Pacific Gas and Electric Company

Climate Change Vulnerability Assessment and Resilience Strategies

Together, Building
a Better California

NOVEMBER 2016

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About the report

Pacific Gas and Electric Company (PG&E) developed this report as part of its participation in the U.S. Department of Energy's Partnership for Energy Sector Climate Resilience—a voluntary, public-private program aimed at enhancing energy security against the impacts of extreme weather and climate change.

It updates PG&E's first *Climate Change Vulnerability Assessment* and shares PG&E's progress as the company examines the physical risks associated with climate change. It also describes and features the steps the company is taking to address these climate risks on behalf of the nearly 16 million Californians who count on PG&E for the energy that fuels their lives. To develop the report, PG&E used available scientific data, as well as the expertise of its own internal staff and best-practice benchmarks across the industry.

Background

Company overview

PG&E is one of the largest combined natural gas and electric companies in the United States. Based in San Francisco, with more than **23,000 employees**, the company delivers some of the nation's cleanest energy to nearly 16 million people throughout a **70,000-square-mile service area** in Northern and Central California.

PG&E serves **5.3 million electric distribution customers** and **4.4 million natural gas distribution customers**.

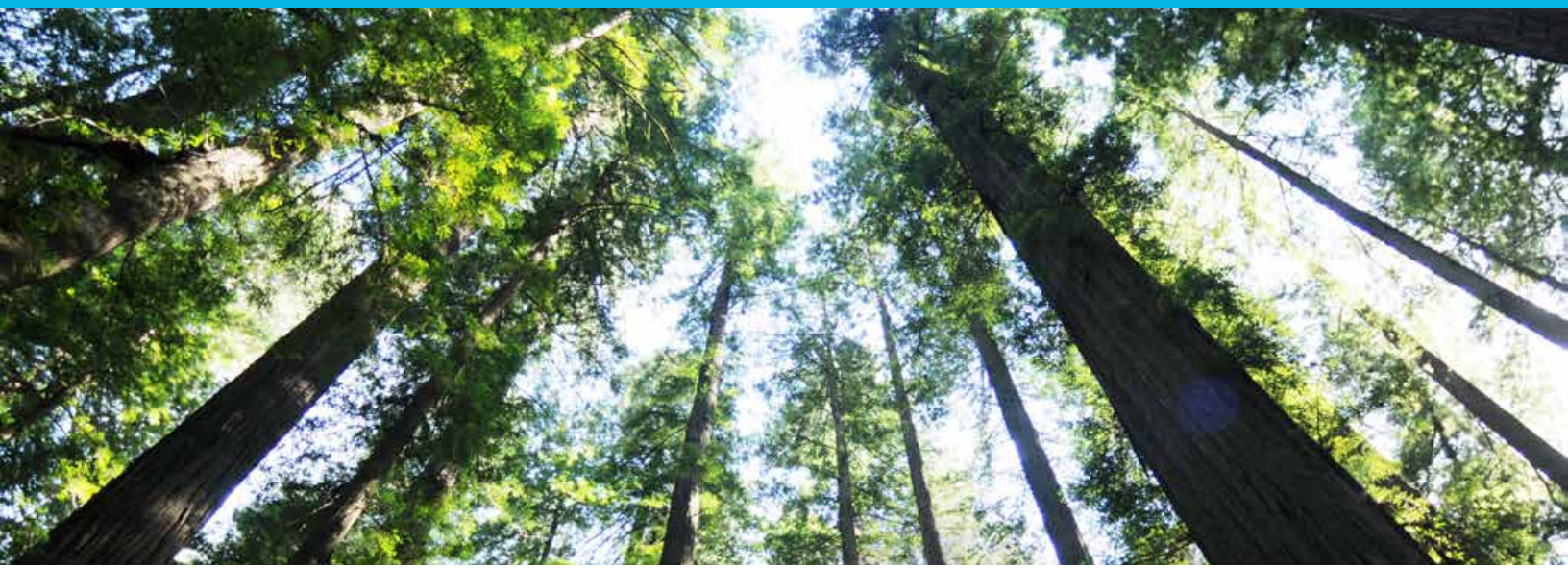
PG&E's system includes:
7,691MW of owned hydroelectric, nuclear, natural gas, solar, and fuel cell generation

Nation's largest investor-owned hydroelectric system, which relies on nearly **100 reservoirs** located primarily in the higher elevations of California's Sierra Nevada and Southern Cascade mountain ranges

Approximately **142,000 circuit miles** of electric distribution lines and approximately **18,400 circuit miles** of electric transmission lines

Approximately **42,800 miles** of gas distribution pipelines, **6,700 miles** of backbone and local gas transmission pipelines, and various gas storage facilities and station facilities, as well as liquefied natural gas (LNG) and compressed natural gas (CNG) portable supply capability

Based in San Francisco, PG&E delivers some of the nation's cleanest energy to nearly 16 million people in Northern and Central California



Increasing focus on climate change resilience

From extreme weather to rising tides, the threat that climate change poses to crucial sectors of the U.S. economy is becoming all too apparent. For energy providers such as PG&E, it requires taking action now to manage the potential risk to both the company's energy infrastructure and operations.

The solution lies in ensuring that PG&E's entire system—as well as the critical systems and supply chains PG&E depends on and the customers and communities it serves—are sufficiently resilient to withstand and recover from any climate-driven events.

PG&E has a long history of taking action to combat climate change and is strongly committed to building greater climate resilience. Doing so is integral to the company's ongoing efforts to provide safe, reliable, affordable and clean energy throughout Northern and Central California.

Building climate resilience is linked to PG&E's long-term success, business strategy, and operational objectives and actions. PG&E is working to better understand the future impacts of climate change and recognizes the need to be holistic, transparent and collaborative in its approach. PG&E is also working to establish an enhanced governance structure and integration across the company, building on the numerous measures already underway.

DEFINING CLIMATE RESILIENCE

For PG&E, climate resilience means understanding the impacts of climate change on its business and being prepared to withstand and rapidly recover from major disruptions to service driven by changing climate conditions and weather events—from near-term risks such as more frequent and extreme drought and wildfires to longer-term risks such as rising temperatures and sea levels.

Across the country, the level of response to climate impacts continues to grow. At the federal level, President Obama's Climate Action Plan, which outlines a comprehensive strategy to address climate change, includes a focus on activities to strengthen resilience to extreme weather and other climate impacts.

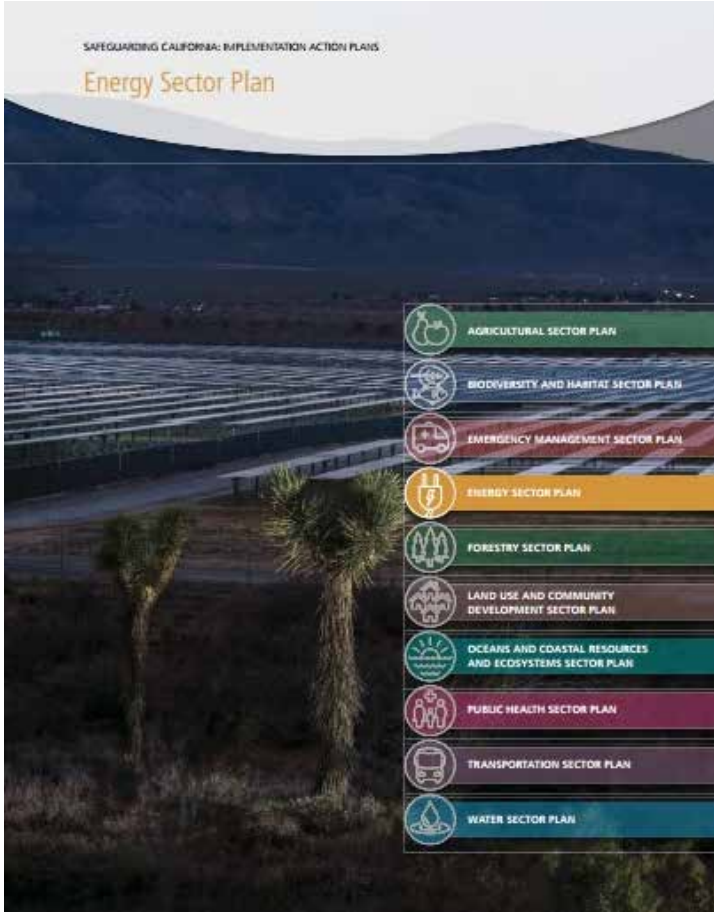
At the state level, California has demonstrated significant leadership, adopting and continuing to enhance a statewide Climate Adaptation Strategy that summarizes climate change impacts and recommends adaptation strategies. In April 2015, Governor Brown signed Executive Order B-30-15, which called for an adaptation plan for each sector of the economy. It also directed the state government to incorporate climate change impacts into the state's five-year infrastructure plan.

The report *Safeguarding California: Implementation Action Plans* establishes a plan for how California will prepare for and adapt to the catastrophic effects of climate change. The state has also conducted significant research, including formal climate change assessments, and developed tools and resources for climate adaptation planning. For example, Cal-Adapt is a web-based tool that allows users to identify potential climate change risks in specific geographic areas throughout the state.

An interagency Adaptation Working Group—which includes the California Public Utilities Commission, California Energy Commission, California Natural Resources Agency, California Office of Emergency Management and the Governor's Office of Planning and Research—is working to coordinate adaptation efforts across the energy sector. The Governor's Office of Planning and Research also established a technical advisory group to help state agencies incorporate climate change impacts into planning and investment decisions.

Additionally, several climate change resilience-related bills have recently become law in California, including Senate Bill 379, which requires local hazard mitigation plans developed by cities and counties to address climate adaptation and resilience.

Demonstrating local leadership, dozens of cities and counties in PG&E's service area have taken steps to strengthen climate resilience, including developing vulnerability assessments and identifying ways in which to work with PG&E and other stakeholders to address future risks.



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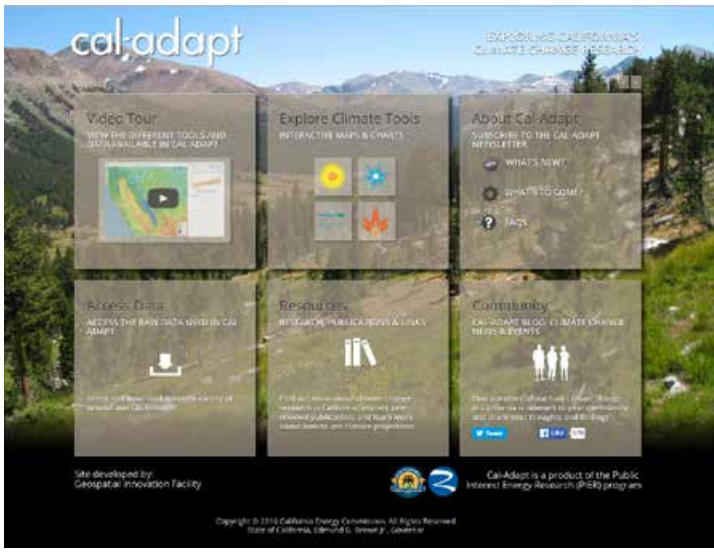


Cal-Adapt is a web-based tool that allows users to identify potential climate change risks in specific geographic areas throughout the state.

Key climate change hazards

Potential impacts

As part of its commitment to addressing climate change, PG&E has identified the primary climate change hazards to its business, including flooding from storm events, sea level rise, land subsidence, heat waves, changes in precipitation patterns and wildfire danger. The table below presents a summary of PG&E's key climate change hazards and their potential impact.[1]

Table 1: Key climate change hazards and potential impact

Hazards	Potential impact
Increased frequency and severity of storm events	Increased risk of infrastructure damage, customer outages and operational costs due to weather factors such as flooding, high winds and heavy snow.
	Potential to significantly impact operations, create the need for emergency response from PG&E crews and require investments in infrastructure to make the system more resilient.
Sea level rise	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.
	Risk of damage to substations and other gas and electric infrastructure.
Change in temperature extremes	Increased electricity demand and loads from more extreme and prolonged hot weather events.
	Risk that certain electrical assets may fail, become less efficient or less reliable, and may need to be modified or replaced as a result of higher temperatures, including warmer daytime maximums and night time minimums, for prolonged periods.
	Increased stress and management of electricity on the transmission system due to higher electrical loads.
	Increased customer outages during extreme heat wave events.
Change in mean (average) temperatures	Higher annual electricity demand if average temperatures increase at the rate global climate models currently predict.
	Lower annual customer natural gas demand.
Change in precipitation patterns and drought	Reduced hydroelectric output, which can increase costs for customers.
	Increased wildfire frequency and intensity due to extreme drought.
	Increased water temperatures in rivers and streams that sustain critical habitats, including for endangered species. Reduction in cold water pools in PG&E's hydroelectric storage reservoirs, limiting the company's ability to comply with regulatory requirements and other mandated license conditions.
	Increased risk to infrastructure from land subsidence that occurs as a result of increased groundwater extraction during extreme drought conditions.
Increased wildfire frequency and intensity	Threat from wildfires to customers as well as PG&E assets such as electric transmission and distribution lines, gas infrastructure and hydroelectric assets—also creating the need for emergency response from PG&E crews.
	Increased customer outages.
	Increased risk of erosion and landslides in affected areas, putting assets at risk.

[1]Each year, PG&E reports its climate change risks, opportunities and strategies to the CDP, an international not-for-profit organization that requests information on behalf of institutional investors.

Resilience measures

The following table includes examples of resilience measures undertaken by PG&E to address the various hazards posed by a changing climate. As an overarching measure, PG&E's Emergency Preparedness and Response efforts take an "all hazards" approach to systematically prepare for and respond to emergencies Additionally, PG&E's in-house science team continues to investigate the different climate change hazards to enable PG&E to identify and evaluate the necessary adaptation strategies.

Table 2: Key climate change hazards and selected resilience measures

Hazard	Selected resilience measures
Increased frequency and severity of storm events	Use storm model developed by PG&E meteorologists to predict the number and timing of sustained power outages each PG&E geographic region can expect during adverse weather conditions—and help determine the number and type of resources needed to restore operations and power delivery back to normal. Use model to identify high risk areas susceptible to rainfall-induced landslides.
	Elevate and reinforce substations and other critical equipment, where necessary, using FEMA flood zone maps. Utilize specialized portable generation systems in an emergency.
	Identify and mitigate potential flooding impacts within gas operations through scheduled patrols, leak surveys and routine maintenance. Use automated notifications for areas at risk of landslides due to heavy rain events. Use LiDAR technology to monitor and track potential land movement in pipeline locations susceptible to erosion and landslides, accompanied by field verification.
Sea level rise	Participate in research and studies to better understand, assess and plan for potential impacts.
	Integrate results of research and studies into near- and long-term infrastructure planning to increase resiliency of critical systems and improve system reliability.
Change in temperature extremes	Use heat storm model developed by PG&E meteorologists to provide advance forecasts of heat wave duration and outage estimates for each PG&E geographic region and enable proactive operational planning.
	Leverage comprehensive suite of demand-response programs—including innovative pilots involving electric vehicles tied to the grid—to mitigate peak demand during heat events.
	Make substantial investments to modernize electric operations focused on maintaining and replacing aging equipment, implementing asset upgrades and using smart grid technology to monitor and reduce the time to restore power to customers.
	Regularly monitor gas assets through remote monitoring systems, equipment inspections, patrols, leak surveys and cathodic protection (corrosion) system monitoring to identify assets that may require additional integrity assessment, repair or replacement.
	Support local "cooling centers" to provide safe, comfortable location for those who need it during heat events.
Change in mean (average) temperatures	Enhance customer energy efficiency and demand response programs to manage higher electricity demand over the long term.
	Explore technology demonstration projects to advance integration of distributed energy resources (DERs), such as solar and battery storage, further unlocking benefits of the electric grid.

(continued on next page)

Table 2: Key climate change hazards and selected resilience measures

Hazard	Selected resilience measures
Change in precipitation patterns and drought	Maintain an internal, cross-departmental Drought Task Force, which works to identify and address impacts on PG&E's operations, customers and communities.
	Manage impacts on hydroelectric operations by analyzing reservoir and stream conditions while collaborating with regulatory agencies and other stakeholders to conserve water whenever possible in individual regions.
	Collaborate on research to better measure and monitor snowpack, climate, soil moisture and other factors to improve monitoring and predictive tools, reduce uncertainty in water forecasts and adapt to climate change.
	Assess and monitor assets in subsidence zones, leveraging available public agency data.
Increased wildfire frequency and intensity	Assess wildfire risk through weather forecast model data and communicate risks to guide operational fire prevention activities and readiness for response.
	Implement broad strategy of wildfire prevention that includes pre-treatment of infrastructure, an infrared program, a wires-down program, right-of-way vegetation management clearances and a wood pole test and treat program.
	Manage vegetation in proximity to overhead electric lines and work with communities and large property owners on projects that manage vegetation to prevent wildfires. Use aerial patrols and lookout cameras to help detect wildfires and assist state and local fire agencies with early fire detection and response.
	Support public education campaigns to raise awareness about wildfire prevention and response.
	Monitor public agency data to assess longer-term risk of increased wildfire frequency.

PG&E's governance for climate resilience

As an infrastructure company that provides critical services, PG&E faces a variety of natural hazards from climate change, including flooding during severe storms, sea level rise, land subsidence, heat waves, changes in precipitation patterns, and wildfire danger.

In fact, climate change is already exacerbating weather-related hazards, leading to more frequent and extreme events, and will only further intensify these episodes in the coming decades.[2]

PG&E's near-term approach

PG&E understands that there is no single approach to building climate change resilience. It involves taking a holistic approach to better understand, plan for and respond to climate change hazards—and doing so in partnership with others. The company is also making substantial investments to build a more modern and resilient gas and electric system that can better withstand extreme weather and natural disasters.

