NUCLEAR POWER IN CALIFORNIA: 2007 STATUS REPORT

EXECUTIVE SUMMARY

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Abstract

This consultant report examines how nuclear power issues have evolved since publication of the consultant report, *Nuclear Power in California: Status Report,* which was prepared for the 2005 IEPR. The report focuses on four broad subject areas: 1) nuclear waste issues, 2) costs of nuclear power, 3) environmental and societal impacts of nuclear power, and 4) nuclear power in the U.S. in the coming years. Nuclear waste issues include the status of a federal repository at Yucca Mountain, the proposed federal reprocessing program, and issues related to the transportation of nuclear waste. The costs of nuclear power are addressed from three angles: the costs of operating California's current nuclear power plants, the costs of building and operating new nuclear power plants, and the cost implications of a "nuclear renaissance." Environmental and societal impacts discussed include the environmental implications of nuclear power, the role of nuclear power in climate change policy, and the security implications of nuclear power generation. Finally, the future of nuclear power is addressed by considering the safety and reliability of the aging U.S. nuclear fleet, license extensions that could keep the current fleet operating for an additional 20 years, and the development of new nuclear power plants in the U.S. The report concludes by offering potential implications for California from these events.

Keywords

nuclear, nuclear power, nuclear waste, spent fuel, Yucca Mountain, interim spent fuel storage, reprocessing, Global Nuclear Energy Partnership, uranium, enrichment, greenhouse gas, once-through cooling, license renewal, relicensing, Diablo Canyon, San Onofre Nuclear Generating Station, SONGS, Humboldt Bay, Rancho Seco, SMUD, NRC, Nuclear Regulatory Commission, U.S. Department of Energy, DOE, electricity, policy, California

EXECUTIVE SUMMARY

In the *2005 Integrated Energy Policy Report*, the California Energy Commission (Energy Commission) reviewed the status of nuclear power as an energy resource for California. Through this review, which was supported by a comprehensive status report and a two-day workshop that brought together a wide range of industry experts, the Energy Commission found, as it had in 1978, that a demonstrated technology for the permanent disposal or reprocessing of high-level waste does not yet exist. Consequently, according to California law, the Energy Commission could not provide land use permits or certification for a new nuclear power plant in California at this time.

In the *2005 Integrated Energy Policy Report*, the Energy Commission additionally made the following findings and recommendations related to nuclear power:

- Reprocessing remains substantially more expensive than waste storage and disposal and has substantial adverse implications for the U.S. effort to halt the proliferation of nuclear weapons.

- Some portion of the funds paid by California ratepayers for a permanent national repository should be returned to the state to help defray the cost of long-term on-site spent fuel storage.

- California should evaluate the long-term implications of the continuing accumulation of spent fuel at California's nuclear power plants.

- California should evaluate the U.S. Department of Energy's increasing use of California routes to transport nuclear waste to and from Nevada.

- California should reexamine the adequacy of California's nuclear transport fees and federal funding programs to cover the state's costs of spent fuel shipments.

- The California Legislature should develop a suitable framework for reviewing the costs and benefits of nuclear plant license extensions and clearly delineate agency responsibilities, scope of evaluation, and the criteria for assessment.

Since the release of the *2005 Integrated Energy Policy Report,* a renewed interest in nuclear power has emerged in the U.S., driven in part by concern over greenhouse gas emissions and by considerable subsidies offered by the federal government for new nuclear power plants.

Nuclear Power in California

Nuclear power plants generate a significant share of California's electricity and provide significant benefits to the state. Nuclear power plants also impose significant costs, risks and impacts. This is the essence of the "Faustian Bargain" described by

nuclear pioneer Alvin Weinberg in 1970. Weinberg called on his colleagues to "weigh, and reweigh...the other side of the balances: the risks in our energy source" (Weinberg 1994, p.175). California's policy toward nuclear power reflects its conclusions from weighing this balance, as California relies upon the state's operating reactors for a significant portion of its electricity supply, while prohibiting the construction of new reactors in the state until the Energy Commission makes certain findings concerning spent fuel disposal.

California relies today on three nuclear power plants for approximately 15 percent of the state's overall electricity supply:

- Diablo Canyon Power Plant: Pacific Gas and Electric owns and operates Diablo Canyon, which has a total generating capacity of 2,220 megawatts in two units. The Diablo Canyon facility is located near San Luis Obispo, along the coast between San Francisco and Los Angeles.
- San Onofre Nuclear Generating Station: Southern California Edison, San Diego Gas and Electric, and the City of Riverside are co-owners of the San Onofre Nuclear Generating Station, which is operated by Southern California Edison. The two operating units have a total capacity of 2,254 megawatts. The San Onofre Nuclear Generating Station is located near the boundary between Southern California Edison's and San Diego Gas and Electric's service territories near San Clemente, in southern California.
- Palo Verde Nuclear Generating Station: Palo Verde is co-owned by Arizona Public Service Corporation, Southern California Edison, and five other utilities. Arizona Public Service Corporation operates the plant. Palo Verde's three units have an overall capacity of 3,810 megawatts. Palo Verde is located near Phoenix in Wintersburg, Arizona. California utilities own 27 percent of the plant.

These plants have been operating for roughly 20 years and are licensed to continue operating for roughly another 15 to 20 years. They provide significant benefits to California in the form of resource diversity, low operating costs, relatively low greenhouse gas emissions, and enhanced grid reliability. There are also three retired nuclear power plants in California: Humboldt Bay, Rancho Seco, and San Onofre Nuclear Generating Station Unit 1.

Many U.S. nuclear power plant operators are seeking approval from the U.S. Nuclear Regulatory Commission for license renewals. These extensions could keep the aging fleet of U.S. nuclear power plants operating for an additional 20 years, with uncertain economic, environmental, and reliability implications. Pacific Gas and Electric, which owns and operates the Diablo Canyon Power Plant, is beginning a license renewal feasibility study for that plant.

