instead of snow will result in extreme flows that will require reservoir operators to release more water, causing undesired spills and retaining less water for the dry months.¹⁸

Winter storm activities, especially if coinciding with earlier snowmelt and high runoff, can cause flooding which, in turn, can cause damage to transmission lines and lead to power outages. Further research is needed in this area to determine the overall vulnerability of the power grid in coastal and delta areas subject to increased flooding in addition to what recommendations should be implemented.

Lower-elevation hydropower units such as the Central Valley Project (CVP) and the State Water Project (SWP) are expected to generate less power under current climate scenarios, but also require less electricity to pump water to Central and Southern California. When the SWP and CVP power supply and power consumption estimates are combined, the water projects require more energy to operate than they generate. By the end of the century, the amount of supplemental power that the combined projects will need decreases by 500-600 GWh/yr.¹⁹ Both could see reductions in energy production of three percent by mid-century and 6 percent by end of the century.²⁰

Changes in precipitation patterns can also be expected to affect other types of infrastructure. For example, sewers and wastewater treatment facilities could see growing strains as climate change proceeds. Expected changes in precipitation patterns include a continued risk of intense rainfall events and associated flooding, with the occasional greater-than-historical flooding events. Such extreme rainfall events and flooding can cause overloading of wastewater systems, as well as physical damage to culverts, canals, and water treatment facilities.

Researchers and the California Department of Transportation also expect increased damage of transportation infrastructure as a result of flooding of tunnels, coastal highways, runways, and railways, and associated business interruptions. The combination of a generally drier climate in the future, which will increase the chance of drought and wildfires, and the occasional extreme downpour, is likely to cause more mud- and landslides which can disrupt major roadways and rail lines. The related debris impacts are historically well known to California, but if they become more frequent, will create greater costs for the state and require more frequent repair.²¹

C. Sea-Level Rise and Extreme Events

Accelerating sea-level rise is likely to cause some of the greatest impacts on California's infrastructure, including vital lines of coastal transportation, possibly some of the power plants located along the coast, a densely developed urban landscape, wastewater treatment facilities, ports, airports, and any other lifelines.

Port infrastructure and airports located near sea level are particularly vulnerable. The San Francisco Bay area for example, is home to three major airports – San Francisco, Oakland, and San Jose – which are all near sea level (Figure 23). Unless these exposed assets are raised and/or protected by seawalls, they will be inundated and will experience increasing flooding as storm surges reach higher and farther inland. Similarly vulnerable are California's seaports, which account for 40 percent of total U.S. shipping volume²² and have extensive docking facilities at risk. The total value of at-risk air and seaport

infrastructure is estimated to total in the multi-billions of dollars.²³ Furthermore, a substantial amount of ground transportation infrastructure, including 2,500 miles of roads and railroads, is projected to be at growing risk from storm-related coastal flooding, elevated due to accelerated sea-level rise.²⁴ This infrastructure is vital to the residents of California as they commute to work and school, is needed for the movement of commercial freight and thus is integral to the functioning of the overall state economy.

Figure 23: Projected sea level rise around San Francisco Airport (SFO). (Source: San Francisco Bay Conservation and Development Commission)



The economic cost associated with the required alteration, fortification, or relocation of existing

infrastructure is likely to be substantial. One example is the proposal by the California Department of Transportation to move three miles of Highway 1 in Big Sur as far as 475 feet inland in order to protect against expected cliff erosion underneath the current stretch of highway.²⁵ Other infrastructure components that may require modifications include raising bridges to ensure marine vessel clearance, fortification of petroleum facilities with ocean exposure, and gravity-assisted outfalls of wastewater discharge.²⁶

Certain types of infrastructure may also be at risk from indirect impacts of climate change and coastal inundation, such as the potential for sea water backflow to impair coastal water sanitation drainage systems during flood events,²⁷ or the collapse of cliffs, due to increased erosion, that underlie housing developments, roadways, and sewers placed on coastal bluffs. Further, substantial sea-level rise may necessitate entirely new drainage systems in low-lying cities with drainage that is pump-driven rather than gravity-driven.²⁸

The extent of needed upgrades to existing infrastructure and the construction of new

protective infrastructure will also be influenced by the scope of climate change-induced damage to *natural* coastal protective barriers, i.e., the degree of erosion of beaches, cliffs, and wetlands.²⁹ Additionally, studies find that protective infrastructure in particular areas may be at risk of heightened dual-sided stress as the incidence and intensity of both of sea-based and land-based waters increasingly act upon these barriers. The Bay-Delta levee system, for example, is exposed to increases in the intensity and coincidence of river flooding-related forces combined with increased sea-level rise-related bayside stress.³⁰

