Yu-Chueh Wang

Instructor McBurnie

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Hidden Danger: Nuclear Waste and the potential solution

California grapples with a multifaceted nuclear dilemma that extends across crucial domains, encompassing environmental justice, community safety, transportation safety, material safety, nuclear waste storage, and the imperative to transition to alternative energy sources. In my earlier essay, "Hidden Dangers: Nuclear Waste and Its Disproportionate Effects on California Residents," I delved into the psychological and environmental justice aspects of the nuclear waste issue, unraveling the intricate interplay between historical industry developments, nuclear storage challenges, and the defunct Yucca Mountain Nuclear Disposal Facility. Analyzing the psychological impact and the pervasive fear of nuclear radioactivity, as well as the "Not In My Backyard" sentiment, underscored the imperative of prioritizing residents' trust and safety.

In this essay, the focus shifts to proposing tangible solutions aligned with the values previously emphasized. The thesis aims to advocate for a comprehensive approach involving intensified geo-surveying, a more organized decision-making process, and a scientifically grounded strategy for nuclear plant closure and waste disposal. Figure 1, derived from a study by Lazard, a financial analysis company, illustrates the escalating costs of nuclear power generation compared to various renewable energy sources in 2023 (Bilic). As nuclear power faces increased economic challenges, this essay will scrutinize potential substitutions for nuclear energy, evaluate the industry's prospects, and conduct a cost analysis for the shutdown of nuclear plants. The examination will span local scales, delving into the community surrounding the Diablo

Nuclear plants, and global perspectives, exploring international policies, and drawing insights from the Swedish nuclear industry.

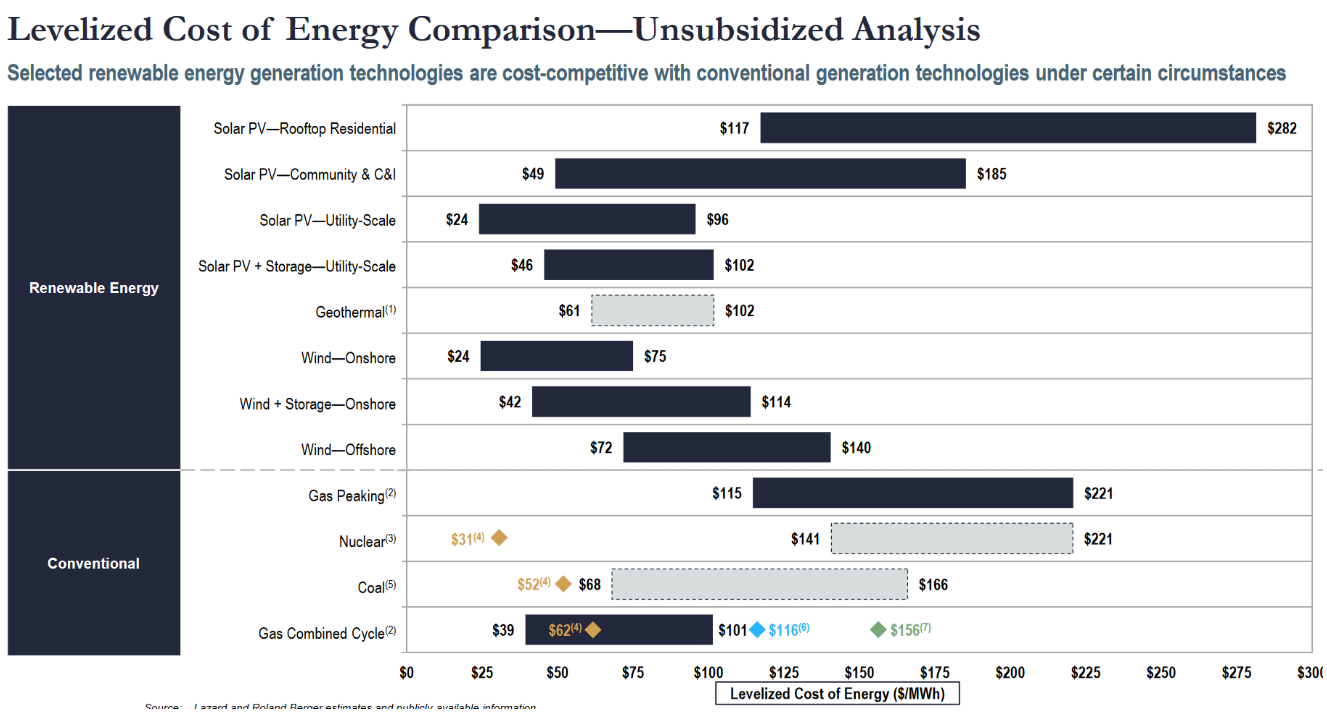
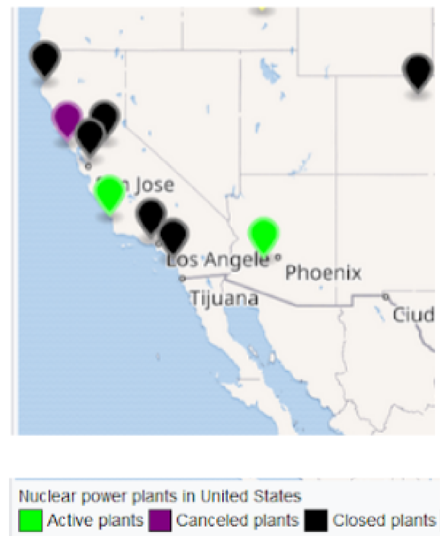



