Title
Evaluating the Potential of Nuclear Energy Generation to Assist in California’s Climate Goals

Author
Bush, Hannaford

Publication Date
2025

Evaluating the Potential of Nuclear Energy Generation to Assist in California's Climate Goals

A public perception analysis in the context of the California nuclear industry and energy consumption

Hannaford Bush

Master of Advanced Study, Climate Science and Policy

Scripps Institution of Oceanography at UC San Diego

December 2023

UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY

Capstone Advisory Committee

Dr. Corey Gabriel, *Committee Chair*
Scripps Institution of Oceanography

Hannah Gruen, *Committee Member*
Scripps Institution of Oceanography

Dr. David Fortunato, *Committee Member*
Global Policy and Strategy

Acknowledgements

I would like to thank my incredible committee for bearing with me throughout this process and let me bounce a million different ideas off them. Dr. Fortunado, thank you for creating the foundation I needed to understand public policy. Hannah, thank you for always being a listening ear and dutifully correcting my spelling mistakes. Corey, thank you for always believing in me and encouraging me endlessly, as well as learning about this subject alongside me. Without them I would have never stepped outside of my comfort zone and to pursue a subject like nuclear energy. This project would also not have been possible without the vast network of industry professionals, researchers, and anyone else who sat and answered all of my questions. I also need to thank my friends who have supported me through this whole process, as well as my CSP cohort and all of the time we spent together learning and growing.

Table of Contents

Abstract:

Since the introduction of nuclear fission in 1938, nuclear energy generators have provided power at state, national, and global levels. As climate change conditions worsen, the clean, firm energy provided by these reactors may be needed to support growing renewable energy plans with intermittency problems. However, with the introduction of a 1976 California moratorium on new nuclear facilities there is no outlined future for nuclear energy, even if there is currently a large reliance on it. Understanding the history of nuclear research, as well as California nuclear energy history in the context of energy consumption can provide a unique perspective into if California will continue to invest in its remaining nuclear power plant, Diablo Canyon in order to meet strict 2030 and 2045 clean energy goals. To fully explore the potential of Diablo Canyon as a case study for nuclear generation in California, researchers and consumers must be aware of historical public perception, the policy environment, and what potential solutions there are to long-standing storage issues.

Part 1: Background and History of Nuclear Research

Introduction:

In 1957, California connected its first nuclear reactor to the electrical grid, *The Santa Susana Sodium Reactor Experiment.* By 1985, California had six operational nuclear plants, ranging from units with capacities of less than one hundred megawatt hours (MWh) to units with over one thousand MWh capacities, which is roughly enough energy to power the instantaneous demand of 750,000 homes[1]. However, the development of nuclear energy production was short lived as in 1976 California State Legislature issued a moratorium on new nuclear facility development until the Federal Nuclear Regulatory Commission (formerly the Atomic Energy Commission) identified and approved technology for firstly a nuclear fuel rod reprocessing plant construction and operation and secondly for a permanent disposal of high-level nuclear waste[2].

[1] *Understanding electricity*. (n.d.). California ISO. Retrieved November 16, 2023, from https://www.caiso.com/about/Pages/OurBusiness/Understanding-electricity.aspx
[2] *The California Nuclear Waste Act [Ballot]*. (2015, February). Legislative Analyst's Office. Retrieved April 25, 2023, from https://lao.ca.gov/BallotAnalysis/Initiative/2015-001

This moratorium put a decided stop to the advancement of nuclear energy that could have mitigated climate change impacts far earlier than the timeline that occurred, preventing issues such as high temperatures decimating crop growth, malnutrition, and rising sea levels[3].

In 1976 when the moratorium was created that stalled development of clean[4] energy, there were 331.92 ppm of carbon dioxide in the atmosphere. In 2023 there will be 416.43 ppm of carbon dioxide in the atmosphere. Clean energy production to effectuate mitigation of the impacts of climate change has become a more pressing problem since the moratorium was passed and eliminated the ability to grow California's nuclear program. However nuclear power was not the only clean energy source in development, and technology led to several different alternatives to fossil fuels including wind power, solar power, hydropower, and more. However, many of the proposed energy sources have potential issues with the ability to supply equivalent to energy demand, such as high intermittency or lack of technological foundation. As a result, California may need to re-evaluate its relationship with nuclear energy as one if not the only firm, clean energy source if it wants to meet 2045 climate goals, while providing reliable energy for the growing population. It will not be possible to overcome the inertia of adoption by creating new nuclear power plants, however the remaining plants can be optimized and provide additional clean energy without high capital costs. The goal of this paper is to serve as an educational resource about nuclear history and generation, as well as provide insight into California's nuclear potential.

