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SMUD Comments on Joint CEC/CPUC Workshop on Climate Adaptation and Resiliency

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Additional submitted attachment is included below.

STATE OF CALIFORNIA
BEFORE THE CALIFORNIA ENERGY COMMISSION and THE CALIFORNIA PUBLIC UTILITIES COMMISSION

In the matter of:	)	Docket No. 18-IEPR-05
	)	
2018 Integrated Energy Policy Report Update—Climate Adaptation and Resiliency	)	SMUD Comments on August 2, 2018
	)	
	)	August 16, 2018

Comments of the Sacramento Municipal Utility District on Joint CEC/ CPUC Workshop on Climate Adaptation and Resiliency

The Sacramento Municipal Utility District (SMUD) appreciates the opportunity to provide the following written comments on the Joint Agency IEPR Workshop on Climate Adaptation and Resiliency. We offer the following comments and information in response to the workshop discussion on fire safety regulations, wildfire risk for energy infrastructure, climate adaptation research, and in response to Chair Weisenmiller's specific request for information from SMUD.

1) Actions taken by SMUD to Address Wildfire Risks for our Infrastructure and Operations Generally

Wildfire risk depends primarily on the existence of overhead power lines, fire fuels, weather and terrain type. SMUD's service area and distribution system exist primarily within Sacramento County and does not cover mountainous or densely forested terrain. SMUD's customers are also primarily urban or suburban. Overall, only a small fraction of SMUD's facilities are located in California's high fire threat district, all of which is outside SMUD's service area. Most significantly, SMUD owns and operates the Upper American River Project (UARP), a hydroelectric project licensed by the Federal Energy Regulatory Commission (FERC), in El Dorado County.

SMUD's Board of Directors has, pursuant to California Public Utilities Code section 8387 (SB 1028, Hill, Statutes of 2016), determined that the UARP area may have a significant risk of catastrophic wildfire and, therefore, SMUD takes advanced measures to manage this risk. Pursuant to its FERC license SMUD has developed a Fire Prevention and Response Plan (FPRP) for the UARP project, which has been approved by the U.S. Forest Service and FERC. SMUD's Board also determined that the FPRP provides appropriate wildfire mitigation measures in accordance with Public Utilities Code section 8387.

SMUD has developed operating procedures for its transmission and distribution systems to address potential fire hazards, including a) inspection and maintenance programs, b) expanded vegetation management programs, and c) procedures for de-energizing lines and de-activating reclosers where conditions warrant. For example, in preparation for fire season, this spring SMUD took extra steps to prevent wildfires that

could be started by electrical faults on equipment by stepping up routine inspections of our electrical infrastructure, enhancing our vegetation management program, designing capital projects to reduce the potential for system faults, establishing protocols for suspending automatic outage restoration technology in designated areas, and developing protocols for de-energizing overhead lines as a last resort when conditions require.

a. Construction, inspection and maintenance

SMUD meets or exceeds federal, state and other industry standards in its overhead line construction and maintenance programs. These programs incorporate the standards set forth in the North American Reliability Corporation (NERC) reliability requirements for the bulk electric system (BES), the California Public Utilities Commission's (CPUC) General Orders (GO) 95 (addressing overhead systems), 128 (addressing underground systems) and 165 (addressing line inspection cycles), and applicable electric codes such as the National Electric Code and National Electric Safety Code. Staff regularly evaluates SMUD's design, construction, operations and maintenance programs, procedures and practices to the ensure safe and reliable operation of our generation, transmission, and distribution assets.

SMUD has implemented several capital projects to replace poles and certain equipment with more spark and fire-resistant options, as available. These projects include: replacing certain over-head distribution equipment with equipment that does not emit sparks during operation and replacing certain types of line connectors with more robust connectors to prevent overhead conductor splice failure (which could otherwise result in downed lines). We are also strategically replacing wood poles with steel when called for by weather and other pole strength conditions.

Areas within the southeastern portion of SMUD's service area and the UARP area are within the State Responsibility Area (SRA), as referenced in Public Resources Code sections 4292-4293. SMUD meets or exceeds the clearance requirements outlined in those sections. Overall, SMUD has approved a budget of $1.34 million for capital projects in our SRA territory in 2020 and beyond. Our ongoing operations & maintenance budget for the SRA territory is $3.18 million in 2020 and beyond.

b. Vegetation Management

SMUD has a robust vegetation management program. Our program meets or exceeds industry standards and regulatory clearance requirements.[1] We trim most trees on a three-year cycle but target fast growing species on a one-and-a-half-year cycle. We also address identified hazard trees and strive to remove 15% of the fastest growing trees annually. SMUD performs targeted patrols on key 69kV circuits each year to identify trees that are outside the normal trimming zone and which could potentially come in contact with energized lines and equipment.

Our vegetation management crews inspect facilities within the High Fire Threat District on an annual basis. The crews create additional vegetation clearances at pole locations

[1] *See*, e.g., GO 95 and Public Resources Code

with switches, fuses, transformers, lightning arresters, dead end poles and corner poles as required by Public Resource Code 4292 and remove all flammable materials from the ground to the highest point of conductor attachment.

SMUD increased its vegetation management budget dramatically over the last three years. We spent nearly $16 million on vegetation management for our distribution system in 2017. Between 2018 and 2019, SMUD has asked our board to double our vegetation management budget for transmission from a (proposed) $2.17 million to $4.07 million. This will primarily be spent in the UARP area.

i. Actions Taken relevant to FERC Regulation

SMUD adheres to the FERC approved NERC Reliability Standard (FAC-003-4 Transmission Vegetation Management) which outlines minimum vegetation clearance requirements for our bulk electric system that are to be established and maintained through an annual vegetation management plan (TVMP). In addition to the minimum requirements of the NERC Standard, SMUD's TVMP also incorporates local guides such as the California Department of Forestry and Fire Protection's (CAL FIRE) Power Line Fire Prevention Field Guide as well as CPUC General Orders associated with fire prevention and vegetation management practices. SMUD is periodically audited on these NERC standards, and has consistently been found to be compliant.

ii. Right of way clearances

SMUD is taking advanced measures to maintain vegetation clearances in our rights-of-way. We are using advanced technologies such as Light Detection and Ranging (LIDAR) to determine the distance of trees from lines, and hyper-spectral imagery to determine the condition of trees (this imagery can spot dying trees that may be a fire risk before they are visibly diseased). SMUD is working with property owners in the High Fire Threat District to expand line clearances. SMUD uses contractors to complete its vegetation management program; however, SMUD employees complete quality control audits (in-field inspections) on the completed contractor work for quality assurance and to ensure compliance with industry standards and contract specifications.

c. Reclosers and de-energizing

SMUD does not activate reclosers on its high voltage transmission lines (230 kV and 115 kV), including in the UARP area and the SRA located within the Sacramento Valley. Our distribution system is located outside of the High Fire Threat District, but we deactivate reclosers on specific distribution feeders located in areas of high vegetation during fire season and severe fire conditions and will de-energize our distribution lines as a last resort when fire threat conditions require.

d. Actions targeted to protecting hydropower/ transmission generation in Upper American River Project (UARP)

As stated above, SMUD plans to double our vegetation management budget to protect our transmission assets in our UARP territory, most of which is on federal land. Conducting vegetation management on federal lands can be particularly challenging, due to additional permits required from the US Forest Service, and additional environmental impact assessment and reporting requirements.

On "red flag" days, as designated by the USFS due to conditions such as low humidity, very hot temperatures, high winds, and low fuel moisture, SMUD (and our contractors on federal lands) call the US Forest Service Project Activity Level (PALS) phone line to determine the appropriate time of day when crews can work with mechanized tools (chainsaws). SMUD is also currently in the process of planning and eventually installing wind speed instrumentation on towers at strategic locations in the UARP.

In mid-2017, SMUD implemented a pilot project to x-ray a sample set of conductor splices at the UARP to assess their condition. Staff is developing a corrective action plan to address anomalies identified during the x-ray, as well as evaluating the effectiveness of the pilot project. Another pilot project is being planned for late spring 2018, to survey the conductor splices in areas with high fuel sources in the UARP.

2) SMUD's Experience with Insurance Cost Increases

SMUD's insurance risk profile is distinct from the large IOUs, and from LADWP in that our service territory is contained within a small and relatively homogeneous terrain. In other words, our footprint is mostly urban and in a flat part of the state. While we own transmission assets in mountainous areas, we do not serve customers in those areas, and therefore insurance companies have generally viewed us as having less risk-prone assets.

Regardless, given the legal climate in the state and the strict liability claims being brought against other utilities in the last few years, SMUD struggled to obtain prudent coverage levels and had to re-structure our approach to fire insurance coverage. To get the expanded coverage we needed, SMUD is now spending four times more on insurance coverage than in 2016.

3) Climate Adaptation Measures and Research

a. SMUD's Readiness Plan

SMUD has been studying and considering the physical risks to our system from climate change since 2009. SMUD's board adopted a climate readiness plan initially in 2012 and adopted an updated "Assessment and Action Plan in November 2016.[2] We are currently in the process of another study and mid-cycle update. The 2016 readiness plan includes a summary risk characterization, a vulnerability assessment, and a list of actions underway or planned to improve SMUD's readiness and capacity to adapt to climate change. SMUD also expanded the risk study to include wind and wildfire risk in its service territory and the locations where it generates, procures and transmits power.

[2] See Attached Climate Readiness Plan

SMUD's Readiness Strategy is referenced in all long-term planning (5+ years) processes at SMUD and includes the following:

- Updating our climate science study every 4 years,
- Supporting community climate readiness efforts,
- Supporting research to address gaps in scientific knowledge of particular concern to SMUD,
- Tracking climate changes as an enterprise risk, and
- Identifying any supply chain risks.

Additionally, SMUD is an active participant in and a financial supporter of the Capital Region Climate Readiness Collaborative, which is a forum for improving local awareness and capacity to address climate risks. SMUD Staff chairs the collaborative. Also, SMUD has participated in the Governor's Executive Order B-30-15 Technical Advisory Committee, the Cal-Adapt Advisory Committee and the Steering Committee for the California Adaptation Forum.

b. Forest Adaptation Research Relevant to Hydropower Assets

Recent UC Merced research[3] indicates that a modest reduction in forest biomass can result in a corresponding increase in stream flow into reservoirs as well as an immediate reduction in wildfire risk, an outcome which could make hydropower more resilient to the impacts of climate change. In addition, meadow restoration projects have been demonstrated to moderate and lengthen runoff and increase overall streamflow volume. Results appear to be watershed/microclimate specific, however, in 2017 SMUD worked with landowners and stakeholders and evaluated the feasibility of specific paired catchment study areas in our watershed. The initial feasibility study concluded that there are a small number of excellent opportunities for collaborative research associated with planned US Forest Service thinning projects. We are considering a ten-year study to better understand the long-term impact of potential changes in forest management practices. This work is of broad interest to both upland and lowland stakeholders for its potential to improve the safety of mountain communities, expand water resources and reduce smoke and air quality impacts associated with catastrophic wildfires.

If SMUD proceeds, our study will be complementary to the "Forest Meadows Restoration Project"[4], which is a joint Federal, NGO, and local government effort to restore public and privately managed forests at the headwaters of the American River. This effort was launched because Forest conditions in the area are unhealthy and at risk of uncharacteristic, high-severity wildfires due to past management, fire suppression, five years of drought, warmer temperatures, and a rapidly expanding bark beetle infestation resulting in millions of dead trees. Severe wildfires in recent years, just downstream of the project area, have caused hundreds of thousands of tons of topsoil to erode into the river system, clogging infrastructure and degrading wildlife habitat and

[3] SNAMP report:
http://snamp.cnr.berkeley.edu/documents/675/index.html
[4] See Attached Factsheet Regarding Forest Meadows Restoration Project partnership

watershed health. The health of this watershed is directly linked to the resiliency of SMUD's UARP hydropower resources.

Thank you for your consideration of this information as you compile the 2018 IEPR Update.

/s/

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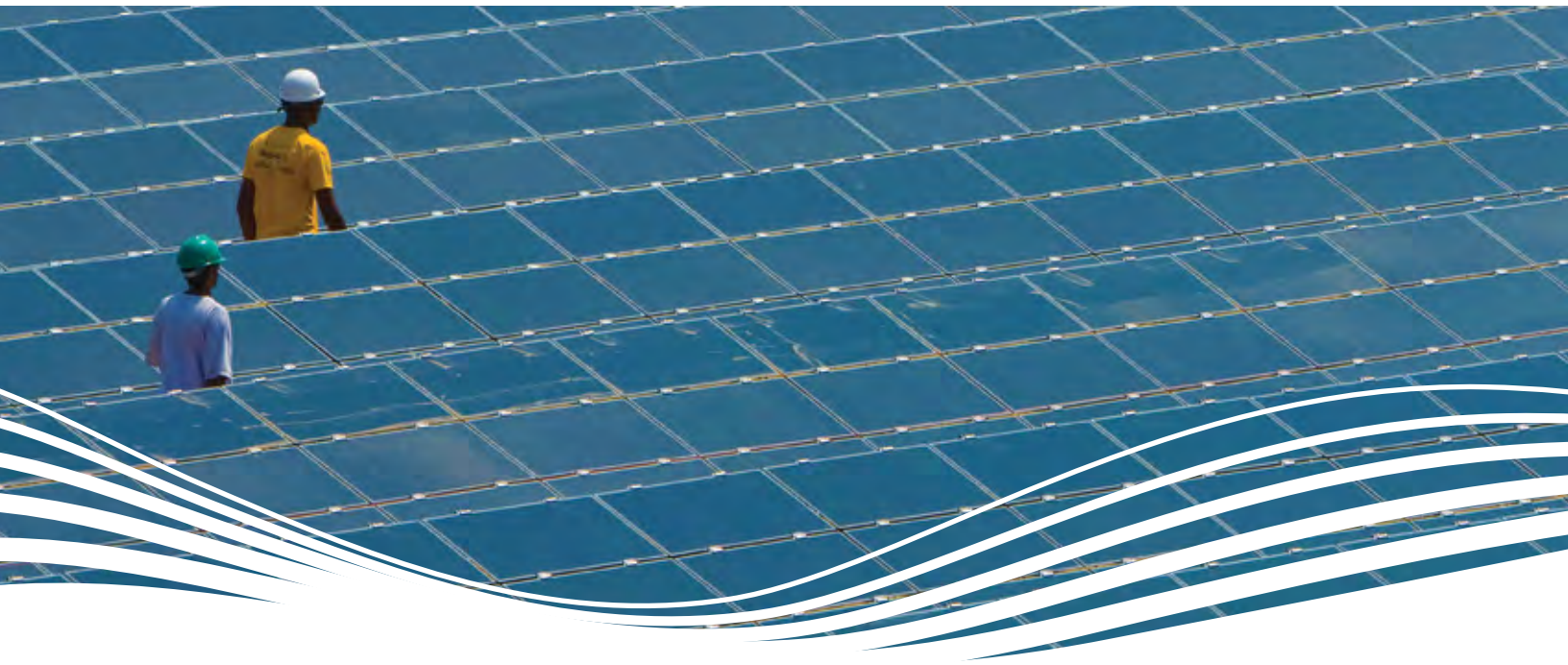
cc: Corporate Files (LEG 2018-0406)

NOVEMBER 2016



Sacramento Municipal Utility District

Climate Readiness

Assessment and Action Plan

SMUD®

NOTES ON THIS DOCUMENT:

In 2013, SMUD's Board of Directors reviewed a summary assessment of the best available climate science research and projections of changes that could impact SMUD's operations in the future. An Ad Hoc Board Committee formed to discuss next steps, and they added "Climate Changes" to the list of items tracked on SMUD's Enterprise Risk Management dashboard. Energy Research & Development staff undertakes an updated science assessment at least every four years. This document contains the 2016 assessment, a full list of utilized references, a summary risk characterization and a list of actions underway or planned to improve SMUD's readiness and capacity to adapt to climate change. Climate science is dynamic and projections are subject to change as more data are observed, modeling methodologies improve and more is learned about the impact of greenhouse gas emissions on the global climate and local microclimates. This document is intended to be used as an information source for other agencies or individuals with an interest in climate-related changes that may occur in and around the Sacramento region, but not as a substitute for ongoing assessments or original research.

Project sponsored by SMUD Energy Research & Development. Research and report drafts completed by WSP | Parsons Brinkerhoff with oversight and input from a cross-functional SMUD working group.

Questions about this report may be sent to Kathleen Ave at ***kathleen.ave@smud.org****.*

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Introduction

The Sacramento Municipal Utility District (SMUD) is a voluntary participant in the U.S. Department of Energy's (DOE) Partnership for Energy Sector Climate Resilience (Partnership), an initiative designed to improve resilience of energy infrastructure to extreme weather and climate change impacts and strengthen energy security. This report was developed as a continuation of SMUD's existing climate change resiliency research and readiness planning and as part of SMUD's participation in the Partnership.

SMUD is one of 18 electric utilities participating in the Partnership, created in 2015 to improve the resilience of the energy sector to climate change impacts and severe weather events. Partners of this initiative commit to identifying and prioritizing climate change vulnerabilities, developing and implementing resilience strategies, and measuring and reporting on the progress and success of implemented strategies. SMUD's participation in the Partnership complements SMUD's local engagements and

efforts, including the Capital Region Climate Readiness Collaborative (Collaborative), which brings together leaders from government, business, academia, labor, and community groups to drive climate change resiliency.

All of these efforts are undertaken in the context of an ever escalating emphasis on climate readiness at the state and local level in California. Legislation such as SB 379, AB 1482, and SB 246 are all driving the allocation of resources to, and the inclusion in planning efforts of, vulnerability assessments and readiness plans. The Governor's Executive Order B-30-15 calls for adaptation strategies and set state level priorities (Governor Brown's climate change pillars) to reduce emissions 40% below 1990 levels by 2030 while safeguarding California in the face of physical risks from climate change.

As an ongoing leader in sustainability, SMUD's Board has set a goal of reducing GHG emissions by 90% relative to 1990 emissions by 2050. Reducing emissions allows SMUD to diminish its contributions to climate change. In addition to reducing its emissions, SMUD is expanding its readiness measures based on research into climate stressors and their potential impacts on SMUD assets and the community we serve.

Executive and Legislative Action Driving Climate Readiness in California

Executive Order B-30-15

- Sets emissions reduction goal of 40% below 1990 levels in 2030
- State infrastructure plans to take climate impacts into account
- Priority given to state investments that build climate preparedness

SB 379

- Requires cities and counties to include a climate vulnerability assessment and adaptation strategies in the safety element of their County General Plan

AB 1482

- Places elements of EO B-30-15 into law including Safeguarding California adaptation implementation plans

SB 246

- Integrates climate adaptation and resilience Program at State Office of Planning and Research
- Coordinates adaptation planning among federal, state, regional and local interests

[1] U.S. Department of Energy Office of Energy Policy and Systems Analysis. Partnership for Energy Sector Climate Resilience. Available at: http://energy.gov/epsa/partnership-energy-sector-climate-resilience

Organization of this Report

This report begins with SMUD's organization profile, our history of climate readiness assessment and planning and the implications of climate change on resiliency in the energy sector. It then transitions to a discussion of our approach to vulnerability assessments followed by a detailed discussion of climate stressors and impacted SMUD assets. For each stressor discussed, specific asset impacts are chronicled and assets at risk are mapped. We then provide our ongoing action plan to address climate risks, including community engagement, enterprise wide programs, capital investments, operational initiatives as well as monitoring and evaluation. We finish with several additional considerations for future action.

Background

SECTION I. ORGANIZATION PROFILE

SMUD is the sixth-largest community-owned electric service provider in the country. SMUD generates, imports, transmits and distributes electricity to a 900-square-mile service area with a population of 1.5 million that includes Sacramento County and a small portion of Placer County. SMUD owns 10,473 miles of primary distribution lines with 143,250 poles and 13,660 line switches. SMUD's system includes 689 circuits (17% of which have remote monitoring and control capability) and 263 substation transformers (72% of which have remote monitoring and control capability). With 617,307 customers, we saw a peak demand of 2,959 MW in 2016, well below the all-time peak of 3,299 MW seen in 2006. Absent the impacts of climate change, SMUD foresees flat or declining load growth due to efficiency gains and distributed energy resources.