As discussed in the Ocean and Coastal Resources chapter, California has already begun to protect its low-lying developments from the sea with construction of many miles of levees, sea walls, bluff-protective structures, and other hard structures. Hardening of the coastline, however, is restricted by coastal law to older structures and to certain emergency situations where essential structures or infrastructure is at risk from immediate loss. However, as sea level continues to rise at a faster pace and coastal storms become more intense due to higher storm surges, existing fortifications will be increasingly inadequate. Not only will existing barriers need to be raised, but new, previously not at-risk sections of coastal and bay-side lands and ecosystems will become at risk.³¹ Moreover, both new and old infrastructure will likely require more frequent and costly maintenance should the intensity and duration of water and wind forces increase as projected.

One study conducted for the 2009 California Impacts Assessment found that about \$100 billion in structures, contents, and infrastructure along the California coast and San Francisco Bay and Delta may be at risk of storm-related inundation by 2100 due to projected increases in mean sea level. This estimate may be conservative as population growth, development and any contribution to sea level from Greenland and West Antarctic ice sheet melting have not been included (see Chapter 3 on sea-level rise projections).³² Nearly 300,000 acres of Bay-Delta lands are already below sea level, sit upon continuously subsiding land and rely upon an aging levee system that was built upon soft peat soils.³³ Furthermore, the amount of at-risk development in the Bay area, without accounting for any future development, could more than double from current levels by 2100.³⁴

Costs associated with constructing the necessary fortifications of natural barriers and new protective infrastructures are likely to be substantial. A 2008 study estimating the cost of coastal protection structures necessary to safeguard *existing* development against rising sea levels found that 1,070 miles of new or upgraded protective levees and seawalls will be needed by 2100 to protect the Bay and open coastline against inundation under a scenario of ~5 feet (1.4 meter) sea-level rise.³⁵ Such coastal protection could conservatively involve a capital cost of over \$14 billion and will require ongoing maintenance, which may add an additional annual cost of 10 percent of the capital cost.³⁶ These estimated costs, however, do not consider potential ecological impacts and unintended consequences or armoring coastal areas and legal restrictions for such actions. Therefore, actual adaptation costs could be much higher. The study also found that the burden of construction costs will be disproportionate along California’s coast, as Southern California will need the greatest investment, with 20 percent of the capital investment required in Los Angeles County alone.³⁷ It would be necessary to fortify existing protective infrastructure by 0.1-0.2 feet per year for the next few decades in order to merely keep pace with rising waters and to maintain the same relative risk of flood-related inundation those lands have had in recent years.³⁸

POTENTIAL INFRASTRUCTURE IMPACTS DUE TO SEA-LEVEL RISE

- Seaside Airports - Vulnerable to Storm-related Inundation
- Seaports and Docks - Inundation and Flooding (Impedes Business)
- Roads and Railroads - Risk of Storms and Coastal Flooding
- Sea-Level Rise and Coastal Surges Requires Increased Fortifications.
- Economic Costs of Fortifications or Relocation is Considerable
- Sea Water - Floods Can Damage Coastal Water Sanitation Systems Requiring Costly Upgrades
- Sea-Level Rise and river Flooding will Impact Bay-Delta Levee System

D. Changing Risks for Infrastructure

To summarize the changing risks that California’s transportation and energy infrastructure may be facing from climate change, the likelihood of occurrence of the projected consequences was qualitatively assessed. The resulting risk profile for California’s infrastructure can be characterized as follows:

- Higher average temperatures and higher summer peaks will greatly affect energy production, distribution (transmission), and demand with increased cooling demand likely to far outpace reductions in heating demand in the winter.
- Higher temperatures, together with a drying climate and less snowpack, will decrease the amount of water available for hydropower generation, especially high-elevation systems. In addition, transmission of electricity is less efficient during hotter periods, leading to electricity deficits especially during peak demand times. The risk of outages is likely to increase.
- Temperature extremes can increase the risk of road and railroad tracks buckling, decreasing transportation safety and creating higher maintenance costs.