It is against this background that this report has been prepared. The report, which is an update to the Energy Commission consultant report, *Nuclear Power in California: Status Report*, examines how nuclear power issues have evolved since 2005. It

focuses on four broad subject areas: 1) nuclear waste issues, 2) costs of nuclear power, 3) environmental and societal impacts of nuclear power, and 4) nuclear power in the U.S. in the coming years. Potential implications for California are also discussed.

Nuclear Waste Issues

Three categories of nuclear waste issues are discussed: storage and disposal of spent fuel, reprocessing of spent fuel, and nuclear waste transport.

Storage and Disposal of Spent Fuel

In *Nuclear Power in California: Status Report* and the workshops for the *2005 Integrated Energy Policy Report,* it became clear that progress in designing and developing the Yucca Mountain waste repository has been and continues to be problematic.

In 1982 Congress passed the Nuclear Waste Policy Act, which led to the creation of a comprehensive national program to permanently dispose of spent fuel and high-level radioactive waste from commercial nuclear facilities and national defense programs. Under the Nuclear Waste Policy Act, as amended in 1987 to focus on the Yucca Mountain site in Nevada, the U.S. Department of Energy is responsible for funding and developing a permanent, deep geologic repository for spent fuel and high-level radioactive waste.

The U.S. Department of Energy was to begin accepting spent fuel for the repository by January 31, 1998. However, nearly 10 years after this deadline, a repository at Yucca Mountain is still more than a decade away from being opened, and the opening date continues to slip. As recently as 2005, the U.S. Department of Energy had been targeting a 2012-2015 opening date. However, the U.S. Department of Energy announced in 2006 that the earliest possible opening date is March 2017 and that a more realistic opening date is September 2020. The U.S. Department of Energy announced in 2007 that the opening date is likely to slip an additional year. The U.S. Department of Energy does not anticipate submitting a repository license application to the Nuclear Regulatory Commission until mid-2008.

In the *2005 Integrated Energy Policy Report*, the Energy Commission noted that “the federal waste disposal program remains plagued with licensing delays, increasing costs, technical challenges, and managerial problems” (Energy Commission 2005b, p.85). Significant and persistent concerns over quality assurance and legal challenges have contributed to these delays. For instance, site characterization work was suspended between 1989 and 1992 due to concerns over quality assurance. Thirteen lawsuits filed by the State of Nevada and environmental organizations requesting review of various licensing requirements and procedures were pending before the U.S. Circuit Court of Appeals for the District of Columbia in 2004.

The Energy Commission also noted in 2005 that “Californians have contributed well over $1 billion to the federal waste disposal development effort.” The Energy Commission recommended that some portion of these funds “be returned to the state to help defray the cost of long-term on-site spent fuel storage” and that the state “evaluate the long-term implications of the continuing accumulation of spent nuclear fuel at California’s nuclear plants” (Energy Commission 2005b, p.85).

Spent fuel disposal also remains a major stumbling block for the U.S. nuclear power industry. John Rowe, Chief Executive Officer of Exelon, the largest nuclear power operator in the U.S., told shareholders in 2006 that he does not want to build a new nuclear power plant until the spent fuel disposal issue is solved: "We have to be able to look the public in the eye and say, 'If we build a plant, here's where the waste will go.' If we can't answer that question honestly to our neighbors, then we're playing politics too high for us to be playing" (Fortune Magazine 2006).

There has been limited progress over the last two years in addressing the waste disposal problem:

- The U.S. Department of Energy released a new schedule in 2006 for licensing and constructing the repository. The U.S. Department of Energy now acknowledges that Yucca Mountain is not likely to open before 2020.
- In lawsuits against the U.S. Department of Energy seeking restitution for interim storage costs, Pacific Gas and Electric and Sacramento Municipal Utility were awarded about $40 million each in compensation for dry cask spent fuel storage costs.

There have also been setbacks for Yucca Mountain and new reasons for concern:

- The U.S. Environmental Protection Agency has yet to release final air regulations for the Yucca Mountain repository to replace the regulations that were remanded by the U.S. Circuit Court of Appeals in 2004. In 2006, the U.S. Environmental Protection Agency claimed that these regulations would be released by the end of that year.
- With the change in control of Congress following the 2006 election, legislative action has focused on alternatives to the near-term completion of Yucca Mountain.
- A private off-site interim storage option, proposed to be built in Utah, was denied critical permits and will likely not be built.
- U.S. Department of Energy efforts to spur construction of new nuclear power plants and to commercialize a new generation of reprocessing technology have raised concerns that the Yucca Mountain effort might suffer from insufficient management and other resources.

Given the lack of progress toward opening a permanent repository, increased attention is being paid to interim storage options, including at Yucca Mountain. Some long-standing proponents of Yucca Mountain, including U.S. Nuclear Regulatory

Commission Commissioner McGaffigan, have suggested that it is time to re-examine the alternatives to Yucca Mountain. New interim spent fuel storage installations have been or are being constructed at all the reactor sites serving California. Regional storage proposals are under consideration, although these are generally opposed by state governments.

Reprocessing of Spent Fuel

Under existing law California's moratorium on building new nuclear power plants will continue until a technology for the permanent disposal or reprocessing of spent nuclear fuel has been demonstrated and approved for use in the U.S. In 1978 the Energy Commission found that high-level nuclear waste disposal technology had not been demonstrated nor approved by the authorized federal agency, that technology for the reprocessing of spent fuel does not yet exist, and that reprocessing of light-water reactor spent fuel is not necessary if the spent fuel can be stored at the reactor site. In 2005 the Energy Commission reaffirmed this finding. As we noted in *Nuclear Power in California: Status Report*, the National Academies, the National Commission on Energy Policy, the Harvard University Project on Managing the Atom, and the Massachusetts Institute of Technology Interdisciplinary Study, *The Future of Nuclear Power*, had all concluded that reprocessing is both uneconomic and burdened by substantial proliferation concerns. The Energy Commission also concluded that reprocessing is more expensive than waste storage and disposal and has "substantial adverse implications for the U.S. effort to halt the proliferation of nuclear weapons." (Energy Commission 2005b, p.85)

In early 2006 the Bush administration and the U.S. Department of Energy proposed the Global Nuclear Energy Partnership with the goal of establishing a proliferation-resistant nuclear fuel cycle based around a newly established domestic reprocessing capability. This initiative marks a significant departure from long-standing U.S. policy discouraging or neglecting domestic commercial reprocessing. Beginning in the late 1970s the U.S. opposed reprocessing on the grounds that the spread of the technology facilitates the proliferation of nuclear weapons. The Global Nuclear Energy Partnership seeks to re-introduce spent fuel reprocessing with new technologies that will discourage the spread of nuclear weapons technology.