SMUD is owned by its customers, who elect a seven-member Board of Directors every four years. Each director represents a different geographic area, or "ward," seen in Figure 1. During their four-year terms, the directors' job is to establish policies and values that guide how SMUD serves its customers and the long-term direction SMUD will take moving forward.[2]

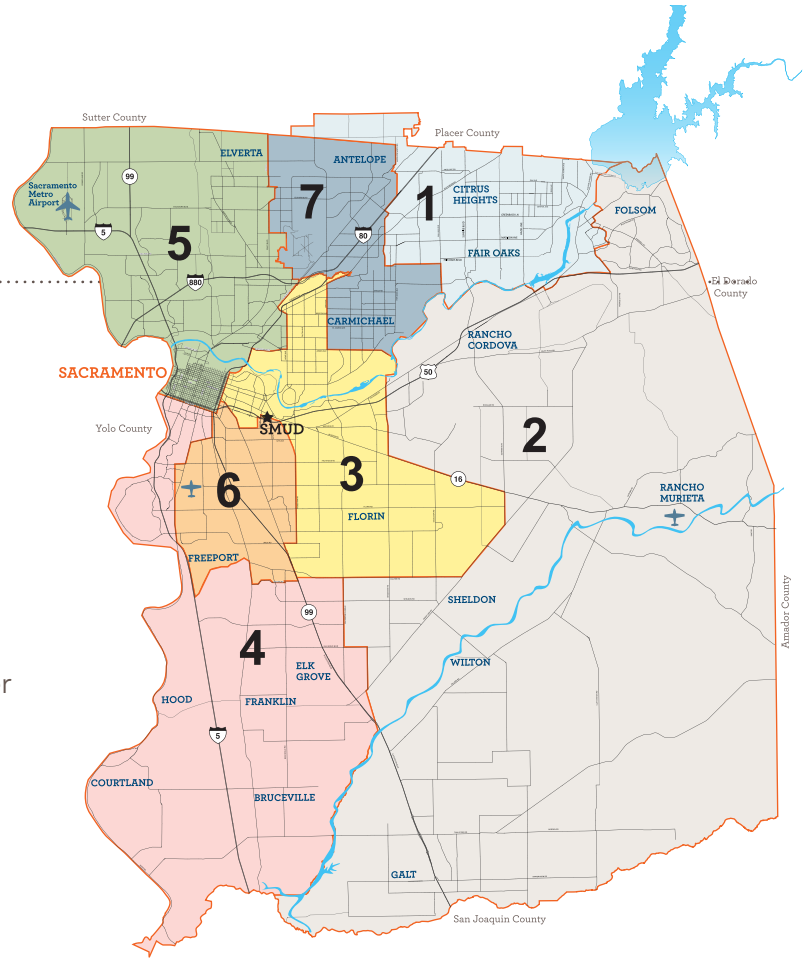


Figure 1. Map of SMUD's service territory. The territory is divided into seven wards (numbered above), each of which is represented by a board member elected to SMUD's Board of Directors. Source: SMUD

SMUD was the first large California utility to receive more than 20% of its energy from renewable resources and currently provides electricity from varied sources including natural-gas-fired generators, carbon-free and renewable

[2] Sacramento Municipal Utility District (SMUD). Our Board of Directors. Available at: https://www.smud.org/en/about-smud/company-information/board-of-directors/

energy such as hydropower, solar and wind power, and power purchased on the wholesale market. The biggest single power source for SMUD is the 500-megawatt natural gas-fired Cosumnes Power Plant in southern Sacramento County that meets the annual electricity needs of 450,000 single-family homes. SMUD's Upper American River Project (UARP), with 11 reservoirs and eight powerhouses, is the cleanest and most economical power source in SMUD's energy portfolio. In a historically average water year, the UARP provides roughly 1.8 billion kilowatt-hours of electricity – enough to supply the annual electricity needs of 180,000 homes. SMUD continues to increase the amount of power derived from renewable resources, and maintains a power mix among the cleanest in the country. Currently, 50% of SMUD's power comes from non-carbon-emitting resources, and 26% of SMUD's power meets the Renewable Portfolio Standard (RPS) outlined by the state of California.

SECTION II. EVOLUTION OF CLIMATE CHANGE RISK AT SMUD

One of SMUD's core values is to "provide leadership in the reduction of the region's total emissions of greenhouse gases through proactive programs in all SMUD activities and development and support of national, State, and regional climate change policies and initiatives."[3] Consistent with this mandate, SMUD has pursued climate change response planning initiatives that seek to understand the current state of climate science, its impacts on the Sacramento region and SMUD service territory, and its interactions with SMUD's assets and operations. In keeping with and furtherance of the State of California's multi-pronged approach to addressing climate change (see Figure 2), SMUD is committed to increasing the share of renewables in its generation mix, promoting the use of electric vehicles, supporting energy efficiency, and improving the capacity of our lands to store and sequester carbon, all while safeguarding California by proactively preparing for the physical risks of climate change.

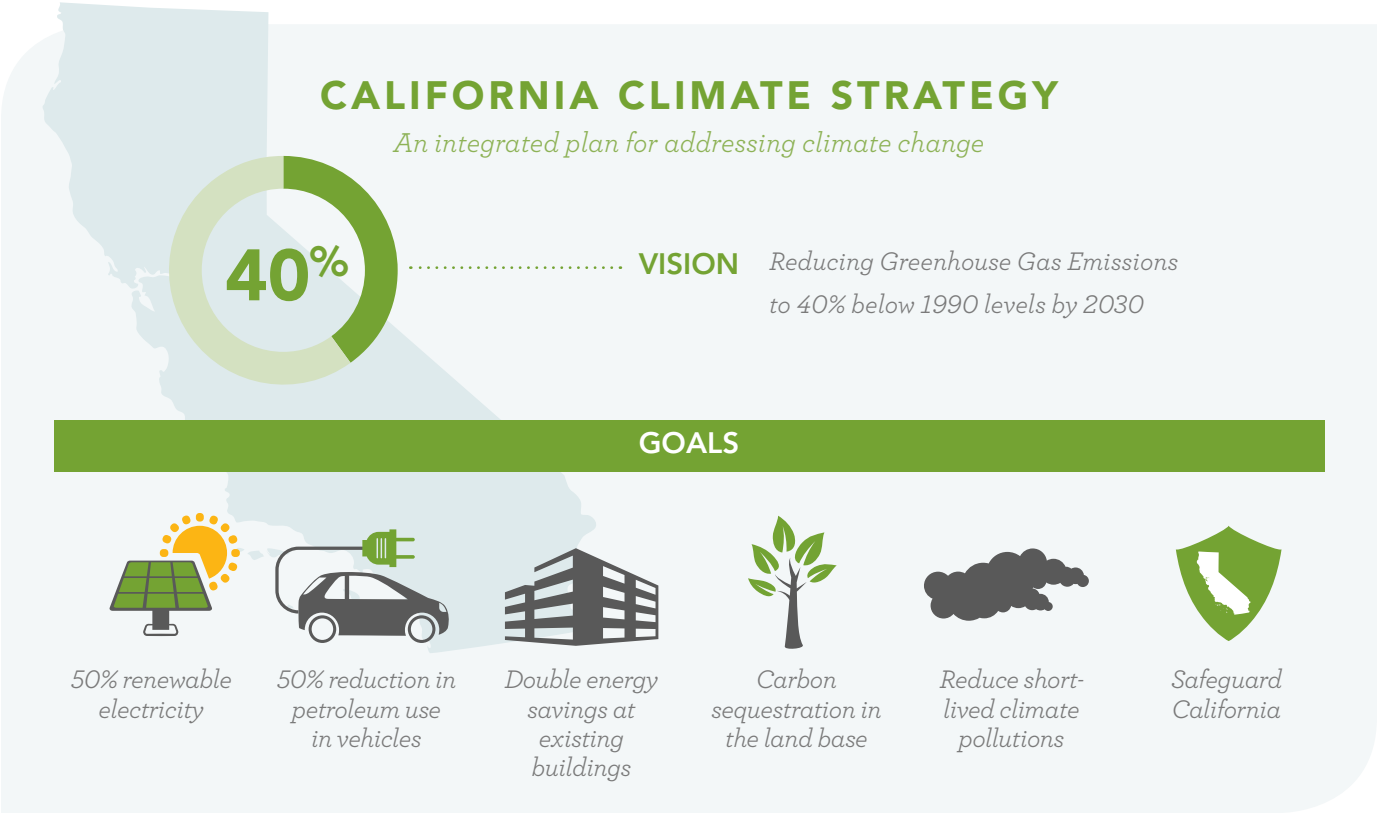


Figure 2. Governor Jerry Brown's climate change strategy pillars

[3] SMUD Board Policy. 2008. SD-7: Environmental Leaderships. Available at: https://www.smud.org/assets/documents/pdf/SD-7.pdf

Starting in 2008, SMUD has commissioned a series of studies and reports that help to move SMUD beyond climate mitigation planning and into more robust climate impact awareness and readiness. The original 2008 report was updated and expanded in 2009, including assessments of SMUD GHG emissions scenarios, physical and regulatory risks, short and long-term mitigation options and a review of SMUD's public outreach and education activities. In 2012, SMUD again engaged a consultant to produce a targeted climate readiness study and adaptation strategy. That strategy built on existing risk mitigation measures with a series of climate readiness actions. The review included a "state of the science" assessment to update scientific findings and incorporate lessons from the California Climate Adaptation Strategy, Adaptation Policy Guide, and a myriad of other resources. The analysis focused on the physical risks most likely to impact SMUD power generation and operations, and incorporated feedback and perspectives from SMUD stakeholders. It also expanded the scope of the prior analysis to include risks from wildfire and shifting wind patterns.

The 2012 report included, among others, the following recommendations:

- Incorporate climate projection scenarios and readiness findings into long-term planning processes at SMUD;
- Participate in the new Sacramento regional adaptation collaborative;
- Support and help fund new research to fill significant gaps in current knowledge; and
- Summarize new scientific conclusions and incorporate into SMUD's Readiness Strategy every four years or as new methodologies warrant.

Through these efforts, SMUD's board has recognized that the pace of change in both the climate system and our understanding of it necessitate regular updates to SMUD's climate strategy. SMUD has determined that every four years an updated "state of the science" assessment should be completed, and we have incorporated the most recent effort into this report. This will help SMUD prioritize actions to address the most critical impacts of climate change and the most vulnerable components of its power generation system and operations as well as improving the readiness of its customers.

The DOE Partnership has aligned with our objectives outlined in the 2012 Readiness Report and our actions since that date to implement the objectives are detailed in this report. Much as previous reports have done, it gives SMUD an opportunity to critically assess climate change risks and strategy and improve our readiness efforts, while providing a venue for sharing and learning best practices, providing transparency to the community, and building on local efforts and building on local efforts with other public and private organizations.

SECTION III. EVOLUTION OF CLIMATE CHANGE RISK ASSESSMENT AT SMUD

In the United States, the electricity sector is the largest emitter of greenhouse gases (GHGs), accounting for 30% of all emissions in 2014 (Figure 3).[4] As the largest contributor to GHG emissions, the electricity sector has a major opportunity to drive emissions reductions.

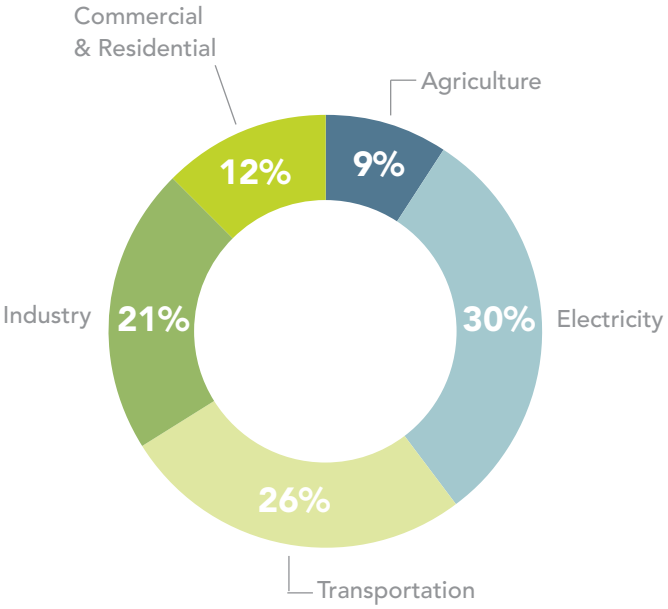


Figure 3. Total U.S. greenhouse gas emissions by economic sector in 2014. Source: U.S. EPA, 2016

The electricity sector must also ensure that its assets are resilient to the impending effects of climate change, including rising temperature, sea-level rise, changes to hydrology, and increased risk of fires.

Climate change means rising energy demand and falling generation and distribution efficiency for the energy sector. Higher ambient temperatures will increase energy demand during the peak summer months by driving use of air-conditioning.[5] Rising temperatures will also decrease the efficiency of thermal conversions, meaning that more resources will be needed to produce the same amount of energy. In addition to higher temperatures, climate change may bring increased frequency and severity of major weather events, which pose a threat to infrastructure. Changing weather patterns may also affect solar-, wind-, and hydro-power generation.[6]

Due to the similar supply chains across the energy sector, the major climate change impact classes are largely consistent from one company to another. However, the geographic scope of assets and the methods of generation differ across the sector, leading to varying degrees of impact for each aspect of climate change. For example, hurricanes are a major concern for utilities with operations along the Gulf or Atlantic Coasts, but are a much smaller concern for utilities with operations along the Pacific Coast, because the warm waters of the Atlantic and Gulf of Mexico drive hurricane weather patterns.

[5] Increased temperatures may also reduce energy demand during winter months but the reader should note temperature changes in the summer are expected to be larger on a nominal basis then changes in the winter. .

[6] University of Cambridge. 2014. Climate Change: Implications for the Energy Sector. Available at: https://www.bmz.de/en/publications/type_of_publication/weitere_materialien/Implications_for_Energy_Briefing_WEB_EN.pdf

The state of California demonstrated its vested interest in mitigating climate change risks through Executive Order B-30-15, issued in April of 2015. The executive order sets aggressive state-wide greenhouse gas (GHG) emission reduction targets.[7] The order also calls for the Natural Resources Agency to identify a lead agency for each sector and update the state's adaptation strategy every three years. The current Energy Sector Plan, released in 2015, was prepared with input from SMUD and four investor-owned California utilities (IOUs).[8]

In January 2016, the California Public Utilities Commission (CPUC) released a guidance document for conducting a vulnerability assessment and developing a resiliency plan to address climate change in the electric sector. CPUC's guidance is intended to fulfill a short-term goal of the Natural Resources Agency's Energy Sector Plan, to support utilities in meeting the requirements of the DOE Partnership, which requires a resilience strategy to be submitted by mid-2017.[9]

[7] Office of Governor Edmund G Brown Jr. Governor Brown Establishes Most Ambitious Greenhouse Gas Reduction Target in North America. 2015. Available at: https://www.gov.ca.gov/news.php?id=18938

[8] California Natural Resources Agency. October 2015. Draft Report - Safeguarding California: Implementing Action Plans. Available at: http://resources.ca.gov/docs/climate/Safeguarding%20California_Implementation%20Action%20Plans%202015%20(CNRA).pdf

[9] Kristin Ralff-Douglas. January 2016. Climate Adaptation in the Electric Sector: Vulnerability Assessments & Resiliency Plans. Available at: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/PPD%20-%20Climate%20Adaptation%20Plans.pdf

Vulnerability Assessment Report

SECTION I. ONGOING PERIODIC ASSESSMENT FRAMEWORK

After completion of the 2012 readiness report, SMUD established a plan to update its vulnerability assessment every four years. These ongoing periodic updates allow SMUD to ensure that the most up-to-date climate change research is included in its analyses. When implementing these periodic updates, SMUD forecasts consider multiple timelines to conform with various planning horizons, as outlined in the SMUD's Assessment Timeframe section below.

Climate change impacts assessed in the 2012 study included ambient temperatures, wildfires, wind patterns, regional hydrology, and flooding. The potential effects of climate change identified in the 2012 study served as the starting point for this updated report. Since the 2012 report, many academic and scientific institutions have continued to study climate science, refining global climate models and downscaling techniques. Sources with updated

information have therefore been considered and included in the present study, including data from the California Energy Commission, the Intergovernmental Panel on Climate Change (IPCC), National Oceanic and Atmospheric Administration (NOAA), and the National Climate Assessment. Additionally, climate impacts to energy infrastructure have been studied more closely since the 2012 strategy report, and findings from the World Business Council for Sustainable Development report on *Building a Resilient Power Sector* were drawn upon and evaluated for their relevance to SMUD assets and operations in the context of each Impact category in this report. Highlights of changes in climate science predictions since 2012 for each impact category are provided in Table 1 below.

Table 1. Changes to the potential effects of climate change on SMUD infrastructure and operations from SMUD's 2012 Climate Readiness Report to this report

Impact Category	Potential Effects to SMUD Infrastructure and Operations	Changes in the Scientific Literature[10]
Ambient Temperatures	• More extreme summertime high temperature events, including daytime and nighttime heat waves • Increased warm season electrical load and peak demand • Reduced thermal and hydroelectric generation • Extreme temperature and variability impacts on system reliability • Increasingly severe "one-in-ten" heat storms effects on overall system reliability • Less efficient operation of transmission and distribution systems, including decreases in facility ratings and loss of operating life	New research confirms an anticipated rise in temperature in the upper range of 2012 predictions, and also highlights the seasonality of this change. While winter is expected to see a 1-3°C (1.8 – 5.4° F) rise in ambient temperatures, already hot summers are modeled to see an increase of 2-4°C (3.6 – 7.2 ° F).
Wildfires	• Projected increase in wildfire frequency and intensity • Potential wildfire impacts to transmission and out-of-district generation sources	Area burned in wildfires has been studied more extensively in recent years, and regional models have improved. While 2012 studies indicated a significant increase in the area burned in wildfires throughout the next century, improved models for the Sacramento region predict instead a small increase in area burned up to 2020, with a leveling out of wildfires through mid-century.
Wind Patterns	• Increases or decreases in wind energy production and timing • Increases or decreases in delta breeze cooling capacity	Wind patterns continue to be difficult to model and predict. New studies predict a continuation of the delta breeze, critical for certain wind generation assets along the delta and to provide relief for high summer temperatures in Sacramento. Models for the Tehachapi Pass show a decrease in wind availability for the region, which could reduce wind generation by 10-15%.
Regional Hydrology	• Effects of changes in temperature and precipitation on snowpack in the Sierra Nevada mountains • Changes in timing and volumes of streamflow and impacts on hydroelectric capacity	While models still show uncertainty regarding the impact of climate on the total amount of rainfall in a year, there is greater consensus that a change in timing of rainfall events and warmer temperatures throughout the year will decrease available Sierra snowpack, impacting the timing of flows available to meet hydroelectric generation demand.
Flooding	• Sacramento flood threats • Localized impacts on electricity infrastructure • Indirect impacts on gas transmission infrastructure in the San Francisco Bay Delta region	Flooding continues to be a concern for Sacramento and the Central Valley, with the additional impact of sea level rise (up to 2 feet by 2050) putting added pressure on the already stressed levees in the delta.

[10] Sources identified below under Summary of Climate Change Risks and Potential Impacts.

In response to the findings of the 2012 study, coupled with recent climate concerns in California, two new impact categories have been added to the 2016 list for further study. Specifically, drought was highlighted as a separate category from the hydrology section in light of the severe drought that California experienced from 2011-2014. Additionally, the change in probability and severity of extreme weather events were considered more closely. Finally, sea level rise has been explicitly included for the compounding effect it can have on potential flooding in the region.

Climate Readiness Working Group

Every four years, SMUD assembles a working group representative of the various departments within the organization. Departments participating in the 2016 working group are shown in Table 2 below. This working group is responsible for reviewing and providing feedback throughout the vulnerability study and readiness plan preparation process. We began preparation for this report in May 2016, by reviewing the findings of our 2012 report and progress to date in implementing its recommendations. Our consultant then prepared a draft outline of the new report and a proposed scope of research for review of the working group. Based on the feedback of the working group the report work plan was developed. After an initial review of the literature to update our understanding of the climate science, we prepared a matrix of the likelihood and scale of potential impacts on SMUD, its assets and the surrounding community from physical changes associated with climate change. The matrix was provided to SMUD organizational units for review, discussion and revision. A final version is shown in the section below under Summary of Climate Change Risks and Impacts.

Table 2. Organizations and Staff Represented on SMUD Climate Readiness Working Group

Organization	
Energy Research and Development	Resource Planning (Economic Analysis)
Emergency Planning	Treasury
Power Generation	Supply Chain
Power Generation (Hydroelectric)	Grid Planning and Operations
Environmental Management	Grid Assets
Local Government	Energy Trading and Contracts
Resource Planning (Load Forecasting)	Enterprise Risk Management

We then turned to a more detailed analysis of local impacts on SMUD assets and suppliers. Given the recent improvement in downscaling climate science data as evidenced in the 2015 Los Angeles study by Walton and Hall,[11] SMUD considered developing and applying downscaled data for the Sacramento region. As we explored the option further, it became clear that such an approach would require financial resources an order of magnitude larger than those we had at our discretion and a potentially longer time frame then we desired, with only limited reductions in ranges of uncertainty. We were fortunate that there is a considerable amount of downscaled data publically available at the California state level.

Cal-Adapt data were used to map potential climate change impacts to SMUD assets within California. Cal-Adapt compiles research from a variety of institutions and allows public access to its source data. Additional peer-reviewed sources were used to confirm potential climate change impacts identified by Cal-Adapt and to provide insight about impacts to SMUD assets outside of California. Once all potential impacts were analyzed and mapped, SMUD used the likelihood and severity of assessed impacts as inputs into development of a comprehensive action plan.

As the cost of downscaling declines, and the uncertainty bands tighten, SMUD, in partnership with regional entities such as Sacramento County and the Capital Region Climate Readiness Collaborative, will continue to evaluate downscaled region-specific data for future studies.

[11] Sun F., Walton, D., and Hall, A. 2015. A hybrid dynamical-statistical downscaling technique, part II: End-of-century warming projections predict a new climate state in the Los Angeles region. Journal of Climate, 28(12): 4618-4636. DOI: 10.1175/JCLI-D-14-00197.1. Available at: http://research.atmos.ucla.edu/csrl/LA_project_summary.html

SECTION II. SMUD'S ASSESSMENT TIMEFRAME

SMUD continues to develop its strategy through both short- and long-term planning horizons for asset management (Figure 4). SMUD's short-term planning takes into account preparation for extreme weather events, while long-term planning includes an integrated resource plan (IRP) and management of generation and transmission assets. Short-term planning projects three years out, while the long-term planning spans 20-years forward, allowing for actionable items in the coming years (2020) and providing insights into longer term trends (2030, 2050). Risks from various climate stressors are assessed through 2050 wherever possible, to ensure that information supporting SMUD's planning horizons aligns temporally.