Motivation:

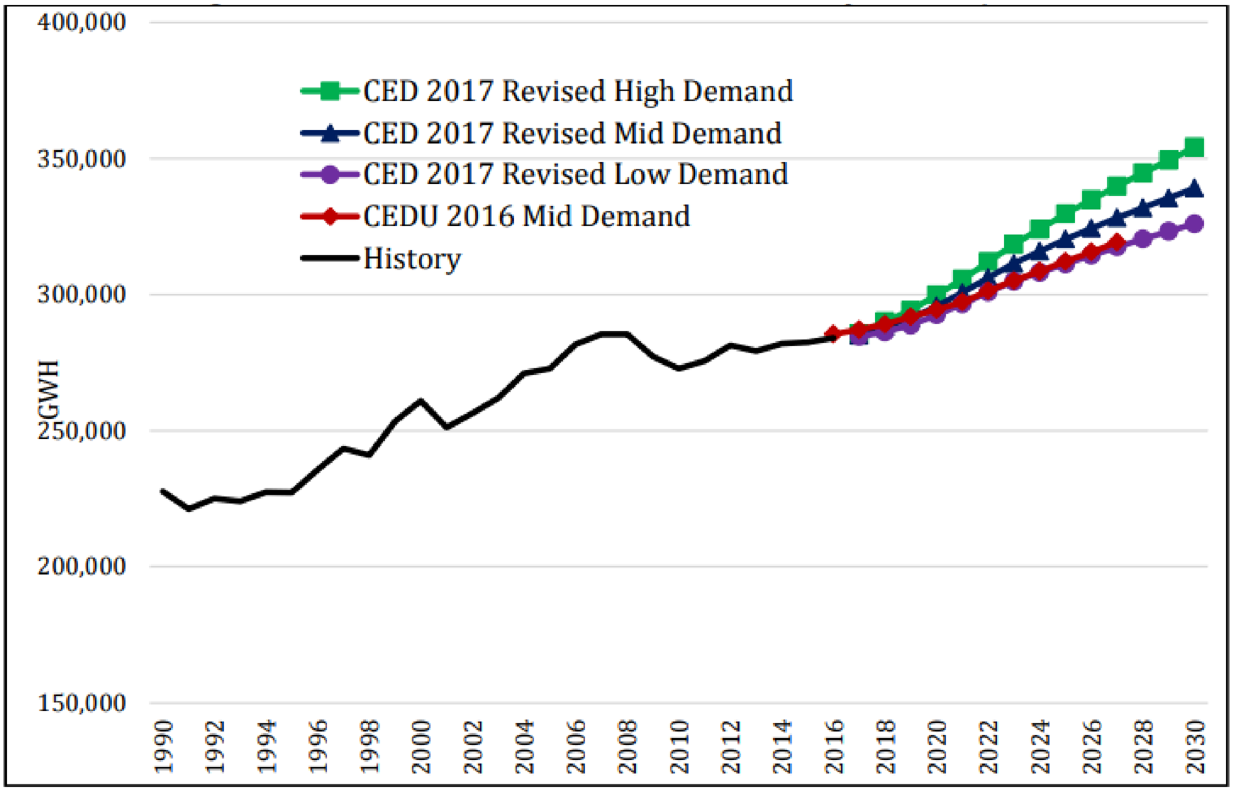
If California looks to cut greenhouse gas emissions by 85% before the year 2045, as well as reduce the state's fossil fuel consumption to less than one tenth of its current usage[5], the state must analyze what realistic fuel alternatives look like. Issues arise with the lack of current energy stability and high energy demand occurring in warmer temperatures, which are also exacerbated

[3] Butler, C. D. (2018, October 16). *Climate Change, Health and Existential Risks to Civilization: A Comprehensive Review (1989–2013)*. NCBI. Retrieved November 5, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6210172/

[4] Clean Energy is defined by the Energy Information Agency as Energy that does not produce carbon emissions

[5] *California Releases Report Charting Path to 100 Percent Clean Electricity*. (2021, March 15). California Energy Commission. Retrieved September 6, 2023, from https://www.energy.ca.gov/news/2021-03/california-releases-report-charting-path-100-percent-clean-electricity

by climate change. While many options exist, currently the energy grid must be able to support 39 million constituents and upwards of 7,359 trillion Btu consumed per year, most of which is supported by natural gas as of 2021[6]. The energy grid in 2030 will need to support a projected 44.1 million residents with an expected energy consumption growth rate of 1.56%, or 11,038 trillion Btu[7], and the caveat that at least 60% of energy generation must be clean.



Source: California Energy Commission, Energy Assessments Division, 2017.

Figure: Statewide baseline annual energy consumption and projections[7]

Solar and wind farming do not yet have enough technological reliability to replace natural gas. These renewables have severe limitations due to source intermittency issues that have not been solved with technology advancements that allow for these sources to provide firm, defined as always available, energy. Currently renewables account for less than 750 trillion Btu of energy consumption.