The Global Nuclear Energy Partnership remains undefined in key respects, and it is far from certain that the proposal will be sustained over the next several years or, if it were, that it would ultimately be successful. There is substantial opposition to the proposal. According to John Deutch, Institute Professor at the Massachusetts Institute of Technology, the program would add to the cost of nuclear power and would likely not be fully deployed until about 2150, "a very, very, very, very, very long time in the future" (Greenwire 2007a). If the Global Nuclear Energy Partnership were successful, California's moratorium on new reactor permitting and certification could require reexamination.

Nuclear Waste Transport

Radioactive waste transport in the U.S. has been common for decades. For example, spent fuel is shipped from research reactors and naval vessels to storage sites, and low-level radioactive waste is shipped from reactor sites and other sources to low-level waste facilities. These shipments provide a framework of experience on which to build in designing the program to bring spent fuel from reactor sites across the country to Yucca Mountain. Nevertheless, all of this experience combined pales in comparison to the volume of shipments that will be required for the Yucca Mountain shipping endeavor.

Considerable uncertainty remains concerning when shipments to Yucca Mountain will begin; however, there is agreement that shipments will not begin in the near term. Based on the U.S. Department of Energy's estimate that Yucca Mountain will open around 2020, shipments are not expected to begin until close to the expiration of the Diablo Canyon and San Onofre Nuclear Generating Station operating licenses.

The U.S. Department of Energy continues to plan for shipments of spent fuel to Yucca Mountain. The U.S. Department of Energy has selected a "mostly-rail" transport option, has announced plans to use "dedicated trains" with certain restrictions on shipments, has released a design for transport casks, and has been investigating routes for the Nevada rail spur. Potential routes being considered could result in a large number of shipments from eastern states being routed through California.

According to the National Academies, spent fuel transport need not be a risky operation if it is managed well. However, social impacts could ensue along transportation routes if the public lacks confidence in the U.S. Department of Energy's ability to develop a transportation plan and safely manage the program. These impacts could include lower property values, a reduction in tourism, and increased public anxiety.

California could be strongly affected, since many spent fuel shipments could be routed through the state en-route to Yucca Mountain. The *Integrated Energy Policy Report* recommended that California evaluate the U.S. Department of Energy's proposed use of California routes to transport nuclear waste to and from Nevada, and reexamine the adequacy of the state's nuclear transport fees and federal funding programs to cover the state's costs of spent fuel shipments. California has repeatedly expressed concerns to the U.S. Department of Energy over route selection and has requested that additional public meetings be held in the state; however, the U.S. Department of Energy has for the most part not been responsive to these concerns.

Low-Level Waste Storage

Low-level radioactive waste will not be stored at Yucca Mountain and low-level waste disposal is the responsibility of the utilities and the states. In the 1980s and 1990s California selected Ward Valley in the Mojave Desert as a site for a low-level waste facility; however, the site is located on federal land and the state was unable to purchase the site from the federal government. Currently, California utilities dispose of their low-level waste in facilities in South Carolina and Utah. Beginning in mid-2008 only the Utah facility will be available and only for the least radioactive grade of wastes. In the near term, once the South Carolina facility closes to California waste, California utilities will be forced to keep their low-level waste on-site. According to California's compact with other western states, California is to be the host site of any commercial low-level waste facility to be opened in the compact states.

Costs of Nuclear Power

Three types of costs are discussed: the costs of California's operating nuclear power plants, the cost to build new nuclear power plants, and the potential implications of a "nuclear renaissance" on the cost of nuclear power.

Costs of California's Nuclear Power Plants

The California Public Utilities Commission has used a combination of traditional ratemaking and incentive-based ratemaking to determine cost recovery for nuclear power plants. In general, incentive-based ratemaking methods are intended to shield ratepayers from cost overruns and poor operating performance. Incentive mechanisms have had a secondary impact of making it more difficult to determine in retrospect the true costs of these plants.[1]

The cost to operate the current plants includes both historic ("sunk") costs and the plants' going-forward costs. Major going-forward costs include large capital investments to replace faulty or degraded reactor components, and operating costs for nuclear fuel procurement and disposal, security, and decommissioning. These costs were reviewed in substantial detail in *Nuclear Power in California: Status Report*.

In general, the cost of power from California's nuclear power plants over the upcoming years should be driven largely by the cost of the steam generator replacement projects and by the extent to which additional large capital projects will be required as the plants age. Unexpected long-term outages and additional U.S. Nuclear Regulatory Commission security requirements could also impact overall costs.

[1] For example, while we know that Pacific Gas and Electric ratepayers paid $34.3 billion (2006 dollars) for power from Diablo Canyon from 1985 through 2006, averaging $99.76 per megawatt-hour, we do not know if these payments cover (or exceed) Pacific Gas and Electric's costs.

New Plants: Range of Potential Costs

In the 1950s it was expected that nuclear power would be "too cheap to meter." In the 1980s nuclear power proved in many cases to be a significant financial burden. Today, with the high cost of natural gas, impending limitations on greenhouse gas emissions, and significant federal subsidies in the Energy Policy Act of 2005, some utilities are considering making another round of commitments to nuclear power. One of the fundamental but as yet unanswered questions is: what will be the cost of these new nuclear commitments?

Historic development costs for nuclear power plants were very uncertain and, for most of the plants that began operating after the Three-Mile Island nuclear accident, development was extremely expensive. Development costs for new power plants are even more highly uncertain, since there has been very little reactor development in the U.S. for the past 20 years. Reactor development projects require large capital investments and very long lead times, and they may be subject to considerable swings in public opinion. These factors all contribute to the risk involved in nuclear power plant development.