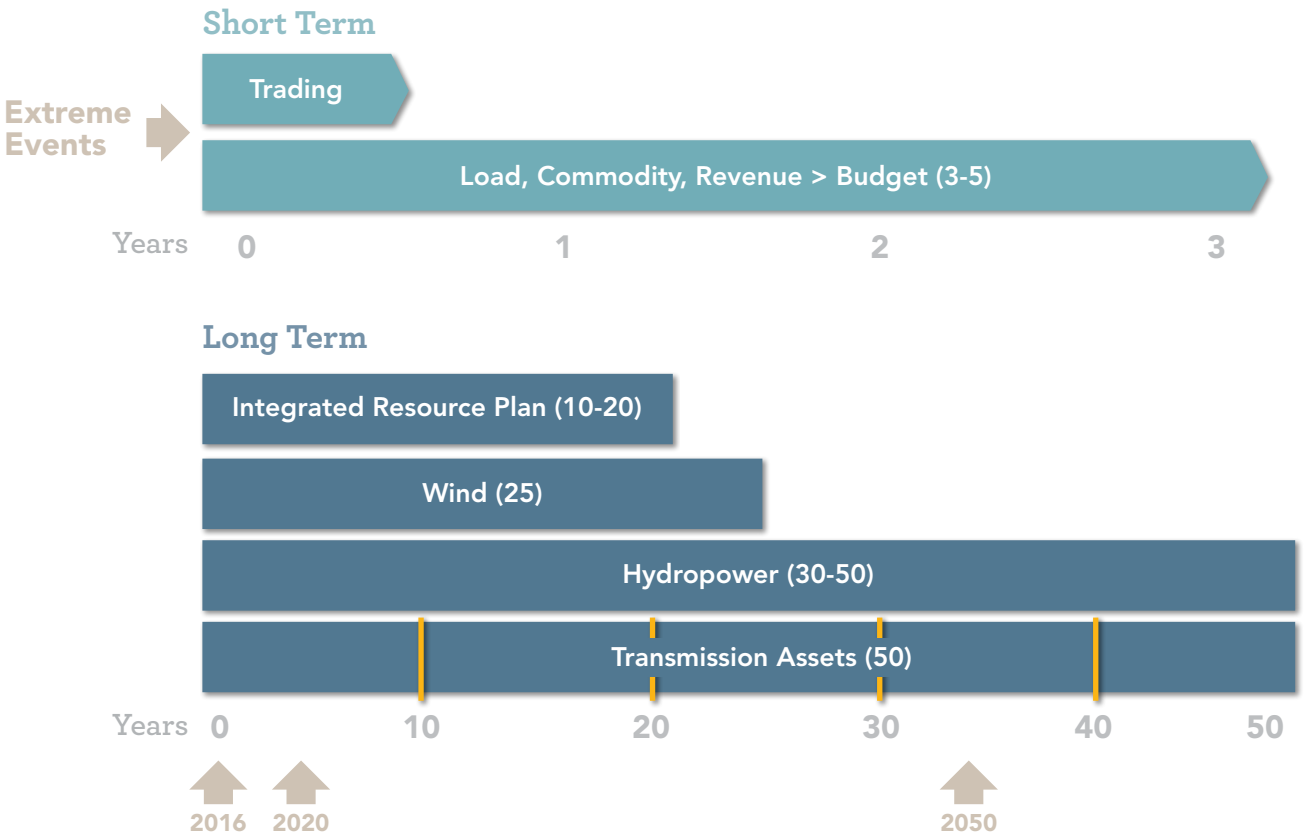


Figure 4. SMUD planning and asset horizons.

Risks and mitigation options over each relevant time frame are informed by rapid developments in the utility sector, particularly changes in state statutes, regulations and the expectations of ratepayers in California. SMUD has a host of initiatives to respond to these changes, including programs for residential time of use, distributed energy resources, electric vehicles, energy efficiency, distributed energy storage and grid modernization which will grow significantly in scale over the next three to five years. The programs, combined with a number of near term capital projects will moderate some of SMUD's exposure to the physical impacts of climate change and will inform our future approaches to readiness. For more on these programs and investments please see below under Action Plan to Address Climate Impacts.

Summary of Climate Change Risks and Potential Impacts

SMUD has categorized risks from climate change into seven major categories, identified as 'indicators' in Table 3. For each indicator, an estimated likelihood of occurrence is provided, categorized as low medium or high. Across these climate change indicators there are a number of specific concerns identified by SMUD, with descriptions such as reduced generation and distribution or damage to infrastructure. For each potential concern the consequence, or scale of the impact is also estimated as low, medium, or high. For example, the science around sea level rise is strong with a narrowing band of uncertainty, thus the probability, or likelihood is high. The impact/consequence of energy infrastructure inundation associated with sea level rise is moderate, because it is likely to impact assets on the coast, outside of the SMUD service area, but could have residual effects to the regional energy system that SMUD depends upon. The likelihood and severity of each risk affecting SMUD have been assessed and mapped

in Figure 5. This report explores SMUD's vulnerability to and management of these risks. While SMUD's Enterprise Risk Management Framework does include the velocity (timing) of these risks, it is important to recall that these impacts do not occur as step changes at discrete moments in time, but rather as ever evolving changes in the probability of events such as drought, heat wave, or wildfire. Climate science suggests that the further out on the timescale we forecast, the greater the likelihood of the most severe changes, but we must consider that the risk of some of these impacts has already grown compared to previous decades.

Table 3. Climate change risks, their anticipated impact level and likelihood of impact on SMUD.

Indicator	Probability/ Likelihood	Description	Impact/ Consequence
Ambient Temperature Rise	High	Reduced generating capacity	Low
		Reduced distribution efficiency	Low
		Increase in customer demand	Moderate
		Population growth due to relocation from warmer areas	Moderate
		Increase in sustained peak demand	Moderate
Drought	Low	Reduced generating capacity due to loss of cooling water and reduced hydroelectric generation	Moderate
Wildfires	Low	Reduced distribution efficiency	Moderate
		Damage to infrastructure	Moderate
Wind Patterns	Low	Reduced generating capacity of wind farms	Moderate
		Increased peak energy demand due to fluctuating Delta Breeze	Low
Hydrology	Moderate	Loss of snowpack and ability to meet demand using hydroelectric generation	Moderate
		Rising tradeoffs between flood protection and water storage	High
Sea-Level Rise & Flooding*	High	Energy infrastructure inundation	Moderate
		Energy transport infrastructure damage and corrosion	Moderate
Storm Events	Moderate	Major storm events	Moderate

*Sea-Level Rise and Flooding were combined for this mapping, due to significant overlap in assets at risk and risk severity and exposure

Figure 5. Map of potential impacts to SMUD from various climate change concerns and the probability and likelihood of each impact affecting SMUD. Severity of impact and likelihood take into account.

	• Hydrology – Rising Tradeoffs Between Flood Protection and Water Storage	
• Wind Patterns – Reduced Generating Capacity at Wind Farms • Wildfires – Reduced Distribution Efficiency & Damage to Infrastructure • Drought – Reduced generating capacity due to loss of cooling water and reduced hydroelectric generation	• Major Storm Events • Hydrology – Loss of snowpack and ability to meet demand using hydroelectric generation	• Ambient Temperature Rise – Increase in Customer Demand & Increase in Sustained Peak Demand • Ambient Temperature Rise – Population Growth • Sea Level Rise and Flooding – Energy Infrastructure • Sea Level Rise & Flooding – Energy Transport Infrastructure Damage and Corrosion
• Wind Patterns – Increased Peak Energy Due to Fluctuating Delta Breeze		• Ambient Temperature Rise – Reduced Generating Capacity

Impact/Consequences

Probability/Likelihood

SECTION I. SMUD SPECIFIC ASSET ANALYSIS

To assess how the aforementioned climate stressors might impact SMUD's assets, we conducted an analysis that considered our power plants, substations, transmission and distribution lines, power supply contracts, and critical suppliers. SMUD-specific climate impact analyses relied on several reference datasets of SMUD assets as seen in Figure 6 and described below.

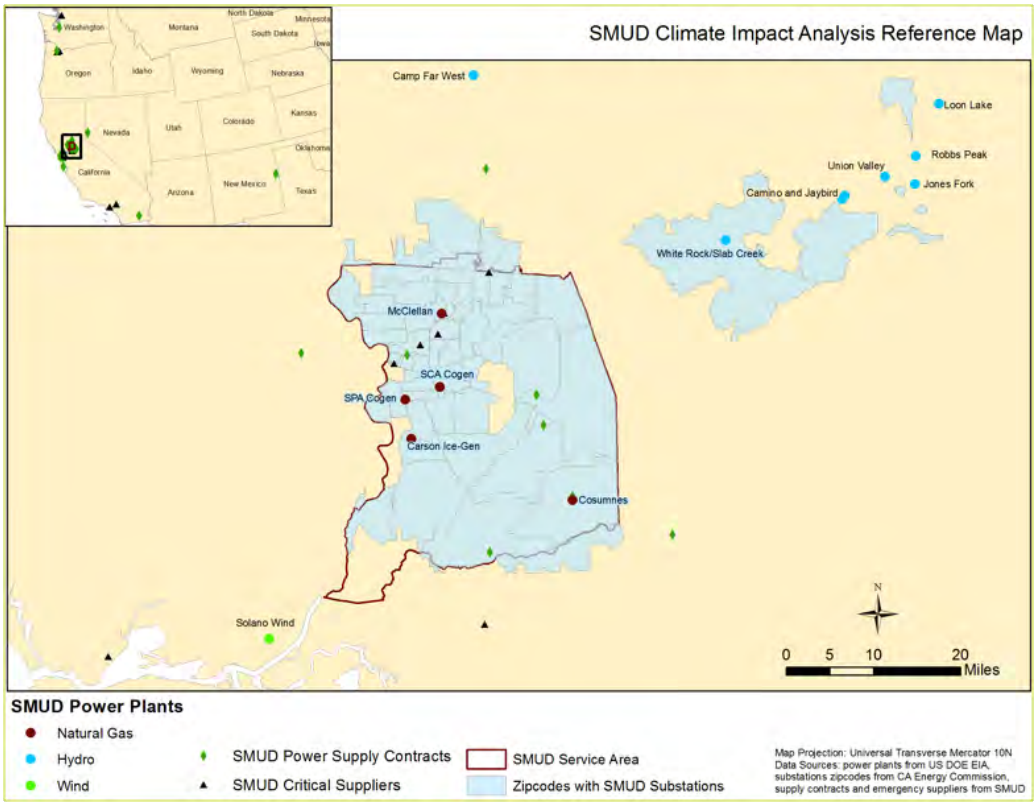


Figure 6. SMUD climate impact analysis reference map showing SMUD power plants, zip codes areas with substations, supply contracts, and critical suppliers within the United States and the SMUD Service Area.

The following list provides a brief summary of the reference datasets and sources utilized for analysis of climate impacts on SMUD assets throughout this report:

- **Power Plants:** This dataset represents SMUD power plants taken from a U.S. Department of Energy, Energy Information Administration dataset of operable electric generating plants in the United States. Drawn from the EIA-860, EIA-860M and EIA-923 forms, these data include all plants that are operating, on standby, or short- or long-term out of service with a nameplate capacity of greater than or equal to 1MW. The data can be found online at: https://www.eia.gov/maps/layer_info-m.php.
- **Substations:** SMUD substation latitude and longitudes were not available at the time of this report, so zip code areas were used as proxy spatial data to represent SMUD substations. SMUD-owned substations were filtered from the California Energy Commission's (CEC) "Statewide Operational Substations" Excel dataset and aggregated by zip code. The CEC substation data is found here: http://www.energy.ca.gov/maps/. The 2015 zip code areas shapefile used to aggregate substations is found here: https://www.census.gov/geo/maps-data/data/cbf/cbf_zcta.html.
- **Transmission and Distribution Lines:** SMUD owns and operates a network of transmission and distribution infrastructure, interconnecting power plants and substations throughout the SMUD territory illustrated above. A visual representation of these lines can be found at: http://www.energy.ca.gov/maps/infrastructure/3P_Enlg.pdf
- **Supply Contracts:** SMUD maintains an array of power supply contracts for renewable energy. Location information for these contracts and the fuel sources they utilize was included in the analysis.
- **Critical Suppliers:** SMUD maintains contracts with critical suppliers that can help reestablish service in case of outage. Location information for these suppliers was included in the analysis.

Each of the above asset types was considered relevant to SMUD's operations and service territory for the purpose of this analysis.

SECTION II. EMISSION SCENARIOS AND DOWNSCALING

Emission scenarios have been published by the Intergovernmental Panel on Climate Change (IPCC), and represent projections of possible future climate change. They are intended to show a representative range of future climate possibilities, but do not encompass all possible emission scenarios, nor do they represent predictions or most likely future states of the world. These models are used to project a range of possible climate impacts in order to aid in climate planning. There are four families of climate scenarios, described below.[12]

- A1 Scenario: Characterized by an integrated global world with rapid economic growth, income convergence, the quick spread of new technologies, and a global population that peaks at nine billion people in 2050.
- A2 Scenario: Characterized by a more divided world of independent, self-reliant nations with pockets of regional economic development and a continuously increasing global population.
- B1 Scenario: Characterized by an integrated global world that is focused on ecologically friendly activity. Includes rapid economic growth, technology improvements and population changes similar to A1, but with a focus on efficiency and solutions to economic, social, and environmental stability.
- B2 Scenario: Characterized by a divided world, but with more ecologically focused activities. It incorporates intermediate economic development, and a steady but slower increase in global population than A2, and the focus is on local solutions to economic, social, and environmental stability.

Throughout this report, the A2 and B1 scenarios are used to represent the high and low emissions scenario for comparison and planning purposes.

Regional downscaling methods are used to translate the information in global climate models into smaller regional models typically used for local impact studies.[13] Downscaling takes into account topography and local climate phenomena at the regional level, and provides greater resolution for focused study. While this study did not rely upon downscaling of the SMUD service area in particular, it did take advantage of downscaling at the California level, and the broader region.

[12] Intergovernmental Panel on Climate Change. 2000. IPCC Special Report Emissions Scenarios. Available at: https://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

[13] Intergovernmental Panel on Climate Change. 2013. IPCC Fifth Assessment Report, Chapter 9. Available at: http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter09_FINAL.pdf

Climate Stressors and Assets Impacted

SECTION I. TEMPERATURE RISE

Climate Stressor Background

Climate models consistently predict rising temperatures throughout California. While these anticipated annual average temperature increases are significant in the Sacramento Region, it is also notable that seasonal differences in temperature are expected to become more pronounced. Already hot summer months are predicted to see a greater rise than more temperate winter months throughout California. Sacramento and Central Valley regions are predicted to see a 1-3° Celsius (1.8 – 5.4° Fahrenheit) rise in winter temperatures, and a 2-4°C (3.6 – 7.2° F) rise in the summer months from 1985-1994 to 2060-2069.[14]

[14] Pierce, D. W. March 2012. Probabilistic estimates of future changes in California. Available at: http://woodland.ucsd.edu/wp-content/uploads/2013/10/Pierce_etal_2013_ClimDyn.pdf

As energy use in California is dominated by summer cooling loads, this seasonal warming pattern is likely to affect both overall energy use and peak load requirements. Extreme heat days, defined as days from April through October where the maximum daily temperature was above the 98th percentile from the historical max temperature from 1961-1990, occurred four times per year on average in the Sacramento region during this historical period.[15] This number is predicted to rise to an average of 17 days per year from 2021-2050, and increase further to as many as 45 days per year by the end of the century.[16] Increasing trends in hot days contribute to increased cooling loads, and are supported by findings from a study at the Lawrence Berkeley National Laboratory predicting customer energy demand will grow by 10-20% on a per capita basis by the end of the century.[17]

Sustained elevated temperatures are also an important component of increased demand, as people are more likely to use air conditioning upon the third consecutive exceptionally hot day. Historically, a 3-day stretch of 40 °C (104° F) days occurred every 1-in-100 years in the Sacramento and Central Valley. Future models predict these elevated temperatures to be a 1-in-2 year occurrence in the same region by the end of the century.[18] As peak demand in SMUD territory tends to occur in the early evening, peak capacity planning may be dominated by other contributors rather than this increase in mid-day air conditioner load.

Urban Heat Islands can significantly increase temperatures in regions as small as a census tract, with differences from ambient temperatures ranging from 0.5 to 5.0 °C (0.9 to 9.0 °F). It is likely that northern and eastern portions of the SMUD service territory will experience the largest effects from the urban heat island effect due to sustained density, urban land use and local wind patterns. The impact of urban heat islands expands during heat waves, placing the greatest burden on system assets.[19]

Further exacerbating increases in demand are projections of increased population. Increases attributable to climate change migration from nearby regions have not been studied directly. However, the Demographic Research Unit at the California Department of Finance predicts a 38% increase in population from 2010 to 2060 throughout California, with projections of growth for counties around the Sacramento region closer to 50% or even higher. In the near term, expanded energy efficiency programs and increased distributed energy resources will offset or exceed anticipated load growth, but over the long term, with increasing energy demands driven by higher temperatures, SMUD will need to increase available peak generation capacity in order to meet rising demand.[20]

[15] Cal-Adapt. Temperature: Extreme Heat Tool. Accessed in October 2016. Tool data provided by Scripps Institution of Oceanography. Available at: http://cal-adapt.org/temperature/heat/

[16] California Energy Commission. 2016. Cal-Adapt Climate Tools. Available at: http://cal-adapt.org/tools/

[17] Lawrence Berkely National Laboratory. 2012. Estimating Risk to California Energy Infrastructure from Projected Climate Change. Prepared for the California Energy Commission. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf

[18] Pierce, D. W. March 2012. Probabilistic estimates of future changes in California. Available at: http://woodland.ucsd.edu/wp-content/uploads/2013/10/Pierce_etal_2013_ClimDyn.pdf

[19] California Energy Commission, Creating and Mapping an Urban Heat Island Index for California, prepared by Altostratus Inc., April 24, 2015, http://www.calepa.ca.gov/UrbanHeat/Report/

[20] California Energy Commission. 2016. Cal-Adapt Climate Tools. Available at: http://cal-adapt.org/tools/

Higher temperatures and increased consumer demand have further implications for electricity infrastructure. Higher demand will result in higher stress on the transmission and distribution system. Higher loads also lead to increased losses throughout the transmission system. Losses increase by 1.5% for every 1% increase in load, with predicted load increases leading to up to a 2.5% increase in losses throughout the California network. Higher ambient temperatures impact the performance of the grid because of detrimental effects on transformers and the conductors in transmission and distribution circuits. Maintaining the reliability of transformers and conductors amid a sustained increase in ambient temperatures will require derating their electrical capacity to prevent catastrophic failure of these components. Transformers can lose up to 0.7% of their rated capacity for every 1°C (1.8°F) rise in ambient temperature. Predicted temperature rise across the state could result in transformer capacity losses of up to 2.7% by the end of the century.[21] This loss of transmission capacity, coupled with an increase in generation requirements, may require more than 30% additional capacity to meet demand.[22]

Higher ambient temperatures also affect the maximum capacity of thermal generation plants as available cooling capacity is lowered. Specifically, simple cycle natural gas turbines operating with air based cooling can see up to a 1% reduction in nameplate capacity for every degree C above 15 °C (59 °F). Across California, plants could lose up to 4.5% capacity due to rising temperatures, compromising their ability to respond to peak loads.[23] With summer temperatures predicted to increase by up to 4 °C (7.2 °F) in the Sacramento region, the capacity of SMUD thermal generating facilities could be reduced by 4% from current levels.

As many of the impacts described above are likely to occur concurrently during the hottest days and months of summer, it is important to also consider their effects in aggregate. Cumulative effects of reduced generating capacity, losses in the transmission and distribution network, and higher customer demand coinciding with the highest temperature increases could result in a required nameplate capacity increase of 27% in order to meet future sustained high peak capacity demand.[24] Other sources predict this increase in generating capacity could need to be as high as 38.5% above current peak.[25]

[21] Pierce, D. W. March 2012. Probabilistic estimates of future changes in California. Available at: http://woodland.ucsd.edu/wp-content/uploads/2013/10/Pierce_etal_2013_ClimDyn.pdf

[22] Lawrence Berkely National Laboratory. 2012. Estimating Risk to California Energy Infrastructure from Projected Climate Change. Prepared for the California Energy Commission. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf

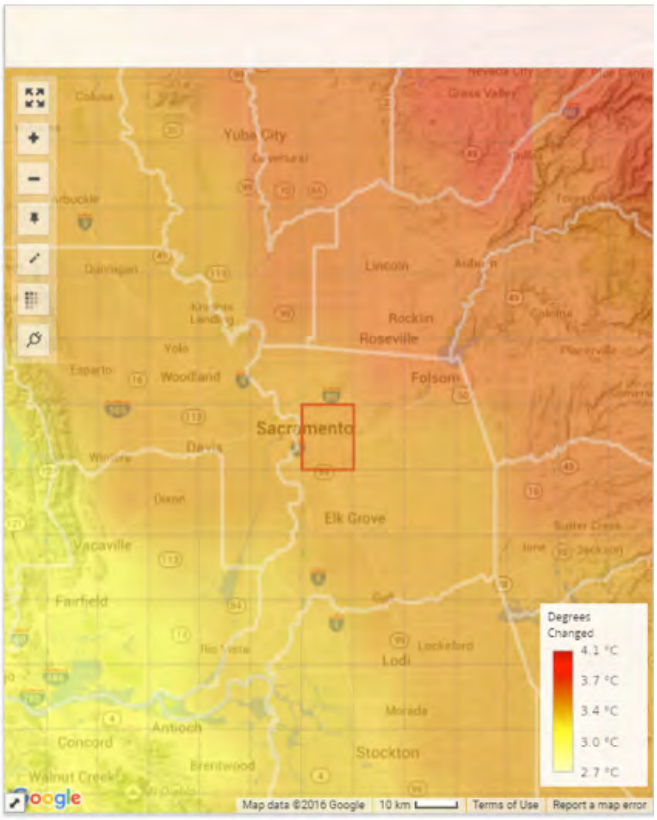
[23] Lawrence Berkely National Laboratory. 2012. Estimating Risk to California Energy Infrastructure from Projected Climate Change. Prepared for the California Energy Commission. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf

[24] California Energy Commission. 2016. Cal-Adapt Climate Tools. Available at: http://cal-adapt.org/tools/

[25] Lawrence Berkely National Laboratory. 2012. Estimating Risk to California Energy Infrastructure from Projected Climate Change. Prepared for the California Energy Commission. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf

Figure 7 and Figure 8 consider the Sacramento region as a whole, and show predicted changes in average annual temperatures ranging from about 3.2-3.6°C (5.8-6.5°F) for the high carbon (A2) emissions scenario, from 1961-1990 to the end of the century 2070-2090. The graph in the lower right illustrates low and high carbon scenarios for the region, and shows that a moderate 1°C increase is still predicted in East Sacramento for the low emissions scenario (B1) over this same time period. Further analysis of the A2 scenario average annual temperature data within the SMUD service area suggests that the service area will see a maximum of nearly a 1°C increase in 2020 and 2.7°C (4.9°F) increase in 2050 from a 2000 base year.[26] Emissions scenarios are developed by the Intergovernmental Panel on Climate Change (IPCC) using a range of assumptions for climate factors including levels of decarbonization in the energy system and population growth.