[6] *California State Energy Profile*. (2023, April 20). EIA. Retrieved September 6, 2023, from https://www.eia.gov/state/print.php?sid=CA

[7] California Energy Commission. (2018, February). *California Energy Demand 2018-2030 Revised Forecast*. California Energy Commission. Retrieved November 06, 2023, from https://www.energy.ca.gov/publications/2018/california-energy-demand-2018-2030-revised-forecast

The nuclear facilities built before the moratorium provided a great deal of clean energy to California, but over time the state has shifted away from its heavy investment in nuclear energy to other energy sources regardless of carbon emissions. Previously even just 20 years ago in 2003 California received 18.4% of its annual energy from nuclear generation[8], which is now down to around 8-10%. However, California did not continue to support and develop its nuclear program leading to a decline of funding that resulted in only one nuclear generating station still supplying energy as of 2018: Diablo Canyon in San Luis Obispo. The moratorium had demonstrated that at the time there was widespread public distrust of nuclear power, with organizations going as far as proposing their own ballots that eliminated all nuclear plants, current and future. The years before the moratorium was placed saw several historic nuclear incidents such as the Idaho Falls meltdown that resulted in the deaths of three operators. This coupled with the global drive to create and use nuclear weapons in war shifted the energy source from being a provider, to being a destroyer. Without the public's support government officials were unwilling to continue to create funding for the California nuclear program that would undoubtedly cause friction with their voters.

At the time, nuclear war was a far larger threat than climate change impacts, but as time has progressed the very real impacts of climate change and the need for clean energy may outweigh the fear of a potential nuclear incident. Since this moratorium was passed there has been significant progress in safety measures which have in turn translated over to increased citizen support for nuclear energy. It may not be possible to overcome the moratorium in time to fulfill the energy demands of California, but Diablo Canyon Power Plant provides untapped resources that California may fail in its goals without. Before evaluating if California will fail in its climate goals without nuclear energy generation, the history of the state's relationship with nuclear energy as well and the history of the science must provide context for the current state of the industry.

---

[8] Energy Information Administration. (n.d.). *Electricity Data Browser*. EIA. Retrieved November 6, 2023, from https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=vvvvu&geo=g00000000004&sec=g&freq=A&start=2001&end=2022&ctype=linechart&ltype=pin&rtype=s&maptype=0&rse=0&pin=

Background:

Nuclear fission research began in as early as 1938 in Berlin with Otto Hahn and Fritz Strassmann demonstrating that when uranium atoms were bombarded with accelerated protons, lighter elements such as barium occurred that were roughly half of the mass of the uranium atoms. This research was continued by Lise Meitner and her nephew, who explained that this process occurred with high enough levels of vibration to split the atom, and calculated the energy release possible for this experiment[9]. As an energy source in the United States, nuclear power established a foothold in 1958 with the construction of the first commercial nuclear power plant in Shippingport, Pennsylvania. There was considerable investment in the beginning stages of nuclear generation, and the amount of nuclear reactors peaked at 112, with a combined summer generation capacity of almost 100,000 megawatt hours[10]. However, since this point the number of reactors has steadily declined to 92 operational national reactors as of 2022, with more set to close in the coming years. Even though the volume of reactors has declined, technological innovations have made it possible for the current reactors to supply a capacity of 94,765 MW, just five thousand less than at the peak. Nationally, nuclear energy generation still provides roughly 18% of the overall energy demand, supplying more than any other single source besides natural gas (#1) and coal (#2) which are both fossil fuels[11].

In 1946 the United States passed the *Atomic Energy Act*, which established the Atomic Energy Commission, the AEC, to oversee atomic energy for peaceful purposes, and align with common defense and public safety[12]. This act was replaced eight years later in 1954, specifically mentioning the ability to use nuclear as a commercial energy provider. The AEC worked in two directions: firstly to establish the potential power associated with nuclear energy, as well as regulate the safety and usage of nuclear energy without overregulating the commercial market.

---

[9] *Outline History of Nuclear Energy*. (2020, November). World Nuclear Association. Retrieved November 8, 2023, from https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx

[10] *U.S. nuclear industry - U.S. Energy Information Administration*. (2023, August 24). EIA. Retrieved August 31, 2023, from https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php

[11] Energy Information Administration. (n.d.). *Frequently Asked Questions (FAQs) - U.S. Energy Information Administration*. Energy Information Administration (EIA). Retrieved November 8, 2023, from https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

[12] *History | NRC.gov*. (2021, September 10). Nuclear Regulatory Commission. Retrieved August 31, 2023, from https://www.nrc.gov/about-nrc/history.html

However even as early as the 1960's the AEC came under attack for not providing stringent enough regulations, specifically around radiation and environmental protection. In 1974 congress abolished the AEC due to the increasingly negative reaction of the public towards proposed regulations, and instead split the agency's responsibilities amongst several others in the *Energy Reorganization Act*. This included giving responsibilities to the Environmental Protection Agency (EPA), the Office of Air and Radiation (OAR), and creating a new agency called the Nuclear Regulatory Commission (NRC)[13].