- More winter precipitation falling as rain instead of snow will result in extreme flows that will require reservoir operators to release more water, causing undesired spills and retaining less water for the dry months.
- Winter storms, especially if coinciding with earlier snowmelt and high runoff, can cause flooding and damage to transmission lines, overloading and damage of wastewater treatment facilities, as well as physical damage to culverts, canals, tunnels, coastal highways, runways, and railways, and associated business interruptions.
- More drought, fires and intense rainfall events will produce more mud- and landslides which can disrupt major roadways and rail lines.
- Sea-level rise is likely to cause the greatest impacts on California's infrastructure, including more frequent storm-related flooding of airports, seaports, roads, and railways in floodplains due to higher sea levels.
- As sea level rises at a faster pace and coastal storm surges increase, existing fortifications will be increasingly inadequate and need to be raised, and areas previously not at-risk will become at risk.
- The economic cost associated with the required alteration, fortification, or relocation of existing infrastructure is likely to be in the tens of billions.
- Sea water backflow will impair coastal water sanitation drainage systems during flood events, requiring costly upgrades and alterations.
- The Bay-Delta levee system, for example, is exposed to increases in the intensity and coincidence of river flooding-related forces combined with increased sea-level rise-related bayside stress.

Infrastructure Adaptation Strategies

Introduction

The state agencies that participated in the Climate Adaptation Working Group (California Energy Commission and California Department of Transportation) developed the following strategies and are responsible for and will spearhead strategy implementation. Climate is already changing in California and its impacts are going to be felt in all sectors of the state's economy. The impacts of climate change on infrastructure will vary at the local level, but it is certain they will be widespread and costly in human and economic terms, and will require significant changes in the planning, design, construction, operation, and maintenance of California's infrastructure. Infrastructure adaptation strategies developed thus far pertain to two aspects of development: transportation and energy.

Transportation routes and infrastructure will be dramatically affected by sea-level rise. Therefore, adaptation strategies focus on this effect of climate change. Adaptation plans will be developed for the long-term with estimations of future growth, demand, and vulnerability issues. A 50-year planning horizon will be used to parallel the time period of current model predictions. Predicted sea-level rise and storm surges will be guarded against by increasing the elevation of streets, bridges, and rail lines, while some at-risk sections of roads and rail lines will be relocated farther inland. Flood zones will be re-mapped to account for different sea-level rise projections. As a result of these updated maps, areas may be identified that will need to be returned to a natural state.

Energy infrastructure will be tested by higher temperatures and intense storm events. Adaptation strategies reflect the "loading order," a state energy policy which calls for meeting new electricity needs first with energy efficiency and demand response; second, with new generation from renewable energy

and distributed generation resources; and third, with clean fossil-fueled generation and transmission infrastructure improvements.. These programs will promote the use of more efficient air conditioning equipment and lighting systems. They will work to increase the level of insulation (ceiling, floor and walls) and window glazing used in new and existing homes. The planting of trees will be used to shade homes and buildings, and the use of roof materials that reflect the heat to reduce the “heat island effect” will be promoted in new construction. Energy strategies such as smart grid technologies also aim to improve the ability of the electricity system to respond to peak demands. Additionally, they will implement modern techniques for the integrated management of water reservoirs in Northern California to improve their management, and include information regarding changing hydrological patterns in that management.

Encouraging the development of distributed and centralized renewable resources will also help the state meet increased energy demand due to climate change. Opportunities to expand renewable distributed generation resources include increased use of solar, biomass (including biomass that is currently being landfilled), and biogas from wastewater treatment plants. Further development of centralized renewable resources is also needed to help meet expected energy demand due to climate change and care will be needed to ensure that associated transmission is developed in the least environmentally sensitive areas. Renewable development needs to be advanced throughout California, including on state, federal, and tribal lands. Further work is needed to assess the impacts of climate change on existing and planned energy infrastructure and to identify the most vulnerable communities.

In addition, the Energy Commission and other responsible planning authorities should assess potential impacts of climate change on species and habitat needs, including movement patterns, when developing natural community conservation plans and other mitigation measures for new power plants.

The impacts of climate change on California’s infrastructure are varied and far-reaching. Infrastructure adaptations to climate change will be costly, but it will be more expensive if the state does not begin planning and adapting before the predicted changes alter the physical landscape. California’s infrastructure is the conduit through which economic activity flows. The production and movement of goods and services relies on existing infrastructure. Disruption of these deliveries will be detrimental to California’s economy. Protection of infrastructure will help ensure California’s future as a leading economic player.