PG&E's approach focuses on four key areas:

1. Near-term planning

Robust emergency response plans and procedures to address near-term risks, including extreme storms, heat waves and wildfires.

2. Staying abreast of the latest science

An in-house science team that regularly reviews the most relevant climate change science and integrates that research into PG&E's risk assessment process.

3. Risk assessment and operational planning

A multi-year, comprehensive risk-assessment process to prioritize infrastructure investments for longer-term risks associated with climate change.

4. External engagement

Active engagement and partnerships at the federal, state and local level on climate change adaptation and resilience.

[2]Intergovernmental Panel on Climate Change, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, 2012.

This work is currently managed through four increasingly integrated groups within the company:

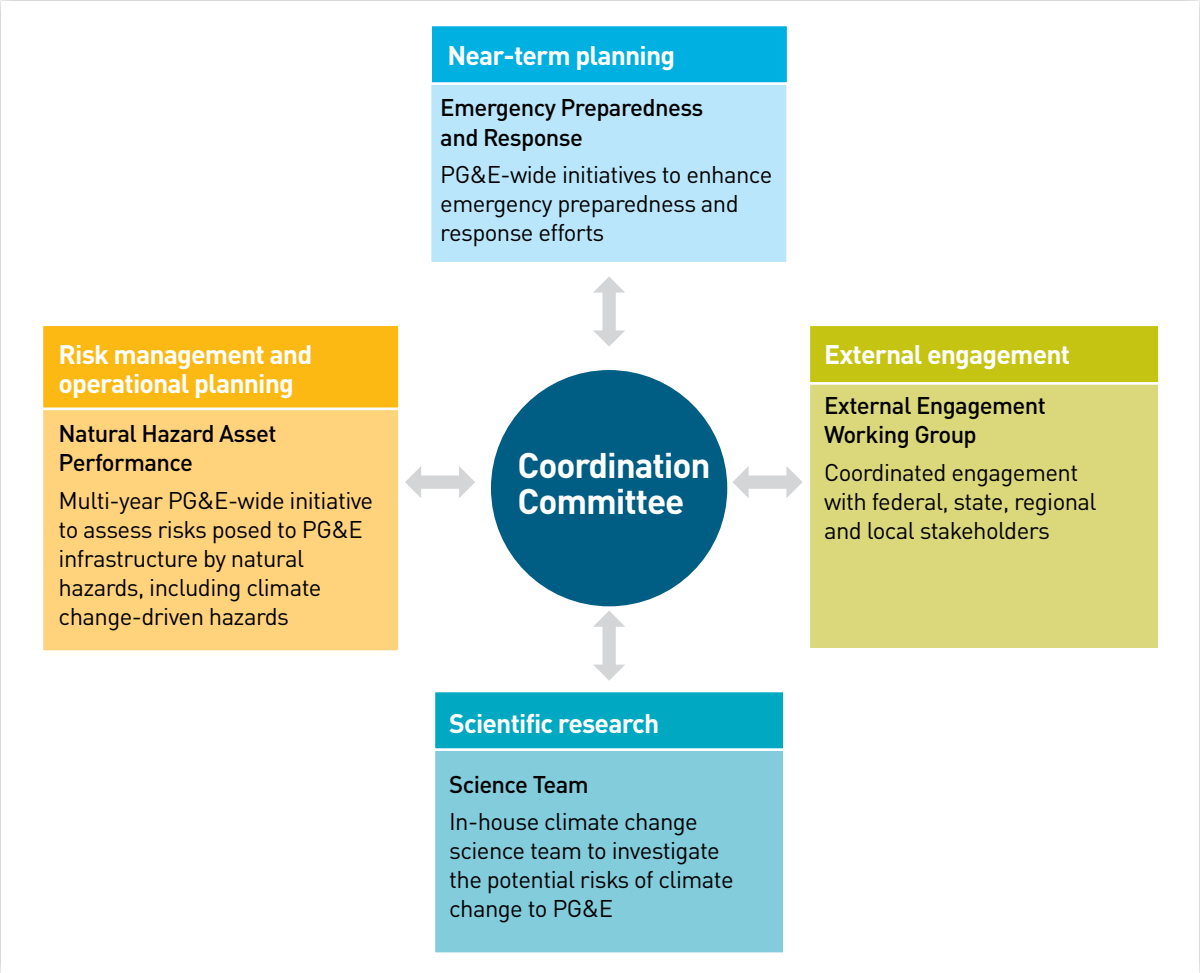


Figure 1: PG&E's governance structure for climate resilience

1. Near-term planning: Emergency preparedness and response

Operating in a region that regularly experiences earthquakes, wildfires, and major storms, it is critical that PG&E implements best-in-class emergency plans and procedures.

PG&E has an internal team that leads initiatives focused on enhancing company-wide emergency preparedness and response efforts. They use industry best practices, lessons learned and incorporate the principles of the National Incident Management System—a systematic, preventative approach to threats and hazards—to improve emergency response. They leverage science-based tools, including a model developed by PG&E meteorologists, to help prepare, plan and respond to storms and other incidents.

The team also facilitates emergency-preparedness exercises to test emergency response and coordination plans, both across all lines of business within the company and across the industry with other gas and electric providers and industry associations.

2. Staying abreast of the latest science: In-house science team

PG&E has maintained an in-house climate change science team since 2008 to help investigate the potential physical risks of climate change to its system. The team is comprised of senior engineers and scientists with backgrounds in meteorology, biology and hydrology.

This team regularly reviews the most relevant scientific literature on how sea level rise, temperature changes, rainfall and runoff patterns, wildfire risk, and storm frequency and intensity affect California and the West—with a focus on climate-related effects expected between now and mid-century. The team distills the most recent global, state and local climate change research into guidance for PG&E's business units.

The climate science team developed a range of natural hazard scenarios, including flooding, sea level rise, and heat storms, for PG&E's risk assessment process.

3. Risk assessment and operational planning: Natural Hazard Asset Performance

While PG&E has been exploring the potential physical risks of climate change to its system for some time, the company recognized the need to take a more holistic, comprehensive approach with standardized scenarios to better understand how its assets would perform under severe weather conditions.

In 2014, PG&E launched the Natural Hazard Asset Performance (NHAP) initiative to conduct a multi-year risk assessment across its entire enterprise, enabling business units to evaluate certain risks and develop response plans using a consistent methodology. The results of the NHAP assessment are being integrated into PG&E's enterprise-wide integrated planning process, as shown in Figure 3. Importantly, the results will also inform PG&E's emergency planning and response activities so the company can continuously improve and make its system more resilient to catastrophic incidents.

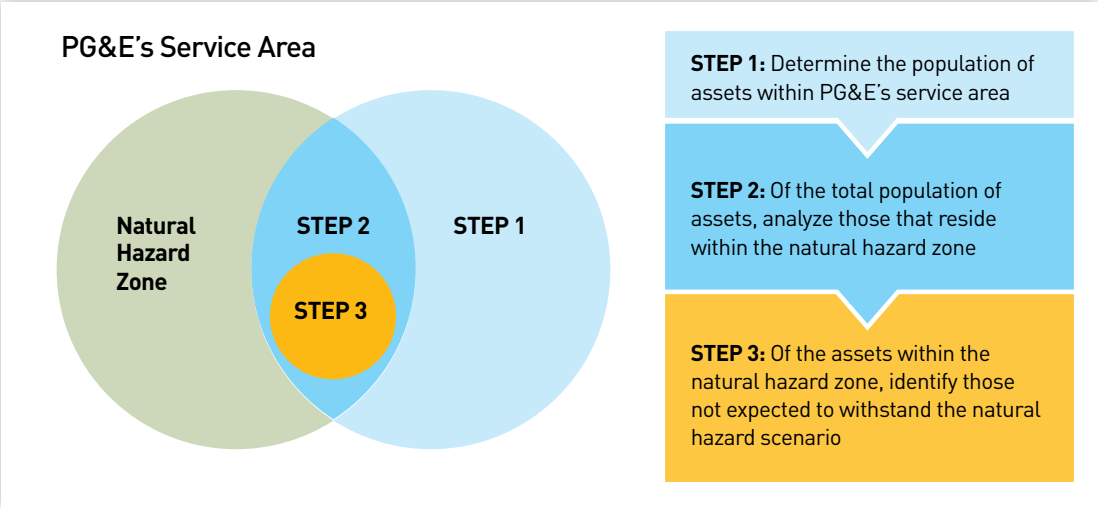


Figure 2: NHAP process to identify assets not expected to withstand a specified natural hazard

4. External engagement working group

PG&E maintains an internal cross-functional working group that meets regularly to coordinate the company's engagement with an array of stakeholders at the federal, state, regional and local level. The group engages with stakeholders to better understand the risks of climate change, keep them informed of the company's progress and problem-solve together for success.

Incorporation into PG&E's Integrated Planning Process

PG&E is working to include risk management of climate hazards into its multiyear integrated planning process, as shown in Figure 3.

PG&E uses an integrated planning process designed to identify top risks and associated compliance requirements; formulate multiyear goals and strategies; align resources; and ensure integration, consistency and continuity in the company's plans. The process focuses first on the company's risks, which leads to a long-term strategy to mitigate these risks and identify PG&E's critical objectives, and then matches PG&E's strategies with resource planning.

PG&E's integrated planning process follows an annual cycle and the NHAP initiative serves as a vehicle to integrate natural hazards into the process. The company's enterprise-wide Risk and Compliance Session is a key step in the process, where PG&E identifies top risks and compliance requirements for the business.

The results of the NHAP initiative will inform PG&E's 2017 Risk and Compliance Session and the company's strategy and execution plans. The NHAP initiative—and PG&E's broader understanding of climate change risks—will also inform PG&E's 2017 Risk Assessment Mitigation Phase (RAMP) filing, a regulatory proceeding that will incorporate a risk-based decision-making framework into PG&E's next General Rate Case.

Near-term workplan

PG&E is conducting the NHAP process in five distinct phases:

	2015–2016		2017		2018
Phases of the NHAP initiative	**1. Planning phase**	**2. Review phase**	**3. Assess resiliency and prioritize vulnerabilities**	**4. Risk response**	**5. Monitor progress and continuous improvement**
	Establish list of assets. Develop natural hazard scenarios.	Review risk exposure of assets against scenarios. Review expected performance of assets that may be impacted.	Assess asset resiliency. Assess adequacy of current controls to manage risks driven by natural hazards.	Develop response plans for business units to address critical asset vulnerabilities.	Monitor progress toward plans and course correct as needed. Monitor climate change impacts. Inform company emergency planning and response activities.
PG&E risk and compliance milestones			Integration into PG&E's 2017 enterprise-wide Risk and Compliance Session	Management by PG&E lines of business: • Integrate into risk registers • Inform monthly Risk and Compliance Committees • Inform asset management and emergency planning	Integration into PG&E's 2017 Risk Assessment Mitigation Phase (RAMP) filing, a proceeding that will support PG&E's 2020-2022 General Rate Case
NHAP governance	**Bi-monthly working group meetings**				
	Regular leadership steering committee meetings				

Figure 3: Phases of the NHAP initiative

Phases of the NHAP initiative

1. Planning

During this phase, PG&E took an inventory of assets across its business units. Using data from the company's in-house climate change science team, PG&E also established a list of different natural hazard scenarios, including flooding, sea level rise, subsidence and heat storms. For each natural hazard, the company assumed a "reasonable and realistic" but "worst case" scenario. PG&E's use of standardized scenarios to assess its assets is a key aspect of the NHAP initiative.

2. Review assets

The goal of this phase is to determine the number of assets that may be affected under each natural hazard scenario, and identify whether or not they are expected to withstand the specified natural hazard. Using geographic information system (GIS) maps to ensure locational accuracy and consistency, PG&E overlaid its assets against each natural hazard scenario, which allowed the company to identify which assets may be affected.

This resulted in an assessment of the risk *exposure* of PG&E's assets, calculated as the percentage of assets in the hazard zone. PG&E is reviewing the risk *performance* of its assets, which entails an assessment of whether assets are sufficiently designed to withstand the natural hazards to which they are exposed. During this process, PG&E has gained a better understanding of the complexities associated with this type of system-wide assessment given the scope and diversity of assets involved.

3. Assess resiliency and prioritize vulnerability

As a next step, PG&E will assess asset resiliency and prioritize vulnerabilities across its different business units, including reviewing the adequacy of current controls to manage risks driven by the different natural hazards. The results of this analysis will inform PG&E's 2017 Risk and Compliance Session and the company's strategy and execution plans. By taking a deliberate course of action—and integrating this work into PG&E's enterprise-wide strategic planning process—the company is assessing climate risks in a systematic manner that it believes will be sustainable over the long term.

4. Risk response

In 2017, as part of PG&E's integrated planning process, the company will develop the necessary risk response plans for its business units, which will allow PG&E to accept, avoid or reduce natural hazard threats to its assets. If a threat is not already accounted for in an existing risk response plan, PG&E will determine the strategies to address it. The results of the NHAP assessment will also inform the company's emergency response plan and departmental business continuity plans.

5. Monitor progress

Once complete, PG&E will monitor the progress and evaluate the performance of its risk response plans and make updates, where needed. The company's climate change science team will regularly evaluate the latest climate-change science and other relevant data such as Federal Emergency Management Agency (FEMA) flood maps to ensure PG&E is using the best available information to develop its plans. PG&E will update its natural hazard scenarios and asset data on a structured basis. Looking forward, the company will continue to integrate its findings into business processes to help guide long-term decision making and future emergency planning and response activities.

Beyond asset management: Developing a holistic, longer-term strategy

Recognizing the broad scope and long-term nature of the challenge, PG&E is developing a multi-year plan to build climate resilience—taking a holistic approach to better understand, plan for and respond to climate change threats. Core to this effort is the recognition that climate change-related hazards have direct impacts across PG&E's value chain—beyond PG&E's core assets that deliver service to include the critical systems and supply chains PG&E depends on, as well as the customers and communities it serves. These impacts pertain to both current and future assets, requiring the need for an iterative process for updates and improvements.

The scope of climate impacts includes:

- **Impacts to PG&E assets** such as company owned and managed gas, electric and hydroelectric infrastructure. The specific impacts, such as direct damage from flooding, interruption of SCADA systems, temporary loss of access to facilities, or corrosion due to saltwater intrusion, will depend on the asset's sensitivity and capacity to recover and adapt.
- **"Upstream" impacts to critical systems** on which PG&E depends such as regional gas and electric systems, suppliers, and water and telecommunications networks. Direct impacts to these systems, such as water availability for hydroelectric operations, have a ripple effect on PG&E's ability to provide resilient service. Understanding and managing these interdependencies impacts PG&E's ability to continue service during and after major incidents.
- **"Downstream" impacts to customers and communities,** recognizing the important interdependency that PG&E's resilience is tied to the resilience of the customers and communities it serves and vice versa. The degree to which communities assess their vulnerabilities and plan for resilience contributes to the overall resilience of PG&E's service.

To mitigate these impacts, PG&E is working to further embed management of climate hazards into key functional areas within the business—from risk management to emergency preparedness and response. PG&E also recognizes that collaborating with—and listening to—external stakeholders is crucial to this process. That is why PG&E is actively engaging at the national, state and local level to help guide its climate resilience strategy.

As PG&E develops its multi-year plan, the company is using the forward-looking guidance issued by the California Public Utilities Commission and U.S. Department of Energy through its Partnership for Energy Sector Climate Resilience.