Temperature: Degrees of Change Map



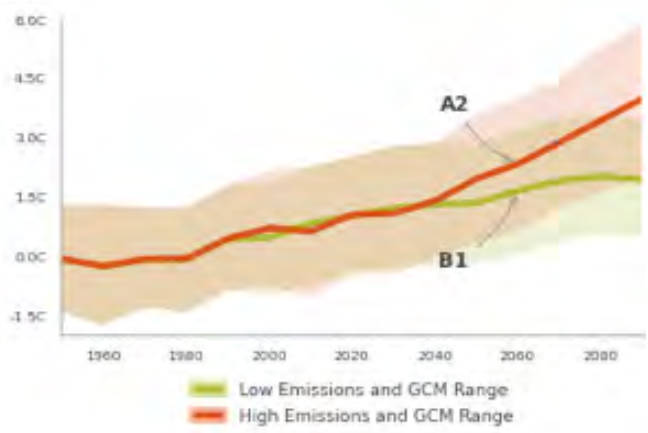


Figure 7. The map depicts temperature projections for the Sacramento region from Cal-Adapt (http://cal-adapt.org/tools/factsheet/). The graph illustrates temperature changes from low and high emissions scenarios for East Sacramento Area.

[26] The year 2000 was used as a base year because 2000 was the most recent year of observed temperature data. Observed data come from the Santa Clara University Department of Civil Engineering while projected data come from the Scripps Institution of Oceanography California Nevada Applications Program as described here: http://cal-adapt.org/data/sources/.

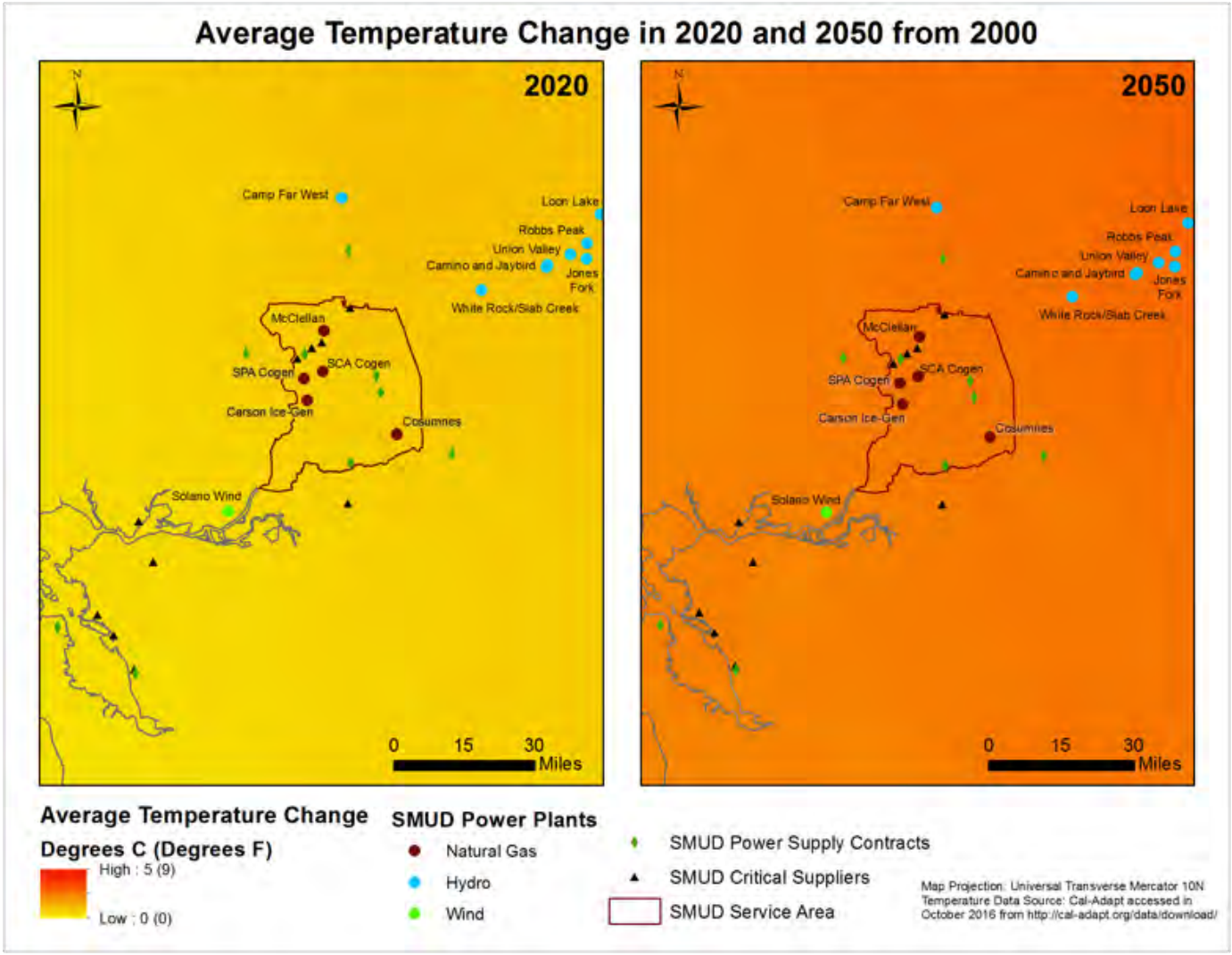


Figure 8. Average temperature change (A2 high carbon emissions scenario) in 2020 and 2050 from a 2000 baseline in the SMUD service area.

SECTION II. DROUGHT

Climate Stressor Background

Climate effects on rainfall patterns are difficult to predict. Though California experienced a severe drought from 2011-2014, multiple studies indicate the precipitation deficits experienced during this drought to be within typical historical variation, leading to a belief that natural climate variation is the likely cause of this event rather than climate change impacts.[27] The higher temperatures predicted throughout the state can exacerbate drought conditions by increasing evaporation rates, though studies do not find a link between temperature rise and changes in precipitation.[28] Climate models show wide variability in predicted rainfall patterns in California, ranging from a 23% decrease to a 9% increase in annual rainfall in the Sierra Nevada range. Average results among these models predict a slight but insignificant decrease in annual rainfall in the Northern part of the state.

[27] NOAA Drought Task Force. December 2014. Causes and Predictability of the 2011-14 California Drought. Available at: http://cpo.noaa.gov/MAPP/californiadroughtreport

[28] Pierce, D. W. March 2012. Probabilistic estimates of future changes in California. Available at: http://woodland.ucsd.edu/wp-content/uploads/2013/10/Pierce_etal_2013_ClimDyn.pdf

Though annual average rainfall values are likely to see little change in California, the distribution of rainfall throughout the year is predicted to change in more significant ways. Regions in Northern California are more likely to see an increase in winter precipitation, while Southern California and the Central Coast show slight decreases in winter precipitation. Results of modeling for the Sacramento region predict a slight increase in the winter months of December, January, February, with Spring and Fall predicted to see the largest reductions in rainfall in the Sacramento region. Summer months are also expected to see a notable reduction in rainfall on a percentage basis, though the already low amount of rainfall in these months renders this change insignificant.

Along with shifting precipitation events, both heavy rain events and consecutive days with less than 0.1 inches of rain are predicted to increase slightly. These variations in rain patterns fall within normal historical year-to-year variation, though the subtle shifts are important for California, especially when coupled with other climate impacts as explored in more detail in the Hydrology section of this report.

Asset Impact Analysis

Table 4 and Figure 9 depict July drought impacts to the SMUD service area and SMUD power plants as defined by the United States drought monitor.[29] Drought conditions in the SMUD area were at their worst from July 2013 to July 2016, with the SMUD service area and all power plants experiencing exceptional drought, the highest drought classification, in at least one of those years. Based on these results SMUD will continue to monitor how drought impacts generation and commodity costs since changes in rainfall patterns have effects on utility generating capacity across multiple types of technologies such as:

- **Hydropower:** Lower water levels impact production capacity in hydroelectric plants, which is discussed in greater detail in the Hydrology section of this report.
- **Thermal Electric:** Reduced rainfall can limit cooling water available for thermal electric generating plants, reducing their operating efficiency and generating capacity.
- **Biomass:** Changes in seasonal precipitation patterns can impact vegetation growth, altering the availability of feedstock for biomass generators.[30]

SMUD has a number of initiatives that reduce risk of water shortages in drought conditions, including the hydro rate stabilization fund that accrues money to purchase replacement power in years with lost hydropower generation and the cooperation of Sacramento Power Authority (SPA) with the Sacramento Regional County Sanitation District (Regional San) to deliver recycled water from Regional San treatment facilities to be used for cooling and fire protection at the SPA power plant. More information about these initiatives is included in the Action Plan section of this report.

[29] Drought shapefiles for July 2001-2016 were downloaded from the U.S. Drought Monitor GIS Data Archive. Available at: http://droughtmonitor.unl.edu/MapsAndData/GISData.aspx

[30] World Business Council for Sustainable Development (WBCSD). March 2014. Building a Resilient Power Sector. Available at: http://www.wbcsd.org/resilience.aspx

Table 4. US Drought Monitor Classifications* from July 2001-2016 for the SMUD service area and SMUD power plants.

Power Plants	Plant Type	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
SMUD Service Area	N/A																
Carson Ice-Gen Project	Natural Gas																
Cosumnes	Natural Gas																
McClellan	Natural Gas																
SCA Cogen 2	Natural Gas																
SPA Cogen 3	Natural Gas																
Solano Wind	Wind																
Camino	Hydro																
Camp Far West	Hydro																
Jaybird	Hydro																
Jones Fork	Hydro																
Loon Lake	Hydro																
Robbs Peak	Hydro																
Union Valley	Hydro																
White Rock/ Slab Creek	Hydro																

No Drought to Abnormally Dry | Moderate Drought | Severe Drought | Extreme Drough | Exceptional Drought

*This table provides an overview of the highest drought category that has affected each of the analyzed SMUD assets between July 2001-2016. Please note that drought conditions fluctuate from year to year and this table is intended to show the most extreme drought conditions that these assets have faced in the past 16 years.

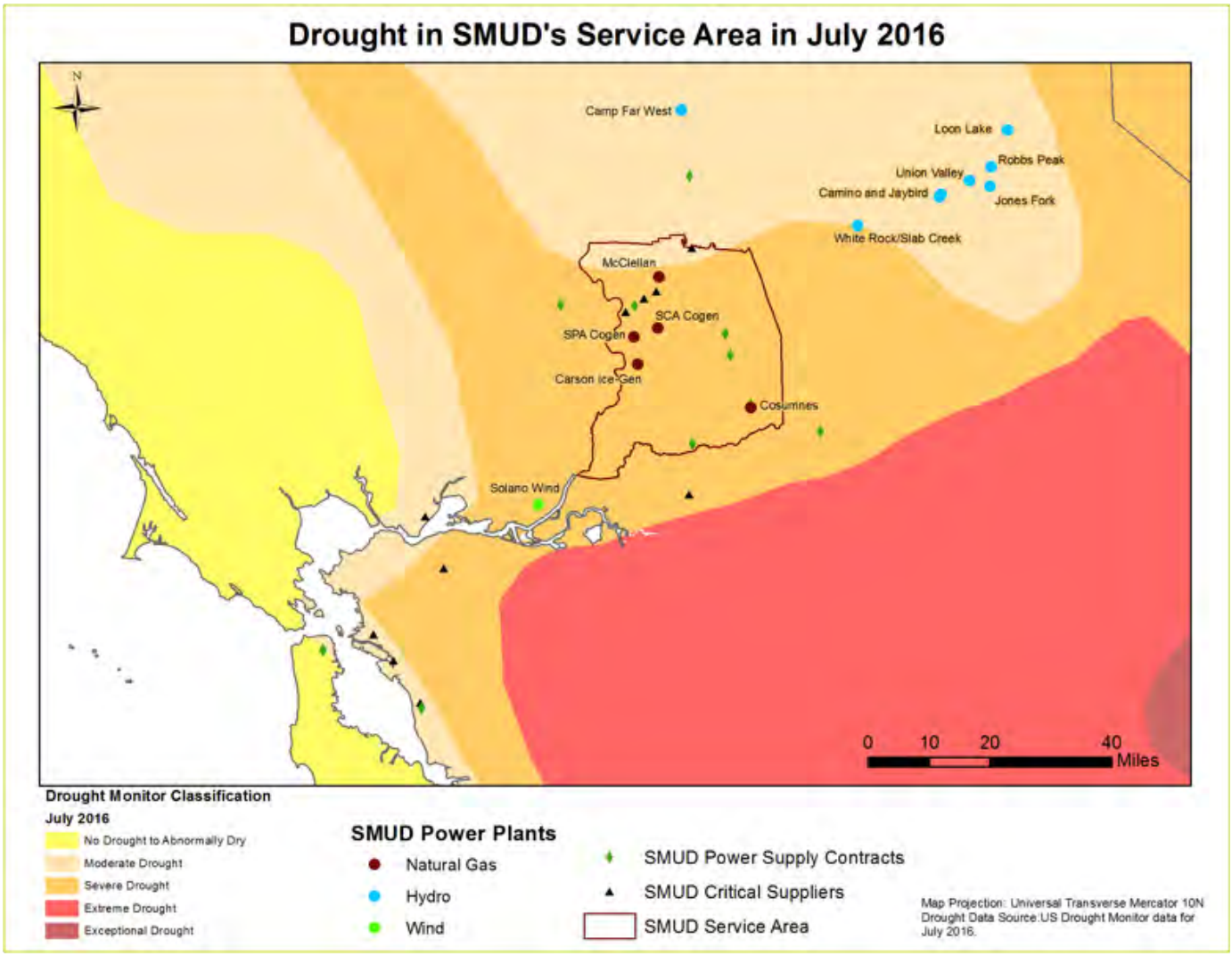


Figure 9. SMUD service area drought conditions for July 2016 as classified by the U.S. Drought Monitor.

SECTION III. WILDFIRES

Climate Stressor Background

California has an extensive history of wildfires, and the risk of fire is influenced by several variables, including climatic factors, topography, available fuel, and sources of ignition. Climate change will only exacerbate the problem as increased temperatures, reduced snowpack, and altered precipitation will lead to increased flammability of fuel for longer periods of time, affecting the size, frequency, and severity of wildfires.[31] Many areas of California, including Northern California, Southern Coast, and the Sierra Nevada foothills are expected to see an increase in wildfires throughout the next century. However, in the Sacramento region, wildfires are projected to maintain similar frequency to those seen over the past 50 years, with a general increase in area burned spiking in 2020 and decreasing slightly from that spike in 2050.

Asset Impact Analysis

Aligning with impacts expected in the Sacramento region,[32] SMUD service areas are expected to see consistent fire frequency with larger burn areas for each fire, as shown in Figure 10 and described below:

- Of SMUD's 263 substations, 43 have an increased risk of wildfire in 2020 and 2050.
- Eight of SMUD's power plants have approximately a one percent increase in area burned in 2020 and 2050 (Table 5).
- Of SMUD's supply contracts, wildfire risk increases in 2020 and 2050 impact Kiefer Landfill, Sierra Pacific Industries biomass, Buena Vista biomass, Rancho Seco Solar, and Sacramento Soleil LLC (solar power purchase agreement).
- Critical suppliers affected by increased wildfire risk in 2020 and 2050 include Southwire in Fontana, CA.

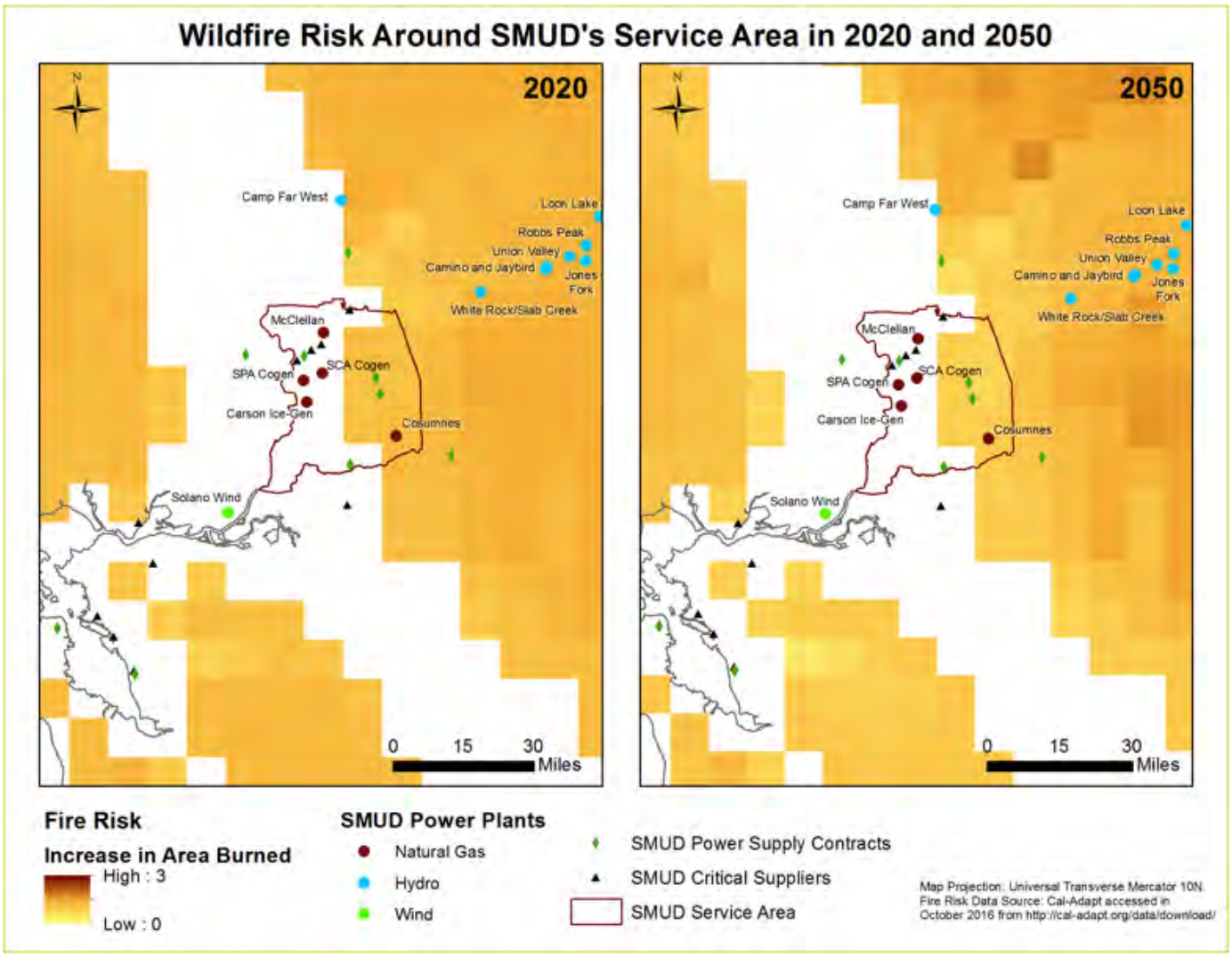
[31] California Energy Commission. 2016. Cal-Adapt Climate Tools. Available at: http://cal-adapt.org/tools/

[32] Wildfire risk data provided by Cal-Adapt at: http://cal-adapt.org/data/download/. Fire risk data in Cal-Adapt originated from the UC Merced Climate Applications Lab. More detailed information can be found in: Westerling, A. L., Bryant, B. P. 2008. Climate Change and Wildfire in California. Climatic Change (2008) 87 (Suppl 1): s231-s249

Table 5. Wildfire risk in 2020 and 2050 for SMUD power plants.