Adaptation Strategies and Actions

The California Energy Commission (Energy Commission) and the California Department of Transportation (CalTrans) have identified the following priorities in addressing climate adaptation for California state agencies. The near term actions referenced below are those actions that have been identified and which can be initiated or completed by 2010. The long term actions include those recommended actions that will require support from that state, and collaboration with multiple state agencies.

Climate is already changing in California and its impacts are going to be felt in all sectors of the state’s economy. The impacts of climate change on infrastructure will vary at the local level, but it is certain they will be widespread and costly in human and economic terms, and will require significant changes in the planning, design, construction, operation, and maintenance of California’s infrastructure. Infrastructure adaptation strategies developed thus far pertain to two aspects of development: energy and transportation.

Strategy 1 – ENERGY: Increase Energy Efficiency Efforts in Climate Vulnerable Areas

Near -Term and Long-Term Actions:

- a. **Meet the Energy Efficiency Goals Outlined in AB32 Scoping Plan** – The Air Resources Board’s (ARB) Scoping Plan has identified 26.3 MMTCO₂e that will be reduced by 2020 through increased use of building and appliance efficiency standards, increased combined heat and power generation and through increased solar water heating improvements (AB1470). Ensuring these measures are met, while increasing these efforts over time, will help ease projected energy demand increases and possible supply disruptions from climate change.
- b. **Facilitate Access to Local, Decentralized Renewable Resources** – The Energy Commission should consider policies and incentives to maximize and to encourage de-centralized (local and near demand) generation and on-site renewable energy generation systems where feasible and appropriate. This deployment of additional renewable generation would reduce GHG emissions and help meet the expected increase in electrical demand due to climate change.

Strategy 2 – ENERGY: Assess environmental impacts from climate change in siting and re-licensing of new energy facilities.

Near -Term and Long-Term Actions:

- a. **Assess Power Plants Vulnerable to Climate Impacts, and Recommend Reasonable Adaptation Measures** – The Energy Commission will assess GHG impacts for power plant siting cases through its Integrated Energy Policy Report, and consider the potential impact of sea-level rise, temperature increases, precipitation changes and extreme events, where relevant.
- b. **Encourage Expansion of Renewable Energy Resources** – The Energy Commission should assess long-term benefits of renewable energy generation in reducing GHG emissions that also provide environmental co-benefits. The state shall encourage additional development of the most suitable and efficient renewable technologies to maximize the amount of electrical generation from renewable sources. The Energy Commission and DFG should encourage renewable energy generation in the least sensitive environmental areas to maintain natural habitats and healthy forests that will further buffer the environmental impacts of climate change.
- c. **Assess the Impacts of Climate Change on Energy Infrastructure** – Use the Energy Commission’s PIER regional climate modeling and related study efforts to assess the potential impacts of climate change on energy infrastructure from sea-level rise, precipitation, and temperature changes and other impacts. The Energy Commission will determine additional actions on its siting and planning programs based on this work.
- d. **Identify the Most Vulnerable Communities** – Develop an energy-use “hot-spot” map to identify areas in the state where increases in temperature, population, and energy-use will make communities most vulnerable to climate change impacts. The Energy Commission will include in this analysis how the lowest-income communities in hot spot areas will be impacted. Also, assess impacts of climate change on tribal lands and ability of tribes to adapt to changing conditions.

Strategy 3 – ENERGY: Develop Hydropower Decision-Support Tools to Better Assess and Manage Climate Change Variability

Near -Term and Long-Term Actions:

- a. **Expand Scientific Climate Research** – The Energy Commission and the DWR will continue to support and develop enhancements and demonstration of modern decision support systems for the management of existing major water reservoirs in California to adapt to current levels of climate variability and increase our resilience to increased levels of climate variability and change in the future.
- b. **Public Interest Energy Research** – The Energy Commission’s PIER program will sponsor research on climate change factors influencing hydropower generation – for example, how hydropower generation would be affected by requirements to release additional water to attenuate increased water temperatures in rivers and streams for environmental purposes.
- c. **Develop Partnerships** –Partner with hydropower generators particularly vulnerable to climate change to identify how public-private partnerships could reduce long-term risks to hydropower generation.

Strategy 4 – ENERGY: Identify how state renewable energy goals could be impacted from future climate impacts.

Near -Term and Long-Term Actions:

- a. **Assess Climate Impacts on Energy** – The Energy Commission’s PIER program will research how climate change impacts could influence the goals of AB32, AB118, and EO S-13-08 goals. For example, climate change will influence wind speeds and patterns, temperature density, etc. that will affect power levels from wind turbines, photovoltaics, etc. In addition, biomass feedstocks could be reduced due to decreased water levels and increased wildfire. It is unclear how this will impact long-term projections for meeting our 2020 and 2050 renewable energy goals.