Climate impacts across PG&E's value chain

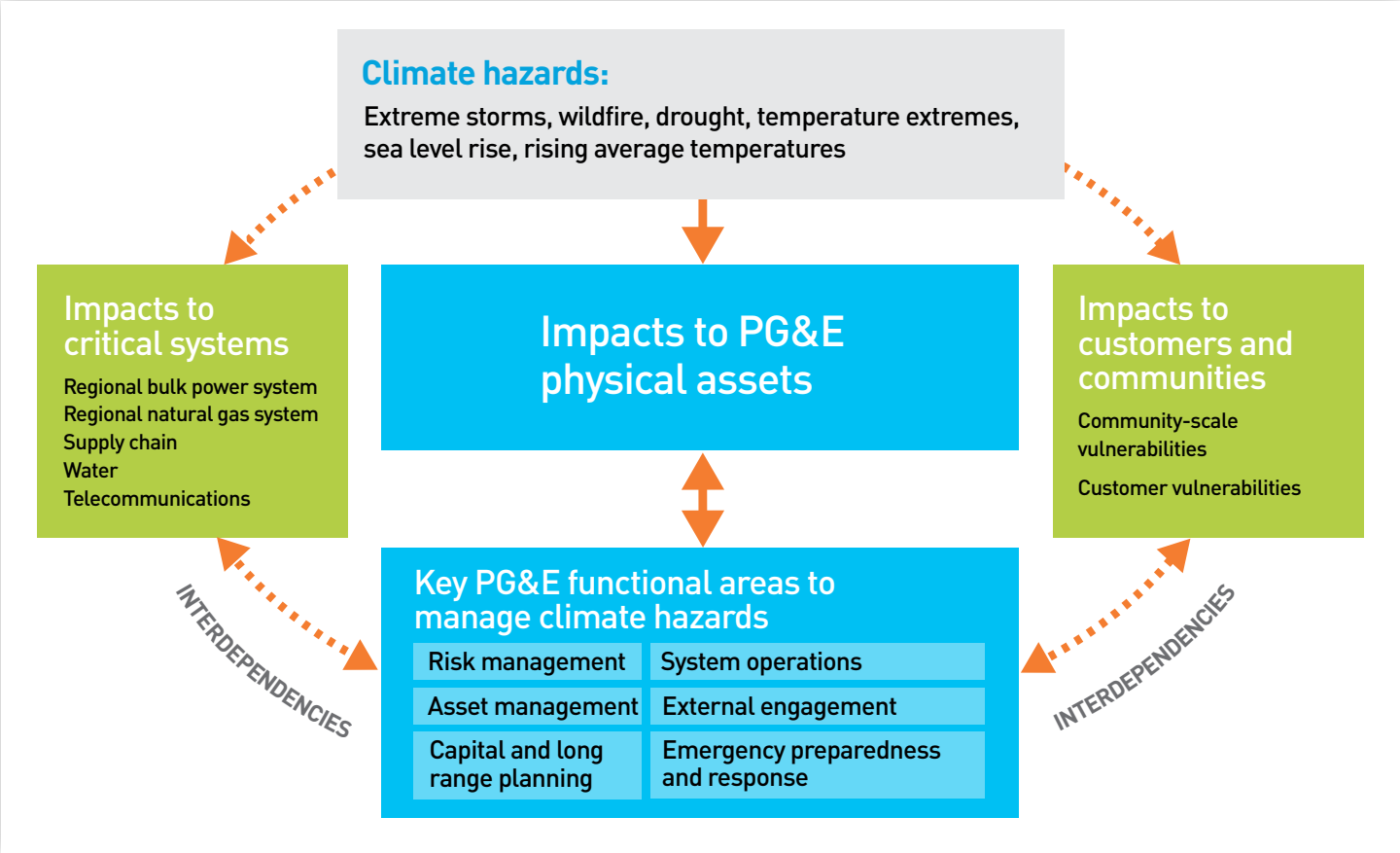


Figure 4: Framework showing how climate change-related hazards have direct impacts across PG&E's value chain

Many aspects of this framework—such as broadening how PG&E defines assets to include its supply chain and other interdependencies as well as the linkage to community resilience—are complex endeavors with a scope that extends well beyond PG&E.

For example, PG&E believes there is a need for more standardized climate scenarios and models to help energy providers with long-term, localized planning. PG&E's plan will include the development of more robust models—similar to what the company uses today for earthquakes—and will capture lessons from these tools and processes that the company can apply to climate risks. PG&E will also continue to integrate the latest science into its decision-making, leveraging the significant work underway by the state and through its Cal-Adapt web-based tool.

PG&E welcomes a continued dialogue with its stakeholders to determine the best path forward—from how best to prioritize the various items to the potential role of the state and other stakeholders in helping to achieve them. Importantly, as PG&E looks longer-term, the company will continue to demonstrate action along the way.

RESILIENCE MEASURES

Resiliency metrics and analytical frameworks

One challenge for energy providers such as PG&E is the current lack of climate resilience metrics and analytical frameworks. Often, the benefits of resiliency measures are estimated using metrics traditionally used for reliability planning. While there are commonalities between resiliency and reliability, there are also critical differences related to the type of hazards and their "low-probability, high-consequence" nature.

To address this challenge, PG&E is partnering with the Electric Power Research Institute (EPRI) and several other energy providers on a multi-year research project to collaboratively review and assess metrics and analysis tools for electric sector resiliency.

Through the project, EPRI will conduct extensive research and engage with a diverse group of stakeholders at the participating companies to:

- Survey, examine and assess the merits and limitations of current practices in resiliency measurement and decision-making, including metrics and cost-benefit approaches.
- Identify opportunities, barriers and key research needs for technically and economically sound approaches to assessing resiliency measures.

The results of this research will inform PG&E's ongoing efforts to assess the costs and benefits of different resilience strategies and enhance the company's framework for managing climate risks across the business.

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

PG&E is partnering with EPRI and other energy providers on a research project to review and assess metrics and frameworks for electric sector resiliency.

Emergency preparedness and response

The following highlights some of PG&E's recent initiatives and the tools the company uses to strengthen its emergency preparedness and response efforts.

Emergency Management Advancement Program (EMAP)

Launched in 2013, EMAP is an enterprise-wide effort to comprehensively review and strengthen PG&E's catastrophic emergency response plans.

The program is working to ensure PG&E has:

- Clearly defined organizational structures, roles, and responsibilities
- Restoration priorities that incorporate community needs to help customers begin returning to normal life
- Effective logistics plans that support restoration needs
- Technology that is ready and available to support PG&E's response
- Employees who are trained and fully understand their emergency roles
- Employees who are personally prepared for emergencies and ready at home, so they can respond at work

PG&E has developed a comprehensive maturity model that provides the company's roadmap to building effective response capabilities. PG&E is using this model to align efforts across the enterprise toward a common goal and assess progress on emergency response.

PG&E conducts emergency-preparedness exercises to test emergency response and coordination plans.

RESILIENCE MEASURES

Company Emergency Response Plan

PG&E's Company Emergency Response Plan (CERP) is an "all-hazards" plan that details the company's planned response to emergencies and provides PG&E personnel with information on how to conduct a safe, efficient and coordinated response to emergencies. The plan outlines PG&E's organizational structure, responsibilities and the activities undertaken in response to emergency situations. In addition, it describes the various coordination efforts and interfaces with outside organizations.

Emergencies include any natural or man-made disaster—including wildfires, floods, storms and earthquakes—that threaten loss of life and property to the public and PG&E, or that require immediate action to protect or restore service or critical business functions.

The CERP is updated annually by PG&E's Emergency Preparedness and Response team to incorporate best practices and lessons learned from the previous year's emergency responses, as well as feedback from subject matter experts and line of business planning leads.

Increased coordination with first responders and emergency officials

PG&E prioritizes coordination and communication with police, fire and other officials during emergency situations in an effort to keep the public and first responders safe. PG&E's emergency response plan—which is developed, shared and tested with emergency officials—defines clear lines of responsibility for PG&E and emergency personnel. PG&E also maintains a secured First Responder website where emergency officials can access training materials and gas transmission infrastructure information and maps.

Each year, PG&E hosts hundreds of training workshops facilitated by its public safety specialists to better prepare firefighters, police, public works officials and other authorities to respond to emergencies involving electricity and natural gas. The company also meets with many of the fire departments in its service area with PG&E gas transmission or distribution facilities in their region.

PG&E also regularly participates in emergency-preparedness exercises to test emergency response and coordination plans. For example, in June 2016, hundreds of employees participated in a functional exercise, which tested PG&E's ability to assess damage, prioritize power restoration and respond to electric and gas emergencies from a simulated 6.9 earthquake and aftershocks. PG&E leveraged its earthquake damage-modeling system to generate rapid, facility-specific damage estimates that help prioritize where to dispatch assessment and repair crews.

After a major catastrophic incident, base camp capabilities are key to an effective response. PG&E has been working to strengthen its base camp deployment by investing in mobile IT capabilities so that company leadership and restoration crews have the situational awareness and communications technologies to make effective decisions in the field. PG&E has also made arrangements for locations to build staging areas and large-scale base camps.

After a major catastrophic incident, base camp capabilities are key to an effective response.

Since 2011, PG&E's partnerships have helped engage nearly two million people in California on emergency preparedness.

Building strong community partnerships

PG&E regularly works with community organizations that share its focus on electric and natural gas safety and disaster preparedness. For example, PG&E partners with the American Red Cross to provide Californians with critical disaster preparedness training and emergency response resources. PG&E's financial support has enabled the Red Cross to build safer, more resilient communities through programs such as the Home Fire Preparedness Campaign and the FEMA award-winning Ready Neighborhoods. Since 2011, PG&E's investments have helped engage nearly two million people in California on emergency preparedness.

PG&E also sponsored the annual California Day of Preparedness, partnering with the state to help Californians learn how to be better prepared for natural or man-made disasters. Hosted by the Governor's Office of Emergency Services, the event featured demonstrations by state and local agencies, PG&E gas and electric safety demonstrations, and emergency response vehicles.

As described later in this report, PG&E also has extensive partnerships to mitigate the risk of wildfires. This includes funding local Fire Safe Councils throughout the state to support fuel reduction, emergency access and defensible-space projects and partnering with CAL FIRE on its "One Less Spark, One Less Wildfire" public safety campaign.

Customers can access PG&E's Facebook site for updates during large storms and incidents.

Communicating with customers

PG&E's social media platforms are essential, real-time communication tools during large storms and incidents, like summer wildfires. Both customers and news media turn to PG&E's social media properties and its news site, **pgecurrents.com**, for updates from the company.

Photos of the low-carbon community microgrid at the Blue Lake Rancheria, a Native American reservation in Humboldt County

RESILIENCE MEASURES

Collaborating on low-carbon community microgrids

In an effort to build community resilience, enhance public safety and address a changing climate, several localities are exploring the potential for community microgrids in collaboration with PG&E and other partners. "Community" microgrids are those designed to ensure that specified loads can remain powered up during a broader grid outage to ensure that critical services can be provided to a broad range of constituents. PG&E is helping to identify how these systems integrate into the broader energy grid and achieve community goals.

Blue Lake Rancheria, a Native American reservation in Humboldt County, is building a low-carbon community microgrid as part of their quest to conserve energy, reduce greenhouse gas emissions and enhance emergency preparedness. Funded in part through a California Energy Commission (CEC) grant, the microgrid will be powered by a 0.5 MW solar photovoltaic installation, 950 kWh battery storage system, biomass fuel cell system and diesel generators.

The microgrid—which is being developed in partnership with PG&E, Humboldt State University and others—will provide the tribe and local citizens with life, health and safety support in the event of an emergency and may serve as a model for other communities looking to prioritize both economic vitality and climate change reduction.

PG&E is also providing technical support to the San Francisco Department of the Environment on a project to assess potential microgrid locations within the city. In the event of an earthquake or other natural disaster, a microgrid could power public facilities where people assemble and receive critical services, including schools, recreation centers and libraries. In addition to identifying potential locations, the project is considering approaches for integrating solar and energy storage for enhanced sustainability.

Finally, PG&E is working with the City of Berkeley as it considers a community microgrid pilot project in the downtown area. In support of its recently published Resilience Strategy, Berkeley is exploring the potential for a community microgrid—with its new Center Street Garage at the heart of the system. The project would advance the city's use of local, clean energy for community resilience and help adapt to a changing climate.

RESILIENCE MEASURES

PG&E donates rapid response truck on anniversary of Napa quake

One year after a powerful earthquake shook homes and buildings in the city of Napa, residents, business leaders and other community members came together to commemorate the temblor and remember the lives changed and lost. At the event, PG&E donated a next-generation, emergency response pickup truck to the city's fire department and invited local residents to have a personal preparedness plan. PG&E also emphasized the value of partnering with local cities, counties and first responders in emergency response.

PG&E also maintains emergency vehicles within its own fleet, including two 39-foot-long Mobile Command Vehicles, which function as an emergency control center with 12 work stations, eight video monitors and high-tech communication and mapping capabilities that can roll to the site of a disaster, such as a wildfire.

Donated by PG&E, this next-generation electric hybrid truck provides the Napa Fire Department with exportable power during an emergency.

Tools and resources

PG&E uses a variety of tools to support its emergency preparedness and response activities. The **Storm Outage Prediction Project (SOPP) model** was developed and is run by the company's in-house meteorology team to provide advanced warning of the number and timing of sustained outages each PG&E geographic region can expect during adverse weather conditions. Originally built to prepare for winter wind storms, the model now has the capability to also forecast outages that arise from other weather incidents such as low elevation snowfall and heat waves. The SOPP model is run on a daily basis, with more frequent updates issued as storms approach.

The outage forecast is a key tool that PG&E uses to determine the number and type of resources needed to restore operations and power delivery back to normal. It also enables PG&E to assess the need to leverage mutual aid and assistance partnerships around the country. In a future climate with more frequent and severe storm events, the SOPP model and advanced intelligence from PG&E's meteorologists will remain critical to PG&E's planning, preparation and response.

While earthquakes are not a climate change risk, PG&E maintains extensive modeling and risk assessment work to better understand and plan for potential earthquakes in its region. PG&E's earthquake damage-modeling system, **Dynamic Automated Seismic Hazard or "DASH,"** generates rapid, facility-specific damage estimates that help prioritize where to dispatch assessment and repair crews. PG&E also uses ShakeCast and ShakeMaps—open-source software developed by the U.S. Geological Survey—to produce near-real-time digital maps of ground motion and shaking intensity, facilitating notification of shaking levels at key facilities. These tools and processes provide lessons that the company can apply to other risks. Additionally, PG&E is actively looking into earthquake early warning systems as another tool to strengthen resiliency and response.

PG&E's three state-of-the-art electric distribution control centers provide enhanced reliability and response to outages and emergencies, such as natural disasters.

External engagement

The need to address climate impacts is growing at all levels across the United States. As part of this effort, PG&E actively engages with an array of stakeholders at the federal, state, regional and local level to help foster greater resilience, including the following highlights:

Communicating climate-related information

PG&E regularly informs its stakeholders of climate-related risks to its business through a number of channels, including PG&E's Annual Corporate Responsibility and Sustainability Report (**pge.com/sustainability**), Annual Report Form 10-K filed with the Securities and Exchange Commission (SEC) and various other climate-related reports, studies and partnerships.

For example, since 2005, PG&E has voluntarily responded to the CDP, an international not-for-profit organization that solicits greenhouse gas emissions and climate risk information on behalf of institutional investors. In 2016, PG&E's response earned the company a spot on the "Climate A List," comprised of companies from around the world identified as leading in their efforts and actions to combat climate change.

PG&E has also spoken about its climate change adaptation and resilience initiatives at numerous recent conferences, webinars and other events, including the California Adaptation Forum, California Climate Action Planning Conference, Climate Leadership Conference and Net Impact Conference—as well as the Clean Energy Ministerial, which brought together a global audience of energy policymakers in San Francisco as a follow-up to the historic climate summit in Paris. PG&E also joined Southern California Edison and San Diego Gas and Electric at the California Independent System Operator for a discussion of climate resilience and energy forecasting.

At the Clean Energy Ministerial in June 2016, PG&E announced the launch of its Better Together Resilient Communities grant program, a shareholder-funded initiative to assist local governments with climate resilience planning.

PG&E joined other electric utilities to launch the U.S. DOE's Partnership for Energy Sector Climate Resilience.

Federal engagement: Collaborating with the U.S. Department of Energy and other agencies

PG&E joined the Partnership for Energy Sector Climate Resilience, a public-private collaboration between the DOE and leading companies in the electric industry, with the goal of improving the resilience of the nation's energy infrastructure to extreme weather and climate change. Under the Partnership, PG&E will develop and pursue strategies to reduce climate and weather-related vulnerabilities and the DOE will assist in the development of information, analytical methods and case studies of emerging best practices.

PG&E also participated in a stakeholder forum led by the Government Accountability Office Comptroller General, culminating in a report entitled, *Preparing for Climate-Related Risks: Lessons from the Private Sector.* Participants included businesses, federal agencies, local governments, academia and non-government organizations. The discussion included public and private sector interdependencies—areas in which groups rely upon one another for support and services—such as infrastructure, supply chains, data and tools. Participants also discussed the implications of these interdependencies for building resilience and the importance of partnerships to examine the resilience of all components of a system, leverage information and resources, and pursue a collective effort that engages all stakeholders.

As PG&E develops its multi-year climate resilience plans, the company is using the forward-looking guidance issued by the California Public Utilities Commission and U.S. Department of Energy through its Partnership for Energy Sector Climate Resilience.

Climate Adaptation in the Electric Sector: Vulnerability Assessments and Resilience Plans

The CPUC issued a paper encouraging the state's investor-owned gas and electric companies to conduct rigorous vulnerability assessments of their key assets, the system as a whole and their customers, and to develop comprehensive resilience plans.

Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning

The U.S. DOE issued guidance to electric power providers for assessing vulnerabilities to climate change and extreme weather and in identifying an appropriate portfolio of resilience solutions. The guide is part of DOE's effort to inform preparedness, resilience planning and response initiatives.

State engagement: Working with California state agencies

PG&E has participated in various state agency efforts to explore climate change impacts and adaptation strategies. For example, PG&E participated in an advisory committee meeting convened by the Little Hoover Commission on climate change adaptation in 2014. The meeting, which focused on the role of risk assessment in climate change adaptation, was part of the Commission's examination of the governance and legal structures needed to effectively adapt to a changing climate. PG&E also shared its plans at a CEC workshop in 2015 focused on the potential effects of land subsidence to natural gas and oil infrastructure.

In both 2015 and 2016, PG&E participated in a climate change adaptation workshop co-hosted by the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC). The events provided an opportunity for Commissioners, stakeholders and interested parties to explore the physical vulnerabilities of California's gas and electric systems due to climate change, as well as the actions that California's energy companies are taking to adapt to those changes. During the events, PG&E shared how the company is working to address climate change and its commitment to building a more modern and resilient gas and electric system that can better withstand extreme weather and natural disasters. PG&E also provided input to California's Sea Level Rise Planning Database, as required under AB 2516.

PG&E is participating in several CEC-led research projects, including a study by the University of California, Berkeley Center for Catastrophic Risk Management to assess the potential impacts of sea level rise and extreme flooding on the company's gas transmission system.

PG&E is also participating on a technical Advisory Committee for Cal-Adapt, which is California's resource for visualizing local and regional climate change-related risks in a manner that sheds light on adaptation needs and possibilities. The state is working to enhance Cal-Adapt to serve electricity and natural gas sector climate-related planning and management needs. The updated Cal-Adapt tool will incorporate climate modeling studies based on the latest Intergovernmental Panel on Climate Change (IPCC) report (AR5, 2014).