**Figure 1**. Comparative Prices per Megawatt-Hour of Energy Generation Methods in 2023 (Bilic).

The Diablo Canyon Power Plant, situated on the coast of California and depicted in Map 2, stands at the epicenter of a heated debate that extends far beyond its operational tenure. As California's last remaining nuclear facility, the decisions surrounding Diablo Canyon have far-reaching implications for the future of nuclear energy in the state. Advocates for its closure, driven by safety concerns related to seismic activity, emphasize the plant's proximity to fault lines(“Diablo Canyon Power Plant”). However, the plant's undeniable contribution to the state's energy portfolio adds complexity to the discourse.




**Map 2.** Distribution of Nuclear Plants in California, including inactive ones. ("Nuclear Power in the United States," Wikimedia Foundation, 17 Aug. 2023).

Closure and the imposition of new regulations may appear as straightforward remedies, yet the issue is intricately layered, with numerous variables interacting and influencing each other. In steering towards decisions that will shape the future, we must draw insights from past experiences and failures, building upon the efforts of pioneers in nuclear safety and policy.

A critical dimension of California's nuclear dilemma involves the residents directly impacted by nuclear facilities. Their safety should be paramount when planning and operating nuclear plants and storage facilities, and the residents have not hesitated to voice their concerns. An interest group, formed by residents and experts, actively campaigns for the closure of the Diablo Canyon Plant. Their perspectives, illuminated in an extensive *Associated Press* report (Blood), reveal a spectrum of worries—ranging from technical safety concerns to apprehensions about the plant's geological location and potential security threats. The interest group aims for the decommissioning of the Diablo Canyon plant by 2025, citing it as a potential hazard to nearby communities. The plant's proximity to fault lines amplifies concerns, drawing parallels to the Fukushima disaster, despite the earthquake-resistant upgrades implemented in 2011.

Diablo Canyon is not the first nuclear facility to cease operations due to seismic concerns; the Vallecitos Nuclear Center and the San Onofre Nuclear Generating Station also closed for similar reasons ("San Onofre Nuclear Generating Station"). Addressing this recurring issue calls for the establishment of elevated standards and stringent regulations governing the construction and operation of nuclear plants in California. Proposed measures include mandatory geological surveys, obligatory earthquake protection measures, and a comprehensive energy plan that prospective operators must submit for approval before commencing operations. Moreover, ensuring public input through transparent procedures is essential to prevent the targeting of minority groups during site selection. Fair compensation for residents near nuclear plants and continuous monitoring of the geological and technical aspects of the plant are imperative for the ongoing safety of the surrounding community. This comprehensive approach aims not only to address the immediate concerns but also to forge a sustainable path for California's nuclear future.