Estimates for the costs of new nuclear power plants are wide-ranging. On the one hand, there is concern that new reactor developers could face extreme cost overruns comparable to those experienced in the 1980s and 1990s, especially since no reactors have been built in the U.S. since that time. On the other hand, there is optimism that new technologies, federal subsidies, standardized reactor designs, and revised U.S. Nuclear Regulatory Commission licensing procedures will keep developers' costs down, especially given that the financial climate today is much better for large investments than the period of 14 percent inflation and 21 percent interest rates during which most of the current fleet of reactors was constructed.

Given these uncertainties, Dr. Paul L. Joskow, Director of the Massachusetts Institute of Technology Center for Energy and Environmental Policy Research, has expressed guarded optimism about the future of nuclear power.[2] He concluded a December 2006 paper by noting that the "future for investment in new nuclear plants in the U.S. is brighter than it has been for many years;" however, "investment in new nuclear plants is likely to proceed more slowly than may be implied by the recent euphoria in the industry" (CEEPR 2006, p.19).

Companies considering nuclear power development are likewise remaining cautious, and they are focusing on risk mitigation strategies to contain their costs. Strategies include forming partnerships, entering into risk-sharing contracts with vendors and contractors, and obtaining cost-recovery assurance from regulators. Most regulators that have faced requests in recent years for nuclear power development cost-recovery assurance have provided only limited assurance.

[2] Dr. Joskow is also Elizabeth and James Killian Professor of Economics and Management at the Massachusetts Institute of Technology.

Cost Implications of a "Nuclear Renaissance"

Revival of interest in nuclear generation is sometimes referred to as a "nuclear renaissance." Such a "renaissance" may pose cost implications for utilities that own nuclear power plants even if they do not build new reactors.

Prices for nuclear fuel have already risen sharply in anticipation of a large worldwide increase in demand. There are concerns over temporary fuel shortages should demand increase rapidly, as uranium supplies and enrichment capability have not been developed to meet the demands of a rapidly growing nuclear industry. In addition, the location of both uranium ore and existing enrichment capacity raises questions of availability to U.S. nuclear operators.

Shortages of key reactor materials could also develop. Globally, little production capacity remains for some of the highly specialized reactor components. An increase in demand could lead to shortages that could also impact owners of currently operating nuclear power plants that need to replace reactor components.

New reactor development could also increase the demand for skilled labor beyond the available supply. According to Tom Christopher of AREVA, the nuclear industry is an aging industry and will require 10,000 to 20,000 new people over the next four to five years (EIR 2006).

Environmental and Societal Impacts of Nuclear Power

In addition to explicit costs to developers and ratepayers, nuclear power also poses costs to society. Some of these costs arise from the environmental impacts and security risks associated with nuclear power.

Nuclear Power and the Environment

The past few years have seen a resurgence of interest in nuclear power as part of a response to concerns over greenhouse gas emissions and global warming. However, designating nuclear power as "clean" because of the low emissions directly associated with electricity generation is controversial. Nuclear power generation poses direct environmental risks, including aquatic impacts from once-through cooling; risk of groundwater contamination with tritium; radiation hazards associated with disposal of radioactive waste; and risks of radioactive releases triggered by earthquakes, tsunamis, accidents, or sabotage. Additional environmental impacts are associated with the full nuclear lifecycle, which starts with uranium mining and extends through reactor construction and operation to spent fuel storage/disposal or reprocessing and finally, decommissioning.

Nuclear power is seen by some as an important tool for reducing greenhouse gas emissions. Others argue that nuclear power should not have a role in greenhouse gas emissions reduction strategies; yet others take a cautious, middle-of-the-road approach and neither rule out nuclear power nor embrace it whole-heartedly.

Supporters and opponents of nuclear power both emphasize the importance of using a number of different technologies to combat global warming. Supporters argue that the urgent need to address climate change precludes closing off any major option, including nuclear power. Opponents argue that nuclear power development could slow down greenhouse gas emissions reductions by shifting investments away from low-greenhouse gas power alternatives, such as renewable energy and energy efficiency, which could be deployed more quickly and more cheaply than new nuclear reactors.

Ultimately, this debate over whether nuclear power should be part of a greenhouse gas reduction strategy is constrained by our limited knowledge of what other resources will be available. Consequently, the best path right now may to pursue all options and defer decisions until more is known, as stated by Harvard University Professor Dr. John P. Holdren:[3]

> [Society] might decide that the combination of improved energy efficiency, advanced fossil fuel technologies and renewable energy technologies of a variety of kinds can meet this [climate change] challenge without nuclear energy. My position is agnostic on this, we don't know yet what the best mix is, we should be trying to fix the problems of fission to see if we want it to be a part of this mix and at the same time we should be pursuing with tremendous vigor the possibilities available to us in improving energy efficiency in renewable energy options and in advanced fossil fuel technologies (ABC Radio 2002).

Security for Reactors and Spent Fuel

The protection of nuclear power plants and spent fuel storage facilities from land-based assaults, attacks by commercial aircraft, and other terrorist attacks has received considerable attention in the wake of the terrorist attacks of September 11, 2001. This heightened concern over security has been reinforced by the many extensions of operating reactors' licenses, a surge in interest in building new nuclear power plants, and growing stockpiles of spent fuel.

In 2004 the National Commission on Energy Policy made the following observation about nuclear safety and security:

> Nuclear power reactors of contemporary design have compiled an excellent safety record. If the number of nuclear reactors in the United States is to double or triple over the next 30 to 50 years, however, and the number worldwide is to grow ten-fold…one would want the probability of a major release of radioactivity, measured per reactor per year, to fall a further ten-

[3] Dr. Holdren is Teresa and John Heinz Professor of Environmental Policy and Director of the Program on Science, Technology, and Public Policy at the Kennedy School, as well as Professor of Environmental Science and Public Policy in the Department of Earth and Planetary Sciences at Harvard University.

> fold or more. This means improved defenses against terrorist attack as well as against malfunction and human error…License extensions for existing plants and the issuance of licenses for new plants should be contingent on the [the U.S. Nuclear Regulatory Commission's] affirmative judgment that that the plants…[are] adequately resistant to terrorist attack (NCEP 2004, pp.58, 60).

