CALIFORNIA ENERGY COMMISSION

AN ASSESSMENT OF CALIFORNIA'S NUCLEAR POWER PLANTS:

AB 1632 REPORT

COMMISSION REPORT

NOVEMBER 2008
CEC-100-2008-009-CMF

Arnold Schwarzenegger, *Governor*

EXECUTIVE SUMMARY

Assembly Bill 1632 (Blakeslee, Chapter 722, Statutes of 2006) directs the California Energy Commission (Energy Commission) to assess the potential vulnerability of California's largest baseload power plants, which are California's two operating commercial nuclear power plants, to a major disruption due to seismic event or plant aging.[1] The Energy Commission is directed to adopt this assessment on or before November 1, 2008, and include it in the *2008 Integrated Energy Policy Report Update (2008 IEPR Update).* The legislation also directs the Energy Commission to assess the impacts that such a disruption would have on California's energy system reliability, public safety, and the economy; assess the costs and impacts from nuclear waste accumulating at these plants; and evaluate other major policy and planning issues affecting the future role of these plants in the state's energy portfolio. AB 1632 also requires updates of the seismic vulnerability assessment to be performed as part of future *Integrated Energy Policy Reports* and that these updates take into account new data or new understandings of seismic hazards for these plants.

The state's two operating commercial nuclear power plants, Pacific Gas & Electric's (PG&E) Diablo Canyon Power Plant (Diablo Canyon) and Southern California Edison's (SCE) San Onofre Nuclear Generating Station (SONGS), account for 12 percent of the state's overall electricity supply and, by some measures, 24 percent of the state's low-carbon electricity supply.[2] Because California's operating nuclear power plants are important to the state's electricity supply, California needs a long-term plan to prevent or significantly reduce the chances of major disruptions and to be prepared should a disruption occur or should one or both of the plants be shut down, such as from regulatory actions following a major event at one plant that leads to a general plant shut down for an indefinite period. Both plants have achieved very high average annual capacity factors in recent years, making them reliable sources of power for the state. With California's current population exceeding 37 million and projected to grow to more than 44 million by 2020, California's electric supply infrastructure will be strained further to meet the state's increasing demand for electricity.

Recent tightening in the credit markets increases the uncertainty regarding the financial viability of new energy projects. A major disruption of California's operating nuclear plants could result in a shutdown of plant operations for several months to more than a year or even cause the retirement of one or more of the plants' reactors. Without license renewals, the plants will be permanently retired at the conclusion of their current operating licenses in the early to mid 2020s.

---

[1] AB 1632 directs the Energy Commission to assess "large baseload generation facilities of 1,700 megawatts or greater." Besides Diablo Canyon and SONGS, there are two generating facilities (Alamitos and Moss Landing) that have a nameplate capacity greater than 1,700 MW. However, because both of these facilities operate below a 60 percent capacity factor, they are not considered baseload generation and were excluded from the study.

[2] California Energy Commission. *"2007 Net System Power Report."* CEC-200-2008-002-CMF. April 2008, pages 4-5. <http://www.energy.ca.gov/2008publications/CEC-200-2008-002/CEC-200-2008-002-CMF.PDF>.

The U.S. Nuclear Regulatory Commission (NRC) has regulatory authority over the radiological safety aspects of nuclear power, including plant licensing and license extensions. The State has much broader authority to set electricity generation priorities based on economic, electricity reliability, and environmental concerns. For example, the California Public Utilities Commission (CPUC) establishes the framework for considering the cost effectiveness of plant license renewal and authorizes funding for license renewal feasibility studies. The CPUC has established a clear link between the Energy Commission's AB 1632 assessment, findings and recommendations and PG&E's license renewal feasibility study. In 2007 the CPUC authorized $16.8 million for PG&E to conduct a Diablo Canyon license renewal feasibility study and required PG&E to: (1) defer its own license renewal feasibility study until after the Energy Commission issues its AB 1632 assessment, (2) incorporate the AB 1632 findings and recommendations into PG&E's own study, and (3) address in its study whether license renewal is cost effective and in the best interest of PG&E's ratepayers. This report, *An Assessment of California's Operating Nuclear Power Plants: AB 1632 Committee Report*, provides findings and recommendations to policymakers and stakeholders about Diablo Canyon and SONGS, as mentioned in the CPUC's 2007 General Rate Case Decision for PG&E, to assist energy policy planning. It is based on a consultant report prepared by MRW & Associates, Inc. for the Energy Commission entitled *AB 1632 Assessment of California's Operating Nuclear Plants* and reflects public comments on the draft consultant report as well as public comments on an earlier draft of this report.[3] A key element of the consultant report was a review of existing scientific studies concerning the potential vulnerability of SONGS and Diablo Canyon to a major disruption due to a seismic event or plant aging.