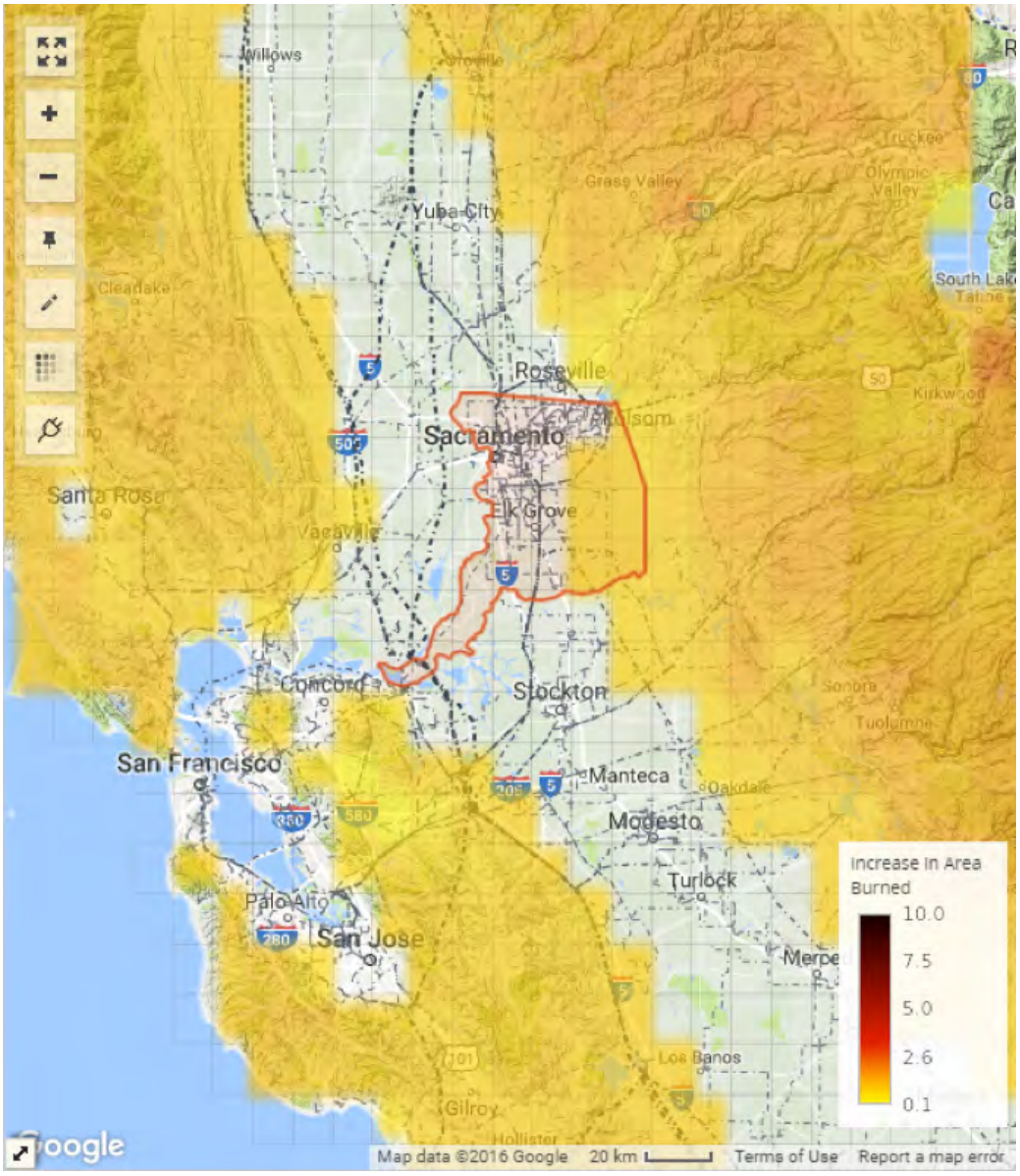
Power Plant Name	Plant Type	2020 Fire Risk *(Increase in Area Burned)*	2050 Fire Risk *(Increase in Area Burned)*
Camino	Hydro	1.3%	1.3%
Jaybird	Hydro	1.3%	1.3%
Loon Lake	Hydro	1.3%	1.3%
Robbs Peak	Hydro	1.3%	1.3%
White Rock/Slab Creek	Hydro	1.2%	1.2%
Camp Far West	Hydro	0%	0%
Jones Fork	Hydro	1.2%	1.2%
McClellan (CA)	Natural Gas	0%	0%
Union Valley	Hydro	1.3%	1.3%
Solano Wind	Wind	0%	0%
Carson Ice-Gen Project (CVFA)	Natural Gas	0%	0%
Proctor and Gamble (SCA Cogen 2)	Natural Gas	0%	0%
Campbell Soup (SPA Cogen 3)	Natural Gas	0%	0%
Cosumnes Power Plant (CPP)	Natural Gas	1.1%	0.9%

Figure 10. Wildfire risk map for the SMUD service area for 2020 and 2050 using the A2 high emissions scenario.



Under a high emissions (A2) climate scenario, a slight increase of up to 10% is predicted for fires affecting transmission lines within the Sacramento and Central Valley region. In the low emission B1 climate scenario, some high voltage transmission lines in the Sacramento region are modeled to see a decrease of about 5% in impact from wildfires from 1975 through the end of the 21st century. Figure 11 shows major transmission lines overlaid on the wildfire projections map, demonstrating that many major Sacramento lines servicing SMUD clients are outside of the areas projected to see an increase in wildfire risk.

Figure 11: Wildfire risk map for 2050, overlaid with transmission lines



Even with little change in their frequency, the wildfires that California experiences on an annual basis can still pose a threat to electricity infrastructure for SMUD. Physical infrastructure in the direct path of a fire can suffer extensive damage, especially smaller lines that are often fitted with wooden poles. Soot collecting on equipment and ionized particulate matter in the air can cause leakage currents or arcing. Firefighting measures can foul lines, requiring extensive cleanup or repair after the fire is cleared. Transmission capacity is affected by the high heat, smoke and particulate matter of the fire, and lines may be shut down preventively as a firefighting measure. As the operating limits of existing infrastructure are maxed out from multiple climate factors, reduced availability and capacity losses of critical transmission lines during wildfire events will further strain the system and its ability to deliver reliable power to SMUD customers.

An increase in debris flow and siltation after a wildfire is common as infiltration capacity of soil is reduced in the wildfire area, especially during rain events within the two years following a significant fire. The distribution of annual precipitation is projected to change through the end of the century, with increases predicted in both rain events with greater than 3-4 inches of rain and consecutive days with less than 0.1 inches of rain. Heavy rain events following a fire may also allow water to infiltrate the loose ground soil, increasing the potential for landslides. Large swings in rainfall from season to season can encourage vegetation growth in rainy periods, leaving more fire feedstock during subsequent dry seasons and priming conditions for the spread of wildfires.

Runoff from heavy rain events also affects the production of hydropower systems that are downstream from fire prone areas, as wildfire soot and residue collects in the waterways that feed the plant. This silt and particulate matter can reduce production or even damage the turbines.[33] As precipitation patterns change in the coming decades, the aftereffects of wildfires could increase concerns for the impact on SMUD infrastructure from runoff, vegetation growth, and landslides.

SMUD has begun utilizing Unmanned Aerial Systems (UAS), or drone technology, to identify drought-related dead or dying vegetation under or near transmission lines for priority removal before it can cause a wildfire. We will also work with landowners and other stakeholders in the Upper American River Project to establish specific forest thinning study areas that may provide immediate wildfire risk reduction and also an increase in stream flows (see Action Plan).

[33] California Energy Commission. 2016. Cal-Adapt Climate Tools. Available at: http://cal-adapt.org/tools/

SECTION IV. WIND PATTERNS

Climate Stressor Background

Between SMUD's 280 megawatt (MW) Solano Wind Project, 50 MW renewable power purchase from the Highlands project (also located in Solano county) and an agreement to purchase power from the 200 MW Grady Wind Energy Center in eastern New Mexico, expected to begin commercial operation late in 2018, SMUD has a vested interest in understanding the implications of climate change for regional wind patterns. In 2015, the Solano Wind Farm generated over 212,000 MWh, which powered about 25,000 homes. Once the Grady Wind Energy Center becomes operational, SMUD's energy supply from wind power will nearly double.

Delta Breeze

The Solano Wind Project is powered primarily by the breezes emanating from the San Francisco Bay Delta (Delta Breeze), which comes from the southwest off of the deltas of the Sacramento River and San Joaquin River. The southwesterly Delta Breezes also play a role in reducing electricity demand on hot summer evenings, by bringing cooler ocean air from the San Francisco Bay, dropping maximum daily temperatures by 1.7°C (3 °F) and reducing peak electric energy demand in the northern Sacramento valley by as much as 5,000 MW across all electricity suppliers.

The Delta Breeze is very complex, which makes modeling difficult. A number of factors contribute to the formation of a substantial Delta Breeze. Given the lack of long-term modeling for the Delta Breeze, modeled forecasts for sea breezes in California broadly provide a proxy for potential changes in the Delta Breeze.

Under climate change conditions, land temperatures are expected to rise more quickly than sea temperatures during hotter months, leading to steeper cross-shore pressure gradients, which drive coastal winds. This change would result in stronger coastal winds during the spring, summer, and fall months.[34] Increasing coastal winds indicate that the Delta Breeze will likely continue to provide energy to the Solano Wind Project and relief to the Sacramento region for the foreseeable future.

Regional Wind Patterns

The impacts of climate change on regional wind patterns is difficult to model due to the large number of factors that affect wind patterns. In a study conducted for the California Energy Commission, it was estimated that Tehachapi Pass, a major wind producing region for California, will see wind speed decreases of 2% - 4%. The estimated decreases in wind speed would reduce generation in Tehachapi Pass by 10% - 15% for summer through winter by 2060.[35]

[35] Largier, J., Cheng, B., Higgason, K. Climate Change Impacts: Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. U.S. Department of Commerce. August 2011. Available at: http://sanctuaries.noaa.gov/science/conservation/pdfs/climate_cbnms.pdf

Another set of studies, compiled for the National Climate Assessment, found no change in wind-energy density for the Southwest was expected by 2060.[36] Based on these findings, annual wind energy in Solano County and New Mexico should not be significantly affected by climate change, however, as more research becomes available these results are subject to change.

Asset Impact Analysis

Cal-Adapt modeling of wind in California shows little change in wind speeds for SMUD's service area and Solano County through 2050 (Figure 12)[w], supporting other research that annual wind speeds are not expected to change significantly in the coming years. Peak wind speeds may be impacted by increased storm events, which will be covered in the Extreme Weather Events section below.

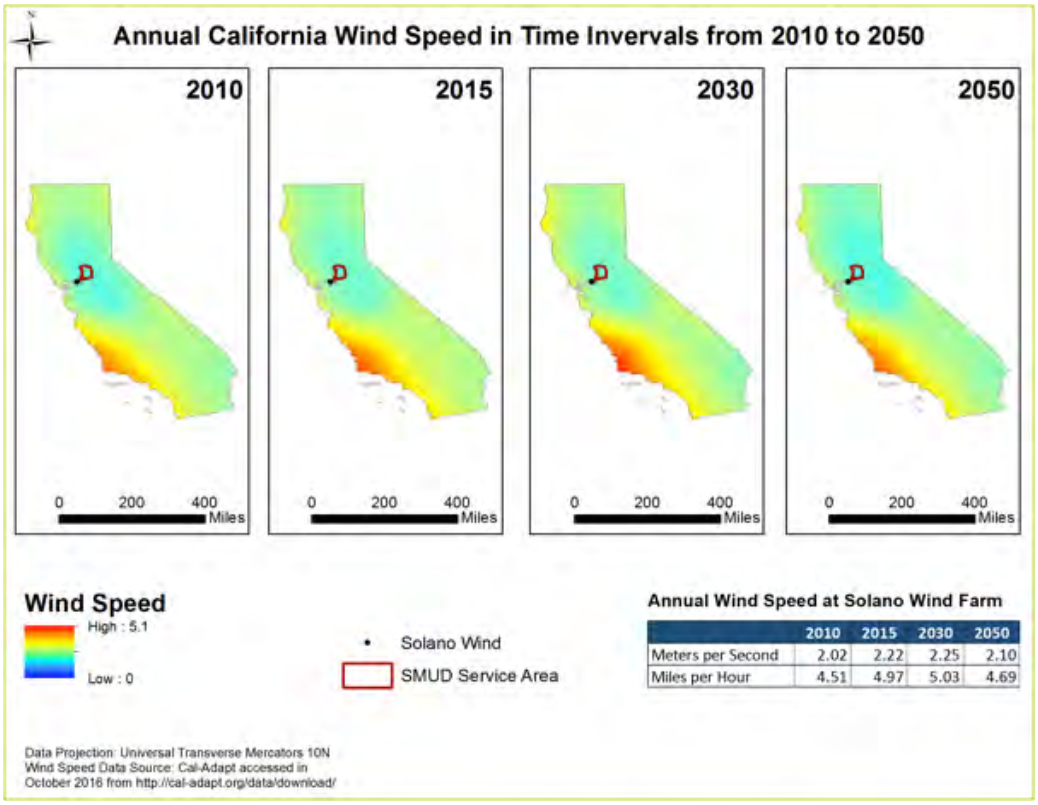


Figure 12. Map of wind speed in California as of 2010 and 2015 and projected wind speeds for 2030 and 2050. The red outline indicates SMUD's service area and the black dot is the location of the Solano Wind project.

[36] Duffy, P.B., Bartlett, J., Dracup, J., Freedman, J., Madani, K., Waight, K. 2014. Climate Change Impacts on Generation of Wind, Solar, and Hydropower in California. California Energy Commission. Available at: http://www.energy.ca.gov/2014publications/CEC-500-2014-111/CEC-500-2014-111.pdf

[37] Garfin, G., Jardine, A., Merideth, R., Black, M., LeRoy, S. 2013. Assessment of Climate Change in the Southwestern United States. Island Press. Available at: http://www.swcarr.arizona.edu/sites/all/themes/files/SW-NCA-color-FINALweb.pdf

SECTION V. HYDROLOGY

Climate Stressor Background

The effect of climate change on hydrology in northern California will likely result in less overall precipitation with a greater percentage falling as rain instead of snow, more variability of precipitation, and less Sierra Nevada snowpack. Over the current century, the Sacramento region will see continued variability in precipitation patterns, and possibly a decrease in annual precipitation totals. Estimates indicate that the western Sierra Nevada range will experience a loss of 3% of historical precipitation totals by 2069.[38] The contributing models individually ranged in forecast annual precipitation from an increase of 9% of historical precipitation to a decrease of 23%. A shift toward the majority of precipitation volume accumulation occurring earlier in the water year as observed by an increase in predicted precipitation during December, January, and February is expected. Spring and Summer months (March to August) are predicted to experience the largest percent decrease in precipitation from historical levels, though the absolute change in the already dry summer months is small.

Along with shifting precipitation events, there will be more dry days in the Sacramento region and central Sierra Nevada, relative to historic conditions, especially toward the end of the 21st century. Studies have indicated that during precipitation events, higher intensity precipitation days will be more likely.[39]

Another projected consequence of climate change is a reduction in the accumulation of annual snowpack. A drier climate and projected increases in air temperature reduce snowfall and cumulatively threaten annual snowpack accumulation in the Sierra Nevada. This will result in increasingly diminished water stored as snow within the Sierra Nevada Range. The projected snow water equivalent (SWE) (i.e. the amount of water contained within the snowpack) is estimated to be reduced by approximately 70% of historical levels by the end of the 21st century.[40] The Water Evaluation and Planning System (WEAP) model simulated losses in snowmelt for the American River from the 2° C (3.6° F) warming expected by 2050 of about 45% of historical snow melt, and more than 90% from a 6° C (10.8° F) warming, the possible outcome of the high emissions scenario by 2100.

[38] Pierce, D.W., Das,T., Cayan, D.R., Maurer, E.P.; Miller, N.L., Bao, Y., Kanamitsu M., Yoshimura, K., Snyder, M.A., Sloan, L.C., Franco, G, and Tyree, M. 2012. Probabilistic estimates of future changes in California temperature and precipitation using statistical and dynamical downscaling. Climate Dynamics. 40: 839-56.

[39] Pierce, D.W., Das,T., Cayan, D.R., Maurer, E.P., Miller, N.L., Bao, Y., Kanamitsu M., Yoshimura, K., Snyder, M.A., Sloan, L.C., Franco, G, and Tyree, M. 2013. The key role of heavy precipitation events in climate model disagreements of future annual precipitation changes in California. Journal of Climate. 26: 5879-5896.

[40] Pierce, D.W. and Cayan, D.R. 2013. The uneven response of different snow measures to human-induced climate warming. Journal of Climate. 26: 4148-4167.

Asset Impact Analysis

SMUD's hydroelectric plants play a critical role in meeting peak power demand on hot summer days, and changes that affect the availability of water in the reservoirs during such peak demand periods could significantly impact SMUD. SMUD's hydroelectric generation is low-cost and accounted for roughly 12% of SMUD's total power generation during 2014, a particularly dry year, but can be as high as 25% when water supply is plentiful.

SMUD's contributing watersheds are projected to experience the largest reduction in snowmelt in the mid-elevation range of 1,000 to 2,500 meters or 3,280 to 8,200 feet (Figure 13).[41] The impact of reduced snowpack, which is projected to be more pronounced in the Sacramento region (Figure 14), would increase early seasons generation and decrease summer generation, requiring replacement power sources during cooling load months.

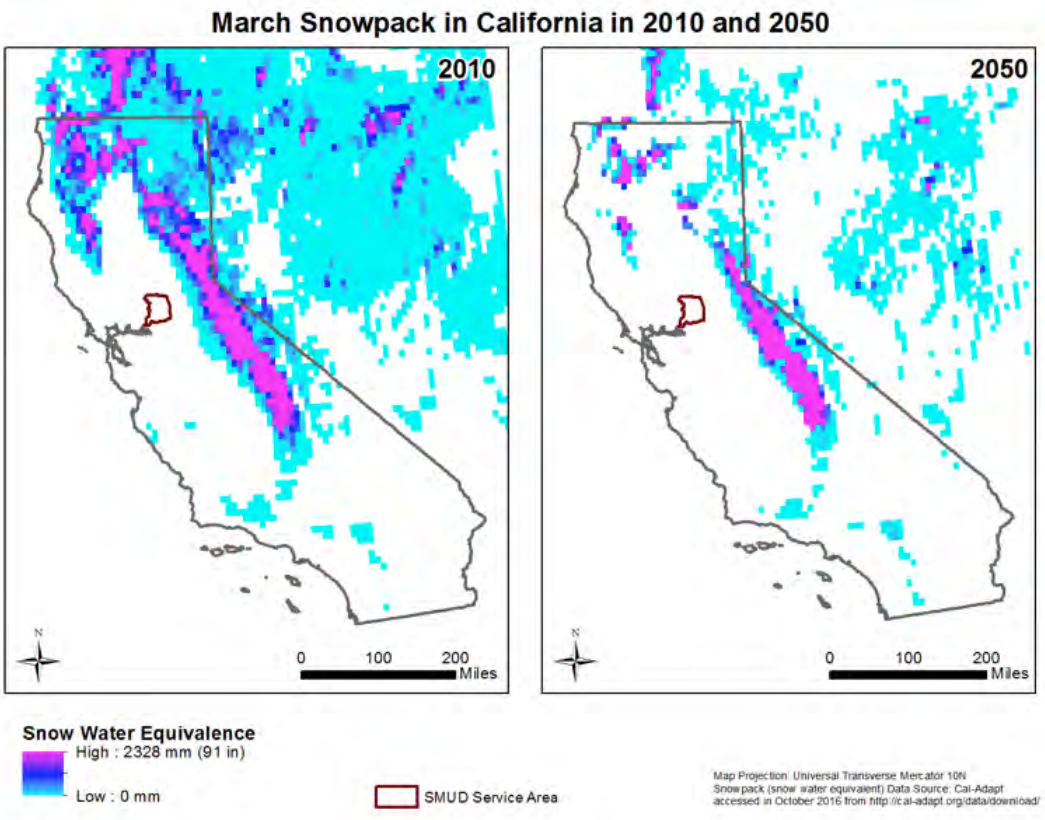


Figure 13. Historical snowpack in 2010 and projected snowpack in 2050 for the Sierra Nevada and surrounding regions during March, a peak month for snowpack in California. The SMUD service area is outlined in red. Source: Cal-Adapt[42]

[41] Ficklin, D.L., Stewart, I.T., and Maurer, E.P. 2012. Projections of 21st Century Sierra Nevada local hydrologic flow components using an ensemble of General Circulation Models. Journal of the American Water Resources Association (JAWRA). 1-21. DOI: 10.1111/j.1752-1688.2012.00675.x

[42] Cal-Adapt. Snowpack: Monthly Snow Water Equivalent. 2016. Available at: http://cal-adapt.org/data/download/

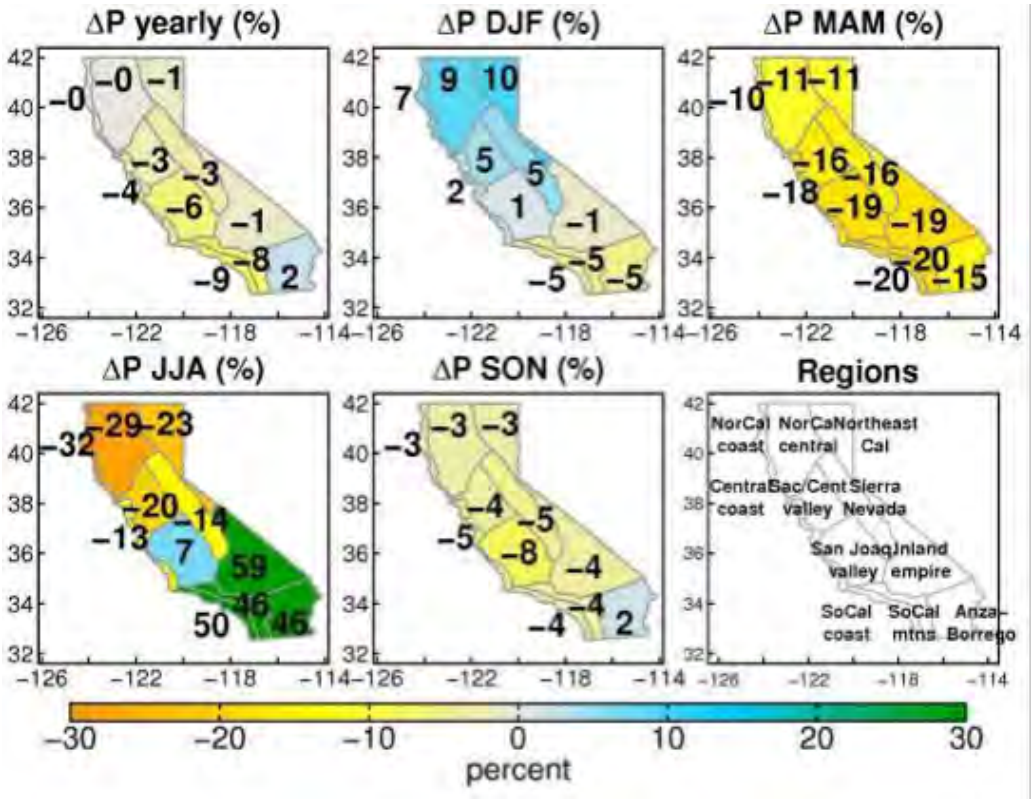


Figure 14. Precipitation change (%), mean over the period 2060- 69 compared to mean over the period 1985-94. Data from all models and downscaling techniques was averaged to generate the values. Source: Pierce et al. 2012

The magnitude and timing of snowmelt is a function of the availability of snowpack and has typically resulted in moderate flows in spring and early summer. Climate change is likely to alter the magnitude and timing of these flows negatively affecting hydroelectric generation throughout the western Sierra Nevada, which supplies much of SMUD's hydropower. SMUD's hydroelectric storage capacity was designed in part because of the large quantity of water storage historically held in snowpack (smaller reservoirs relative to total annual generation). The California Energy Commission (CEC) identifies hydroelectric facilities in the American River systems as among those most likely to be affected by climate change because of large hydropower to storage capacity ratios, and considering that changes in projected runoff are large relative to current storage capacity.[43]

[43] California Energy Commission. January 2009. Potential Impacts of Climate Change on California's Energy Infrastructure and Identification of Adaptation Measures. CEC-150-2009-001. Available at http://www.energy.ca.gov/2009publications/CEC-150-2009-001/CEC-150-2009-001.PDF

Hydrology Impacts to Native Habitats

In addition to serving its customers, SMUD has a deep commitment to species and land stewardship. Conservation efforts are integrated into our operational priorities to ensure healthy ecosystems for future generations. For example, to support aquatic species in the Upper American River Project, SMUD measures include:

- Increased minimum streamflows below dams
- Pulse Flows
- Ramping Rates
- Temperature mitigation "block of water" flows
- Fish population monitoring
- Macroinvertebrate monitoring
- Amphibian and Reptile monitoring
- Foothill Yellow legged frog monitoring
- Mountain yellow frog monitoring
- Riparian vegetation monitoring
- Algae monitoring
- Geomorphology monitoring
- Water temperature monitoring
- Water quality monitoring
- Metals bioaccumulation monitoring
- Cancellation of recreation flows if certain biological cues are reached
- Fish stocking

As described in the Action Plan section of this report, SMUD also began site monitoring in 2011 for a Nature Preserve Mitigation Bank and by 2014 it was fully operational. It now has a market value of $26 million in endangered species and habitat mitigation credits. We have the option of selling credits to third parties, providing a regional land preservation and protection resource and a safe preserve for listed species.