Efforts to enhance the safety of nuclear plants and disposal facilities have seen international progress. Quevenco, a member of the International Atomic Energy Agency (IAEA) Office of Public Information and Communication, highlights in his report that the United States, including certain states, lags in adopting stricter and safer regulations outlined by the Convention on the Physical Protection of Nuclear Material (CPPNM). This convention, established by the IAEA, addresses safety concerns related to the domestic safety of nuclear materials. Reflecting this international standard in California's nuclear policy framework is crucial. Legislators in California could benefit significantly from incorporating the principles of the CPPNM and learning from the practices of other countries to establish a safer and more sensible nuclear policy that prioritizes community safety and well-being.

Even though better laws could help improve the current climate of California's nuclear industry, many are still very much in favor of decommissioning the Diablo Canyon Power Plant. What many fail to account for is the cost and extra pollution that would come about when a nuclear plant is decommissioned before its expected time. Take, for example, the San Onofre Nuclear Generating Station, another nuclear plant pressured to close early because of its proximity to the fault line. As one of the writers at *San Diego Union-Tribune*, Lee pointed out after the initial shutdown, mass layoffs and power demand immediately became problematic (Lee). To address the resulting power surplus, the only recourse was an increased reliance on natural gas power generators, not only exacerbating pollution concerns but also escalating power bills.

The regulatory framework established by the Environmental Protection Agency (EPA) mandates that the federal government assumes responsibility for the storage and monitoring of high-level nuclear waste. However, the only designated deep geological nuclear storage facility, the Yucca Mountain nuclear waste repository, has been closed due to safety concerns, leaving an unresolved gap shortly. Consequently, numerous nuclear plants, including inactive ones, find themselves compelled to store their nuclear waste on-site. An illustrative case is the San Onofre Nuclear Plant in California, which, despite its extended closure, has accumulated tons of nuclear waste at its now-defunct site, as reported by Mishkin ("Mishkin"). In scrutinizing the risks associated with these materials, Mishkin emphasizes the potential dangers to local communities near nuclear plants or coastal areas. The absence of centralized nuclear storage facilities both nationally and within California implies that the decommissioning of the Diablo Canyon Power

Plant could encounter analogous challenges in nuclear waste management as observed in the case of the San Onofre Nuclear Plant. Achieving clarity in federal policy and adopting a more robust approach to centralized nuclear waste storage becomes imperative to ensure the safe and effective management of nuclear waste within the state.

Quantifying the cost implications of closing a nuclear plant requires a meticulous breakdown of incurred expenses at each stage of decommissioning. Professor Samseth, a distinguished figure in Physics and engineering at a Norwegian university, conducted an analysis in his paper, "Closing and decommissioning nuclear power reactors: another look following the Fukushima accident." His observations on the trend of nuclear plant shutdowns post-Fukushima offer valuable insights, emphasizing the importance of careful decommissioning. The key lies in minimizing the mixing of contaminated and non-contaminated materials, with materials from the nuclear reaction process requiring specialized treatment based on their radiation levels (Samseth). Table 3 from Samseth's paper classifies nuclear waste into four categories, detailing the radioactivity, and treatment requirements, and providing examples for each type. Effective separation of these waste types not only reduces costs but also enables the recycling of uncontaminated material, mitigates greenhouse gas emissions, and minimizes the volume of waste necessitating further treatment.