STUDY APPROACH

This report draws heavily from a consultant report prepared for the California Energy Commission. The consultant report was developed by an interdisciplinary Study Team led by MRW & Associates. The Study Team reviewed materials that included academic and scientific journal articles, reports, and studies; federal, state, and local governmental studies, reports, bulletins, planning documents, and budgets; federal and state regulatory proceeding filings and rulings; and data provided by the nuclear plant owners. To assist with the seismic vulnerability assessment, the Energy Commission formed a Seismic Vulnerability Advisory Team made up of senior staff from the California Seismic Safety Commission, the California Geological Survey, and the California Coastal Commission. The Advisory Team reviewed and commented on the seismic vulnerability assessment, in particular, the Request for Proposals for the AB 1632 seismic assessment, the proposed study plan, a list of the literature reviewed by the Study Team, and the Study Team's preliminary assessment of the seismic vulnerabilities of Diablo Canyon and SONGS.

Members of the public also contributed by identifying studies for review in the AB 1632 overall assessment and by providing comments on the draft study plan and on the draft consultant report. To maintain the independence of the assessment, the Energy Commission staff and

---

3 The final consultant report and public comments on the draft of this report can be obtained from the Energy Commission's website at: http://www.energy.ca.gov/ab1632/documents/index.html.

Study Team did not meet with the nuclear plant owners or other interested parties on the AB 1632 assessment. The plant owners, members of the public and interested stakeholders were provided the opportunity to submit written comments and participate in a public workshop on December 12, 2007, on the proposed study plan and submitted written comments and participated in a public workshop on September 25, 2008, on the Draft Consultant Report.[4] A second public workshop to receive comments on this Draft Committee Report was held October 20, 2008 and written comments on this report were received through October 22, 2008. This Final Committee Report is planned for release on October 30, 2008, and the Energy Commission will consider adopting the AB 1632 Committee Report as part of the *2008 Integrated Policy Report Update* at the Energy Commission's Business Meeting on November 19, 2008.

The Committee's major findings and recommendations from this analysis are provided below and are organized into the following major study areas: Seismic Vulnerability, Vulnerability to Plant –Aging Related Degradation,, Impacts of a Major Disruption, Economic, Environmental and Policy Issues, Nuclear Waste Accumulation, Land Use and Economic Implications of On-Site Waste Storage, Power Generation Options, and License Renewal Issues for State Policymakers.

SEISMIC VULNERABILITY

According to the California Seismic Safety Commission staff, there is a risk of a major earthquake in California on the order of 2 to 3 percent per year. According to the 2007 Working Group on Earthquake Probabilities, California faces a 99.7 percent chance of a magnitude 6.7 or larger earthquake during the next 30 years. The likelihood of an even more powerful quake of magnitude 7.5 or greater in the next 30 years is 46 percent.

The seismic vulnerability assessment consists of three parts: 1) an assessment of the geology and seismic hazards in the vicinity of Diablo Canyon and SONGS, 2) an assessment of the seismic design of the power plants, and 3) an assessment of the seismic and other vulnerabilities of the spent fuel storage facilities located at the plants, and of the transmission systems leading to and from the plants, and the access roadways for the plants.