Nuclear energy is created through the process of fission: splitting the nuclei of an atom into several parts. Nuclear reactors function by using the heat created from fission of an atom, most commonly uranium-235 which occurs at a prevalence of .7%, but uranium-238 which makes up the other 99.3% is able to be enriched into U-235 which is then usable[14]. Before uranium-235 may be used in the fission process, it must be enriched. Uranium enrichment, which is the process of making the uranium-235 isotope percentage increase in natural uranium through techniques such as gaseous diffusion or laser isotope separation, it can be used in nuclear reactors for three to five years before it must be disposed of[15].This fission process is used to heat a cooling agent and produce steam. This steam is then used to spin a turbine and create electricity.. This process produces virtually no carbon emissions, qualifying it as a clean energy source. The spent nuclear fuel is where the radioactive atoms reside after their time in the reactor, but spent fuel has the potential for being recycled in nuclear reactors to create new usable fuel by utilizing the byproduct plutonium as a fuel source. If no recycling occurs, it is stored as radioactive spent fuel in cooling pools, commonly in the nuclear reactor itself until it can be transported and stored in dry facilities with safety measures in place.

Nuclear energy cannot be considered a true clean energy source if the process of mining uranium for fuel is included. Uranium (U) has a naturally occurring concentration of roughly 2.8 ppm in the Earth's crust. Uranium mines can function with concentrations of uranium ranging from

[13] *U.S. nuclear industry - U.S. Energy Information Administration*. (2023, August 24). EIA. Retrieved August 31, 2023, from https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php
[14] *Outline History of Nuclear Energy*. (2020, November). World Nuclear Association. Retrieved November 8, 2023, from https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx
[15] *The nuclear fuel cycle - U.S. Energy Information Administration*. (2022, July 12). EIA. Retrieved September 6, 2023, from https://www.eia.gov/energyexplained/nuclear/the-nuclear-fuel-cycle.php

.02% to upwards of 20% U above grade. While there are mines spread throughout the world, over 55% of the uranium produced in 2022 came from just 10 mines across 5 countries[16]. However, uranium can also be recovered as a by-product from other mines of copper, gold, or phosphate deposits. The high costs of uranium mining are often a huge barrier to investors looking to contribute to the nuclear energy market. These mines require significant amounts of capital investment, yet likely will not be ready for 10-15 years with the cost of equipment totaling to over 100 million dollars. The market for uranium itself can be very volatile, with peaks in the last decade of $300/kg, and lows of $41/kg[17]. The stress of limiting profits has led to many uranium mines entering into "care and maintenance mode," and these will restart when the uranium spot price is above the cost of production, but also when the price will stay stable for a period of time or increase. With instability occurring in the fuel production aspect of nuclear energy production, it is hard to encourage states to continue investing in their clean energy nuclear programs, especially when other options are becoming more scalable and potentially can secure additional subsidies to decrease the cost of production. Nuclear energy generation does not come without its share of issues, namely the instability of uranium mines and charged perception landscape. However nuclear energy does not need to be utilized as the sole energy provider in a system, but can instead function as a clean baseload provider that fills in intermittency gaps with renewable energy to create a diverse and established energy portfolio.

Two of the most developed technologies used for clean energy production are solar generation and wind farms, with onshore wind production already implemented and offshore wind in development. Solar generation has seen exponential growth over the past decade, as well as decreasing costs that make it into a clear competitor for states as a clean energy source. Yet there are many residual issues with solar energy technologies, such as heat islands and biodiversity loss, inability to store energy, threatened resilience by having a solar dominated energy mix, and intermittency[18]. Offshore wind power is currently incredibly limited in the United States, with

---

[16] *Uranium Mining Overview*. (2023, August). World Nuclear Association. Retrieved September 6, 2023, from https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview.aspx

[17] *URAM-2018: Ebb and Flow — the Economics of Uranium Mining*. (2018, June 22). International Atomic Energy Agency. Retrieved September 6, 2023, from https://www.iaea.org/newscenter/news/uram-2018-ebb-and-flow-the-economics-of-uranium-mining

[18] Tabassum, S., Rahman, T., Islam, A. U., Rahman, S., Dipta, D. R., Roy, S., Mohammad, N., Nawar, N., & Hossain, E. (2021, December 04). *Solar Energy in the United States: Development, Challenges and Future Prospects*. MDPI. Retrieved August 31, 2023, from https://www.mdpi.com/1996-1073/14/23/8142

most of the development occurring in Europe and Asia. There are some benefits to offshore wind development, such as the timing of wind power picking up more after dark, but many harmful effects also occur such as changes to vessel traffic, risk of collision, and food web impacts. Offshore wind also requires more expensive equipment to track wind patterns, and is not predicted to supply significant energy until 2040[19]. Currently there are only two functional offshore wind farms in the United States, totalling to 42 mW/h in capacity. Transitioning to clean energy is urgent, but there are many intervening variables with all forms of technology that limit the desire for investment and use.