Over the past five years, the U.S. Nuclear Regulatory Commission has instituted a number of measures to improve the security of U.S. reactors. The agency struggles to balance the concerns of plant operators that additional security requirements are excessive and too costly with critics' concerns that the same requirements are inadequate. In addition, the U.S. Nuclear Regulatory Commission's process for determining which concerns need to be addressed and how they should be addressed has not always been transparent, even to governmental or quasi-governmental organizations such as the U.S. Government Accountability Office and the National Academies.

For example, the U.S. Nuclear Regulatory Commission has not explained why it rejected some of its staff's proposals for requiring reactors to be secured against certain types of attacks. Similarly, the U.S. Nuclear Regulatory Commission has not explained why the agency is confident that the current fleet of U.S. reactors would stand up to aircraft attacks with a very low probability of radiation release, while some professional studies appear to have come to very different conclusions. For instance, a 1982 report by Argonne National Lab concluded that aircraft crashes might subject nuclear power plants to numerous multiple failures that could lead to "total meltdown" even without damaging the containment structure. U.S. Representative Bart Gordon noted that while this report did not address plant design changes, it clearly showed that design changes could help mitigate the potential impact of aircraft hazards at nuclear power plants (Gordon 2006).

This secrecy, particularly with regard to the U.S. Government Accountability Office and the National Academies, has made it difficult for the U.S. Nuclear Regulatory Commission to develop public confidence in its actions regarding plant security. Indeed, critics and members of the public continue to question the adequacy of the U.S. Nuclear Regulatory Commission's security regulations.

Nuclear Power in the Coming Years

The continued use of nuclear power in the U.S. depends largely on three factors: the reliability of the current fleet of reactors, how many of these reactors continue to operate past their initial operating license periods, and whether new reactors are built.

Reliability of U.S. Nuclear Power Plants

The aging of the U.S. fleet of nuclear power reactors presents challenges in terms of the reliability, safety and performance of nuclear power plants. In recent years, U.S.

nuclear power plants have proven to be reliable generation sources, with an average availability rate of 90 percent in 2006. However, some plants have experienced significant difficulties and poor availability. In all, of the 130 power reactors ever licensed in the U.S., 41 have had at least one outage lasting a year or more.

In addition, industry critics argue that the current reactor oversight process is ineffective at spotting and preventing problems before they require expensive repairs and extended shutdowns. If their concerns are correct, reliability levels at a plant could plummet with little warning at any time, as they did at Davis Bessie in 2002 and at Palo Verde beginning in 2003.

The Future of Nuclear Power in the U.S.

Commercial nuclear power is riding a wave of renewed interest and support in several arenas. Many owners of nuclear power plants are pursuing license renewals, which will allow their plants to continue operating for an additional 20 years. In addition, a number of Bush administration policy initiatives and the financial incentives included in the Energy Policy Act of 2005 have resulted in consideration by U.S. utilities for building new nuclear power plants.

The U.S. Nuclear Regulatory Commission license renewal process focuses on ensuring that the aging of plant components will not degrade reactor safety and that significant environmental impacts will not ensue from the license renewal. Cooling water impacts are among the environmental impacts considered by the U.S. Nuclear Regulatory Commission. However, some other issues of concern to the State of California, such as seismic safety and terrorist risks, are not considered, and the State has only a limited role within the proceeding. The State can have a role in determining whether or not a utility applies for or uses an extended operating license. For example, the California Public Utilities Commission has ruled that Pacific Gas and Electric, which has begun a license renewal feasibility study, must apply to the California Public Utilities Commission for permission before applying for a license renewal.

Alongside these activities, the first new U.S. reactors in 30 years are being planned, and research is underway to improve the economics, performance, and safety of the next generation of nuclear reactors. If instead no new reactors are built, the last units in the U.S. nuclear fleet will cease operating by 2056, even if all currently operating reactors receive 20-year license renewals.

Implications for California

Following are some preliminary assessments for consideration by the Integrated Energy Policy Report Committee of how the state may be impacted by the events described in this report and how the state and the Energy Commission might respond. These preliminary assessments are intended to provide starting points for consideration by the public and Commissioners. All parties are encouraged to

submit comments on this draft report and their own proposed assessments to the Integrated Energy Policy Report Committee.

New and Existing Nuclear Power Plants in California

The legislature should develop a suitable framework for reviewing the costs and benefits of nuclear power plant license extensions and clearly delineate agency responsibilities, scope of evaluation, and the criteria for assessment.

The Energy Commission is not likely to receive a license application from Pacific Gas and Electric or Southern California Edison or from a third party group for the construction of a new nuclear power plant in California in the next two years. In light of California's moratorium on nuclear power development, until progress is made in disposing of or reprocessing spent fuel, the Energy Commission could not provide land use permits or certification for such a power plant at this time. It is unlikely that the Energy Commission will be able to provide land use permits or certification for a new nuclear power plant in California in the near future.

Spent Fuel Reprocessing and Implications for California

At this time the Energy Commission can conclude that reprocessing is still substantially more expensive than waste storage and disposal and that is still has substantial implications for U.S. efforts to halt the proliferation of nuclear weapons material.

The Energy Commission should continue to monitor the federal reprocessing initiative.

Waste Storage and Disposal and Implications for California

At this time the Energy Commission cannot conclude that the U.S. Department of Energy will ever succeed in opening the permanent repository at Yucca Mountain. Until a permanent repository at Yucca Mountain or at an alternative location either begins operation or can be credibly expected to begin operation using a demonstrated disposal technology, the Commission cannot find that the federal government has approved and that there exists a demonstrated technology for the permanent disposal of spent fuel from these facilities. The U.S. Department of Energy's failure to license and operate a permanent repository has imposed substantial costs on California's consumers who have paid over a billion dollars to the federal government for this service and have had to incur the costs of building and operating interim fuel storage facilities.

The Energy Commission should continue to monitor the federal high-level waste disposal and spent fuel storage and management programs with regard to their implications for California and the moratorium on new nuclear power permitting and certification in the state.