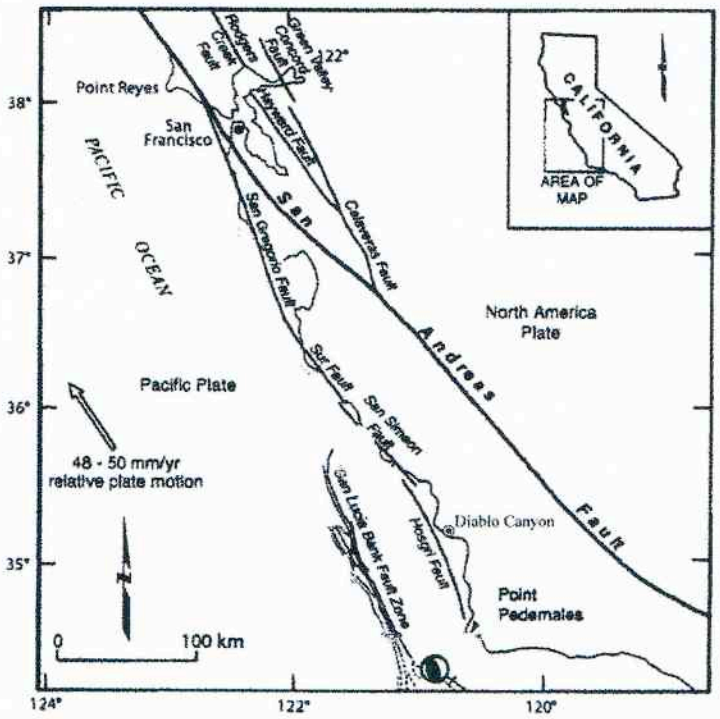
Seismic Hazards at Diablo Canyon

The offshore Hosgri Fault zone, 4.5 kilometers west of Diablo Canyon, creates the primary seismic hazard at the plant site (Figure 1). Over the years there has been uncertainty regarding the tectonic setting of this fault zone, and the characterization of the Hosgri Fault as either a lateral strike-slip fault or as a thrust fault (Figure 2). The distinction is significant for the ground motion hazard at the Diablo Canyon site: a strike-slip fault is steeply (i.e. close to vertically) inclined, and a thrust fault has a shallower angle and extends diagonally beneath the surface. If the Hosgri Fault were a thrust fault with an eastward dip, the fault would extend closer to the Diablo Canyon site, and the ground motion from an earthquake could be greater.

---

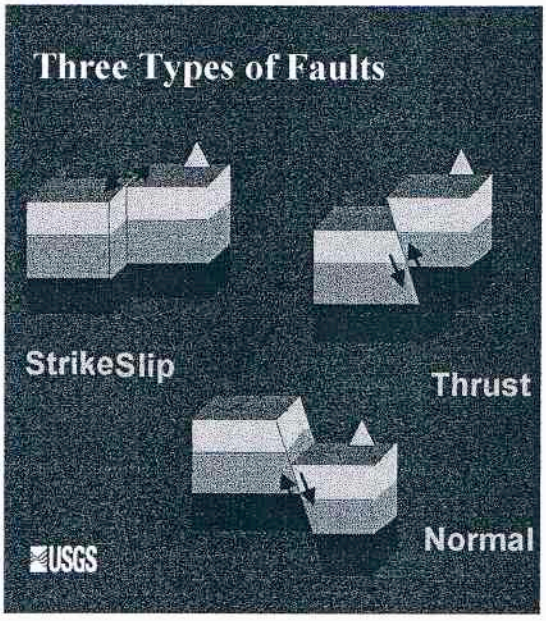
4 Copies of stakeholder comments may be viewed on the Energy Commission's web site at: http://www.energy.ca.gov/ab1632/index.html

Figure 1: Seismic Setting of Diablo Canyon



The Hosgri Fault System shown in relation to other faults of western California and the offshore November 4, 1927, magnitude 7.0 Lompoc earthquake. The arrow shows the rate and direction of relative movement between the North America and Pacific tectonic plate.