Local engagement: Working with communities

PG&E engages with numerous stakeholders on climate change adaptation projects, including working with local governments on studies to assess vulnerability and develop resilience strategies. Doing so helps PG&E learn more about the climate risks in the communities it serves and identify ways to partner on strategies to address those risks.

Regional partners include the Bay Area Council and the Capital Region Climate Readiness Collaborative. For example, PG&E participated in the Bay Area Council Economic Institute's *Surviving the Storm* report, which looked at the economic impact of a Superstorm and associated flooding on the Bay Area economy. Published in 2015, the report found that a Superstorm and the associated flooding could have a $10.4 billion impact on the San Francisco Bay Area economy. Included in the report is PG&E's estimate that disruption to several Bay Area substations (see map to the right) could result in an economic impact of up to $125 million—an impact mitigated by PG&E's redundant electric system where substations are interconnected through the electric grid and typically can play a back-up role to one another to help minimize customer service interruptions. This estimate represents the associated outage cost—or loss of value—to PG&E customers, not the cost of replacing or repairing equipment.

PG&E also participates in resilience studies and vulnerability assessments conducted by local governing bodies. For example, PG&E is participating in San Mateo County's effort to identify and assess community assets and natural resources that will be most affected by sea level rise and storm events along the County's bayshore and coastline. The study will lay the groundwork for developing adaptation strategies to improve the resiliency and safety of the County's coastside and bayshore communities. PG&E also contributed to Marin's sea level rise study; Silicon Valley 2.0, an initiative to develop regional planning tools to help Santa Clara County communities plan for and adapt to climate change impacts; and a study conducted by the Bay Conservation and Development Commission to assess adaptation scenarios in the Oakland/Alameda area.

PG&E is also supporting the Resilient by Design Challenge, an initiative that will bring interdisciplinary teams to the San Francisco Bay Area to work together to design solutions that protect the bayshore and make the region more resilient to sea level rise.

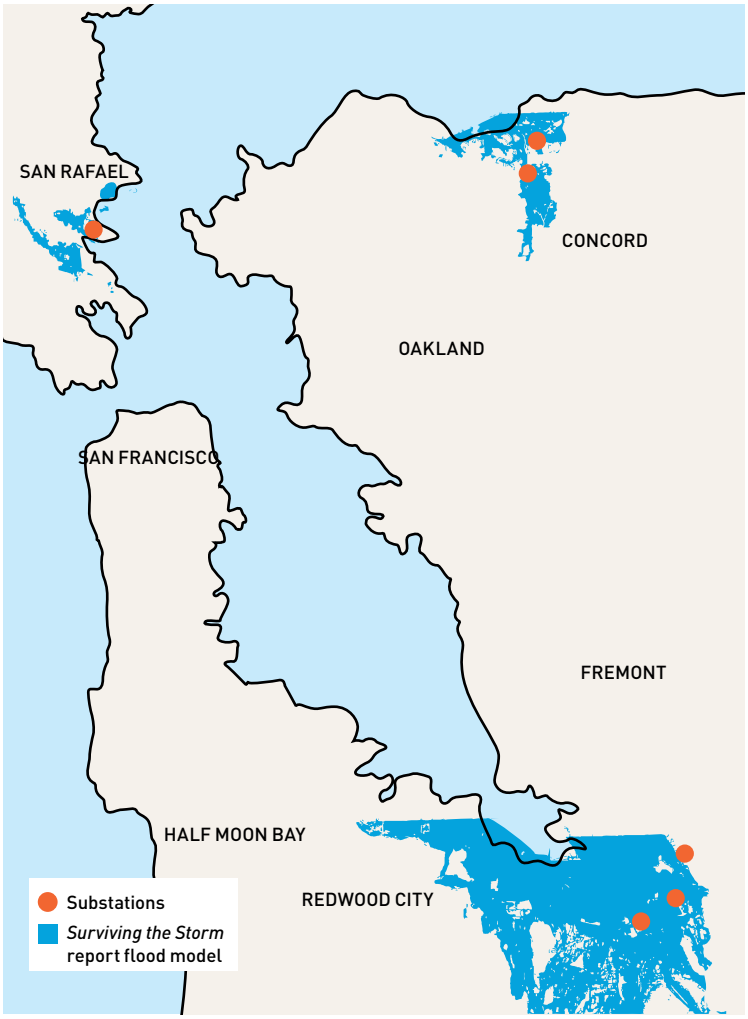


Figure 5: Map of the projected flooding from the *Surviving the Storm* report, as well as the PG&E substations that could be impacted by the modeled Superstorm

PG&E Corporation Chairman and CEO Tony Earley joined local leaders in support of Measure AA for a Clean and Healthy Bay, which will help fund environmental restoration, pollution reduction and critical flood protection around the San Francisco Bay.

RESILIENCE MEASURES

Supporting climate resilience in communities

From extreme weather to rising sea levels, the threat that climate change poses to communities across California is becoming all too apparent. In an effort to promote local resilience to climate change, PG&E is offering the Better Together Resilient Communities grant program.

Through the program, PG&E will invest $1 million over five years to support local planning efforts to build greater climate resilience throughout Northern and Central California. The program will launch in 2017 and, each year, PG&E will award a total of $200,000 in shareholder-funded grants through a competitive process.

The results of the grants will be made publicly available to help communities better understand, plan for and respond to climate change risks and encourage partnership with others. A panel of community and sustainability leaders, including members of PG&E's external Sustainability Advisory Council, will play an advisory role with the program.

To assess grant proposals, PG&E will use the following criteria:

- **Replicability:** the extent to which others can learn from and adopt the strategies and solutions
- **Partnerships:** the extent to which the grant proposal reflects a multi-organizational and collaborative effort
- **Disadvantaged communities:** the extent to which the grant proposal and partnership focuses on disadvantaged communities and identified community needs
- **Measurable impact:** the extent to which the grant proposal includes practical, measurable and innovative ways to address community need and climate risks

To be eligible, applicants must be a governmental organization, educational institution or 501(c)3 nonprofit organization. All applicants must have a local government within PG&E's Northern and Central California service area as a partner.

RESILIENCE MEASURES

Supporting 'Yes on Measure AA for a Clean and Healthy Bay'

As part of its commitment to public safety, the environment and serving the community, PG&E Corporation made a $250,000 shareholder-funded commitment to the People for a Clean and Healthy Bay Coalition. With this contribution, PG&E joined a growing list of local leaders in support of a successful measure to advance environmental restoration, pollution reduction and critical flood protection around the San Francisco Bay.

Natural Hazard Asset Performance initiative—key hazards and resilience measures

This section presents the results of PG&E's preliminary assessment of its electric and gas infrastructure under four natural hazards: flooding, sea level rise, subsidence and heat storms.

This assessment represents the risk exposure of PG&E assets, calculated as the percentage of assets in the hazard zone. It does not reflect the ability of those assets to withstand the natural hazard, which is the next step in PG&E's process.

For sea level rise, PG&E is focusing its analysis on the year 2050 because it is a common target; other hazard scenarios have different thresholds as described in this section.

This section also includes examples of resilience measures undertaken by PG&E to address the various hazards posed by a changing climate. As an overarching measure, PG&E's Emergency Preparedness and Response efforts take an "all hazards" approach to systematically prepare for and respond to emergencies—from earthquakes to climate change-driven risks such as wildfires and major storms. Additionally, PG&E's in-house science team continues to investigate the different climate change hazards to enable PG&E to identify and evaluate the necessary adaptation strategies.

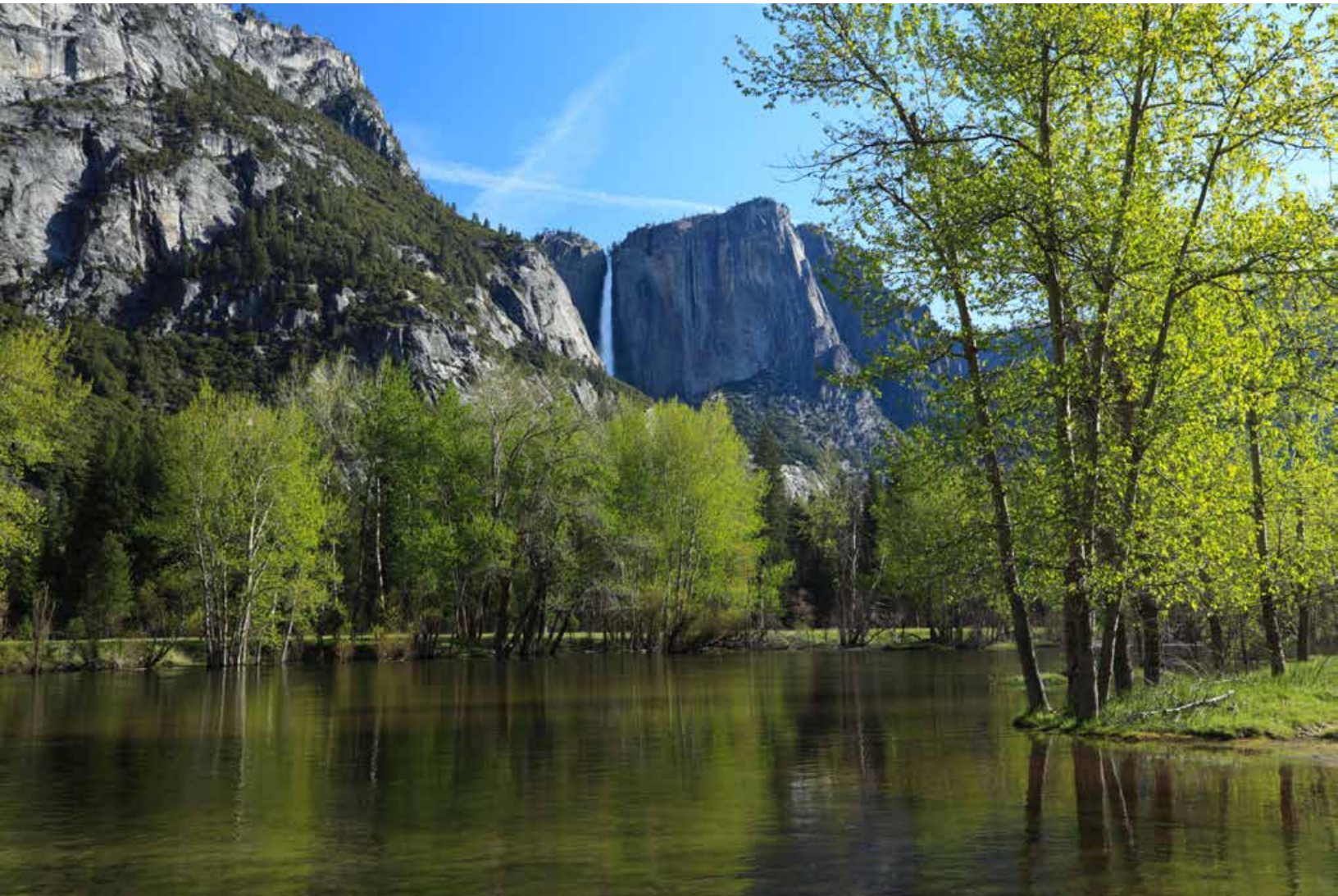
Additionally, for certain risks such as increased electricity demand from more extreme, persistent and frequent hot weather, PG&E believes its strategies to reduce greenhouse gas emissions—such as energy efficiency and demand response programs and the support of renewable energy development and storage—will help adapt to changing climate conditions.

FLOODING

Scenario: Assess PG&E assets against FEMA 100- and 500-year flood zone maps

FEMA's flood zone maps are the standard used for floodplain management nationwide. In any given year, FEMA's 100-Year Flood Zones represent a one percent chance of a flood event, while FEMA's 500-Year Flood Zones represent a 0.2 percent chance of a flood event in a particular location.

Compared to sea level rise, FEMA's flood zones put a larger number of PG&E's assets at risk given the streams and tributaries within a watershed that eventually flow into the Bay or ocean. Importantly, similar to earthquake zones, it is not expected that all of these zones would be affected by a flooding incident at the same time. It is also difficult to determine how frequent the 100-year storm may be; however, it could become a 1-in-10-year flood event by 2050 based on the California Climate Change Council's Third Assessment.



Electric

PG&E reviewed its electric infrastructure assets against the flooding scenario and identified the following assets located in the hazard zone represented by FEMA's 100- and 500-year flood zone maps. PG&E's preliminary assessment represents the risk exposure of its assets, calculated as the percentage of assets in the hazard zone. This does not represent the ability of the asset to withstand the natural hazard.

PG&E evaluated its substations within the nine San Francisco Bay Area counties and identified 24 Bay Area substations at risk of flooding based on the 100-year flood zone (see Figure 6).

Table 3: Percent exposure of electric assets to 100- and 500-year FEMA flood zones

Electric assets	FEMA 100-flood zone exposure	500-Year flood zone exposure
Distribution lines	9%	13%
Distribution transformers (pad-mount)	6%	17%
Transmission lines	14%	18%
Substations	26%	39%
Power generation facilities	0%	0%

Figure 6: PG&E's electric substations identified within the 100-year FEMA flood zone

PG&E uses a model developed by its meteorology services group to predict the number and timing of sustained power outages each PG&E geographic region can expect during adverse weather conditions.

RESILIENCE MEASURES

Protecting electric infrastructure

When making repairs or modifications to facilities, PG&E takes into account any additional modifications necessary to protect structures within the 100- and 500-year flood zones. For example, PG&E has elevated structures at several of its substations[3] to reduce the risk of flooding, including the San Mateo 115kV GIS Building, Napa Substation Building and Switchgear, and Richmond R Building and Switchgear. In some cases, the company also looks to reinforce identified substations; in other cases, in the event of a flood, the reliability of the electric grid can allow the flexibility to serve customer load through other parts of the system.

PG&E also uses the SOPP model developed by its meteorology services group to predict the number and timing of sustained power outages each PG&E geographic region can expect during adverse weather conditions. The model is run on a daily basis, with more frequent updates issued as storms approach. The model outage forecast information is a key tool that PG&E uses to determine the number and type of resources needed to restore operations and power delivery back to normal.

Photo of PG&E's San Mateo 115kV GIS Building, which was designed nine feet above grade based on studies of potential flood risk.

[8]These buildings contain controls and monitoring equipment to operate the substation, which are water-sensitive and may not function in submerged conditions.

Photo of portable generators at PG&E's Cholame substation in San Luis Obispo County, which kept power flowing to customers during a planned outage.

RESILIENCE MEASURES

Deploying portable generation systems

PG&E is expanding its use of specialized portable generation systems to keep lights on for customers while crews perform work on power lines and substation equipment. PG&E has successfully completed several pilot projects that confirmed its ability to use these generators for both large and small scale projects.

In addition to planned upgrades and maintenance, PG&E is exploring the use of these generators to restore power more quickly in response to emergencies such as an earthquake, wildfire or flooding incident. During an emergency exercise, PG&E used the portable generators to supply power at a base camp, a site that plays a critical role in PG&E's response to catastrophic emergencies and serves as a place to stage crews and equipment in heavily impacted areas. The generators have the potential to power an entire neighborhood in an emergency.

RESILIENCE MEASURES

Integrating advanced communications and control technologies

PG&E continues to integrate a wide range of advanced communications and control technologies throughout the energy grid to help enhance the resiliency of the system and restore power outages more quickly.

PG&E has constructed three state-of-the-art electric distribution control centers that manage its more than 140,000 miles of electric distribution lines. The centers provide enhanced reliability and response to outages and emergencies, such as natural disasters.

PG&E has also installed advanced automation technology on power lines throughout its service area. The technology, installed on more than 700 electric distribution circuits, can automatically "self-heal" the grid by rerouting the flow of electricity around a damaged power line, often restoring power to the majority of impacted customers within minutes.

Since the program began in 2012, these systems have been installed on more than 20 percent of PG&E's electrical distribution circuits and have helped the company avoid 130 million customer outage minutes and prevented more than 1.3 million customers from experiencing a sustained outage.

PG&E has also installed nearly 10 million electric and gas SmartMeter™ devices across its service area. The meters enable PG&E to better detect areas affected by outages, resulting in faster and more accurate service restoration.

Gas

PG&E reviewed its gas infrastructure assets against the flooding scenario and identified the following assets located in the hazard zone represented by FEMA's 100- and 500-year flood zone maps. PG&E's preliminary assessment represents the risk exposure of its assets, calculated as the percentage of assets in the hazard zone. See Figure 7 for PG&E's gas transmission pipelines identified within the 100-year FEMA flood zone. Please note that this analysis does not represent the ability of the asset to withstand the natural hazard.

Table 4: Percent exposure of gas assets to 100- and 500-year FEMA flood zones

Gas assets	100-Year flood zone exposure	500-Year flood zone exposure
Distribution mains	7%	14%
Distribution services	4%	12%
Distribution regulating stations	9%	10%
Transmission pipe	28%	34%
Transmission stations	13%	21%
Storage fields	25%	25%
CNG/LNG stations	9%	23%

Figure 7: Map of PG&E's gas transmission pipelines in the San Francisco Bay region, about 35 percent of which intersect with the 100-Year FEMA flood zone

PG&E identifies and mitigates potential impacts from flooding through scheduled patrols, leak surveys and routine maintenance.

RESILIENCE MEASURES

Protecting gas infrastructure

From a planning perspective, PG&E's Gas Emergency Response Plan prescribes immediate actions to be taken to ensure safety and reliability in major flooding events. PG&E has prioritized areas of exposed pipeline and pipeline spans in flood zones and coordinated on response plans for assets with higher-risk exposure to flood zones. PG&E is also developing long-term plans to address areas of gas transmission pipeline at risk of erosion and landslides.