California has limited options for the storage and disposal of low-level nuclear wastes. California utilities may need to permanently store low-level nuclear wastes at the coastal sites of their nuclear power plants.

Consequences of Failure to Develop Yucca Mountain

The State should encourage the utilities to continue to seek damages from the U.S. Department of Energy to recover all costs related to interim waste storage.

The State should monitor the developments at the Diablo Canyon interim spent fuel storage facility and the likelihood that the facility operation will be delayed for an extended period.

The State should consider the implications of disputes regarding the vulnerability of spent fuel pools and interim spent fuel storage facilities to terrorist attack, and encourage the U.S. Nuclear Regulatory Commission to work with the National Academies' panel of experts to resolve these concerns. The State should also consider other means to ensure that a study of the implications of terrorism is performed, such as a request to the Department of Homeland Security or the U.S. Government Accountability Office.

Spent Fuel Transportation

The State should evaluate the U.S. Department of Energy's increasing use of California routes to transport nuclear waste to and from Nevada.

The Energy Commission should continue its participation in collaborative processes at the national and regional level regarding spent fuel transportation to ensure that the State's interests are represented. The Energy Commission should also continue to coordinate the California Interagency Transport Working Group to plan, prepare, and initiate state needs assessments for spent fuel and other large radioactive shipments in California.

The Energy Commission should continue to participate in the U.S. Department of Energy's route selection and transportation planning proceedings.

As recommended in 2005, the State should reexamine the adequacy of California's nuclear transport fees and federal funding programs to cover the state's costs of spent fuel shipments.

The State should continue to work with other states to ensure that the U.S. Department of Energy provides states with the support that they need to prepare for shipments and establishes flexible procedures.

Environmental Impacts of Nuclear Power Plants

As part of the state policy reducing greenhouse gas emissions, the Energy Commission should examine the policy implications of lifecycle greenhouse gas

assessments for energy technologies, including nuclear power. The State, in conjunction with other western states, should also decide what role imported or in-state nuclear power can play in a low-greenhouse gas emissions portfolio.

The Energy Commission should continue to assess the reliability implications of federal and state once-through cooling regulations.

Reliability of California's Nuclear Power Plants

California utilities should be directed to develop power supply contingency plans in the event that performance degradation at the state's nuclear power plants leads to prolonged plant outages.

Potential Expansion of Nuclear Power

The State should continue to monitor the status of the U.S. Department of Energy's programs that support new nuclear power development and the cost and progress of new reactor development in the U.S. When more information is available, the State should seek to determine the fuel cycle costs and performance of advanced nuclear reactors.

CHAPTER 13: NUCLEAR POWER 2007: IMPLICATIONS FOR CALIFORNIA

Nuclear power as an electric resource option has gained visibility in the two years since the release of the 2005 IEPR. The body of this report provides a factual background for assessing the nuclear power option for California, given the state's current resource situation and the nuclear policy embodied in the 1976 nuclear statutes. This chapter provides preliminary assessments for consideration by the IEPR Committee of how the state may be impacted by the events described in this report and how the state and the Energy Commission might respond. These preliminary assessments are intended to provide starting points for consideration by the public and Commissioners. All parties are encouraged to submit comments on this draft report and their own proposed assessments to the IEPR Committee.

New and Existing Nuclear Power Plants in California

Over the next two years the primary focus for the owners of California's operating nuclear power plants should be the safety and reliability of these plants, the successful replacement of the steam generators and other major components, and the completion of new interim spent fuel storage facilities. Transferring spent fuel from spent fuel pools to interim storage facilities is likely to enhance the safety of these power plants. Replacing the steam generators is necessary for long term operation of the plants.

In addition, California's utilities should continue to monitor the efforts of the NRC, the Arizona Corporation Commission, and the Arizona Public Service Corporation to make Palo Verde once again a reliable and low cost facility while maintaining high standards of safety. At the same time, SCE, the Southern California Public Power Authority, and the Los Angeles Department of Water and Power should develop contingency procurement plans to address the potential loss of all or part of Palo Verde generation.

California's utilities are also involved in decommissioning reactors at Rancho Seco, SONGS Unit 1 and Humboldt Bay. Decommissioning activities are relatively complete at Rancho Seco and SONGS Unit 1, and they are just beginning at Humboldt Bay. California utilities need to successfully complete these decommissioning projects.

PG&E will begin its engineering assessment of the costs and benefits of renewing its license for the Diablo Canyon facility over the next two years. The CPUC has directed PG&E to consider the results of the Energy Commission's assessment of the vulnerability of the plants to aging and seismic events ("AB 1632 assessment"), while allowing sufficient time for the CPUC to review the implications for PG&E's power procurement plans of either shutting down Diablo Canyon or extending its license. It is likely that SCE will monitor PG&E's efforts for any lessons learned, as SCE considers whether to pursue renewal of the SONGS license and whether to

participate in the license renewal of Palo Verde (assuming Palo Verde can be returned to acceptable performance levels).

The Legislature should develop a suitable framework for reviewing the costs and benefits of nuclear power plant license extensions and clearly delineate agency responsibilities, scope of evaluation, and the criteria for assessment.

At this time there are no pending applications to construct new nuclear power plants in California. PG&E and SCE have stated that they are not interested in developing new nuclear power plants in California or in participating in new nuclear power plants outside of California for at least the next ten years.

The Fresno Nuclear Energy Group, LLC is exploring the option of building a nuclear power plant in Fresno, California. The group has announced that it is considering putting a nuclear initiative on the state ballot for November 2008. The proposal is at an early stage and the group has yet to commit substantial funds - securing a Construction and Operating License from the NRC will likely require $30 to $100 million, and a statewide initiative campaign is another multi-million dollar effort. CPUC President Peevey has concluded that their proposal is a “nonstarter.”

Therefore, the Energy Commission is not likely to receive a license application from PG&E or SCE or from a third party group for the construction of a new nuclear power plant in California in the next two years.