Figure 2: Three Types of Faults



Current published geologic and seismologic research literature, much of which has been developed through PG&E's Long-Term Seismic Program (LTSP),[5] supports the interpretation that the Hosgri Fault is predominantly characterized by strike-slip faulting. Experts with the U.S. Geological Survey (USGS), the California Geological Survey, and the Southern California Earthquake Center have accepted the strike-slip characterization for the Hosgri Fault. However, a minority of scientists disagrees with this characterization and believes that the Hosgri Fault is a thrust fault.

The implications of a thrust fault characterization for the seismic vulnerability of Diablo Canyon are uncertain. PG&E and the NRC separately evaluated the seismic hazard at Diablo Canyon from the Hosgri Fault assuming up to 33 percent thrust faulting. They found that there was sufficient safety margin in the plant design to accommodate the resulting ground motion from the Hosgri Fault under this assumption,, even though this motion was greater than had been anticipated when the plant was designed. PG&E has not published an analysis showing the implications of 100 percent thrust faulting on the safety of the plant, and such an interpretation is extreme in the context of the current professional consensus.

Another potential seismic hazard at Diablo Canyon occurs from the possibility of an earthquake directly beneath the plant. Based on seismologic interpretations and conclusions from investigations of the 2003 San Simeon earthquake (magnitude 6.5) that occurred approximately 35 miles north of the Diablo Canyon site, the tectonic (geologic plate) setting where this earthquake occurred appears similar to the local tectonic setting of Diablo Canyon. The deep geometry of faults that bound the San Luis-Pismo structural block, where Diablo Canyon sits, is not understood sufficiently to rule out a San Simeon-type earthquake directly beneath the plant. It is necessary to better define the deep geometry of bounding faults of the San Luis-Pismo block and to better understand the lateral continuity of these fault zones. Although these fault zones are unlikely to replace the Hosgri Fault as the dominant source of seismic hazard at the plant, improved characterizations of these fault zones would refine estimates of the ground motion that is likely to occur at different frequencies. This information may be significant for engineering vulnerability assessments.

The Diablo Canyon seismic setting has been extensively studied, largely under PG&E's Long Term Seismic Program (LTSP), and PG&E continues to study it. Further study using advanced technology may help resolve remaining uncertainties. For example, high quality three-dimensional geophysical seismic reflection mapping could resolve questions about the characterization of the Hosgri Fault and might change estimates of the seismic hazard at the plant. Similarly, direct imaging of the subsurface structure at Diablo Canyon could determine if faults exist near the site that do not break to the surface and could also serve to refine knowledge of the deep geometry, continuity, and interaction of poorly expressed faults that comprise the structural boundaries of the San Luis–Pismo Block. A permanent global

---

[5] The Long-Term Seismic Program is a unique program developed in response to the discovery of the Hosgri Fault during the licensing of Diablo Canyon.

positioning system (GPS) array, currently under development in the onshore region of the Diablo Canyon site, could refine models of tectonic block movements in the plant vicinity. Results of these surveys might alter fault parameters that are used in existing seismic hazard assessments.

Additional information on the seismic hazards at Diablo Canyon can be derived from the "Uniform California Rupture Forecast, Version 2 (UCERF-2)" database of faults and rupture probabilities in California, which was recently updated by the USGS, California Geological Survey, and the Southern California Earthquake Center. This database, used in conjunction with USGS models, would provide additional useful information regarding the seismic hazards at Diablo Canyon. To obtain accurate seismic hazard data, the USGS models must be modified to reflect site-specific conditions at the plants.

Finally, since Diablo Canyon was built, scientists have learned more about the ground motions that could result from an earthquake rupture. One important finding is that ground motion can be highly variable in the region near a rupture, with significant amplification of ground motion in some areas. This could be important at Diablo Canyon since the plant lies within five kilometers of the Hosgri Fault. PG&E is working collaboratively with the USGS to study earthquake hazards along the coastline in central and northern California, including the area surrounding Diablo Canyon.