But the anticipated shifts in regional hydrology will affect aquatic habitats both in downstream valley reaches and alpine reaches, complicating existing efforts and exacerbating stresses on sensitive systems. Both the water quality of the runoff entering the aquatic system and the quantity and velocity of the runoff can be influenced by increasing severity of wildfires, as discussed in the Wildfires section of this report. Salmonid species require cool flowing water with high oxygen concentration.[44] The projected summer conditions of the natural regional hydrology are expected to stress these species and conservation efforts will likely require dam releases of stored water at times that are beneficial to the species but not necessarily coinciding with requirements to meet energy demands. In addition, the salinity of the Sacramento/San Joaquin Delta is dependent on freshwater flows from upstream rivers that maintain a brackish condition. Increases in salinity of the Delta region resulting from less snowpack runoff and increased saltwater intrusion from sea-level rise would increase stress to species within the Delta ecosystem that are unable to adapt to the new conditions, and increase the possibility of saltwater intrusion of inland aquifers.[45] Existing monitoring and management regimes will provide early alerts as these potential complications arise, and inform appropriate management responses.

[44] National Marine Fisheries Service. Recovery Plan For the evolutionarily significant units of Sacramento River winter-run Chinook salmon and central valley spring-run chinook salmon and the distinct population segment of California central valley steelhead. Available at: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/california_central_valley/final_recovery_plan_07-11-2014.pdf

[45] Knowles, N & Cayan, DR. 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. Geophysical Research Letters, 29(18), 1891

A potentially drier climate would also have impacts on the Western Area Power Administration (WAPA) and its hydroelectric facilities across the Central Valley Project, which supplies 700 to 900 gigawatt hours (GWh) per year to SMUD. Beyond California, SMUD also has vested interest in hydrological changes in the Pacific Northwest, as hydroelectric power availability from Pacific Northwest affects the energy imported into California. Overall annual runoff across the State of Washington is projected to increase by 2-3% by the 2040s, driven largely by an increase in winter precipitation.[46]

[46] Elsner, M.E., Cuo, L., Voisin, B., JDeems, J.S., Hamlet, A.F., Vano, J.A., Mickelson, K.E.B., Lee, S.Y., and Lettenmaier, D.P. 2010. Implications of 21st century climate change for the hydrology of Washington State. Climatic Change 102(1-2): 225-260, doi: 10.1007/s10584-010-9855-0.

SECTION VI. FLOODING AND SEA LEVEL RISE

Climate Stressor Background

SMUD will likely encounter direct and indirect impacts from sea level rise and flooding in the next several decades. While sea level rise and flooding are each a concern of climate change in their own right, the impacts compound in the Sacramento region due to the interconnected nature of snowmelt from the Sierras and ocean access from the Sacramento-San Joaquin Delta (the Delta). The Sacramento Area Flood Agency (SAFCA) suggests that Sacramento has the one of the highest risks of flooding when compared to all other cities in the United States.[47]

[47] Sacramento Area Flood Control Agency (SAFCA). Flood History – Sacramento Flood Threat. Accessed on July 11, 2016. http://www.safca.org/floodinsurance/faqs.html

Sea level along California's coast has risen approximately 7 inches in the last century,[48] and this rate is expected to accelerate south of Cape Mendocino 5 - 24in (5in - 2ft) by 2050 and 17 - 66in (1.4 - 5.5ft) by 2100 relative to a 2000 baseline dependent on specific emissions scenarios.[49] With current sea-level rise conditions, the Risky Business Project predicts that roughly $8-$10 billion of existing property in California could be flooded by 2050 with an additional $6-$10 billion susceptible to flooding in 2100.[50] Combined with Sacramento's particular vulnerability to flooding, sea level rise could have major implications to assets and infrastructure on which SMUD is dependent.

Asset Impact Analysis

To help mitigate flood risk, SMUD has used SAFCA flood mapping scenarios (Figure 15) to develop a flood response strategy to guide SMUD's preparation for a potential flood situation. Analysis of these scenarios indicate that a large portion of SMUD's service territory is unaffected by flooding, but there are some areas in SMUD's service area that could be significantly impacted. Flooding north of the American River will most affect the Campus Commons, Cal Expo, Arden and Natomas areas, impacting over 62,000 residential and commercial customers. Scenarios south of the American River most affect the Downtown Sacramento and Pocket areas where over 126,000 SMUD residential and commercial customers reside.[51] Furthermore, SMUD's utility system components that could be impacted include:

- 45-370 pad-mounted switchgear components (Full Restoration = 2-4 months);
- 402,800 network and pad-mounted transformers (Full Restoration = 2-4 months);
- 8-14 distribution substations (Full Restoration = 2-6 months);
- Hurley and Natomas transmission substations (Full Restoration = 6 months); and
- Minimal damage to overhead lines.

[48] California Climate Change Center. 2012. Our Changing Climate 2012 Vulnerability & Adaptation to the Increasing Risks from Climate Change in California – Brochure. Publication # CEC-500-2012-007. Available at: http://climatechange.ca.gov/climate_action_team/reports/third_assessment/

[49] NRC (National Research Council). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Washington, DC: The National Academies Press. Available at: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/sea-level-rise-brief-final.pdf

[50] Risky Business Project. 2015. The Economic Risks of Climate Change in the United States: From Boom to Bust? Climate Risk in the Golden State. Available at: http://riskybusiness.org/report/from-boom-to-bust-climate-risk-in-the-golden-state/

[51] SMUD Board Energy Resources & Customer Services Committee. Summary of SMUD's Grid Sustainability, Flood Response Plan. Presented on April 30, 2014.

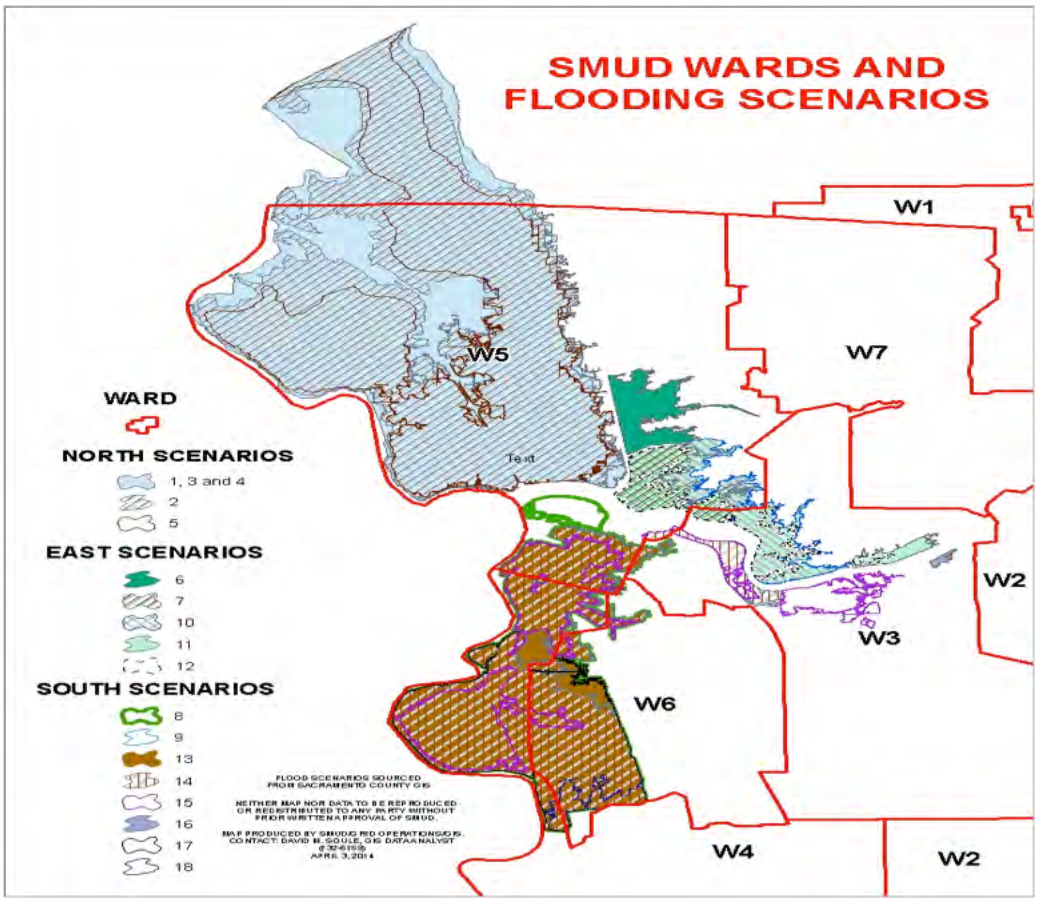


Figure 15. SMUD wards and flooding scenarios from SAFCA.[52]

[52] Map adapted from SMUD's Grid Sustainability, Flood Response Plan, presented on April 30, 2014.

SMUD's mitigation plan allows for planning, coordination and communication around potential future flood events. SMUD will not only need to continue preparing to address potential impacted system components, but also partner with local jurisdictions to increase their preparedness to address affected employees and customers.

Energy infrastructure along the California coast, particularly along the San Francisco Bay and Sacramento-San Joaquin Delta, is prone to inundation from sea level rise and storm surge. Recent studies suggest that approximately 13 power plants and numerous storage facilities and substations in the San Francisco Bay and the Delta area are at risk of a 100 year flood with 4.5ft (1.4m) of sea level rise (Figure 16).[53] Furthermore, coastal flooding as a result of sea level rise and storm surge makes energy infrastructure, particularly fuel transport structures such as pipelines, in low lying areas more susceptible to impacts from flood-borne debris and corrosion from salt water. As sea levels rise, erosion and flooding may expose, damage, and corrode buried pipes and other fuel transport infrastructure such as pumping stations, port terminals and low-lying railroad equipment. Flooding and damage to roadways also reduces land-based capacity to transport fuels across the Bay and Delta region.[54] It is important to note that although average water levels in the Delta are expected to rise as sea level rises, "landward" or inland reaches of the Delta will likely see less water rise than "seaward" reaches of the Delta, meaning that areas closer to SMUD's service area will be more directly affected by flooding from river flow or hydrology rather than sea level rise.[55]

[53] Sathaye, J. A., L. L. Dale, P. H. Larsen, G. A. Fitts, K. Koy, S. M. Lewis, and A. F. P. de Lucena. 2012. Estimating Risk to California Energy Infrastructure from Projected Climate Change. Sacramento, CA: California Energy Commission. July. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf.

[54] U.S. Department of Energy (DOE). 2015. State of California: Energy Sector Risk Profile. Washington, DC. Available at: http://www.energy.gov/sites/prod/files/2015/05/f22/CA-Energy%20Sector%20Risk%20Profile.pdf.

[55] Sathaye et al. 2012, p.51. Information in Sathaye et al. 2012 references a 2010 personal communication with Knowles.

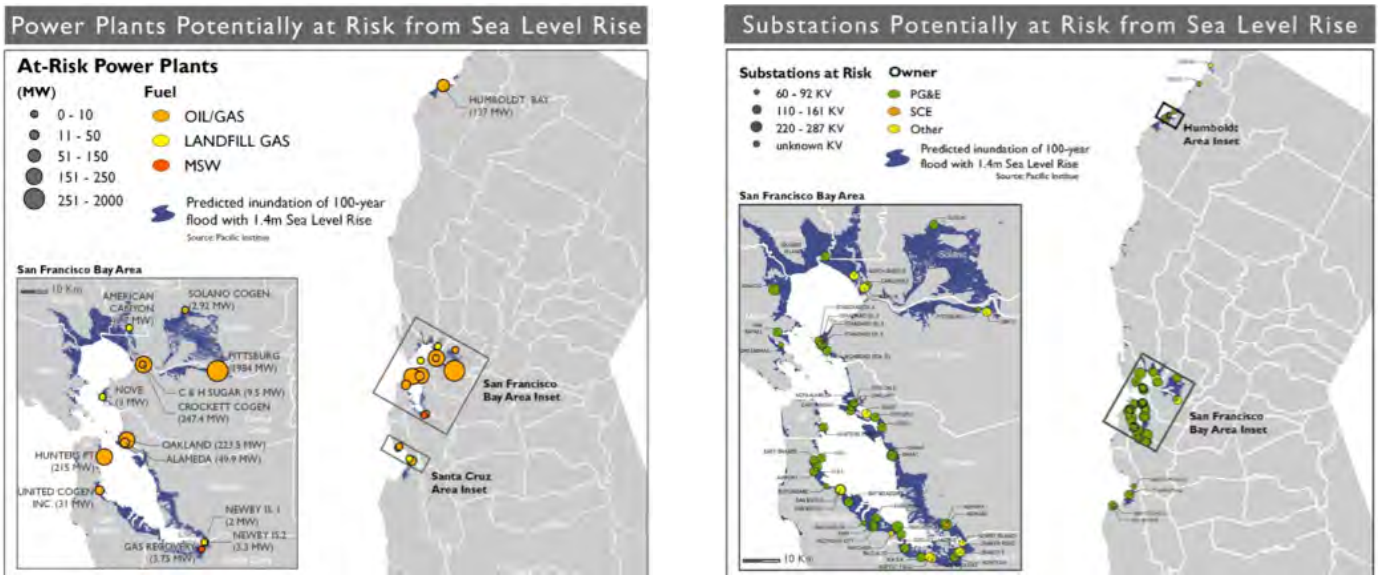


Figure 16. Potential risk of sea level rise on power plants and substations in the San Francisco Bay Area (Map adapted from Sathaye et. al. 2012).

While SMUD does not own infrastructure in the Bay Area, impacts to equipment and distribution pipelines in that area could have impacts on SMUD's access to natural gas as SMUD hooks into PG&E's pipeline in Winters, California. PG&E ranks sea level rise as a likely, medium-high magnitude of impact risk driver[56] because critical assets such as the natural gas storage facility on McDonald Island are operating at or below sea level.[57] PG&E identified the following potential impacts from sea level rise that also may affect SMUD operations if they were to occur:

- Higher inundation and flooding potential at coastal and low elevation facilities due to sea level rise when combined with high tides, storm runoff and storm surges;
- Levee erosion or failure, putting assets at risk; and
- Risk of damage to substations and other gas and electric infrastructure.

Although PG&E's assessment results yield a low percentage of electric and gas assets exposed to sea level rise, many assets in the Bay area are in 100- or 500-year floodplains, putting them at greater risk to flooding from high tides and storm surges during extreme weather events.[58]

[56] PG&E (Pacific Gas and Electric Company). 2016. Climate Change Vulnerability Assessment. Available at: http://www.pgecurrents.com/wp-content/uploads/2016/02/PGE_climate_resilience.pdf

[57] Sathaye, J. A., L. L. Dale, P. H. Larsen, G. A. Fitts, K. Koy, S. M. Lewis, and A. F. P. de Lucena. 2012. Estimating Risk to California Energy Infrastructure from Projected Climate Change. Sacramento, CA: California Energy Commission. July. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf.

[58] PG&E (Pacific Gas and Electric Company). 2016. Climate Change Vulnerability Assessment. Available at: http://www.pgecurrents.com/wp-content/uploads/2016/02/PGE_climate_resilience.pdf

SECTION VII. EXTREME WEATHER EVENTS

Climate Stressor Background

Much of the weather-related damage along the California coast is a result of storms, particularly the combination of large waves, storm surges and high tides during strong El Niño events. The World Business Council on Sustainable Development (WBCSD) suggests that storm surges could be the greatest of hazards to power infrastructure.[59] On top of these events, a compounding factor that could affect infrastructure vulnerability in the Bay and Delta regions is the potential failure of levees currently protecting energy assets. A combination of subsidence from ground-water pumping and hydrocarbon extraction[60], tectonic activity and sea level rise could endanger the integrity of the Delta's 1,100 miles of levees.[61]

[59] WBCSD. March 2014. Building a Resilient Power Sector. Available at: http://www.wbcsd.org/resilience.aspx

[60] Faunt, C.C., Sneed, M., Traum, J. and J.T. Brandt. 2015. Water availability and land subsidence in the Central Valley, California, USA. Hydrogeology Journal 24: 675-684. Available at: http://link.springer.com/article/10.1007%2Fs10040-015-1339-x

[61] Risky Business Project. 2015. The Economic Risks of Climate Change in the United States: From Boom to Bust? Climate Risk in the Golden State. Available at: http://riskybusiness.org/report/from-boom-to-bust-climate-risk-in-the-golden-state/

Heavy precipitation events in the United States are likely to become twice as frequent by the end of the century, with the greatest increases in frequency occurring in the Northeast, Midwest, Northwest, and Alaska.[62] Although California is in one of the areas expecting the lowest increase in extreme storm events, the effects of these storms are compounded when paired with the impacts of other climatic conditions such as drought, temperature rise and, in particular, sea level rise.

Despite the potential for storm impacts and levee failure, research suggests that there is little consensus on how climate change will affect the severity of storms in the northeast Pacific. Even if the frequency of storms does not increase over time, sea level rise will amplify storm surges and high waves along the California coast,[63] putting coastal energy infrastructure at risk.

Asset Impact Analysis

Major storm events have the potential to damage energy infrastructure critical to SMUD's assets and operations, including the following storm impacts:

- **El Niño:** large El Niño events during the winter months will create high tides and raised sea levels.[64]
- **Drought:** Droughts in the state, if they continue, will likely intensify the impacts of heavy precipitation events.
- **Temperature Rise and Precipitation:** Temperature rise will further complicate major winter storms by causing more precipitation to fall as rain instead of snow. Storms coming off of the Pacific can drop more than 100 inches of snow in the mountains, which could be more than 10 inches worth of perceptible water,[65] an impact that could affect the potential for flooding in the region.
- **Wind:** Increasingly frequent storm events can also bring extreme winds, which can damage transmission and distribution lines and wind turbines.[66]

Even though extreme weather and sea level rise may not directly impact SMUD assets, SMUD should be cognizant of these issues as they could affect other utilities' assets upon which SMUD is dependent.

[62] Kharin, V.V., F.W. Zwiers, X. Zhang, M. Wehrner. 2013. "Changes in Temperature and Precipitation Extremes in the CMIP5 Ensemble." Climatic Change 119: 345–357. Available at: http://link.springer.com/article/10.1007/s10584-013-0705-8

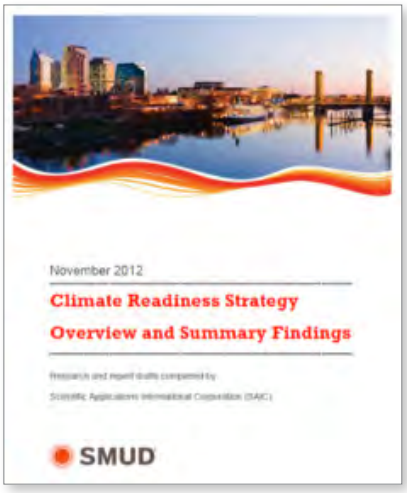
[63] NRC (National Research Council). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Washington, DC: The National Academies Press. Available at: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/sea-level-rise-brief-final.pdf.

[64] NRC (National Research Council). 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Washington, DC: The National Academies Press. Available at: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/sea-level-rise-brief-final.pdf

[65] Bales, R., Rice, R. 2012. California is Home to Extreme Weather, Too. University of California, Merced. Available at: http://www.ucmerced.edu/news/california-home-extreme-weather-too

[66] WBCSD. March 2014. Building a Resilient Power Sector. Available at: http://www.wbcsd.org/resilience.aspx

Action Plan to Address Climate Risks



SECTION I.
SMUD'S WORK TO DATE TO ADDRESS CLIMATE CHANGE

Since the completion of its 2012 Climate Readiness Strategy, SMUD has undertaken a broad array of initiatives to mitigate risks and improve our climate readiness. SMUD has used the information gathered for this report to update its understanding of the potential impacts of climate change to its operations and to community stakeholders and to guide continued development of its climate change readiness strategy.