The near term actions referenced below are those actions that have been identified and which can be initiated by 2010, subject to availability of necessary information to ensure credibility of the analysis and authority of the information, and will require collaboration with multiple state, regional and local agencies as well as adequate funding. The climate impact data serving as the basis of these actions will stem from ongoing research undertaken by the PIER program, and centralized through the CAT. The long term actions include those recommended actions that will require support from the state and collaboration with multiple state, regional, and local agencies.

Strategy 5 – TRANSPORTATION: Develop a detailed climate vulnerability assessment and adaptation plan for California’s transportation infrastructure.

Near -Term and Long-Term Actions:

- a. **Vulnerability and Adaptation Planning** – BTH (Business, Transportation and Housing Agency) and CALTRANS will develop a climate vulnerability plan that will assess how California’s transportation infrastructure facilities are vulnerable to future climate impacts, assess climate adaptation options, prioritize for implementation, and select adaptation strategies to adopt in coordination with stakeholders. This plan will be coordinated with an updated climate mitigation plan that will act as BTH’s and Caltrans’ overall transportation climate policy.

- i. Develop a transportation use “hot-spot” map – Caltrans will research and identify transportation “hot spots”, using updated NAS and other appropriate study efforts, to identify across the state where the mixture of climate change impacts, population increases, and transportation demand increases will make communities most vulnerable to climate change impacts. Caltrans will include in this analysis how the lowest-income communities in hot spot areas will be impacted.
- b. **Economic Impacts Assessment** – Complete an overall economic assessment for projected climate impacts on the state’s transportation system and other related infrastructure along transportation corridors as appropriate under a “do nothing” scenario and under climate policy scenarios identified by BTH/Caltrans.
 - i. Prepare a list of transportation adaptation strategies or measures based on the “hot spot” map and prepare an economic assessment and cost-benefit analysis for these strategies vs. a do nothing scenario.

Strategy 6 – TRANSPORTATION: Incorporate climate change vulnerability assessment planning tools, policies, and strategies into existing transportation and investment decisions.

Near -Term and Long-Term Actions:

- a. **Integrate Mitigation and Adaptation System-wide** –Caltrans will develop and incorporate climate change mitigation and adaptation policies and strategies throughout state strategic, system and regional planning efforts. These will be included in key phases of the following planning and project development phases when appropriate:
 - i. Strategic Planning (Governor’s Strategic Growth Plan and California Transportation Plan)
 - ii. System Planning (i.e., District System Management Plan, Inter-regional Strategic Plan, Corridor System Management Plan, and Transportation Concept Report)
 - iii. Regional Transportation Planning (Regional Transportation Plan Guidelines and Regional Blueprint Planning)
 - iv. Project planning (Project Development Procedures Manual, Project Initiation Document, Project Report, Design and engineering standards, Environmental Guidelines)
 - v. Programming (State Transportation Improvement Program, State Highway Operations and Protection Program, California Transportation Commission State Transportation Improvement Program Guidelines)

Strategy 7 – TRANSPORTATION: Develop transportation design and engineering standards to minimize climate change risks to vulnerable transportation infrastructure.

Near-Term and Long Term Actions:

- a. **Transportation Infrastructure Assessment** - Caltrans will assess existing transportation design standards as to their adequacy to withstand climate forces from sea level rise and extreme weather events beyond those considered.
- b. **Buffer Zone Guidelines** - Develop guidelines to establish buffer areas and set backs to avoid risks to structures within projected “high” future sea level rise or flooding inundation zones.
- c. **Stormwater Quality** - Assess how climate changes could alter size and design requirements for stormwater quality BMP’s.

Strategy 8 – TRANSPORTATION: Incorporate climate change impact considerations into disaster preparedness planning for all transportation modes.

Near -Term and Long Term Actions:

- a. **Emergency Preparedness** – CALTRANS provides significant emergency preparedness abilities for all transportation modes across the state. The transportation system is sensitive to rapid increases in precipitation, storm severity, wave run-up and other extreme weather events. CALTRANS will assess the type of climate-induced impact information necessary to respond to district emergencies. Results will be incorporated into existing operations management plans.
- b. **Decision Support** – CALTRANS will identify how climate impact information can be integrated into existing Intelligent Transportation Systems and Transportation Management Center operations.