| | very low level waste (VLLW) | low level waste (LLW) | intermediate level waste (ILW) | high level waste (HLW) |
|---|---|---|---|---|
| radioactivity | contains very limited concentrations of long-lived radioactive isotopes with activity concentrations usually above the clearance levels | contains limited concentrations of long-lived radioactive isotopes but has high radioactivity | contains long-lived radioactive isotopes that will not decay to a level of activity concentration acceptable for near surface disposal | contains levels of activity concentration high enough to generate significant quantities of heat by radioactive decay or with large amounts of long-lived radioactive isotopes |
| examples of waste sources | concrete rubble, soil | clothing, glass, building materials | fuel rod casings, reactor vessel part | debris of spent fuel |
| isolation | engineered surface landfill | near surface disposal at depth up to 30 metres | shallow disposal at depth from a few tens to a few hundred metres | deep geological formations |
| need shielding | no | no | yes | yes |
| need cooling | no | no | no | yes |

**Table 3.** A comparison of different levels of nuclear waste and the treatment required (Samseth).

California legislators, often at the forefront of advocating for renewable energy, are currently propelling innovation through laws like The Clean Energy and Pollution Reduction Act, fostering the development of various renewable energy sources such as desert renewable energy, offshore wind farms, and geothermal energy ("Renewable Energy"). The potential decrease in power generation capacity with the closure of nuclear plants can be addressed by amplifying existing sustainable energy programs and incentivizing the establishment of more such sources. The gradual phase-out of nuclear plants should be approached with careful consideration, evaluating each stage with attention to local economics, safety, and worker rights. Establishing a decommissioning committee to monitor protocols and plan budgets, along with aligning laws with current science and technology principles, is paramount to prevent negative environmental impacts, and pollution, and ensure comprehensive risk assessments. Figure 4 from Professor Samseth's paper outlines additional costs during decommissioning, distinguishing between base costs and variable costs for different stages. The orange region represents base costs such as annual surveillance and maintenance, while the purple region encompasses variable costs that can significantly vary across decommissioning stages. Professor Samseth's findings underscore the importance of avoiding hasty decommissioning efforts.