As the 2016 working group reviewed and discussed the updated findings, they provided ideas for new programs and projects that could help reduce climate risks for SMUD and our customers. In addition, team members provided insight into projects underway or planned within their departments that are expected to deliver adaptive benefits, now or in the future. In an effort to ensure organizational and fiscal efficiency, the project team undertook an analysis of major SMUD strategic planning efforts and funded capital projects to capture all the major initiatives expected to help improve climate readiness. SMUD used all of this input to establish the elements of its readiness plan.

Our readiness plan builds and expands existing efforts across five different components of the organization:

1. Community engagement;
2. Enterprise programs;
3. Capital projects;
4. Operational Initiatives; and
5. Monitoring and Evaluation.

These initiatives are summarized in Table 6 below:

Table 6. Action Plan Components, Impacts Addressed and Timeframe

Plan Component	Title	Impacts Addressed	Timeframe
Community Engagement	Capital Region Climate Readiness Collaborative	All	Ongoing
Community Engagement	Regional Urban Heat Island Initiative	Temperature	Beginning 2017
Community Engagement	Regional Biosequestration	All	Begin Dec. 2017
Enterprise Program	Sacramento Resilient Grid Initiative (REDI Grant)	Flooding	Complete Dec. 2017
Enterprise Program	Climate Change And Enterprise Risk Management	All	Monthly Review
Enterprise Program	Customer Evaluation Research and Program Metrics	All	Complete 2017
Enterprise Program	Environmental Sustainability	All	Complete Dec. 2020
Enterprise Program	Long Range Asset Management Plan	All	Complete 2017
Enterprise Program	Focused Climate Research	Hydrology, Wind	To be Determined
Enterprise Program	Contract Climate Exposure Evaluation	All	Pilot Launch 2017
Enterprise Program	Flood Data Analysis and Preparedness Planning	Flooding	Complete 2017
Enterprise Program	Emergency Preparedness	All	Ongoing
Capital Project	SPA County Recycled Water Project	Drought, Hydrology	Fall 2017
Capital Project	SMUD Nature preserve Mitigation Bank	Native Species	Operational 2014 Monitoring Through 2017
Capital Project	SMUD Headquarters Design and Renovation	All	Renovation Began 2016
Operational Initiative	Forest Thinning, Stream and Revenue Flows in UARP	Wildfire	2017 - 2021
Operational Initiative	Unmanned Aerial Systems Risk Identification Program	Wildfire	Annual
Operational Initiative	Cloud Seeding	Drought	Annual
Operational Initiative	Hydropower Risk Mitigation Strategies	Drought, Hydrology, Wildfire	Ongoing
Operational Initiative	SMUD Cool Roof Incentive	Temperature	Ongoing
Operational Initiative	SMUD Shade Tree Program	Temperature	Ongoing
Operational Initiative	Savings By Design ILFI Incentive	All	Ongoing
Operational Initiative	AB327 / More than Smart Grid Modernization Research	All	2016-2020
Operational Initiative	Distributed Energy Resource Strategy	All	2016-2020

SECTION II. COMMUNITY ENGAGEMENT

Beyond its work on a national scale, through the DOE Partnership, SMUD participates in many local community partnerships. For example, SMUD is a founding member of the Capital Region Climate Readiness Collaborative, which brings together leaders from government, business, academia, labor, and community groups to drive climate change resiliency. SMUD has two employees on the steering committee, which serves as the primary governing and decision-making body for the Collaborative. Additionally, SMUD is assisting the Collaborative's efforts to improve energy efficiency, electricity and grid resiliency and public health through its development of an urban heat island initiative.

In the past, SMUD has provided data to university and national lab researchers, and contributed to research by the California Climate Change Center and other efforts. For example, SMUD has provided data for long-range energy alternatives planning (LEAP) and water evaluation and planning (WEAP) modeling, and contributed to the California Energy Commission's (CEC) Public Interest Energy Research (PIER) program research. SMUD plans to continue supporting climate change vulnerability and resiliency research throughout California.

SMUD also engages with customers through efficiency, rebate, and offset programs. Through a grant from the DOE, SMUD offers customers a low cost appraisal of overall energy efficiency in their homes and provides up to $9,000/home in incentives for home energy improvements. Customers can use SMUD's 'Greenergy' program to choose how much of their electricity needs are met through renewable energy sources or purchase carbon offsets that support local projects to reduce carbon emissions. SMUD also has a Community Solar program, which provides solar to local schools, non-profit organizations and low-income housing organizations such as Habitat for Humanity, through a partnership with its customers.

Capital Region Climate Readiness Collaborative (CRCRC)

One of the recommendations contained in the 2012 Climate Readiness Strategy was to support the formation and growth of regional climate readiness efforts. At the time, a regional group was forming to focus on climate adaptation, spearheaded by the Sacramento Metropolitan Air Quality Management District (SMAQMD), UC Davis, Valley Vision and the Local Government Commission. SMUD staff became actively involved to assist, and since that time the Capital Region Climate Readiness Collaborative has grown to include 26 members from both the public and the private sectors. The Collaborative helps stakeholders come together across market and jurisdictional boundaries to share information and best practices, leverage efforts and resources, avoid duplication, identify critical needs and strategies, and develop funding strategies. By developing and implementing a set of comprehensive adaptation strategies, the region can increase its resilience, protect its unique resources and assets, strengthen its economy, leverage new opportunities, and ensure a healthy and prosperous future. CRCRC also represents the region within the Alliance of Regional Collaboratives for Climate Adaptation, a statewide group working to coordinate regional efforts and guide state policy to be more responsive to regional climate concerns.

Regional Urban Heat Island Initiative

Recent Cal EPA research identifies the areas within SMUD service territory that currently experience the most intense urban heat island effect, which will be exacerbated by increasing average temperatures in the region. In 2017, the Capital Region Climate Readiness Collaborative will define the scientific basis and additional research needs for a joint effort with regional partners to more precisely identify the sources of the heat and the projected impacts on electrical load and health. This work will enable mitigation measures (cool roofs, pavements and urban greening) to be more effectively targeted and used to greatest effect. This initiative will be managed by the CRCRC and involve a broad range of local partners including health systems, SMAQMD, the Sacramento Tree Foundation, the local roofing industry and local governments.

Regional Biosequestration

To support both climate mitigation and adaptation, SMUD has begun investigating ways to sequester carbon that can restore natural systems and provide cleaner air, cleaner water, flood protection and expanded wildlife habitat and protection of agricultural and range lands in and around our service territory. Based on initial research conducted in 2013 and 2014 on the largest potential for local carbon offset project development and the major opportunities for regional carbon neutrality, ER&D staff began more detailed research into the potential for public-private partnership to accelerate carbon sequestration in the land base. This project is anticipated to be a significant focus in 2017 and beyond. Potential project partners may include the Sacramento Area Council of Governments, Sacramento County, Placer Land Trust, Placer County Air Pollution Control District, Sacramento–San Joaquin Delta Conservancy, Natomas Basin Conservancy, American River Conservancy, Rangeland Trust, Nature Conservancy and others.

SECTION III. ENTERPRISE RISK MITIGATION STRATEGIES

SMUD has established plans to manage overall system reliability and consider factors that will be more dynamic with a changing climate. These plans are based on criteria for maintaining system capacity sufficient to reliably serve load during extreme and emergency events, such as during heat storms, and consider reduced generator performance and transformer capacity and critically dry water year impacts on hydro-generation.

Additionally, SMUD maintains emergency response plans and actively engages with other emergency planning efforts in the region. Currently, SMUD's overarching strategy revolves around SMUD's Resilient Grid Initiative, outlined below. In addition, SMUD takes actions to address specific risks associated with climate change, such as ambient temperature change, rising severity of wildfires, and changes to regional hydrology.

Sacramento Resilient Grid Initiative (REDI Grant)

SMUD is executing a contract with DOE to receive grant funds as part of the Sacramento Resilient Initiative (REDI Grant). This work will improve grid resiliency by implementing smart grid technologies and strategies that will increase grid availability, improve grid efficiency and increase reliability. This project will include the installation and commission of eight to ten automated 69kV switches with reinforced poles and SCADA in selected flood prone areas and up to twenty low-voltage correction devices to demonstrate advanced conservation voltage reduction (CVR) for peak load reduction on a select number of SCADA enabled substations. The project also includes the operation of equipment for pilot demonstrations and documentation and validation of results. In 2016, the project is accelerating and expanding due to an unexpected increase in the number of car-pole accidents, downed trees (potentially due to extended drought) and outages affecting larger groups of customers. A total of 45 automated switches are planned for installation by mid-2017.

Climate Change & Enterprise Risk Management

SMUD operates in an inherently risky environment. By strategically managing risk, we can reduce the chance of loss, create greater financial stability and protect our resources so we can support the organization's mission, creating more value for our customers. Under the purview of SMUD's Chief Financial Officer, the Enterprise Risk Management Office (ERMO) coordinates the management of SMUD's portfolio of risk. ERMO helps to maintain an early warning system to monitor changes in, and the emergence of risks that affect the organization's business objectives. As a part of this strategic approach to managing risk, the ERMO provides a framework to support business units in identifying, assessing, mitigating, monitoring and escalating risk. The risks in the framework are evaluated and updates provided to the SMUD Board of Directors on a monthly basis. In 2013, the category 'Climate Changes' was added to the framework to ensure ongoing analysis of scientific findings regarding the climate impacts relevant to SMUD. This drives the four year cycle of scientific literature review and analysis conducted by SMUD's Energy Research & Development department with review and input from a cross-functional working group and interim analysis conducted as needed. The research supports the ongoing organizational assessment and monitoring of climate risks as they evolve.

Customer Program Evaluation and Metrics Research

In 2016, SMUD Customer Strategy staff undertook a comprehensive analysis of existing customer facing programs, evaluating their performance against four points of SMUD's "North Star" guiding principles: "Financially Fit," "Operational Excellence," "Value our Customers and Community," and "Sustainable Future." The results of this analysis are still being discussed and considered, but it is expected to influence program development and execution in the future. The analysis led to the realization that dollars and carbon were the only common denominators available to compare results of very disparate programs, such as electric vehicle charging and Shade Trees. Some of SMUD's most popular programs don't deliver kWh savings, historically a standard utility program evaluation metric. In addition, already there are hours of the day in certain seasons in which renewable electricity supplies are abundant, and incentivizing additional kWh savings during those times is becoming counterintuitive. Recognizing this challenge, as well as the California regulatory environment with its shifting emphasis on meeting the state's carbon targets, SMUD started a new research project to explore various methodologies for development of a parallel cost- and carbon-accounting framework. Such a framework could be used by SMUD's incentive program managers and planners to better capture costs and benefits and to show alignment with internal, state and regional greenhouse gas reduction targets. The research is underway and expected to be completed in early 2017. If implemented, these metrics will support more transparent carbon reduction activities which are important steps towards building a "climate ready" utility and community.

Environmental Sustainability Program

This project is developing and will implement SMUD's overall Environmental Sustainability Program, including a five-year plan to inform, focus and coordinate our efforts while strategically addressing any gaps. Physical impacts of climate change have been addressed as part of the process, in addition to opportunities for greenhouse gas mitigation. This effort is intended to engage employees across SMUD to enhance SMUD's environmental efforts and readiness for climate change and to establish a model for other entities.

Long Range Asset Management Plan

This program will develop a SMUD long range asset plan that identifies current assets and provides a plan for the development of lands, infrastructure and services to support the population growth and changing business needs of SMUD's employees and community. The Asset and Vision Plan will guide the strategic development and use of all SMUD lands, assets and infrastructure. The long range plan will develop a comprehensive evaluation of infrastructure requirements needed to meet SMUD's mission to provide our customers with reliable electricity at affordable rates. It will also provide a timeline for the development of future campus-specific master plans beginning with the SMUD Headquarters Campus, with a programmatic Environmental Impact Report created to address the master plans at other campuses and the proposed projects that result. Projected changes in climate will be directly addressed in each of these master plans as they are developed. Importantly, each master plan will be re-evaluated every five years, so evolving climate change research and impact findings will be incorporated and the documents modified accordingly.

Focused Climate Research

Projections of temperature and extreme events likely to impact SMUD's generation and service territory are becoming clear, but projections of precipitation and wind are uncertain. Drawing conclusions is complicated by SMUD's location, straddling two NOAA climate zones. To the north, wetter conditions are anticipated; to the south, a drying trend. Historical observations at SMUD's hydropower project show spring snowmelt trending earlier but no clear increase or decrease in seasonal precipitation volume. Similarly, no studies have been made of wind patterns which influence SMUD's wind power project and the cooling "delta breeze" so influential in summer evening air conditioning demand. Better information and increased confidence in the expected direction of precipitation and wind trends would inform long-term energy planning and guide investment strategy. Because of the importance of hydro and wind to SMUD's energy supply portfolio, staff will seek collaborative research partners and opportunities focused on identifying trends in these resources.

Contract Climate Exposure Evaluation - Energy Trading & Contracts

SMUD's Energy Trading & Contracts department establishes long-term agreements for purchased power, which makes up a significant portion of SMUD's energy supply. Projects that supply such power are located in multiple climate zones and may experience unique physical impacts from climate change. Some of these changes could alter project performance over the course of a 20-30 year agreement, by changing overall project efficiency and output, feedstock availability or storm vulnerability, for example. SMUD is exploring the introduction of a new element in its Request for Offer process, in which project developers will be asked to provide information on the projected climate impacts to their projects for the duration of the proposed agreement. This evaluation process will be developed in 2017 and piloted for a period of time to determine the quality of the information received and establish an internal process to evaluate it so that it can be utilized effectively. After an assessment of this pilot experience, a determination will be made regarding implementation of the new evaluation criteria on an ongoing basis.

Flood Data Analysis and Preparedness Planning

In 2014, SMUD's Grid Assets staff undertook an analysis of potential flood impacts to SMUD infrastructure, based on available Flood Depth and Evacuation maps published by the City of Sacramento Department of Utilities and the County of Sacramento. The analysis estimated the depth and timing of inundation associated with multiple potential levee break locations and identified the SMUD infrastructure that could be impacted. The study also estimated the number of SMUD field employees who reside in the projected flood zones. As a result of that work, Grid Assets staff are evaluating a proposal for a capital investment in the Hurley Substation, a critical distribution hub that is particularly vulnerable to flood. Also, the City of Sacramento recently updated the levee break scenarios and the flood maps, based on completed levee improvements. Grid Assets and GIS staff plan have begun importing the new maps, along with an update to the Federal Emergency Management Agency Flood Insurance Rate Maps (FEMA FIRM), and will complete an update of the infrastructure and human resource analysis by early 2017. This effort will include a review of insurance requirements, facility designs and relevant building codes, as well as identification of any additional recommended infrastructure investments. SMUD staff expect to conduct this analysis on an as needed basis, as significant modifications to flood maps become available. SMUD will also continue to coordinate with the City of Sacramento on the locations of SMUD's critical facilities such that if a warning occurs in an area of concern, the City can immediately relay the emergency situation to SMUD in an expeditious manner.

Emergency Preparedness

SMUD operational and emergency preparedness groups have established plans to manage overall system reliability and consider factors that will be more dynamic with a changing climate. These operational requirements at the federal and state levels already consider extreme events during planning. These plans are based on criteria for maintaining system capacity sufficient to reliably serve load during extreme and emergency events, such as during heat storms and major winter storm events. They consider reduced generator performance and transformer capacity and critically dry water year impacts on hydro-generation. Additionally, SMUD maintains emergency response plans for multi-hazard response and actively engages with other emergency planning efforts in the region developed by local governments, the State of California, and federal agencies under Emergency Support Function Twelve (ESF-12). Notably, however, cooperative planning in emergency response is limited to a near-term planning horizon, and climate change is generally not a topic of discussion among regional participants. This presents a challenge to more informed discussion about alternatives to be more proactive to long-term climate changes. As impacts from extreme weather events, floods and wildfires become more regular and have greater intensity, SMUD and others will need to appropriate growing resources for mitigation, preparedness and response. We expect this coordination to enhance over time as current implausible events become more commonplace.

SECTION IV. CAPITAL PROJECTS

SMUD has an ongoing capital program that mitigates risks associated with the physical impacts of climate change. These include typical ongoing infrastructure maintenance at substations, replacement of utility poles damaged by storms and replacement of vaulted transformers. In addition we have several atypical projects that mitigate the risk of drought and threats to native species from climate change.

Sacramento Power Authority County Recycled Water Reclamation Contract

In 2016 SMUD began the permitting, design and construction of a recycled water interconnection and appropriate plant facilities at the Sacramento Power Authority (SPA) cogeneration plant. This project will allow for the use of the Sacramento Regional County Sanitation District's Title 22 recycled water for plant cooling and fire protection, saving up to a million gallons of potable water per day. The interconnection project will be completed in early 2017 and the first recycled water deliveries are expected in late 2017. This project will significantly reduce the SPA use of City of Sacramento potable water.

SMUD Nature Preserve Mitigation Bank

This multi-year project will provide endangered species mitigation for future SMUD infrastructure projects in SMUD's service territory, providing valuable protections to species that will become increasingly threatened as a result of climate change. The market value of the Mitigation Bank is approximately $26 million in endangered species and habitat mitigation credits. SMUD has the option to sell credits to 3rd parties, providing a regional land preservation and protection resource and providing a safe preserve for listed species. Site monitoring began in 2011 and the Mitigation Bank was officially established in 2014. Five years of interim monitoring is required and is anticipated to be completed in 2017. SMUD intends to maintain this Bank in perpetuity, supported by an endowment fund.

SMUD Headquarters Building and Site Rehabilitation Project

Almost 60 years ago the SMUD Headquarters facility, including a 131,495 square foot building and a 13.66 acre site, opened to provide administrative offices and parking for the growing utility company. In 2010, the Headquarters Building was listed on the National Register of Historic Places for its timeless design in the Modern International Style. Located near downtown Sacramento, the Headquarters Facility is situated on a campus that includes the Customer Service Center, space for Board meetings, a cafeteria, a Fitness Center, mature trees and landscaping, as well as parking. The rehabilitation project, started in 2015, will bring the facility into compliance with respect to current codes for life safety, fire safety, seismic safety, energy, green building, disability access, security, etc. The major building systems, namely mechanical, electrical, plumbing, will also be replaced.

Additionally, the work environment within SMUD is changing and requires more meeting spaces and work areas to promote collaboration and streamlined internal communication, cultural norms critical to SMUD's ability to respond quickly to climate challenges. Flexible use of space and sustainability are important guiding principles for the rehabilitation project which will allow the Headquarters to function safely and securely for the next 50 years. SMUD plans to pursue a Leadership in Energy and Environmental Design (LEED) Gold V4.0 Building Design and Construction (BD+C) Certification. Examples of building and site features under consideration to help ensure a "climate ready" design include:

- Building commissioning and sub-metering for enhanced energy efficiency and performance.
- Sophisticated lighting strategies including LED and advanced lighting controls such as personal controls, tuning, day light harvesting and occupancy sensors.
- Water efficient landscape design and irrigation utilizing non-potable water systems sourced from rooftop harvesting or other means, as well as the use of drought-tolerant plants.

SECTION V. OPERATIONAL INITIATIVES

Stakeholders generally think about climate adaptation in terms of large scale capital projects but more often it is operational initiatives that can greatly improve climate readiness. Some of these are long-practiced measures such as unmanned aerial systems risk identification, cloud seeding or hydropower risk mitigation strategies. Others are responses to rapid changes in the nature of the electric utility sector such as the rapid adoption of distributed energy resources.

Forest Thinning, Stream and Revenue Flows in UARP

UC Merced research indicates that a 10% reduction in forest biomass can suppress wildfire and result in a 10% increase in stream flows, but results are watershed/microclimate specific. This project will work with landowners and other stakeholders in the UARP to establish specific forest thinning study areas for data collection, document baseline and post-treatment conditions, and evaluate results. Calibration with existing general and/or remote estimation techniques (such as temperature, leaf cover, etc.) will be completed as well, to better understand the cost/benefit of remote sensing technologies and forest management regimes. Finally, results of the study can help determine the viability of a "Resilience Bond" form of project funding, by modeling and monetizing the risk reduction benefits of the project. Resilience bonds could allow SMUD or other funding partners to finance adaptation efforts through rebates in insurance premiums.

Unmanned Aerial Systems Risk Identification Program

SMUD has begun utilizing Unmanned Aerial Systems (UAS, also known as drone technology) to improve information about its transmission and distribution assets and reduce wildfire risk. This program will acquire aerial video and photos for routine maintenance in monitoring and analyzing overhead transmission facilities and plants along rights-of-way in Sacramento and El Dorado counties. UAS technology delivers significant operational efficiency and improved safety to SMUD, our customers, employees and the community. Much of the urban and Sierra Nevada forest has been damaged by years of drought and other factors. Trees, especially dead and dying, can fall into transmission lines and create public safety and electric reliability concerns. The UAS can identify drought-related dead or dying vegetation under or near transmission lines for priority removal. On an ongoing basis, the drones will help SMUD identify trees and other plants to be pruned or removed prior to storm season and determine clearance space between vegetation and transmission lines. Routine maintenance reduces outages and enhances reliability, and also aids in fire protection and prevention efforts. UAS technology costs much less than conventional monitoring, which can require traditional helicopter flights. SMUD will seek available grants from the California governor's office for analysis of fire danger associated with tree mortality to complement the efforts. The U.S. Forest Service and Sierra Pacific Industries may be end users of the analysis to help determine vegetation mortality rates. The use of drones will complement SMUD's continued use of LIDAR (Light Detection and Ranging) technology.