From an operational perspective, PG&E continues to identify and mitigate potential impacts from flooding through scheduled patrols, leak surveys and routine maintenance. PG&E uses automated notifications for areas at risk of landslides due to heavy rain events. PG&E also identifies and monitors pre-determined gas transmission pipeline locations susceptible to erosion and landslides through use of Light Detection and Ranging (LiDAR) to monitor and track potential land movement, accompanied by field verification.

PG&E's meteorological department forecasts where and when storms are likely to arrive and progress through PG&E's service area, including identifying potential areas of greatest rainfall intensity. A PG&E-developed model enables the company's gas operations to identify high risk areas susceptible to rainfall-induced landslides. Together, the rainfall forecasts and associated models help PG&E to better understand the potential impact to its gas system infrastructure from storms.

PG&E has also reviewed the *Pipeline and Hazardous Materials Safety Administration Advisory Bulletin, Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Flooding, River Scour, and River Channel Migration*, issued on January 19, 2016, and considered its applicability to PG&E's natural gas facilities and implemented additional mitigation plans.

SEA LEVEL RISE

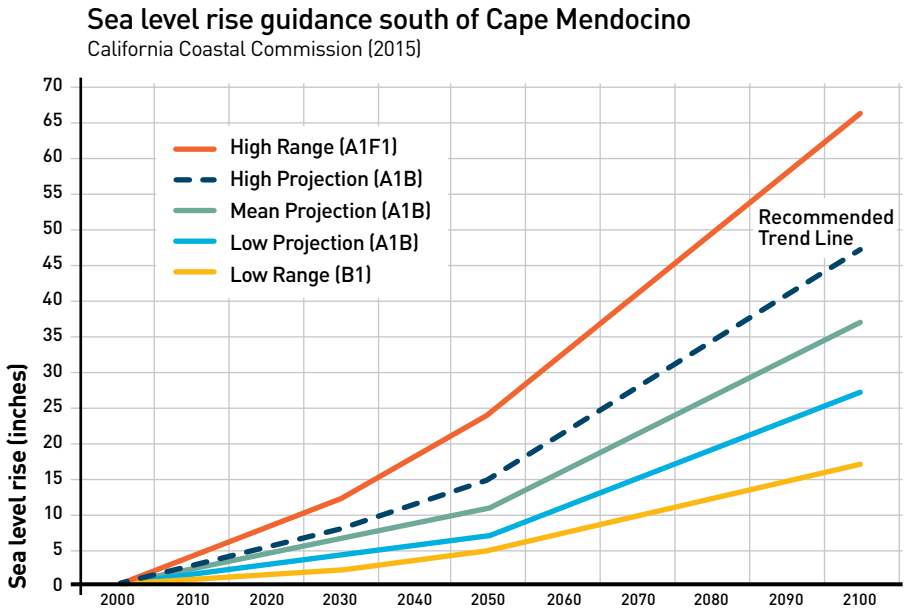
Scenario: Assess potential impact on PG&E assets of 24 inches of sea level rise by 2050

The scenario for PG&E's risk assessment is 24 inches—or two feet—of sea level rise above the Mean Higher High Water (MHHW), defined as the average of the highest of the two daily high tides. PG&E selected 24 inches because it represents the high end of the forecasted range of sea level rise for 2050, based on the California Coastal Commission Sea Level Rise Guidance issued in August 2015. Cal-Adapt does not currently provide sea level rise guidance for specific years or decades, but recommends following California Coastal Commission guidance.

PG&E used data from the NOAA Coastal Services Center to map the sea level rise inundation. PG&E's sea level rise analysis shows future coastal high-tide inundation, not flooding associated with storm incidents.

PG&E is also undertaking a more robust coastal flood risk analysis of at-risk assets using additional scenarios of sea level rise that consider factors such as high tides and storms surges.

The following chart shows the recommended guidance from PG&E's climate change science team, which considers projected levels of sea level rise along the coast south of Cape Mendocino through the end of this century. To ensure a conservative approach, PG&E chose the high end of the current climate change science team sea level rise estimate for 2050. One challenge is the wide range of uncertainty in sea level rise projections in light of rapidly evolving science—as well as the need for more standardized scenarios using consistent input parameters and a standardized mapping platform.



IPCC Emission Scenarios:

A1F1: Rapid economic growth trend; fossil fuel intensive
A1B: Rapid economic growth trend; balanced fuel sources
B1: Balanced economic growth fueled by clean resource-efficient technologies

Sea Level Rise Guidance

Year	Trend line (inches)	Low/high range (inches)
2020	5	1 to 8
2030	8	2 to 12
2040	12	3 to 18
2050	15	5 to 24
2060	21	7 to 32
2070	28	10 to 41
2080	34	12 to 49
2090	41	15 to 58
2100	47	17 to 66

Range values taken from California Coastal Commission Sea Level Rise Guidance, August, 2015

Figure 8: Sea level rise guidance

Electric

PG&E reviewed its electric infrastructure assets against the sea level rise scenario and identified the following assets located in the areas of likely high-tide inundation by 2050. PG&E's preliminary assessment represents the risk exposure of its assets, calculated as the percentage of assets in the hazard zone. This does not represent the ability of the asset to withstand the natural hazard.

Table 5: Percent exposure of electric assets in the hazard zone to frequent inundation based on 24 inches of sea level rise and MHHW

Electric assets	Sea level rise exposure
Distribution lines	< 1%
Distribution transformers (pad-mount)	1%
Transmission lines	1%
Substations	< 1%
Power generation facilities	0%

RESILIENCE MEASURES

Protecting electric infrastructure

Because this is a longer-term risk, PG&E is participating in a variety of local government-led studies and initiatives to better understand and plan for potential impacts. PG&E also provided input to California's Sea Level Rise Planning Database on PG&E's activities, as required under AB 2516. In the near term, PG&E is also undertaking a more robust coastal flood risk analysis of at-risk assets using additional scenarios of sea level rise.

Figure 9: PG&E's substations within areas modeled for two feet of sea level rise plus MHHW in the San Francisco Bay region

Gas

PG&E reviewed its gas infrastructure assets against the sea level rise scenario and identified the following assets located in the areas of likely high-tide inundation by 2050. PG&E's preliminary assessment represents the risk exposure of its assets, calculated as the percentage of assets in the hazard zone. This does not represent the ability of the asset to withstand the natural hazard.

Table 6: Percent exposure of gas assets in the hazard zone to frequent inundation based on 24 inches of sea level rise and MHHW

Gas assets	Sea level rise exposure
Distribution mains	< 1%
Distribution services	< 1%
Distribution regulating stations	< 1%
Transmission pipe	1%
Transmission stations	1%
Storage fields	0%
CNG/LNG stations	0%

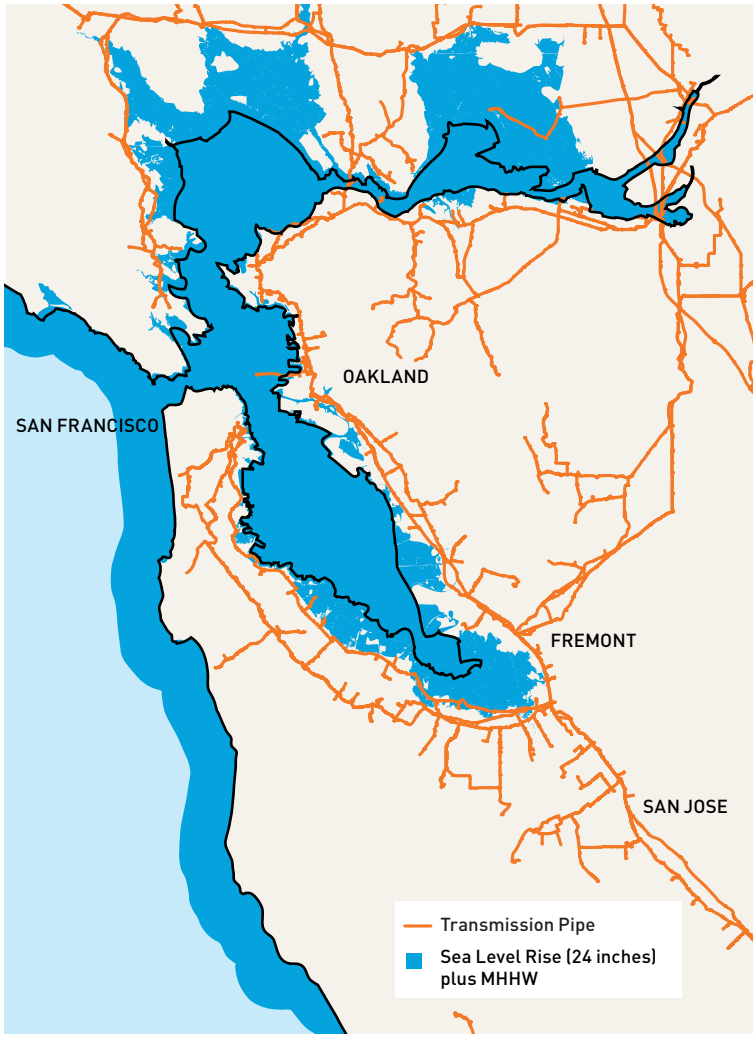


Figure 10: Map of PG&E's gas transmission pipelines in the San Francisco Bay region, about five percent of which are within areas modeled for two feet of sea level rise plus MHHW

RESILIENCE MEASURES

Assessing natural gas pipeline vulnerability to sea level rise

PG&E is working with the research community to explore the physical vulnerabilities of California's natural gas system due to climate change so that the company can prepare for the actions needed to adapt to those changes.

PG&E partnered with the University of California, Berkeley's Center for Catastrophic Risk Management on a California Energy Commission-funded study to assess the potential impacts of sea level rise and extreme flooding on the company's gas transmission system. The results of this study will inform PG&E's ongoing efforts to better understand, plan for and respond to future climate change risks to its gas transmission infrastructure.

The study, entitled *Assessment of Bay Area Natural Gas Pipeline Vulnerability to Climate Change*, used a worst case future scenario of 1.41 meters (4.6 feet) of sea level rise coupled with a 100-year storm event and focused on the San Francisco Bay Area, Sacramento-San Joaquin Delta, and Coastal California. Researchers used geographic information systems (GIS) and a state-of-the-art hydrodynamic model to simulate the location and depth of potential inundation under a realistic extreme storm event coupled with sea level rise.

Importantly, 1.41 meters of sea level rise is a scenario that climate scientists project for the year 2100. PG&E selected this worst-case scenario to enable both the company and the research team to assess a higher threshold of potential impacts to the company's natural gas transmission system.

The study found that approximately 36 miles of PG&E's gas transmission pipeline, more than 475 valves and nearly 100 stations could be impacted by the report's worst case scenario and may result in costs to replace, modify and deactivate aspects of the gas transmission pipeline system. The study estimated that the potential annual cost of transmission infrastructure upgrades would be between $4 and $7 million. PG&E plans to integrate the results of the study into its risk assessment process to inform its ongoing resiliency planning.

SUBSIDENCE

Scenario: Assess potential impact of ground subsidence in areas where subsidence has occurred

California's historic drought has resulted in land subsidence in the San Joaquin Valley due to groundwater overdrafting, where the use of groundwater has exceeded the amount of water recharged into the groundwater basins. PG&E's subsidence scenario uses Interferometric Synthetic Aperture Radar (InSAR) datasets from the NASA-Jet Propulsion Laboratory (JPL) showing areas where additional ground subsidence has occurred between two time periods: June 2007–January 2011 and May 2014–January 2015. Using the 2007–2011 data, PG&E assessed its assets at a range of thresholds, with several based on historical minimum levels of subsidence at which damage may occur. Due to the need for enhancements to the 2014–2015 data, PG&E was only able to conduct a qualitative analysis of the impacts of this more recent dataset. PG&E continues to work with federal and state agencies to obtain the latest available subsidence data, and for at-risk areas, collaborate on monitoring efforts.

Electric

PG&E reviewed its electric infrastructure assets against the subsidence scenario and identified the following assets located in the 2007–2011 hazard zone. PG&E's preliminary assessment represents the risk exposure of its assets, calculated as the percentage of assets in the hazard zone. This does not represent the ability of the asset to withstand the natural hazard.

Generally speaking, PG&E found:

- Low exposure risk of electric assets to damage from subsidence
- No significant past damage reported for electric system

Table 7: Percent exposure of electric assets to minimum threshold subsidence at which damage may occur within the hazard zones (from the 2007–2011 NASA-JPL data)

Electric assets	Minimum threshold	Subsidence exposure (%)
Distribution lines (overhead)	2 feet	< 1%
Distribution lines (underground)	1 feet	< 1%
Transmission structures	Towers: 3 feet Poles: 2 feet	< 1%
Transmission lines (underground)	0.5 feet	0%
Substations	0.5 feet	2%
Top critical substations	0.5 feet	0%
Critical facilities	0.5 feet	0%

RESILIENCE MEASURES

Protecting electric infrastructure

PG&E is currently developing a strategy to assess and monitor its electric assets in subsidence zones.

Electric transmission lines within San Joaquin subsidence zone (2007–2011 subsidence data)

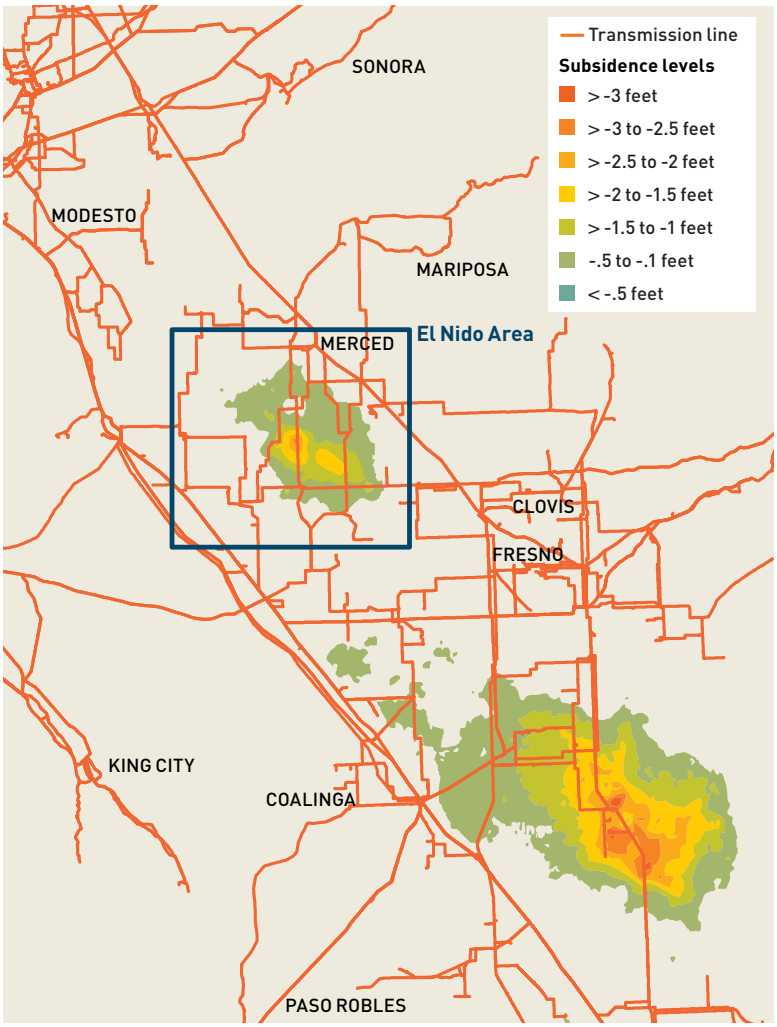


Figure 11: Electric transmission lines identified within the San Joaquin subsidence zone (from the 2007–2011 NASA-JPL data)

Electric transmission lines within San Joaquin subsidence zone (2014–2015 subsidence data)

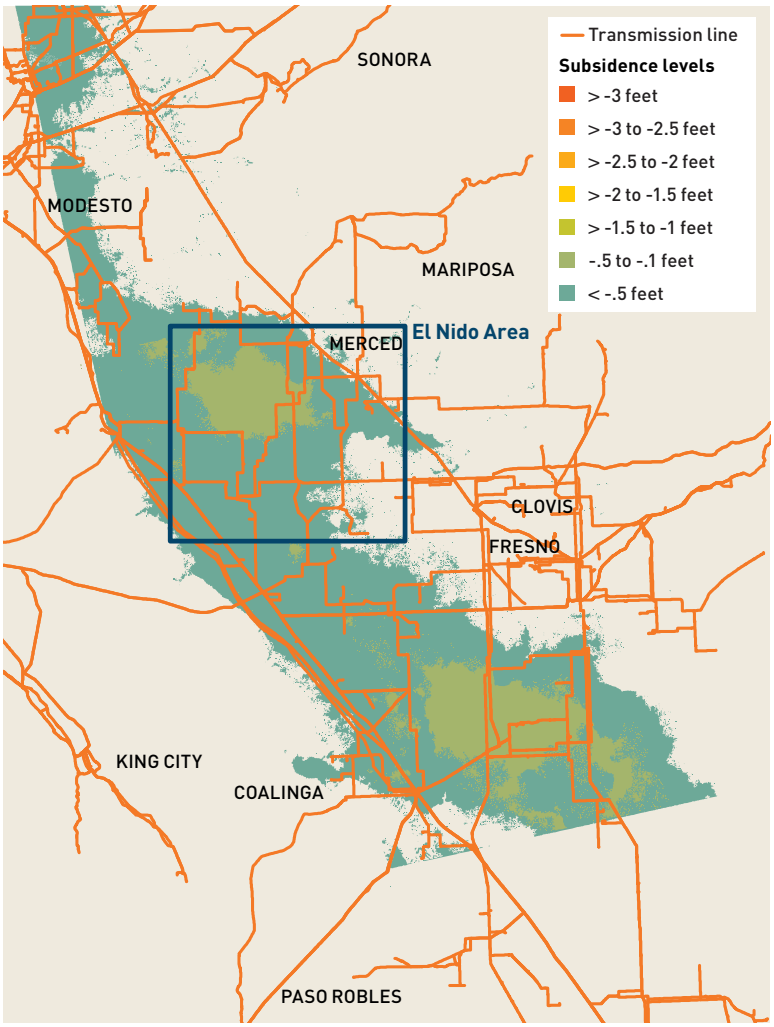


Figure 12: Electric transmission lines identified within the San Joaquin subsidence zone (from the 2014–2015 NASA-JPL data)

Gas

PG&E reviewed its gas infrastructure assets against the subsidence scenario and identified the following assets located in the hazard zone. The table below shows PG&E's preliminary assessment of the 2007–2011 NASA-JPL data representing the risk exposure of its assets, calculated as the percentage of assets in the hazard zone. This does not represent the ability of the asset to withstand the natural hazard. PG&E found no significant past damage reported for the gas system in subsidence zones.