The resource plans of California utilities do not include proposals for new nuclear power plants. Challenges for future development of nuclear power in California by its utilities include overcoming highly uncertain construction costs; availability of financing in a regulatory system that has never provided CWIP recovery; seismic, security and safety concerns; scarcity of water for plant cooling; and unresolved spent fuel disposal problems.

California law prohibits the permitting and certification of a nuclear power plant in California until the Energy Commission finds that there has been developed, that the U.S. through its authorized agency has approved, and that there exists a demonstrated technology or means for the disposal of high-level nuclear waste (PRC 25524). In addition, for plants requiring the reprocessing of spent fuel, the permitting and certification of new nuclear power plants in California is prohibited until the Energy Commission finds that the U.S. through its authorized agency has identified and approved, and that there exists, a technology for the reprocessing of spent nuclear fuel rods (PRC 25524).

Since such findings have not been made to date, we conclude that the Energy Commission could not provide land use permits or certification for a nuclear power plant in California at this time. It is unlikely that the Energy Commission would be able to make such a finding in the near future.

Spent Fuel Reprocessing and Implications for California

Since the release of the 2005 IEPR, DOE has announced a research and development plan for domestic commercial reprocessing, known as GNEP. The GNEP program seeks to develop and commercialize a new generation of reprocessing technologies together with new nuclear reactor designs based on advanced technologies. The program is still being defined, but would require a major restructuring of the nuclear industry; this would be quite challenging and would likely require tens of billions of dollars and many decades.

The GNEP proposal is controversial. In the past ten years reprocessing has been evaluated by NCEP, the Harvard University Project on Managing the Atom, and an MIT interdisciplinary team focused on the future of nuclear power. All of these groups have concluded that reprocessing would increase the costs of spent fuel disposal relative to storage and disposal in a geological repository. They have also concluded that reprocessing would have substantial adverse implications for U.S. efforts to halt the proliferation of nuclear weapons material. Numerous public interest groups, such as NRDC and UCS, have reached similar conclusions. DOE's proposed "proliferation-resistant" technologies have been met by skepticism.

It is difficult to imagine DOE successfully managing the timely opening of the national repository at Yucca Mountain, the subsidy programs authorized in EPAct 2005 for new nuclear power plants, and the technology development efforts proposed under GNEP. It is unlikely that the federal government can fund all these major nuclear initiatives, while at the same time funding the energy efficiency, renewable energy, clean fuels, and clean coal sequestration programs endorsed by the National Commission on Energy Policy. The state, and specifically the Energy Commission, should convey to the federal government its preferred order of priorities for federal research development and demonstration programs, consistent with the goals set forth in the Energy Action Plan.

At this time the Energy Commission can conclude that reprocessing is still substantially more expensive than waste storage and disposal.

At this time the Energy Commission can conclude that reprocessing still has substantial implications for U.S. efforts to halt the proliferation of nuclear weapons material.

The Energy Commission should continue to monitor the GNEP program.

Waste Storage and Disposal and Implications for California

In the past two years, the announced schedule for the opening of Yucca Mountain has slid at least five years, and current expectations are that the repository will open sometime after 2020. Given the lack of progress toward opening a permanent repository, increased attention is being paid to interim storage options, including at Yucca Mountain. Some long-standing proponents of Yucca Mountain from the

federal government and from industry have suggested that it is time to re-examine the alternatives to Yucca Mountain. New interim spent fuel storage installations have been or are being constructed at all the reactor sites serving California. Regional storage proposals are under consideration, though these are generally opposed by state governments.

At this time the Energy Commission has no basis to conclude that DOE will succeed in opening the permanent repository at Yucca Mountain in the near future. Until a permanent repository at Yucca Mountain or at an alternative location either begins operation or can be credibly expected to begin operation using a demonstrated disposal technology, the Commission cannot find that the federal government has approved and that there exists a demonstrated technology for the permanent disposal of spent fuel from these facilities. DOE's failure to license and operate a permanent repository has imposed substantial costs on California's consumers who have paid over a billion dollars to the federal government for this service and have had to incur the costs of building and operating interim fuel storage facilities.

The Energy Commission should continue to monitor the federal high-level waste disposal and spent fuel storage and management programs with regard to their implications for California and the moratorium on new nuclear power plant permitting and certification in the state.

There is only one low-level waste facility currently open to California utilities that will accept more than the least radioactive grade of nuclear waste. This facility will be closing to most states, including California, in 2008. California utilities will then be forced to store much of their low-level waste at the reactor sites unless a new low-level waste facility is opened. According to California's compact with other western states, California is to be the host site of any low-level waste facility to be opened in the compact states.

California has limited options for the storage and disposal of low-level nuclear wastes. California utilities may need to permanently store low-level nuclear wastes at the coastal sites of their nuclear power plants.

Consequences of Failure to Develop Yucca Mountain

The spent fuel pools at SONGS and Diablo Canyon are approaching engineering and safety limits to the amount of fuel that can be stored. Both SCE and PG&E have proposed to build or have already built on-site interim fuel storage facilities where spent fuel will be temporarily stored in dry casks rather than in spent fuel pools. The design of these interim facilities is intended to permit the safe storage of spent fuel for decades after the expiration of the existing operating licenses. In effect, the facilities buy time to design, license and construct a permanent repository correctly.

In 2005 the Energy Commission concluded that California needs a comprehensive assessment of the implications of indefinitely relying on at-reactor interim fuel

storage facilities. Since that time AB 1632, requiring such a study, has been enacted. The Energy Commission will complete this study by November 2008.

PG&E, SCE, SMUD, and APS have sued DOE to recover the costs of building interim storage facilities that would not have been necessary had a federal repository opened on schedule. PG&E and SMUD have received preliminary judgments and awards (though appeals continue). These awards recover only costs already incurred. The utilities will have to return to the courts at a later date to recover additional costs.

The State should encourage the utilities to continue to seek damages from DOE to recover all costs related to interim waste storage.

In the heightened security environment since September 11, 2001, increased attention has been paid to the vulnerability of nuclear facilities to potential acts of terrorism. The licensing of the Diablo Canyon interim storage facility was successfully challenged due to concerns about impacts of a potential terrorist attack at the facility. The NRC's preliminary assessment is that these impacts are insignificant. It is likely that the storage facility will open before the Diablo Canyon spent fuel pool reaches its limits, and that no interruption to the operation of Diablo Canyon will be necessary.