Cloud Seeding

Since 1969, SMUD has utilized cloud seeding techniques to increase precipitation and raise reservoir water levels in the UARP hydropower project. SMUD estimates that each inch of precipitation results in 35,000 megawatt hours (MWh) of generation, so storm events are critical to SMUD's supply portfolio. Cloud seeding involves the stationary or aerial release of silver iodide during winter storm events, which can enhance the capacity of clouds to deliver precipitation. Thirteen other hydropower project operators in California have used cloud seeding, making it a fairly common practice. Accurately tracking the direct result of a cloud seeding operation is challenging, however various experiments have estimated the range of impact to be a 5-10% increase in precipitation in the treated area. Due to the challenge of long-term drought conditions projected for the region, SMUD staff expects to continue cloud seeding operations in the UARP and to add additional performance measurements to track the results.

Hydropower Risk Mitigation Strategies

SMUD utilizes two hydropower risk mitigation strategies to address uncertainties and natural variation in water years, the Hydro Rate Stabilization Fund (HRSF)/Hydro Generation Adjustment (HGA), and the WAPA Base Resource Rate Stabilization Fund (RSF). The Hydro Rate Stabilization Fund (HRSF)/Hydro Generation Adjustment (HGA) are financial instruments used to mitigate the increase in energy supply costs due to the loss of UARP generation experienced in lower than normal water years. SMUD deposits money into the HRSF during wetter than normal years and draws money out during drier than normal years. If the HRSF is depleted, the HGA allows for a rate increase to be levied on customer bills. In extremely wet years, a credit can be levied on customer bills. In recent drought conditions, the HRSF/HGA has provided funds to purchase replacement power for lost UARP generation, minimizing impacts to SMUD's energy supply costs. The RSF is another commodity supply cost hedging instrument used to mitigate against lower than normal deliveries from SMUD's largest contracted hydroelectric resource, the WAPA Base Resource. Similar to the HRSF, SMUD deposits money into the RSF in years where energy deliveries from the WAPA BR exceed budgeted energy; in years where energy deliveries are less than budgeted, SMUD may draw on the RSF to help pay for replacement power costs. In addition to the HRSF/HGA and the RSF, SMUD procures precipitation insurance to mitigate impacts to energy supply costs during extreme draught conditions which fall outside normal year-to-year precipitation variation. SMUD refers to these insurance policies as "Precipitation Tail Insurance" as they hedge the left most tail of possible precipitation outcomes. SMUD staff expect to continue utilizing such instruments, with adjustments as necessary based on market conditions, new product offerings and Board of Director approval as required.

SMUD Cool Roof Incentive

Cool roof installations can reduce building energy use and combat the urban heat island effect, which is already significant. Since 2006, SMUD has offered rebates to residential customers who use cool roofing technologies. In 2016, in an effort to expand the reach and impact of the program, incentives were doubled and program standards modified. The utility offers a 30-cent-per-square-foot rebate to customers who own single-family, multi-family, or mobile homes with flat roofs. The rebate for sloped roofs is 10 or 20 cents per square foot, depending on the reflectivity and/or emissivity of the product used. Under this program, a single family could earn a $300 rebate (or more) for incorporating a cool roof, and save an estimated $50 per year on their annual cooling bill. Program utilization has more than doubled in 2016, although it is still quite modest.

SMUD Shade Tree Program

Since 1990, the Sacramento Municipal Utility District (SMUD) has partnered with the Sacramento Tree Foundation to provide more than 1,000,000 free shade trees to residents in the Sacramento area. This program encourages residents to strategically plant vegetation around their homes to reduce energy consumption. Homes with an eastern, western, or southern exposure that heats up during the summer are eligible for this program. SMUD provides trees between four and seven feet tall (1.2–2.2 meters), as well as stakes, ties, fertilizer, tree delivery, and expert advice on tree selection and planting techniques free of charge. Homeowners must agree to plant and care for the trees.

Savings by Design International Living Future Incentive

In 2016, SMUD began offering a Savings by Design incentive supplement for qualified construction or renovation projects attempting the Energy Petal of the Living Building Challenge. The International Living Futures Institute (ILFI) is an ambitious certification program driving net zero energy and water use for buildings and communities. ILFI has created a Living Building Challenge and a Living Community Challenge which require projects to submit one full year of performance data in order to achieve certification. The Building challenge prohibits fossil fuel use and requires 105% of electricity demand to be supplied onsite. ILFI homes and businesses could support demand response and distributed generation programs in the future and help build the market for all electric homes. There is a small collaborative of ILFI practitioners in the Sacramento region which formed to learn more about the program and share experience. SMUD hosted an all day workshop on the Living Building Challenge in its Energy & Technology Center in October 2016, with plans for additional instruction in the future.

AB327 / More than Smart Grid Modernization Research

SMUD's current distribution planning processes utilize traditional infrastructure to meet capacity, reliability, and power quality requirements. While it doesn't technically apply to SMUD, California's Assembly Bill 327 requires the state's investor owned utilities to also consider DER as part of this planning process when they are economically competitive with traditional solutions. The overall goal of this project is for SMUD to build the capability to pursue similar DER alternative assessments and project deployments. This broadens distribution planning efforts to consider DER alternatives when cost effective in comparison to traditional projects and includes distribution infrastructure deferral demonstrations using DER. Research will help to determine how DER can address the technical and operational needs of traditional infrastructure and develop a locational & temporal valuation methodology for DER for projects, planning, & operations. These findings will help drive the creation of sustainable business models to support expansion of distributed generation, thus increasing adaptive energy capacity in the region. This program is beginning in 2016 and is expected to continue through 2020.

Distributed Energy Resource (DER) Strategy

The expected rapid expansion in adoption of distributed energy resources has important implications for SMUD's energy generation and distribution. Managing this expansion well can yield important benefits for climate readiness, reducing load in some cases and increasing potential for electrification in others, providing redundant generation resources and allowing the utility to limit and isolate grid outages. With the right controls schemes in place, distributed generation has the potential to increase resilience by reducing dependence on a small number of centralized sources of electricity. The reliability of the electric grid will likely become even more important as building and transportation electrification trends intensify. Expanded focus on energy efficiency and demand response programs can help reduce summer cooling bills and improve customer comfort in the midst of higher summer average temperatures and longer, more frequent heat storms. Opportunities for vehicle battery-to-home energy usage are just beginning to be explored and hold potential for providing some of the benefits of stationary energy storage including back-up power in case of outages.

In 2015 SMUD launched a comprehensive program to address DER that includes strategies for distributed photovoltaics, improved demand response, advanced energy storage, electric vehicles, energy efficiency and grid modernization. Between 2016 and 2020 multiple research projects, demonstrations and new program implementations are planned. Examples of projects currently under development as part of SMUD's DER strategy include:

- Expansion and diversification of SMUD's Solar Shares program, Residential and Commercial DER pilot projects, smart inverter research and Low-income PV partnerships are planned to advance cost-effective and grid supportive Distributed PV.
- Enhanced education and outreach, residential, commercial and multifamily incentives, DC fast charger incentives, managed charging for light and heavy duty vehicles are expected to accelerate adoption of electric vehicles in the Sacramento region.
- Increasingly challenging energy efficiency goals will drive expanded investment in energy efficiency offerings for our customers. These goals will be accomplished with improved data analytics, electrification of gas end-uses including all-electric homes, and expansion of pay for performance models. In addition, a new energy efficiency metering platform will leverage AMI interval data and provide near real-time measurement and verification and improved portfolio planning, helping reduce costs and improve performance of programs.
- Demand response programs will focus initially on expansion of current commercial and residential programs, eventually enlisting aggregators to guarantee resource performance, integrating with SMUD's Distributed Energy Resource Management System (DERMS) and Time of Use/Critical Peak Pricing Rates.
- Anticipating significant cost declines in energy storage, programs are in development that will help determine optimal commercial and residential business models, rates and incentives and system siting for multiple benefit streams.

SECTION VI. PLANS FOR MONITORING AND EVALUATING

As SMUD crafted a plan for meeting its readiness objectives it needed to establish a monitoring and evaluation framework that met the following criteria:

- Implementable;
- Intuitive so that they would be understandable to internal and external stakeholders;
- Usable in a planning context;
- Informative for decision making;
- Material; and
- Includes only a manageable number of performance metrics.

In 2013, the category Climate Changes was added to SMUD's Enterprise Risk Management Framework (ERMF). Upon reflection it became clear that this framework could become an invaluable tool for monitoring and evaluation of our readiness plans. Thus, we are in the process of adding additional detail on the climate indicators assessed in this report to the ERMF. For each indicator, the probability/likelihood, impact/consequence and velocity of the indicator will be ranked on a scale of one to five. Velocity represents the pace at which we expect these threats to occur and is combined with likelihood and then multiplied by impact to derive a normalized aggregate value for inherent (without mitigation) risk. Mitigation options for each inherent risk are then evaluated and where implemented, risk is recalculated using the same formula to derive residual risk. These rankings are reviewed annually to evaluate efficacy of mitigation measures, new potential risks, remaining residual risk and potential additional mitigation measures required.

Potential Areas of Additional Work

SMUD has made significant progress in improving its climate readiness since our first climate impact and readiness study was undertaken in 2008. But we believe there remains much to learn and we are committed to continuously improving our readiness on behalf of our customers, community and stakeholders. Areas of additional work that we may pursue include:

- More detailed cost-benefit analysis of our action plan elements, as appropriate;
- Improved downscaling of climate impacts for our service territory and other critical locations;
- Ongoing monitoring of our climate related risks and progress of our mitigation actions, with adjustments as needed;
- Cost-benefit analysis of drought impacts on hydroelectric generation;
- Further analysis of post-wildfire risks of landslide and debris flow;
- Improved assessments of regional carbon sequestration potential and research to support expanded offset protocols to support;
- Investigation of opportunities to employ resilience bonds to finance further readiness measures;
- Further collaborative research on potential changes to wind resources;
- Opportunities for expanding regional partnership and actions to reduce urban heat island;
- Better understanding of the future load impacts of distributed energy resources and their potential for reducing risks from the physical impacts of climate change.
- More systematic consideration of climate change projections in internal program planning and capital budget development and approval;
- Collaborative analysis of opportunities for coordinated community projects, identifying common objectives and leveraging planned spending with that of other public agencies.

References

Bales, R., Rice, R. 2012. *California is Home to Extreme Weather, Too.* University of California, Merced. Available at: http://www.ucmerced.edu/news/california-home-extreme-weather-too

Cal-Adapt. *Temperature: Extreme Heat Tool.* Accessed October 2016. Tool data provided by Scripps Institution of Oceanography. Available at: http://cal-adapt.org/temperature/heat/

California Climate Change Center. 2012. *Our Changing Climate 2012 Vulnerability & Adaptation to the Increasing Risks from Climate Change in California – Brochure.* CEC-500-2012-007. Available at: http://climatechange.ca.gov/climate_action_team/reports/third_assessment/

California Energy Commission. *Cal-Adapt Climate Tools.* Accessed September 2016. Available at: http://cal-adapt.org/tools/

California Energy Commission. January 2009. *Potential Impacts of Climate Change on California's Energy Infrastructure and Identification of Adaptation Measures.* CEC-150-2009-001. Available at http://www.energy.ca.gov/2009publications/CEC-150-2009-001/CEC-150-2009-001.PDF

California Energy Commission, *Creating and Mapping an Urban Heat Island Index for California*, prepared by Altostratus Inc., April 24, 2015, Available at http://www.calepa.ca.gov/UrbanHeat/Report/

California Natural Resources Agency. October 2015. *Draft Report - Safeguarding California: Implementing Action Plans.* Available at: http://resources.ca.gov/docs/climate/Safeguarding%20California_Implementation%20Action%20Plans%202015%20(CNRA).pdf

Duffy, P.B., Bartlett, J., Dracup, J., Freedman, J., Madani, K., Waight, K. 2014. *Climate Change Impacts on Generation of Wind, Solar, and Hydropower in California. California Energy Commission.* Available at: http://www.energy.ca.gov/2014publications/CEC-500-2014-111/CEC-500-2014-111.pdf

Elsner, M.E., Cuo, L., Voisin, B., JDeems, J.S., Hamlet, A.F., Vano, J.A., Mickelson, K.E.B., Lee, S.Y., and Lettenmaier, D.P. 2010. *Implications of 21st century climate change for the hydrology of Washington State.* Climatic Change 102(1-2): 225-260, doi: 10.1007/s10584-010-9855-0.

Faunt, C.C., Sneed, M., Traum, J. and J.T. Brandt. 2015. *Water availability and land subsidence in the Central Valley, California, USA.* Hydrogeology Journal 24: 675-684. Available at: http://link.springer.com/article/10.1007%2Fs10040-015-1339-x

Ficklin, D.L., Stewart, I.T., and Maurer, E.P. 2012. *Projections of 21st Century Sierra Nevada local hydrologic flow components using an ensemble of General Circulation Models.* Journal of the American Water Resources Association (JAWRA) 1-21. DOI: 10.1111/j.1752-1688.2012.00675.x

Garfin, G., Jardine, A., Merideth, R., Black, M., and LeRoy, S. 2013. *Assessment of Climate Change in the Southwestern United States. Island Press*. Available at: http://www.swcarr.arizona.edu/sites/all/themes/files/SW-NCA-color-FINALweb.pdf

Intergovernmental Panel on Climate Change. 2000. *IPCC Special Report Emissions Scenarios*. Available at: https://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

Intergovernmental Panel on Climate Change. 2013. *IPCC Fifth Assessment Report*, Chapter 9. Available at: http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter09_FINAL.pdf

Kharin, V.V., F.W. Zwiers, X. Zhang, M. Wehrner. 2013. *Changes in Temperature and Precipitation Extremes in the CMIP5 Ensemble*. Climatic Change 119: 345–357. Available at: http://link.springer.com/article/10.1007/s10584-013-0705-8

Knowles, N & Cayan, DR. 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. Geophysical Research Letters, 29(18), 1891 National Oceanic and Atmospheric Administration (NOAA) Drought Task Force. December 2014. *Causes and Predictability of the 2011-14 California Drought*. Available at: http://cpo.noaa.gov/MAPP/californiadroughtreport

Kristin Ralff-Douglas. January 2016. *Climate Adaptation in the Electric Sector: Vulnerability Assessments & Resiliency Plans*. Available at: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/PPD%20-%20Climate%20Adaptation%20Plans.pdf

Lawrence Berkely National Laboratory. 2012. *Estimating Risk to California Energy Infrastructure from Projected Climate Change*. Prepared for the California Energy Commission. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf

Largier, J., Cheng, B., Higgason, K. August 2011. *Climate Change Impacts: Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. U.S. Department of Commerce*. Available at: http://sanctuaries.noaa.gov/science/conservation/pdfs/climate_cbnms.pdf

National Marine Fisheries Service. Recovery Plan For the evolutionarily significant units of Sacramento River winter-run Chinook salmon and central valley spring-run chinook salmon and the distinct population segment of California central valley steelhead. Available at: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/california_central_valley/final_recovery_plan_07-11-2014.pdf

NRC (National Research Council). 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. Washington, DC: The National Academies Press. Available at: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/sea-level-rise-brief-final.pdf

Office of Governor Edmund G Brown Jr. 2015. *Governor Brown Establishes Most Ambitious Greenhouse Gas Reduction Target in North America*. Available at: https://www.gov.ca.gov/news.php?id=18938

Pierce, D. W. March 2012. *Probabilistic estimates of future changes in California*. Available at: http://woodland.ucsd.edu/wp-content/uploads/2013/10/Pierce_etal_2013_ClimDyn.pdf

Pierce, D.W., Das,T., Cayan, D.R., Maurer, E.P., Miller, N.L., Bao, Y., Kanamitsu M., Yoshimura, K., Snyder, M.A., Sloan, L.C., Franco, G, and Tyree, M. 2012. *Probabilistic estimates of future changes in California temperature and precipitation using statistical and dynamical downscaling*. Climate Dynamics 40: 839-56.

Pierce, D.W. and Cayan, D.R. 2013. T*he uneven response of different snow measures to human-induced climate warming*. Journal of Climate 26: 4148-4167.

Pierce, D.W., Das,T., Cayan, D.R., Maurer, E.P., Miller, N.L., Bao, Y., Kanamitsu M., Yoshimura, K., Snyder, M.A., Sloan, L.C., Franco, G, and Tyree, M. 2013. *The key role of heavy precipitation events in climate model disagreements of future annual precipitation changes in California*. Journal of Climate 26: 5879-5896.

Pacific Gas and Electric Company (PG&E). 2016. *Climate Change Vulnerability Assessment*. Available at: http://www.pgecurrents.com/wp-content/uploads/2016/02/PGE_climate_resilience.pdf

Risky Business Project. 2015. *The Economic Risks of Climate Change in the United States: From Boom to Bust? Climate Risk in the Golden State*. Available at: http://riskybusiness.org/report/from-boom-to-bust-climate-risk-in-the-golden-state/

Sacramento Area Flood Control Agency (SAFCA). *Flood History – Sacramento Flood Threat*. Accessed on July 11, 2016. http://www.safca.org/floodinsurance/faqs.html

Sacramento Municipal Utility District (SMUD). 2008. *Board Policy*. SD-7: Environmental Leaderships. Available at: https://www.smud.org/assets/documents/pdf/SD-7.pdf

Sacramento Municipal Utility District (SMUD). *Our Board of Directors*. Available at: https://www.smud.org/en/about-smud/company-information/board-of-directors/

Sacramento Municipal Utility District (SMUD). *Board Energy Resources & Customer Services Committee. Summary of SMUD's Grid Sustainability, Flood Response Plan*. Presented on April 30, 2014.

Sathaye, J. A., L. L. Dale, P. H. Larsen, G. A. Fitts, K. Koy, S. M. Lewis, and A. F. P. de Lucena. 2012. *Estimating Risk to California Energy Infrastructure from Projected Climate Change*. Sacramento, CA: California Energy Commission. July. Available at: http://www.energy.ca.gov/2012publications/CEC-500-2012-057/CEC-500-2012-057.pdf.

Sun F., Walton, D., and Hall, A. 2015. *A hybrid dynamical-statistical downscaling technique, part II: End-of-century warming projections predict a new climate state in the Los Angeles region*. Journal of Climate, 28(12): 4618-4636. DOI: 10.1175/JCLI-D-14-00197.1. Available at: http://research.atmos.ucla.edu/csrl/LA_project_summary.html

University of Cambridge. 2014. *Climate Change: Implications for the Energy Sector*. Available at: https://www.bmz.de/en/publications/type_of_publication/weitere_materialien/Implications_for_Energy_Briefing_WEB_EN.pdf

U.S. Department of Energy Office of Energy Policy and Systems Analysis. *Partnership for Energy Sector Climate Resilience*. Available at: http://energy.gov/epsa/partnership-energy-sector-climate-resilience

U.S. Department of Energy. 2015. *State of California: Energy Sector Risk Profile*. Washington, DC. Available at: http://www.energy.gov/sites/prod/files/2015/05/f22/CA-Energy%20Sector%20Risk%20Profile.pdf.

U.S. Drought Monitor. *GIS Data Archives: Drought Monitor Shapefiles for July 2001-2016*. Available at: http://droughtmonitor.unl.edu/MapsAndData/GISData.aspx

U.S. Environmental Protection Agency. 2016. *Sources of Greenhouse Gas Emissions*. Available at: https://www3.epa.gov/climatechange/ghgemissions/sources/industry.html

World Business Council for Sustainable Development (WBCSD). March 2014. *Building a Resilient Power Sector*. Available at: http://www.wbcsd.org/resilience.aspx

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FRENCH MEADOWS FOREST RESTORATION PROJECT

French Meadow Reservoir

A diverse partnership is working to advance the French Meadows Forest Restoration Project on public and private lands in the headwaters of the American River, west of Lake Tahoe. The partnership includes the Tahoe National Forest, which manages extensive lands in the project area; American River Conservancy, which owns over 10,000 acres adjacent to Forest Service lands; Placer County Water Agency, which manages two reservoirs downstream of the project for municipal water and power; The Nature Conservancy; Sierra Nevada Conservancy, a state agency; Placer County; and the Sierra Nevada Research Institute at the University of California, Merced.

The partners have developed a memorandum of understanding to advance ecologically based forest management in the American River Headwaters using an "all lands" approach. The goal is to increase the pace and scale of forest restoration in a critical municipal watershed by collaborating to develop project goals and direction, manage the project, contribute in-kind staff and expertise, and raise necessary funds. The project area includes lands managed by the Forest Service and lands owned by American River Conservancy.

Forest conditions in the area are unhealthy and at risk of uncharacteristic, high-severity wildfire due to past management, fire suppression, five years of drought, warmer temperatures, and a rapidly expanding bark beetle infestation resulting in millions of dead trees. Severe wildfires in recent years, just downstream of the project area, have caused hundreds of thousands of tons of topsoil to erode into the river system, clogging infrastructure and degrading wildlife habitat and watershed health.

The French Meadows Project aims to "get ahead of the curve" by accelerating ecologically based forest management to reduce wildfire risk and promote more resilient forest conditions. In addition, the Project includes an important research component to study the relationship between forest restoration and downstream water supply.

The partners are working together to raise funds from a variety of public and private sources. To date, the Forest Service and Placer County Water Agency have funded planning activities on public lands, American River Conservancy and The Nature Conservancy (with funding from Sierra Nevada Conservancy, among others) have supported restoration on private lands, and several corporate donors (including Nestle, PepsiCo, MillerCoors, and Coca Cola) have donated or committed funds to the restoration.

In addition, the partners are exploring opportunities to utilize the "Good Neighbor" authority contained in the 2014 Farm Bill, which allows state agencies to perform forest and watershed restoration on Forest Service lands. The California Natural Resources Agency has signed a Master Good Neighbor Agreement with the Forest Service to enable this kind of cooperative land management throughout the state.

Through this innovative collaboration, the partners hope to create a new model for advancing the pace and scale of forest and watershed restoration in the Sierra Nevada and across the western United States.

The Nature Conservancy

AMERICAN RIVER CONSERVANCY
Preserving Rivers and Land for Life

County of Placer

PCWA

Forest Service U.S. Department of Agriculture

Sierra Nevada Conservancy

UC Merced SNRI