Recommendations

- The Energy Commission acknowledges PG&E's ongoing efforts to understand the seismic hazards affecting the Diablo Canyon site through its Long Term Seismic Program (LTSP), and recommends that this work continue. As part of future IEPR assessments, beginning with the 2009 IEPR, PG&E should report to the Energy Commission on the overall status and results of its research efforts. As ground motion models are refined to account for a greater understanding of the motion near an earthquake rupture, it will be important for PG&E to consider whether the models indicate larger than expected seismic hazards at Diablo Canyon and, if so, whether the plant was built with sufficient design margins to continue operating reliably after experiencing these larger ground motions.

- The California Energy Commission recommends that PG&E should use three-dimensional geophysical seismic reflection mapping and other advanced techniques to explore fault zones near Diablo Canyon;. PG&E should report on their progress and their most recent seismic vulnerability assessment for Diablo Cnyon in the 2009 IEPR. This action will supplement PG&E's Long Term Seismic Program and help resolve uncertainties surrounding the seismic hazard at Diablo Canyon. Given the potential for an extended plant shutdown following a major seismic event, the Energy Commission, in consultation with appropriate state agencies, should evaluate whether these studies should be required as part of the Diablo Canyon license renewal feasibility study for the CPUC.

- PG&E should assess the implications of a San Simeon-type earthquake beneath Diablo Canyon.[6] This assessment should include expected ground motions and vulnerability assessments for safety-related and non safety-related plant systems and components that might be sensitive to long-period motions in the near field of an earthquake rupture.
- The Energy Commission, in cooperation with other appropriate state agencies, should consider the relevance of the USGS National Seismic Hazard Mapping Project models and the UCERF-2 database in the context of studies required as part of the license renewal feasibility assessment at Diablo Canyon for the CPUC. Updated seismic hazard analyses incorporating these inputs would provide additional information for regulators and the public regarding the seismic hazard at the plant site.

Seismic Hazards at SONGS

Seismologic and geologic data that have become available since SONGS was built indicate that the SONGS site could experience larger and more frequent earthquakes than had been anticipated when the plant was designed. For example, underground ("blind thrust") faults in the vicinity of SONGS have been postulated since the plant was built, and the estimated frequency of a design basis ("safe shutdown") earthquake at the plant increased from 1 in 7,194 years in a 1995 study to 1 in 5,747 years in a 2001 study. A recent review by the California Coastal Commission in connection with the construction of a proposed spent fuel storage facility states, "there is credible reason to believe that the design basis earthquake approved by U.S. Nuclear Regulatory Commission (NRC) at the time of the licensing of SONGS 2 and 3 ... may underestimate the seismic risk at the site."

This new information does not necessarily imply that the facility is unsafe. Since the plant was engineered with a large margin of safety, it likely would withstand earthquakes of greater magnitude and frequency than originally expected. However, the possibility that the safety margin is shrinking suggests that further study is necessary to characterize the seismic hazard at the site, especially since much less is known about the seismic setting of SONGS than the seismic setting of Diablo Canyon. While SCE periodically evaluates the implications of new seismic data that become available, there is no ongoing program at SONGS similar to PG&E's Long-Term Seismic Program at Diablo Canyon.

The major uncertainties regarding the seismology of the SONGS site relate to the continuity, structure, and earthquake potential of a nearby offshore fault zone (the South Coast Offshore Fault Zone) and the faulting that connects faults in the Los Angeles and San Diego regions. There is also uncertainty regarding the potential for blind thrust faults near the plant. Well planned, high-quality three-dimensional seismic reflection data at strategically chosen locations

---

[6] PG&E has considered a San Simeon-type earthquake scenario within probabilistic seismic hazard assessments for Diablo Canyon. However, further studies that consider such an earthquake from a deterministic basis (i.e., using a probability of 1) are recommended to evaluate the full implications of this earthquake, particularly for non-safety related plant components and reliability.