[19] Chen, C.-H., & Su, N.-J. (2022, September 21). *Global Trends and Characteristics of Offshore Wind Farm Research over the Past Three Decades: A Bibliometric Analysis*. MDPI. Retrieved August 31, 2023, from https://www.mdpi.com/2077-1312/10/10/1339

Part 2: United States Citizens Perspective of Nuclear Generation and Federal Policies

One of the driving issues with nuclear generation in the United States comes not from technologic issues, but instead arises from the general perception held of nuclear power and its impact on policy maker's decisions. Public perception of nuclear energy generation has paralleled generator construction, with widespread support early on in the nuclear lifetime as more generators were being built, and decreasing with more generators being decommissioned as time went on, aside from a few unique incidents such as the Fukushima nuclear incident that have left greater impacts. After World War II, the American public responded positively in polls, supporting nuclear generation and exports, even if the generator was located near their residence. These feelings changed overtime, especially with above-ground weapons testing that included nuclear fallout, but had no bearing on nuclear energy generation. The public's distrust of the Atomic Energy Commission due to this fallout grew, regardless of the fact that it was nuclear weapons testing that created risks, not energy generation[20]. Yet, during the 1970's, the opposition towards nuclear energy generation was not directed at the power itself, but instead at increased local construction. This developed into a sentiment that nuclear power generators should be built, but more than 5 miles away from constituents' homes[21]. Since the 1980's the opposition to nuclear power has outweighed the support in almost all polls given. However, several sources from the most recent decade show a growing support for nuclear energy once again. It is nowhere near as strong as it once was, but is nearing roughly 65% of Americans that are in support of nuclear energy. But these polls demonstrate another issue with nuclear power, and that is public education and access to updated information about nuclear energy. Polls performed state that roughly 65% of Americans are in support of nuclear energy, but many of these were administered or funded by nuclear organizations, likely only reaching citizens that are already informed about nuclear energy. Largely, there are three theorized reasons behind why the American public turned against nuclear power that transcend specific events[22].

---

[20] *Moments in NRC History: Founding of the NRC-- January 19th, 1975*. (2014, February 4). YouTube. Retrieved September 21, 2023, from https://www.youtube.com/watch?v=uhijG_aLd-8&list=PL27FC68CD5516246D&index=7

[21] Melber, B., Nealey, S., Hammersla, J., & Rankin, W. (1977, November 1). *Nuclear power and the public: analysis of collected survey research (Technical Report)*. OSTI.GOV. Retrieved September 5, 2023, from https://www.osti.gov/biblio/5234344

[22] Rosa, E. A., & Dunlap, R. E. (1994, January 1). The Polls- Poll Trends: Nuclear Power: Three Decades of Public Opinion. *Public Opinion Quarterly*, *58*(2), 295-324. https://doi.org/10.1086/269425

Firstly is the thought that US opinion shifted away from nuclear generation due to high costs of nuclear energy, especially with the development of natural gas reserves. The capital costs of building nuclear power plants do outrank other energy sources capital costs, with nuclear power ranging from 4 billion US dollars to 9 billion US dollars to build a plant. According to a 2023 Levelized Cost of Energy Analysis from Lazard, the unsubsidized cost of nuclear generation per megawatt hour ranges from $118 to $192, however the midpoint of marginal cost shows at $29 per MWh[23]. These prices are higher than that of Solar PV at a utility scale, as well as wind, but are similar in cost to rooftop solar and community solar, and cost significantly less than rooftop residential solar. However, when this report discusses the cost of energy comparison including government subsidies, nuclear is left out of the discussion entirely. In order to operate at the scale of demand in the United States, low cost energy solutions like solar and wind would need to be greatly increased, however in the same Lazard report the cost of using existing nuclear plants to generate energy is significantly lower than the cost of building new wind and solar farms, regardless of it is subsidized or not.