Table 8: Percent exposure of gas assets within the San Joaquin subsidence zone (from the 2007–2011 NASA-JPL data)

Gas assets	Subsidence exposure (%)
Distribution mains	< 1%
Distribution services	< 1%
Distribution regulating stations	< 1%
Transmission pipe	< 1%
Transmission stations	0%
Storage fields	0%
CNG/LNG stations (count)	0%

Gas transmission lines within San Joaquin subsidence zone (2007–2011 subsidence data)

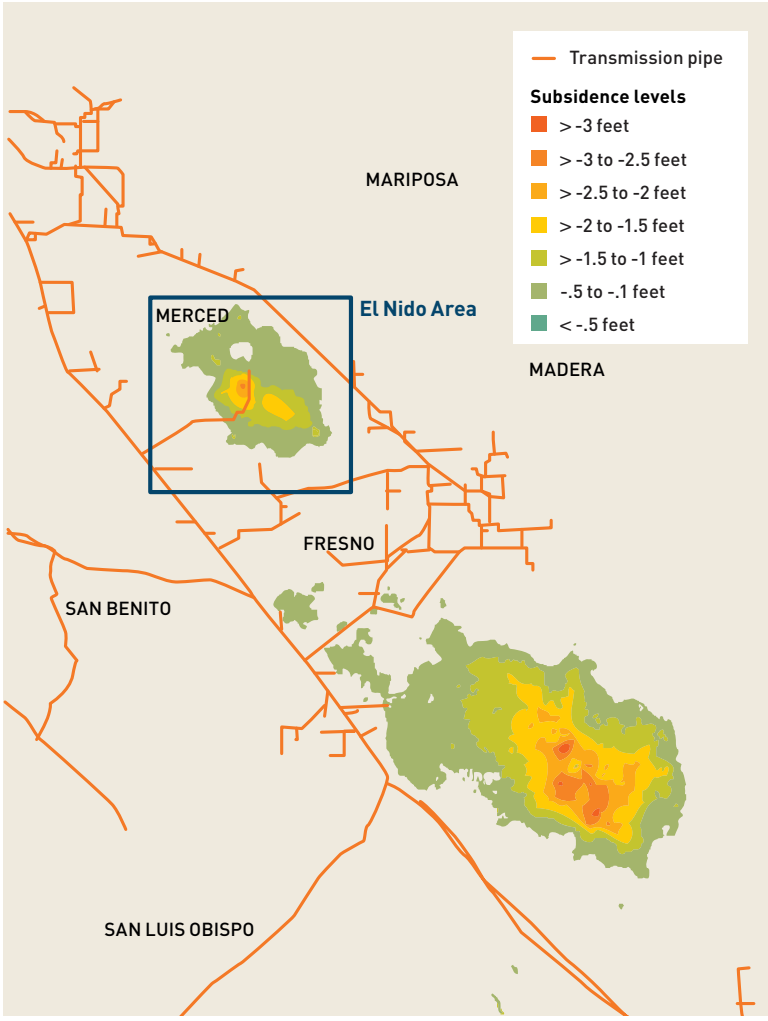


Figure 13: Gas transmission pipeline identified within the San Joaquin subsidence zone (from the 2007–2011 NASA-JPL data)

Gas transmission lines within San Joaquin subsidence zone (2014–2015 subsidence data)

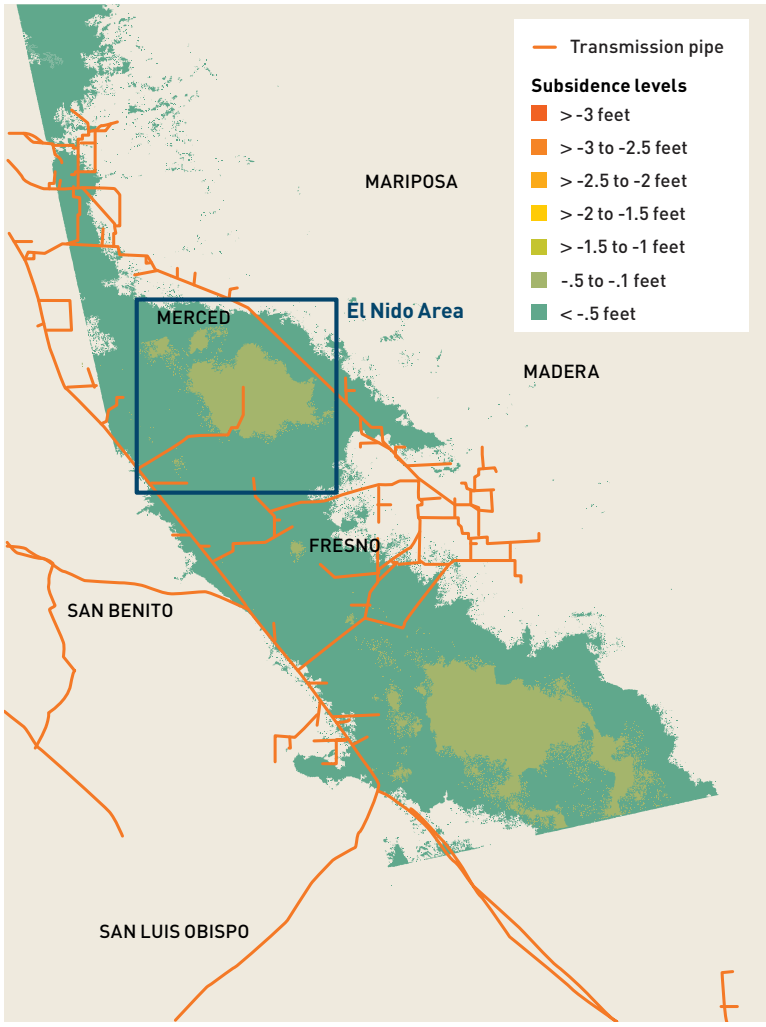


Figure 14: Gas transmission pipeline identified within the San Joaquin subsidence zone (from the 2014–2015 NASA-JPL data)

PG&E conducted a third-party led pilot project to better understand the potential impact of subsidence on its natural gas transmission pipeline near El Nido in California's Central Valley.

RESILIENCE MEASURES

Assessing natural gas pipeline vulnerability to subsidence

California's Central Valley has experienced land subsidence as a result of groundwater withdrawal and it has been a significant challenge to understand the potential impacts to infrastructure such as roads, railways, bridges and pipelines. In the region south of El Nido, NASA's Jet Propulsion Laboratory documented approximately two feet of subsidence between 2007 and 2011 and an additional foot of subsidence between 2014 and 2015.

Given these findings, PG&E conducted a third-party led pilot project to better understand the potential impact of subsidence on its natural gas transmission pipeline (Line 186) near El Nido and enable the company to identify appropriate pipeline integrity management measures. The research team conducted a full geotechnical and pipeline structural integrity assessment of ground displacement related to continued groundwater withdrawal in the region.

The analytic modeling of the subsidence in the El Nido region for Line 186, both accumulated to date and predicted in the future, indicated that the subsidence poses a low risk and that the pipeline is fit for service. The team further recommended that PG&E continue to monitor the El Nido subsidence basin over the coming years using available public agency data to ensure that the subsidence coincides with the pattern predicted by the modeling. The team also recommended that PG&E reassess the pipeline's integrity in future years based on projections from future subsidence data.

Moving forward, PG&E will continue working to better understand the effects of subsidence through pipe analysis and modeling efforts, resulting in the development of risk-informed monitoring strategies.

HEAT STORMS AND CHANGE IN TEMPERATURE EXTREMES

Scenario: Assess potential impact on assets of long-duration heat wave

Heat waves increase electricity demand from customers and can put pressure on the grid. PG&E's scenario is to assess its system against the catastrophic July 2006 California heat wave, the worst heat wave to impact the state in the past 60 years.

The event lasted almost two weeks—with the maximum temperature in Fresno over 105 degrees for 12 consecutive days and, during the height of the event, over 110 degrees for five consecutive days. Compounding the challenge was the extreme nighttime minimum temperatures; during the peak of the event, Fresno did not cool below 80 degrees for five consecutive nights. The general duration and magnitude of the July 2006 heat wave is comparable with the suggested maximum heat wave duration and peak daily temperature tools provided by Cal-Adapt around year 2050.

The July 2006 California heat-wave was estimated to have a $150 to $300 million impact due to infrastructure repair costs and the increased cost of electricity due to peak demand.

Climate models suggest events of this magnitude will likely occur more frequently. The following table indicates that the number of hot days per summer in California's Central Valley will increase as the century progresses.

Table 9: The number of hot days per summer are projected to increase as the century progresses based on climate change models

	High emission scenario	Low emission scenario
Decade ending	Modeled # days ≥ 100°f	Modeled # days ≥ 100°f
2020	12	13
2030	14	10
2040	18	19
2050	21	17
2060	24	18
2070	28	26
2080	37	20
2090	47	26
2100	57	27

Source: Cal-Adapt on-line database for Central Valley location with a 98% (4 days per year) maximum temperature of 100 degrees Fahrenheit relative to a 1961–1990 April–October baseline.

Electric

The July 2006 heat wave caused significant customer sustained interruptions and affected various electrical assets, including transformers, substations, and transmission and distribution lines. PG&E reviewed its current electric infrastructure assets against the heat storm scenario and the preliminary assessment found:

- High exposure risk to distribution line transformers
- Low exposure risk to transmission lines and substations

RESILIENCE MEASURES

Electric system upgrades

PG&E made a number of improvements after the 2006 heat storm:

- Re-evaluated company standards, procedures, guidelines and policies
- Added new tools for load growth planning that better predict system overloads
- Installed more than five million electric SmartMeters and started aggregating transformer loads in real time for better overload prediction
- Replaced nearly 500 distribution line transformers to avoid overloading
- Increased emergency stock levels of equipment
- Developed a temperature-dependent outage forecast model (SOPP) for advanced warning and planning for heat events
- Completed the Cornerstone project, which improved reliability and significantly increased capacity to the distribution grid through new feeders and substation transformers

Today, PG&E has a structured process to mitigate the impacts of hot weather on its system. On an annual basis, the company uses a sophisticated model and past summer season data to forecast peak load relative to the system's capacity, so that PG&E can take the necessary steps to meet customer demand—from reconfiguring the system to installing new equipment.

More broadly, PG&E is investing significant resources to modernize its electric operations. This includes substantial investments focused on maintaining and replacing aging equipment, making asset upgrades and using new technology to monitor and reduce the time to restore power to customers.

RESILIENCE MEASURES

Innovative demand response pilots

During heat events, PG&E's wide-ranging demand response programs can help relieve pressure on the grid and save customers money with incentives to reduce their energy use or shift it to another time. Through new data platforms, programs and pilots, PG&E continues to partner with third parties to deliver innovative products and services that help ensure the reliability of the energy grid.

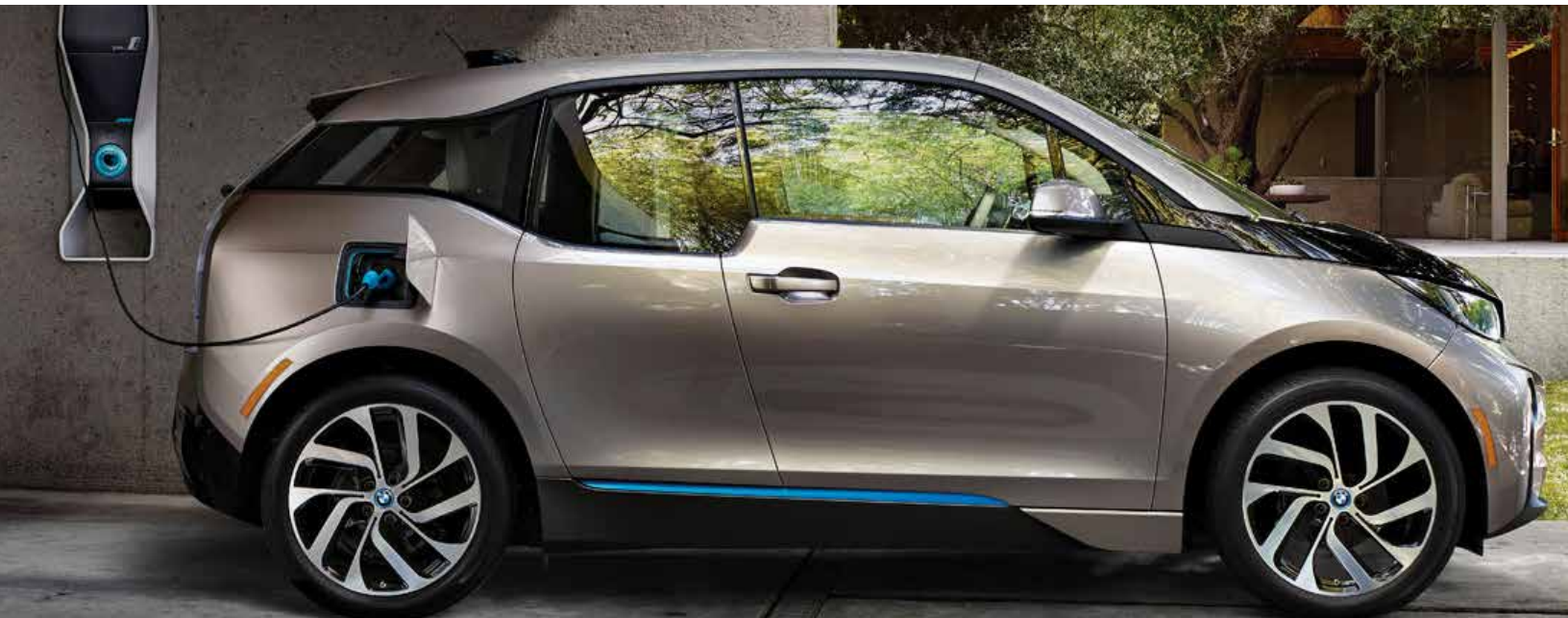
PG&E and automaker BMW teamed up on a smart charging pilot project to test the potential for electric vehicle batteries to provide valuable services to the energy grid. BMW enlisted 100 owners of its BMW i3 electric vehicles to take part in the pilot. During the test period, PG&E is sending BMW an alert over the Internet, indicating how much load to reduce and for how long. BMW then signals the telemetry equipment in each participating vehicle, telling it to halt its charging for the duration of the event.

The automaker also uses second-life electric vehicle batteries in a stationary storage system to ensure PG&E's full request is met. The successful pilot program could help ensure that the growing electric vehicle charging load is managed efficiently on the grid and provides value to vehicle owners who can be flexible with their charging.

In addition, PG&E launched a supply-side pilot program through which participants define when, how much and at what price they are willing to reduce their energy load. This differs from traditional demand response programs, where PG&E signals when to reduce electricity use.

As another example, a new two-year demand response auction mechanism pilot enables California's investor-owned gas and electric companies to procure demand response services from third parties via a competitive auction. These third parties offer innovative services and tools that incentivize customers to participate in programs that reduce energy usage.

PG&E and automaker BMW are teaming up to test the potential for electric vehicle batteries to provide valuable services to the energy grid.



Gas

PG&E reviewed its gas infrastructure assets against the heat storm scenario and found:

- Low exposure risk to gas system
- No significant past damage reported for gas system

RESILIENCE MEASURES

Protecting natural gas infrastructure

PG&E operates gas assets under conditions that vary widely depending on the season and location. For pipes located above ground level, extreme temperatures may accelerate the degradation of coating caused by air exposure. For station equipment, temperatures exceeding design limits and cooling capabilities may result in decreased performance or shutdown in response to safety instrument monitoring.

To maintain the safety and reliability of its system, PG&E monitors its gas assets regularly through remote monitoring systems, equipment inspections, patrols, leak surveys and cathodic protection (corrosion) system monitoring to identify assets that may require additional integrity assessment, repair or replacement.

RESILIENCE MEASURES

Supporting local cooling centers

To support local communities as summer temperatures rise, PG&E provides grants to help fund cooling centers, which provide a safe, comfortable location for those who need it. The cooling centers open when temperatures reach 105 degrees or higher.