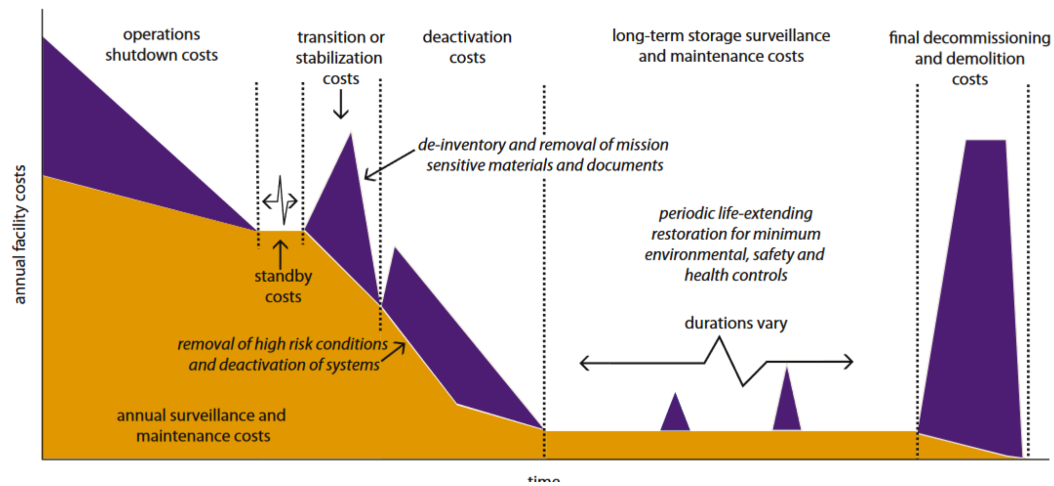



**Figure 4**. Graph depicting Additional Costs Throughout the Phases of Nuclear Plant Closure Beyond Base Costs

Tackling the persistent challenge of nuclear waste storage is central to California's complex nuclear dilemma. While the state currently operates three NRC-licensed Low-Level Waste facilities, effectively managing less hazardous waste, a permanent solution for high-level nuclear waste remains elusive ("Nuclear Waste"). Proposals like "reprocessing" high-level waste face skepticism due to concerns about compatibility and challenges posed by the increased size of waste. The most viable solution involves establishing a centralized deep geological repository capable of managing all scattered nuclear waste within the state. This aligns with the views of experts like James Flynn, who has scrutinized the difficulties in constructing such a repository, including preventing corrosion, inhibiting the spread of radioactive materials, ensuring repeatability, and implementing effective monitoring strategies (Flynn). Sweden's success with deep geological repositories stands as a testament to the potential feasibility of this solution. A publication by SKB, Sweden's Nuclear Waste Treatment company, emphasizes the importance of strategic location, continuous research, and experimentation to enhance safety, and trial-and-error methods to understand geological conditions and drilling techniques for optimal results ("Deep geological repository"). The transition to such centralized repositories holds promise for addressing California's nuclear waste management challenges effectively.

California faces a pivotal decision in determining the trajectory of its approach to nuclear waste management. The staged approach involves initiating the construction of a deep repository for low or intermediate-level waste, allowing for valuable insights and experiences before progressing to establish a more permanent storage solution for high-level waste and spent fuel. While the staged approach may be cost-intensive, its promise of delivering optimal long-term results provides a compelling argument for its adoption. Alternatively, in the event that California opts to eliminate nuclear technology entirely, a temporary solution involves outsourcing nuclear waste disposal to trusted companies or other nations, compensating them for their services. Although potentially costly, this solution becomes more attractive when viewed in the context of a nuclear-free California, where expedient disposal methods might be favored. In navigating these complexities, California must carefully weigh the costs, benefits, and long-term implications of each approach to ensure a sustainable and responsible resolution to its nuclear waste challenge.

In conclusion, California is faced with a complex nuclear dilemma that involves environmental justice, community safety, transportation safety, material safety, nuclear waste storage, and the need to transition to alternative energy sources. Our previous essay sheds light on the psychological and environmental justice aspects of nuclear waste and the intricate interplay between historical industry developments and the pressing need for safe disposal solutions. In this essay, we propose tangible solutions that are aligned with the values of intensified geo-surveying, organized decision-making, and a scientifically grounded strategy for nuclear plant closure and waste disposal.

The case of the Diablo Canyon Power Plant exemplifies the profound implications of decisions surrounding California's last remaining nuclear facility. Advocates for closure emphasize safety concerns related to seismic activity and underscore the need for comprehensive regulations and elevated standards in nuclear plant construction and operation. A comprehensive approach that addresses the fears and perspectives of residents directly impacted by nuclear facilities ensures public input, fair compensation, and ongoing monitoring, aiming not only to address immediate concerns but also to forge a sustainable path for California's nuclear future.

The international dimension adds a crucial layer to California's nuclear policy considerations. Learning from global best practices, adopting stricter and safer regulations outlined by the International Atomic Energy Agency (IAEA), and incorporating principles from the Convention on the Physical Protection of Nuclear Material (CPPNM) can contribute to a safer and more sensible nuclear policy that prioritizes community safety and well-being.

Despite the potential benefits of decommissioning nuclear plants, a nuanced understanding of the cost implications, potential power generation gaps, and environmental impacts is imperative. Careful decommissioning involves minimizing the mixing of contaminated and non-contaminated materials and effective separation of different levels of nuclear waste. The phased approach, aligning with existing sustainable energy programs, incentivizing the development of renewable energy sources, and establishing decommissioning committees, provides a roadmap to navigate the challenges associated with nuclear plant closures.

Crucially, the persistent challenge of nuclear waste storage necessitates a proactive and strategic approach. The establishment of a centralized deep geological repository, drawing inspiration from successful models such as Sweden's, emerges as a promising solution. California must carefully weigh the costs, benefits, and long-term implications of either adopting a staged approach or outsourcing nuclear waste disposal to ensure a sustainable and responsible resolution to its nuclear waste challenge. In the face of these complexities, California has the opportunity to lead the way in developing a comprehensive and forward-thinking approach to nuclear energy that prioritizes safety, environmental sustainability, and the well-being of its communities.

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