[23] *2023 Levelized Cost Of Energy+*. (2023, April 12). Lazard. Retrieved September 6, 2023, from https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/

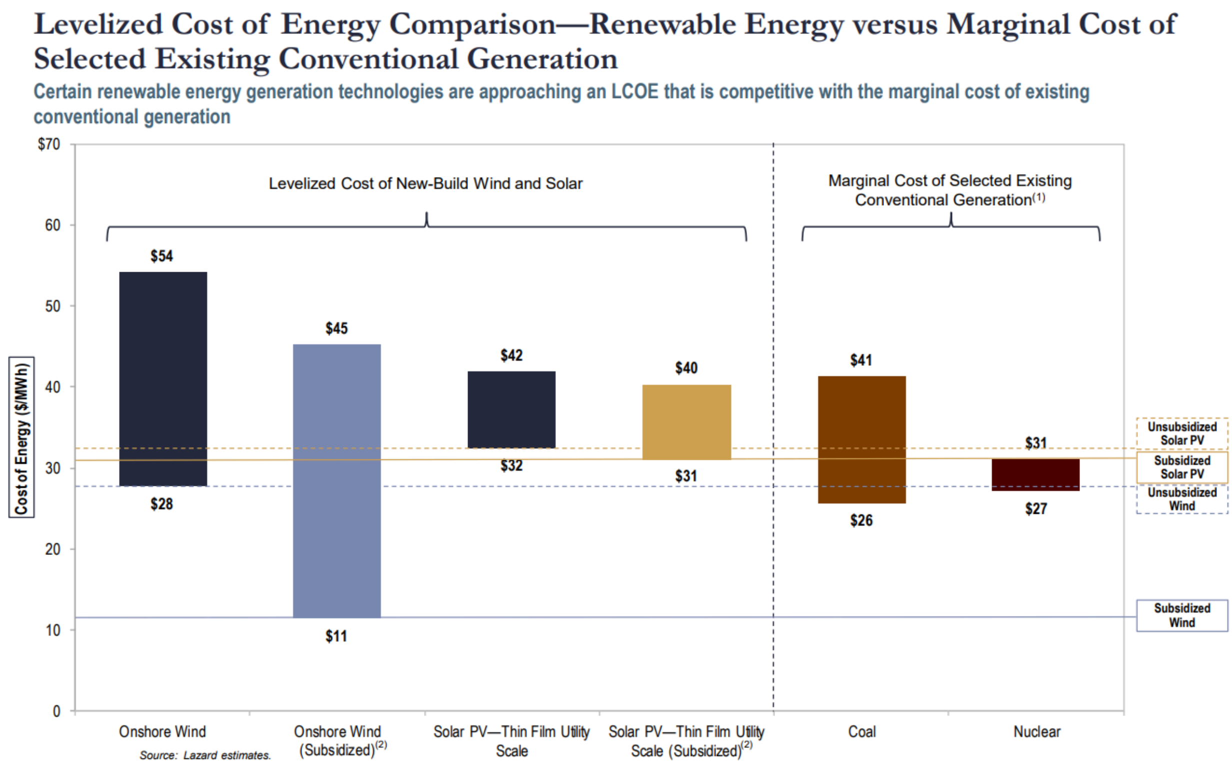


Figure: Lazard Levelized Cost of Energy Comparison 2019

Lastly, ignoring many other factors that impact energy generation, the more cost efficient energy sources are not able to be used as a baseload energy source, with base load plants being qualified as plants that are designed to take all or part of the minimum load of a system that produces energy and runs continuously[24]. It may be more expensive to build new nuclear plants, but in order to supply the level of energy needed nuclear is currently the most cost efficient clean energy on the market.

Secondly, ongoing negative perspectives of safety partially due to events, but also including general fear of the inherent radioactivity of uranium have led to less interest from investors and consumers, possibly contributing to high costs of nuclear generation. This second potential reasoning opens up a much greater issue surrounding nuclear power, which is that it is difficult to correctly combine the social discussion of nuclear generation with the scientific principles of safety. Many of the polls given to gain an understanding of public perception delve into what the

[24] *Glossary - U.S. Energy Information Administration*. (n.d.). Glossary - U.S. Energy Information Administration (EIA). Retrieved September 6, 2023, from https://www.eia.gov/tools/glossary/?id=B

public thinks, but do not progress into gathering how much of nuclear science the American public understands[25]. This has left great space in the American psyche to be influenced by large events, rather than the consistency that many other power plants have provided. Three large nuclear accidents have left permanent impacts on the pro-nuclear movement, yet only one incident occurred in the United States.