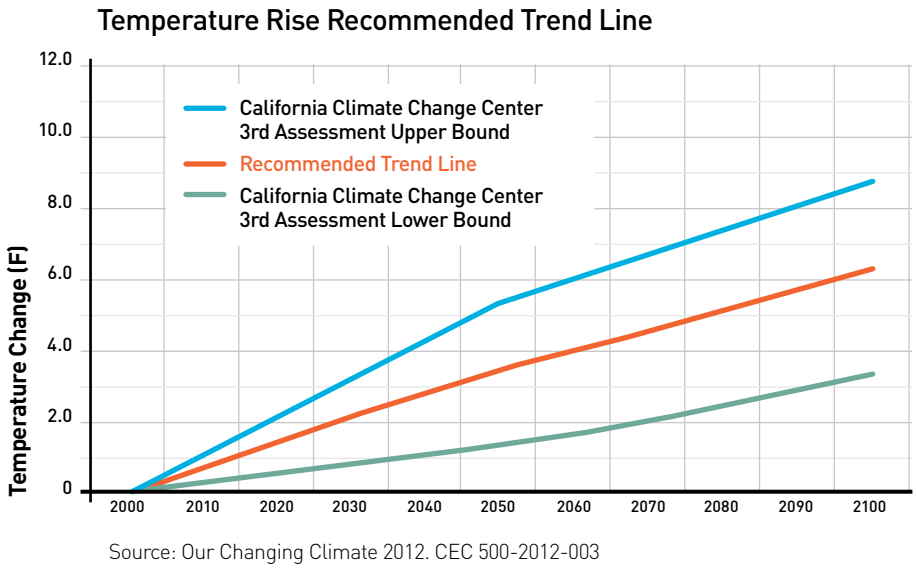
PG&E began funding cooling centers as part of a pilot project in 2007 following the 2006 heat wave in California. Since then, the company has provided more than $500,000 to support cooling centers, primarily located in established local government-run senior centers, neighborhood parks and recreation centers.

PG&E's website provides information on cooling centers and also encourages customers to contact their local city or county to find a cooling center.

PG&E provides grants to help fund cooling centers, which provide a safe, comfortable location for those who need it during heat waves.

Change in mean temperatures

PG&E's science team developed a projected trend line for temperature rise based on California's Third Climate Change Assessment, with a forecasted 3.6 degree Fahrenheit (°F) increase by 2050.



PG&E Science Team Guidance

Year	Temp Change (F)
2020	1.4
2030	2.2
2040	2.9
2050	3.6
2060	4.1
2070	4.7
2080	5.2
2090	5.8
2100	6.3

Figure 15: PG&E's science team temperature rise guidance for this century

Other key hazards and resilience measures

California has recently faced one of the most severe droughts in modern history. In addition to land subsidence, the operational consequences of extreme drought include reduced hydroelectric output and increased wildfire frequency and intensity. The sections below describe PG&E's preliminary assessment of the key risks and potential impacts of drought and wildfires, including actions taken to address them.

DROUGHT

Water is essential to the California economy, as well as the health and well-being of its citizens. It is also deeply intertwined with the state's energy infrastructure, including PG&E's vast hydroelectric system. A hotter and drier climate, along with potentially more frequent and severe droughts, could alter fire fuel conditions in ways that promote larger, more catastrophic fires able to threaten energy company assets.

In 2015, California experienced a fourth year of extreme drought conditions. In parallel with the NHAP initiative, PG&E has been actively addressing the key risks and impacts of the drought and the land subsidence issues associated with accelerated rates of groundwater extraction.

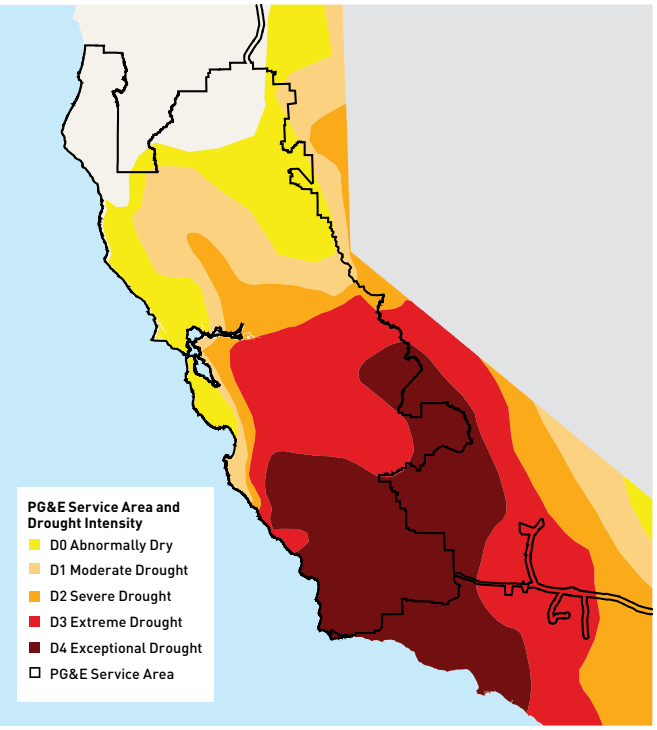


Figure 16: U.S. Drought Monitor drought intensity map overlain with PG&E's service area as of November 1, 2016

PG&E created the Lake Pillsbury Drought Working Group, which collaborated to conserve water in Lake Pillsbury and ensure a water supply for local watersheds.

Reduced hydroelectric generation

PG&E owns and operates the nation's largest investor-owned hydroelectric system, with a total generating capacity of nearly 4,000MW. PG&E's system relies on nearly 100 reservoirs located primarily in the higher elevations of California's Sierra Nevada and Southern Cascade ranges to store water for power generation. PG&E also uses water for energy storage to help balance daily variations in electric demand at its 1,212MW Helms Pumped Storage Project.

The California Department of Water Resources' (DWR) annual snow survey is considered critical to gauging the snowmelt that will fill the state's reservoirs in summer months. The April 2015 survey revealed the lowest snowpack measurement ever recorded, just five percent of average for that date and an indication of the severity of the recent drought. These conditions impact PG&E's hydroelectric system as less mountain snowpack and earlier spring snowmelt results in less hydroelectricity.

The cost of climate change impacts on hydroelectric production will vary greatly by year. In 2016, the Pacific Institute released an assessment of the costs to California of lost hydroelectricity during the four years of drought from October 2011 to the end of September 2015. The report found that the four years of drought led to an increase in electricity costs of more than $2 billion and the additional combustion of fossil fuels for electric generation also led to a 10 percent increase in the release of carbon dioxide from California power plants.

RESILIENCE MEASURES

Near-term strategies to manage hydroelectric facilities

As California experiences persistent drought conditions, PG&E is working closely with water districts, first responders and regulatory agencies to address the drought's effects, including limited water deliveries, increased fire danger and environmental impacts.

In the near-term, PG&E is continually analyzing reservoir and stream conditions while collaborating with regulatory agencies and other stakeholders to conserve water whenever possible in individual regions. PG&E is working to assess the required water releases from its reservoirs to lessen the drought's impact on the environment and prolong availability of water for downstream users' needs.

For example, Lake Pillsbury, a storage reservoir, became perilously dry as a result of the drought—threatening PG&E's ability to provide water to protect Chinook salmon and steelhead populations in the Eel River watershed and for agricultural and domestic water use in the Russian River watershed. In response, PG&E created the Lake Pillsbury Drought Working Group, which collaborated to conserve water in Lake Pillsbury and ensure a water supply for both watersheds. Without the working group, storage levels in Lake Pillsbury would have dropped below critical levels and led to water curtailment.

PG&E is working with researchers to improve hydroelectric monitoring and predictive tools, reduce uncertainty in water forecasts and adapt to climate change.

RESILIENCE MEASURES

Collaborative research to improve hydroelectric system forecasting and management

Climate scientists predict that climate change will result in significant reductions in snowpack in parts of the Sierra Nevada Mountains and altered precipitation patterns.

To better understand precipitation patterns and potential impacts on PG&E's hydroelectric generation, the company is partnering with the University of California, Berkeley and the California Department of Water Resources on a multi-year research project involving PG&E's North Fork Feather River facilities.

Using California Energy Commission funding, the research team is installing a next-generation hydrographic data network that integrates satellite remote sensing data with ground-based measurements. This will enable PG&E to better measure and monitor snowpack, climate, soil moisture and other factors to improve monitoring and predictive tools, reduce uncertainty in water forecasts and adapt to climate change.

The project will also assess the costs and benefits of using the intelligent water information system as compared to current statistical forecasts.

Enhanced planning and operation of PG&E's hydropower system is also increasingly important as the company expands supplies of intermittent renewable energy sources such as wind and solar. Hydropower facilities provide a flexible resource that can help integrate additional renewables into the system, but doing so will require more precise control of available water supplies.

Beyond this research, a team of PG&E hydrographers regularly measures snowpack to determine the spring runoff that ultimately will forecast how much hydroelectricity PG&E will generate for the coming year. PG&E also uses a number of sophisticated models and systems to manage its hydroelectric system, including hydrologic data, models and statistical tracking tools.

Impacts to operations and customers

As California's drought continues, water conservation and efficiency are critical to managing the state's surface and groundwater supplies. In 2015, the State Water Resources Control Board issued the first ever mandatory water reduction regulations mandating that cities and towns across the state reduce water use by 25 percent. Agricultural customers have increased reliance on groundwater, resulting in increased pump usage and energy bills.

RESILIENCE MEASURES

Conserving water at PG&E facilities

PG&E is working vigorously to conserve water in its operations and at its facilities, as well as help customers to reduce water use and encourage employees to do the same at work and at home. The company is also collaborating with state agencies, municipalities and others to limit the threat of wildfire due to the drought and protect the many watersheds that contribute to the vibrancy of the state.

In response to California's drought, PG&E has actively promoted water conservation with both customers and employees.

PG&E helped customers save about 1.2 billion gallons of water through energy efficiency in 2015.

RESILIENCE MEASURES

PG&E's drought response

PG&E's work is led by an internal Drought Task Force, charged with addressing the impact to PG&E's operations, as well as customers and communities. These measures include:

- **Maintaining low freshwater use at power generation facilities:** PG&E relies on air, not freshwater, for cooling its three natural gas power plants. At the 2,240MW Diablo Canyon Power Plant, PG&E uses saltwater from the Pacific Ocean for once-through cooling. Further, PG&E uses on-site desalination to support the majority of freshwater demand for internal operations of Diablo Canyon Power Plant.
- **Conserving water at office facilities:** PG&E has achieved significant reductions in water consumption at office facilities and service yards. In 2015, the company reduced water use by 7.8 percent by finding and repairing leaks and replacing facility landscapes with drought-resistant designs, plants and materials. Through a Water Wise Pledge Campaign, more than 20 percent of its workforce pledged to take specific actions such as shorter showers, checking for leaks and installing water-saving aerators.
- **Helping customers reduce water use:** PG&E offers customers a range of options to help them reduce their water use. Solutions for residential customers include rebates for high-efficiency appliances, such as clothes washers and shower heads, and free wood chips for landscape mulching, which reduces evaporation. PG&E also offers incentives to agricultural customers who convert from sprinkler systems to water-efficient drip irrigation, as well as programs for energy efficient pumping systems. Altogether, customers who participated in PG&E's programs in 2015 reduced their water consumption by about 1.2 billion gallons.

Save Our Water

RESILIENCE MEASURES

Supporting nature-based solutions

Across the country, there is growing interest in using nature-based solutions to protect against the hazards of climate change, such as extreme drought, wildfires, storms and sea level rise.

As one of the largest land owners in California, PG&E has numerous initiatives underway that are building climate resilience by managing lands and waters in an environmentally responsible way. This includes restoring aspen meadows near headwaters, safeguarding watershed lands and maintaining forest lands to minimize the threat of wildfire.

- **Restoring aspen meadows.** For many years in the forests it manages, PG&E has been working to restore meadows with native aspen stands. At each site, PG&E mechanically removes encroaching conifers that shade-out and compete with re-sprouting aspen trees and native grasses. To date, PG&E has restored about 370 acres of aspen groves and meadows in the Sierra and Cascade mountains.

  Doing so may help address drought conditions. That's because many of these meadows are located near headwaters, which are the high-elevation sources of water for California's rivers and streams. Early research suggests that proactive forest management such as meadow restoration can contribute to improved water storage and filtration.

- **Restoring areas damaged by wildfire.** PG&E is working to improve forest health and diversity in areas damaged by wildfire to help these forests become more resilient to future climate impacts. For example, on its property and right-of-ways in the Sierra foothills, PG&E has been actively removing dead and hazard trees, installing erosion control measures and taking other steps to help suppress future wildfires. PG&E is also replanting impacted areas with conifers and oaks to improve forest diversity.
- **Safeguarding watershed lands**. As part of its Land Conservation Commitment, PG&E is permanently protecting some of California's most beautiful watershed lands—totaling 140,000 acres—through the donations of fee title and conservation easements to public agencies and qualified conservation organizations. Preserving, restoring and conserving these lands also builds climate resilience by providing essential wildlife habitat, filtering water, improving water quality and sequestering carbon.
- **Engaging in local tidal restoration.** PG&E is partnering with the U.S. Fish and Wildlife Service Don Edwards National Wildlife Refuge, California Department of Fish and Wildlife Eden Landing Ecological Reserve and the U.S. Army Corps of Engineers San Francisco District as they design and engineer tidal restoration plans in the San Francisco Bay Area. PG&E identifies facilities that may be impacted by the tidal restoration work and collaborates on design and engineering solutions to allow for continued safe operations and maintenance activities.
- **Better Together Nature Restoration Grants.** Through its partnership with the National Fish and Wildlife Foundation (NFWF), which supports community-based projects to restore natural habitats, PG&E has awarded grants to support restoration projects within its service area. The projects have also developed community capacity to sustain local natural resources for future generations. In 2016, PG&E and NFWF are engaging military veterans in forest restoration work in the Sierra Nevada range. The veterans will protect forest ecosystems and watersheds, improve fish and wildlife habitat and develop conservation restoration skills as they transition from military to civilian life.

WILDFIRES

The combined effects of climate change and drought create dry conditions that increase the risk of fires.[4] In 2015, California experienced one of the worst fire seasons in its history.

Wildfires pose a serious threat to critical energy infrastructure, including electric and gas transmission and distribution lines and hydro generation facilities. The threat can contribute to increased maintenance costs and reduced operating efficiency. Climate change will only exacerbate the problem, as rising temperatures, a reduced snowpack and altered precipitation patterns increase the flammability of potential fuel sources over longer periods of time, which will affect wildfire size, frequency and severity.[5]

PG&E's service area endured eight out of 10[6] of the largest forest fires in California in 2015. More than 1,400 PG&E employees responded to wildfire-caused infrastructure damage that affected service to about 33,000 customers. In August 2015, PG&E had four incident teams responding to three major wildfires at the same time—a first for the company. PG&E spent approximately $55.8 million responding to the major wildfires, and $183 million repairing infrastructure damage.

Table 10: California's largest forest fires in 2015

Fire name	County	Acres	Start date
Rough	Fresno	151,623	July 3
River Complex	Trinity	77,074	July 30
Valley	Lake	76,067	September 12
Mad River Complex	Humboldt	73,137	July 30
Butte	Amador and Calaveras	70,868	September 9
Rocky	Lake	69,438	July 29
Fork Complex	Shasta	36,499	July 30
Lake[6]	San Bernardino	31,359	June 17
Gasquet[6]	Del Norte	30,368	August 3
Jerusalem	Lake and Napa	24,118	August 9

PG&E has a broad strategy for assessing and helping to prevent wildfire risk. In the event of a wildfire, however, PG&E mobilizes an incident management team and base camps to actively support the effort. PG&E works closely with state and local agencies and first responders to restore power and support the community. Integrated emergency response teams often work across challenging terrain to assess damage, remove hazardous trees and rebuild equipment to help expedite the safe return of residents to their homes. PG&E may also provide exportable power to evacuation centers and essential businesses.

PG&E also masticates, or mulches, its right-of-ways to help add protection to its infrastructure and provide contingency fire lines. Through mastication, PG&E can provide a fire break without disrupting the mineral layer of the soil, which reduces the impact to nearby waterways and does not require post-fire rehabilitation.

[4]Source: CEC energy.ca.gov/drought/drought_FAQs.html

[5]Sathaye, J., L. Dale, P. Larsen, G. Fitts, K. Koy, S. Lewis, and A. Lucena. 2012. Estimating risk to California energy infrastructure from projected climate change. CEC-500-2012-057. Sacramento, CA: California Energy Commission.

[6]Lake and Gasquet fires occurred outside of PG&E's service area

PG&E's meteorology department uses state-of-the-art weather forecast model data and information to evaluate short- to medium-term fire weather risks across the company's service area.

RESILIENCE MEASURES

Assessing wildfire risk

PG&E's meteorology department uses state-of-the-art weather forecast model data and information from the National Weather Service, United States Forest Service Wildland Fire Assessment System, and other agencies to evaluate short- to medium-term fire weather risks across the company's service area.

To communicate daily fire risks and guide operational decisions, PG&E disseminates "very high" and "extreme" fire danger alerts each day through its Fire Adjective Index System using a map of the company's service area, as shown to the right. The map of fire index ratings includes different levels of fire danger for subsets of PG&E's service area. PG&E also evaluates Red Flag Warnings or Watches issued by the National Weather Service, as well as weather model data, to assess short-term fire weather risk. Each morning, PG&E communicates the information through a daily weather forecast. PG&E's meteorology team also communicates directly with the company's electric organization through daily operational calls.