The State should monitor the developments at the Diablo Canyon interim spent fuel storage facility and the likelihood that facility operation will be delayed for an extended period.

Nuclear power plants are difficult terrorist targets due to their substantial containment vessels, but spent fuel pools and interim fuel storage facilities may be more vulnerable. There has been a vigorous debate between the NRC, the National Academies, and the Government Accountability Office on this topic. Some of this debate has concerned the implications of terrorists using commercial aircraft as weapons of mass destruction.

The State should consider the implications of these disputes and encourage the NRC to work with the National Academies' panel of experts to resolve these concerns.

The California Attorney General filed a petition with the NRC in March 2007 requesting that the impacts of terrorism on spent fuel pools be considered in all decisions approving high-density spent fuel pool storage. This petition has not yet been considered, and the NRC has resisted other efforts to require it to consider the impacts of terrorism in its licensing decisions.

The State should consider other means to ensure that a study of the implications of terrorism is performed, such as a request to the Department of Homeland Security or the Government Accountability Office.

Spent Fuel Transportation

Spent fuel will need to be transported from reactor sites throughout the country to Yucca Mountain or other waste storage, treatment, or disposal facilities. In the event that interim storage or reprocessing is adopted, spent fuel may need to be transported multiple times to different facilities.

Numerous federal and state agencies are involved in regulating the transport of nuclear material and ensuring that safety standards are met. However, final coordination of spent fuel transportation will be managed by DOE, and states may not be able to direct how regulations are defined and complied with. Furthermore, DOE has ultimate control over the selection of shipment routes, and currently-proposed routes could disproportionately impact California.

The State should evaluate DOE's increasing use of California routes to transport nuclear waste to and from Nevada.

The Energy Commission should continue its participation in collaborative processes at the national and regional level to ensure that the State's interests are represented.

The Energy Commission should continue to coordinate the California Interagency Transport Working Group to plan, prepare, and initiate state needs assessments for spent fuel and other large radioactive shipments in California.

The Energy Commission should continue to participate in DOE's route selection and transportation planning proceedings.

California will incur significant costs in facilitating the safe transport of nuclear waste shipments and in providing emergency response services. California's fees for these services are lower than in some other states and may be inadequate to cover state costs incurred for shipment activities, such as shipment inspections and escorts.

As recommended in 2005, the State should reexamine the adequacy of California's nuclear transport fees and federal funding programs to cover the state's costs of spent fuel shipments.

The federal government is required to provide both technical and financial supports to states that are involved with nuclear waste transport to Yucca Mountain. The apportionment of this support among states and the rules for how the support may be used are under development.

The State should continue to work with other states to ensure that DOE provides states with the support that they need to prepare for shipments and establishes flexible procedures.

Environmental Impacts of Nuclear Power Plants

Power production at nuclear power plants does not require combustion of fossil fuels. Accordingly, there are reduced emissions of air pollutants and greenhouse gases when nuclear power is used in place of gas-fired or coal-fired power.

However, there are also significant environmental impacts from activities that support nuclear power—the nuclear lifecycle. These impacts include radiological hazards from uranium mining and milling; greenhouse gas emissions from uranium enrichment, transportation, and fuel fabrication and from plant construction; aquatic impacts from once-through cooling; risk of groundwater contamination with tritium; radiation hazards associated with the disposal of spent fuel or reprocessing waste; and risks of radioactive releases triggered by earthquakes, tsunamis, accidents, or sabotage.

In light of these impacts and due to the great expense and uncertainty associated with new nuclear power development, many experts oppose relying predominantly on nuclear power to reduce U.S. GHG emissions. Experts disagree as to whether nuclear power should be included at all in a low-GHG emissions portfolio.

As part of the state policy reducing GHG emissions, the Energy Commission should examine the policy implications of lifecycle GHG assessments for energy technologies, including nuclear power. The State, in conjunction with other western states, should also decide what role imported or in-state nuclear power can play in a low-GHG emissions portfolio.

One of the significant impacts of nuclear power production results from the use of ocean water for once-through cooling. State and federal agencies have been reviewing regulations to reduce the marine impacts of once-through cooling. Some of the proposed regulations would limit compliance options and could force California's coastal power plants to switch to an alternate cooling method. For the nuclear power plants, this would be a very expensive operation and could lead to lower plant efficiency or other environmental impacts.

The Energy Commission should continue to assess the reliability implications of federal and state once-through cooling regulations.

Reliability of California's Nuclear Power Plants

California's in-state nuclear power plants have been reliable in recent years; however, the Palo Verde reactors have had significant and repeated operational difficulties that have led to extended shutdowns. The inability of the NRC and INPO to prevent these difficulties and to quickly turn around the plant's performance when troubles began raises concerns over the effectiveness of these oversight processes. In particular, the oversight processes may be ineffective at correcting weak elements of the safety culture, such as the overly-narrow problem-solving processes that have been identified at Palo Verde.

California utilities should be directed to develop power supply contingency plans in the event that performance degradation at the state's nuclear power plants leads to prolonged plant outages.

Potential Expansion of Nuclear Power

The federal government has offered significant incentives to the developers of the first new nuclear power plants in the U.S. in the coming years. These incentives, along with the need for power sources with low GHG emissions, have spurred interest in new nuclear power development. However, it remains to be seen whether this interest will result in a nuclear renaissance or just a handful of highly subsidized new reactors. The companies that have expressed the intent to apply for NRC licenses have not fully committed to building new plants. State legislators and regulators have for the most part not provided these companies with the level of cost recovery assurance that the nuclear industry has sought. Moreover, the cost of these plants remains highly uncertain, and current experience with new reactor construction in Finland raises the specter of significant cost-overruns, such as was experienced by the nuclear power industry in the 1970s and 1980s.

The State should continue to monitor the status of DOE's programs and the cost and progress of new reactor development in the U.S. When more information is available, the State should seek to determine the fuel cycle costs and performance of advanced reactors.