On Wednesday, March 28th, 1979 the Three Mile Island Unit 2 reactor located near Harrisburg, Pennsylvania, experienced a failure in the non-nuclear portion of the plant. The secondary cooling circuit experienced a minor issue, which caused the primary coolant to attempt to balance out, rising and shutting down the reactor automatically as intended. However, during this shutdown a relief valve did not close and a significant amount of the primary coolant drained away, leaving too little to adequately cool down the reactor core. The inability of operators to respond completely to the emergency based on too little instrumentation led to severe damage of the fuel reactors, and some radioactive gas escaping into the environment. The original emergency of inadequate cooling was resolved just over 12 hours after the shutdown occurred, leaving the radioactive gas containment left to manage. Over the next few days operators would isolate the gas to waste gas decay tanks, and most other radionuclides that leaked out of the compressors were isolated through HEPA and charcoal filters, dropping the remaining radioactive gas release to 370 PBq of specifically noble gasses, and since these elements have short half-lives and are biologically inert they were not health hazards. However, this well contained issue was not what was communicated to the public, which led to a large misinformation campaign and confusion from the local public as to what truly happened[26].

The third potential reason is that many consumers do not feel that problems regarding waste storage have been properly addressed enough to consider nuclear a feasible long term fuel solution[27]. There have been several viable solutions proposed over the years, with one plan being the focus: to create underground repositories. Currently, most high level waste and spent fuel is

---

[25] Downey, G. L. (1986, November). Risk in Culture: The American Conflict over Nuclear Power. *Cultural Anthropology*, *1*(4), 388-412. JSTOR. https://www.jstor.org/stable/656378
[26] *Three Mile Island | TMI 2 |Three Mile Island Accident.* (2022, April). World Nuclear Association. Retrieved September 13, 2023, from https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx
[27] Baron, J., & Herzog, S. (2020, October). Public opinion on nuclear energy and nuclear weapons: the attitudinal nexus in the United States. *Energy Research and Social Science*, *68*. ScienceDirect. https://doi.org/10.1016/j.erss.2020.101567

stored on site on the decommissioned reactor in special casks or in the cooling pools. However, this is not a long term solution, but underground repositories may be. Radioactive spent fuel would be transported to specific locations in the country that would store the material in specifically designed casks under specific geological conditions for hundreds of thousands of years[28]. The public fear surrounds the idea that it is not possible to accurately determine how materials will function over hundreds of thousands of years, as there is no way to have studied it in the full time period. There are two methods that nuclear waste from these repositories could enter the surrounding area, firstly from localized, small releases from human intrusion near the repository which would leave the radiation contained to a few individuals, but would result in higher doses. The second mode that radiation exposure could occur is far into the future with the gradual release of radioactivity from the spent fuel into ground water leading to smaller doses in a larger population. A large repository was proposed in Yucca Mountain, Nevada in 2002, but the project was shut down in 2010 due to public concerns about long term storage. There have been no other repositories proposed for reactor spent fuel, however there is a Waste Isolation Pilot Plant located in Carlsbad, New Mexico that houses nuclear defense waste that has been functioning since 1999[29]. While the proposed repository did not move through to implementation, impacts of climate change are not waiting for a reasonable clean energy solution to develop.

Researchers are divided on which of these thought processes had led to the public perception of nuclear power, but it is most likely a combination of the three, along with general negativity bias. Negativity bias is where negative stimuli carry greater informational value than positive stimuli, and adults often spend more time analyzing negative stimuli rather than positive stimuli[30]. Additionally, this phenomenon has been revealed in adult’s judgment as something that causes them to weigh the negative aspects or events more heavily than the positive other aspects. Putting this in the context of nuclear energy generation, it may be much easier to recall events like Fukushima or Three Mile Island, and not the steady energy provided by 440 reactors

---

[28] Ramana, M. V. (2018, February 27). Technical and Social Problems of Nuclear Waste. *WIREs Energy and Environment*. Wiley Online Library. https://doi.org/10.1002/wene.289
[29] *About*. (n.d.). Waste Isolation Pilot Plant. Retrieved September 13, 2023, from https://wipp.energy.gov/index.asp
[30] Vaish, A., Grossmann, T., & Woodward, A. (2008, May). Not all emotions are created equal: The negativity bias in social-emotional development. *National Library of Medicine*. PubMed Central. 10.1037/0033-2909.134.3.383

globally[31]. Nuclear incidents occur at a stable level of .003 events per plant per year, noting a steep drop off after Three Mile Island and Chernobyl, indicating that the industry is learning from its mistakes. Additionally, 84% of the damage evaluated in the study occurred from Chernobyl and Fukushima solely[32].

Regardless of what the root cause is, public perception has incredible impacts on the nuclear industry; possibly more impact than the volatile price of uranium. Many organizations oppose nuclear power on a variety of positions, such as the Californians for Nuclear Safeguards organization which pushed heavily for halting all nuclear production in California in 1976, or the California Surfrider organization that was instrumental in the early decommissioning of San Onofre Nuclear Generating Station in 2018, or even the organizations that spoke against the AEC in the early 1970's that resulted in the creation of the NRC. Easily accessible nuclear information and history is crucial to making sure that the public perception is informed enough to make their own decisions. If citizens are more informed, then hopefully policy makers will feel more comfortable speaking in favor of nuclear power, or at least creating similar subsidiaries or policies that make solar and offshore wind more affordable and supported.