For the week ahead, PG&E's meteorology department sends out a day-by-day assessment of fire risk to serve as an advanced warning of potentially significant periods of fire danger. The assessments are based on weather model data and combined with governmental fire danger forecasts. The information assists local teams in both fire prevention activities and readiness for response.

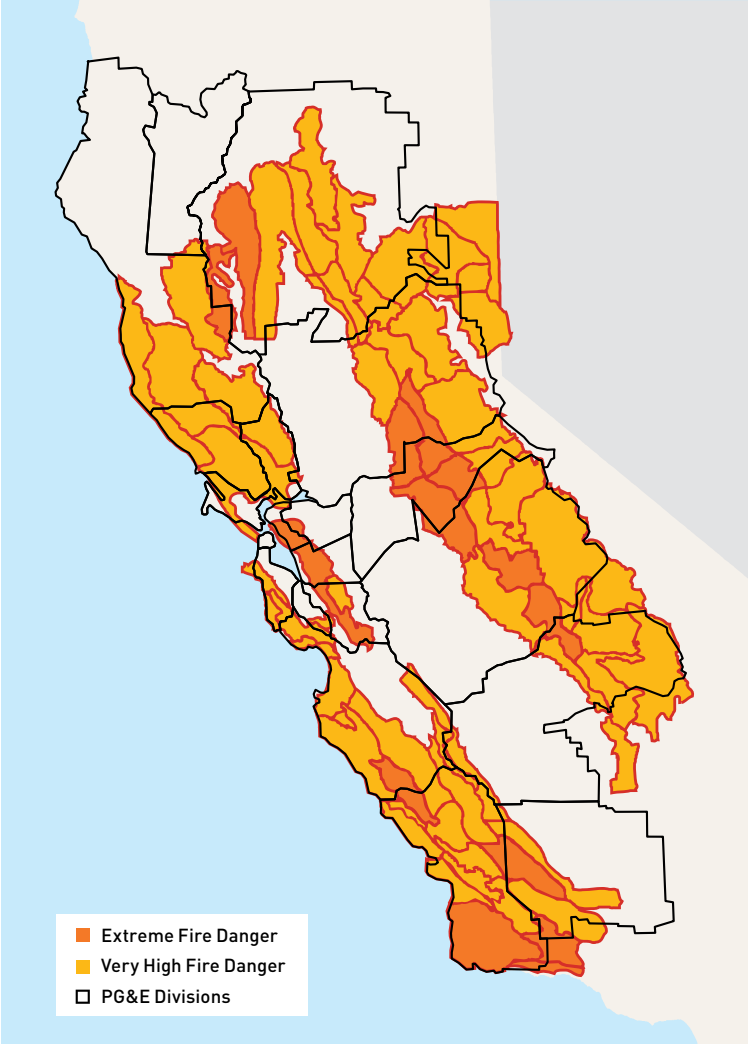


Figure 17: Example of PG&E's daily map of fire index ratings including different levels of fire danger for subsets of PG&E's service area

The fire danger forecasts use the following template and levels to convey the general risk of fire danger across PG&E's service area.

General Fire Danger Forecast for PG&E's service area

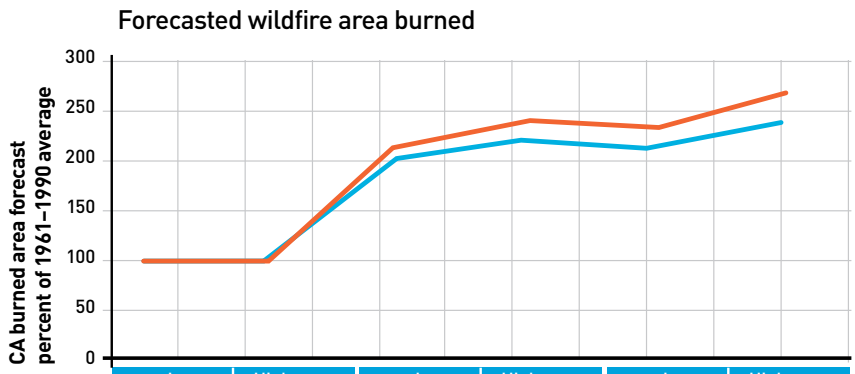
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Very high	High	High	High	Very high	Very high	Very high

General fire danger level

Low	Little to no risk of large fires
Moderate	Some weather risk combined with dry conditions
High	Dry surface conditions and moderate weather risk
Very high	Dry surface conditions and high weather risk
Extreme	Critical fire danger expected, Red Flags or dry lightning likely

Figure 18: PG&E's General Fire Danger Forecast, which provides an advanced warning of potentially significant periods of fire danger

Longer term, researchers estimate that non-urban areas burned by wildfire will increase more than 200 percent by 2050 compared to the 1961–1990 average.



	1961–1990 Low	1961–1990 High	2035–2064 Low	2035–2064 High	2070–2099 Low	2070–2099 High
SRES B1	100	100	205	225	215	240
SRES A2	100	100	215	240	235	270

Figure 19: Bryant, B. P., and A. L. Westerling. 2012. Scenarios to Evaluate Long-Term Wildfire Risk in California: New Methods for Considering Links Between Changing Demography, Land Use, and Climate. California Energy Commission. Publication number: CEC-500-2012-030. SRES B1 and A2 represent IPCC AR4 emission scenarios.

PG&E's Fire Prevention Plan includes a Fire Threat Map across the system. In areas of very high or extreme fire danger, PG&E's Fire Prevention Plan goes into effect. Measures include limits on off-road driving in PG&E fleet vehicles and bans on welding in the field. Operations will also suspend remote line testing, which it uses to assess outage causes; if a wire is on the ground, sending a test charge could spark a grass fire.

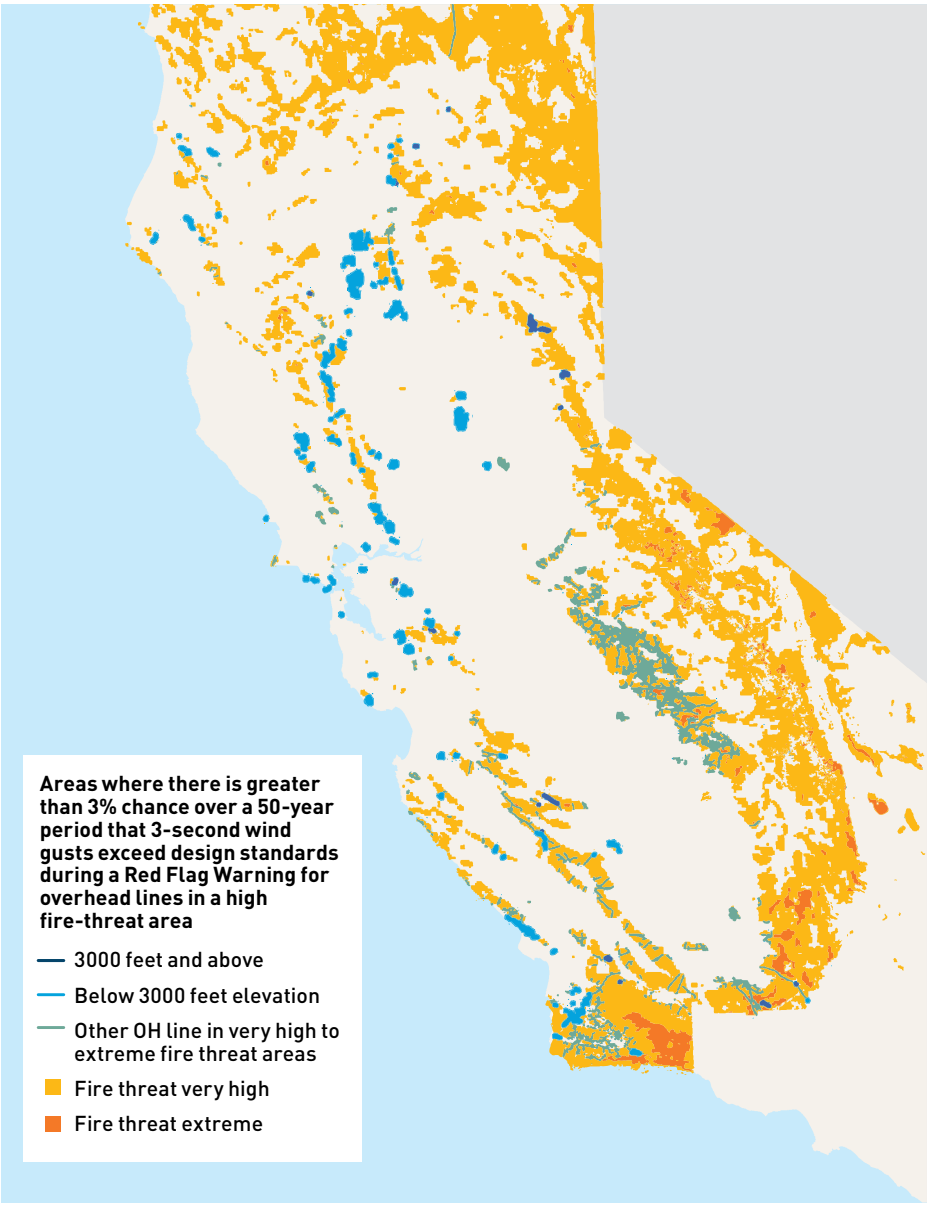


Figure 20: PG&E's Fire Threat Map as reported in the company's 2015 Fire Prevention Plan

RESILIENCE MEASURES

Fire prevention

Fire management activities are integrated into PG&E's operations and monitoring activities. The company participates in regulatory proceedings and benchmarks its methods against other energy providers to help shape policy and identify and implement best practices to minimize and manage risk. To reduce the wildfire risk to its electric operations, PG&E has a broad strategy that includes:

Pre-treatment of energy infrastructure during wildfires

PG&E takes every opportunity to prevent damage to its generation, gas and electric transmission and distribution, and communications infrastructure—both to ensure the safety of the public, first responders and employees; and to maintain service reliability, minimize economic damage and reduce disruption of normal business activities.

During wildfires, PG&E works in concert with the fire incident command team to identify PG&E assets at risk. Based on that assessment, and when safe to do so, PG&E will send crews ahead of the fire and pre-treat infrastructure with fire retardant. During the 2015 wildfires, aggressive asset-protection actions such as pre-treating poles with fire retardant reduced the loss rate, which in turn prevented the public and first responders from being exposed to energy infrastructure debris and helped speed the restoration of service.

In 2016, PG&E crews responded to Lake County's Clayton Fire, which burned nearly 4,000 acres, consumed 300 structures and caused $10 million in damage.

Infrared program and line connection equipment inventory

In PG&E-designated wildland fire prevention areas, the company has a multi-year program to identify, inventory and minimize potential faults or failures over the entire electric distribution system. PG&E uses forward looking infrared technology and visual inspection to identify weaknesses in wire connection equipment that could cause lines to separate. PG&E evaluates the results to prioritize repair and replacement work.

Wires-down program

PG&E performs site visits to locations of downed power lines and obtains data that helps reduce future events—from establishing failure rates for conductor types and sizes to obtaining data that, once added to the company's GIS system, inform planning efforts.

Wood pole test and treat program

PG&E tests all wooden distribution and transmission poles on a 10-year cycle to identify and mitigate decay, which in turn reduces failures. This program exceeds the CPUC's inspection cycle requirements[7] and incorporates wood preservation practices beyond the regulatory standard. The program also allows for preventative reinforcement or replacement of poles.

[7]CPUC General Order 165 mandates this testing on 20–25 year increments depending on the time of installation.

RESILIENCE MEASURES

Vegetation management drought response

PG&E manages the vegetation in proximity to its overhead electric lines, reducing the likelihood of an ignition associated with vegetation contact. PG&E goes beyond the regulatory requirements and works with communities and large property owners to develop and execute projects that manage vegetation for a variety of purposes, including wildland fire prevention.

In response to the drought, PG&E has implemented four initiatives as part of the program:

1. **Enhanced vegetation inspection and mitigation:** PG&E operates redundant air, ground and LiDAR remote sensing patrols in high fire hazard areas, re-inspecting about 40,000 miles of the 134,000 miles of total overhead wires. In 2015, PG&E completed trimming or removal on about 21,000 trees and cleared vegetation around 1,425 poles.
2. **Fuel reduction and emergency response access:** PG&E has funded local Fire Safe Councils to reduce fuel density and increase defensible space and escape route safety, with $2 million allocated throughout the company's service area.
3. **Early detection and response to wildfires and forest disease and infestation:** PG&E has used air patrols and lookout cameras to help detect wildfires and assist state and local fire agencies with early fire detection and response to stop fires from spreading. PG&E-funded surveys and cameras spotted about 150 fires, of which 25 were the first report in 2015. In 2016, PG&E-funded aerial patrols spotted 142 fires, of which seven were the first report.
4. **Public education:** PG&E has supported CAL FIRE's broadcast, print and billboard advertising to make homeowners aware that bark beetles are killing millions of trees in California, which then become fuel for fire, and to educate residents on steps they can take to reduce wildfire risk.

RESILIENCE MEASURES

Collaborating to predict future tree mortality

PG&E continues to look for new tools to improve its proactive response to tree mortality and associated wildfire risks. This includes working with researchers at Humboldt State University to build a model to predict locations of future tree mortality across its service area. The results will be available as a five-year predictive map to help PG&E assess forest health and the risk of wildfire. To develop the model and predictions, researchers considered factors such as historic data on tree mortality, drought impacted areas, forest type and climate data.

More than 100 million trees have died in California since 2010.

RESILIENCE MEASURES

Addressing bark beetle impacts

According to the U.S. Forest Service, more than 100 million trees have died in California since 2010. These dead trees are fuel for wildfire.

PG&E expects to prune or remove about 1.1 million trees along its power lines in 2016 under its annual routine maintenance program to prevent power outages and wildfires. As part of PG&E's response to the tree mortality crisis, approximately 180,000 to 200,000 additional dead or dying hazard trees will be removed—about five times the pre-drought annual average.

The company is also taking its work a step further. Normally, because the wood is the property of the homeowner, PG&E leaves it behind in manageable pieces for the homeowner to use or dispose of on their own. But with the high volume of limbs and trunks on the ground creating a fire hazard, PG&E launched an expanded debris management program to help customers stay safe.

Available in the counties hit hardest by tree mortality, the expanded debris management program is available to customers with dead or dying trees that could come in contact with PG&E electric lines and other system components. If the debris meets certain criteria, for example being within 20 feet of serviceable roadways, PG&E will haul away the wood at no cost to the homeowner.

PG&E has also supported CAL FIRE's "Prepare for Bark Beetle" public awareness campaign by increasing inspections and pruning or removing hazardous trees around the company's power lines. The company also provided funding to support CAL FIRE's outreach to inform homeowners about the wildfire risk posed by bark beetles and how to safely take action.

Looking forward

As an infrastructure company that provides critical services, PG&E faces a variety of risks from a changing climate, including heat waves, more frequent and extreme storms, wildfires, and rising sea levels. Assessing and addressing these hazards will continue to be integral to PG&E's efforts to provide safe, reliable and affordable gas and electric service to customers—and to the company's long history of taking action to combat climate change from an operational, investment and policy perspective.

Near-term focus

PG&E recognizes that building climate resilience is linked to the company's long-term success, business strategy, and operational objectives and actions. As the company looks ahead, an important near-term priority is enhancing its governance structure to better coordinate and integrate activities across the company.

Another priority is advancing the multi-year assessment of the risks to PG&E's assets from potential climate change impacts. PG&E's preliminary work has shown that risks and strategies vary widely by line of business, asset class and timescale. The company's near term goal is to incorporate the results of the assessment—known as NHAP—into:

- PG&E's integrated planning process, which will include the company's 2017 enterprise-wide Risk and Compliance Session and the risk registers managed by the different lines of business.
- PG&E's 2017 Risk Assessment Mitigation Phase filing, a regulatory proceeding that will incorporate a risk-based decision-making framework into PG&E's 2020–2022 General Rate Case.

Longer-term focus

PG&E also recognizes that adapting to climate change is a long-term challenge that will require a sustained, increasingly localized approach—as well as a high degree of collaboration. Over the long-term, PG&E will explore ways to build on NHAP to further integrate climate hazards into the company's risk management and operational planning with a focus on areas such as:

- Strengthening processes for assessing, prioritizing and addressing climate hazards across lines of business
- Further integrating climate hazards within PG&E's emergency preparedness and response activities
- Conducting local operational pilots to assess "downscaled" climate risks

PG&E is developing a multi-year plan to build climate resilience—taking a holistic approach to better understand, plan for and respond to climate change threats. Core to this effort is the recognition that climate change-related hazards have direct impacts across PG&E's value chain—beyond PG&E's core assets that deliver service to include the critical systems and supply chains PG&E depends on, as well as the customers and communities it serves. PG&E also recognizes the need to better understand multiple hazards in combination, such as a wildfire combined with an extreme heat event.

PG&E looks forward to continuing to engage with the state in its work toward actionable scientific research that serves the growing needs of state- and local-level decision makers from a variety of sectors; more standardized climate scenarios, guidance and downscaled climate data to support resiliency planning; and enhanced tools and resources such as Cal-Adapt. More broadly, PG&E will also continue to look for ways to expand its stakeholder engagement and partnerships on climate resilience with communities, state and federal agencies, the research community and other gas and electric companies to share best practices for continuous improvement and support increased regional coordination.

Moving forward, PG&E will also continue to invest to build a more modern and resilient gas and electric system that can better withstand extreme weather and natural disasters. A smarter, more flexible and more distributed grid will be a more resilient system in the face of a changing climate—and will continue to ensure the delivery of safe, reliable, affordable and clean energy that PG&E's customers count on.

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