However, federal organizations struggle to meet the needs of both the nuclear energy industry and the American public not only because the needs are so vastly different, but also because each state has its own nuclear regulations and reliance. For example, Illinois in 2019 generated 59% of its energy from its nuclear plants, while states like Wyoming or Nevada do not contain any nuclear plants[33]. Georgia has two plants under production, while California has regulation in place preventing the construction of more nuclear plants. Lastly, there are states that export a great deal of their nuclear generation, such as the Palo Verde plant in Arizona. Managing all these states with a central organization is nearly impossible, but many states look to the NRC to

---

[31] *Nuclear Power Today | Nuclear Energy*. (2023, November 15). World Nuclear Association. Retrieved December 5, 2023, from https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

[32] Wheatley, S., Sovacool, B. K., & Sornette, D. (2016, May). Reassessing the Safety of Nuclear Power. *Energy Research and Social Science*, *15*, 96-100. Elsevier. https://doi.org/10.1016/j.erss.2015.12.026

[33] *Twelve U.S. States generate more than 30% of their electricity from nuclear power*. (2020, March 26). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved September 22, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=43256

create regulation that assists in their goals, without the understanding of how other states are functioning.

There are still some current policies that the NRC and United States nuclear industry use that do work to federally support different states. *The Atomic Energy Act of 1954* states that all nuclear facilities must be licensed through the NRC and governed by their standards. However, this act also includes a section that details the NRC's ability to enter into an agreement with a state to turn over regulatory authority to said state, as long as the regulatory program is compatible with the NRC[34]. This should allow for more flexibility while maintaining a standard quality level. *The Energy Reorganization Act of 1974* reorganized the AEC into the NRC which is responsible for civilian uses of nuclear materials, while nuclear weapons development now rests in the hands of the department of energy. This ideally ensures that there is no crossover between military development and civilian energy production, potentially assisting with the public's fears of the United States energy system and consequently its spent fuel storage being managed as if it were a part of the military. There are specifically several other acts that focus on spent fuel: the *Nuclear Waste Policy Act of 1982*, the *Low- Level Radioactive Waste Policy Amendment Act of 1985*, and the *Uranium Mill Tailings Radiation Control Act of 1978*. The first act listed dictates the shared responsibility of the NRC to provide a place for the permanent disposal of high-level radioactive waste (HLW), and the states responsibility to fund the permanent disposal. The federal government has, technically, completed their portion of the act with the site at Yucca Mountain, Nevada, however since construction has stopped the site is not usable. The 1985 act dictates that responsibility of disposing of low level waste (LLW) is given to the generators of waste, but also supports states in making compacts with each other to find disposal solutions. These sites are governed by states that are in agreement with the NRC or by the NRC itself to ensure that the NRC is providing standards for determining when waste is labeled as "below regulatory concern". The NRC has established this to mean waste that does not pose a health threat, identified as below 25 millirems of radioactivity to the whole body, below 75 millirems to the thyroid, or below 25 millirems to any other organ if released[35]. The final act listed governs

[34] *Governing Legislation | NRC.gov*. (2021, September 10). Nuclear Regulatory Commission. Retrieved September 22, 2023, from https://www.nrc.gov/about-nrc/governing-laws.html
[35] *NUREG BR-0121, Regulating the Disposal of Low-Level Radioactive Waste, A Guide to The Nuclear Regulatory Commission's 10 CFR*. (1989, August). Nuclear Regulatory Commission. Retrieved September 22, 2023, from https://www.nrc.gov/docs/ML1207/ML120720225.pdf

uranium mill tailings, which are the residuals remaining after the processing of natural ore to extract uranium and thorium. The act gives governing responsibility to the NRC for all sites licensed by that organization to minimize the diffusion of rado into the environment. These regulations are responsible mostly for deciding where responsibility lies, but unfortunately do little to push actionable change or solutions. Those responsibilities, according to the act, lie on the states, but many states like California are waiting on the NRC to present solutions. The remainder of this paper will be spent on California's potential to include or exclude nuclear power over the coming years.

Part 3: California's Nuclear History and Current State of the Industry

As climate change and its impacts progress, governments need to stay committed to decreasing carbon emissions, not just adaptation. California has declared that it will supply 100% of energy from renewable and zero carbon energy sources by 2045, aiming to supply 60% by 2030[36]. The resources that this energy production will come from vary from increased solar and wind, to renewable natural gas, but often nuclear power is left off the table due to the current lack of investment. However, California used to boast of a robust nuclear program with both publicly and privately owned power plants. These plants have historically provided a great deal of clean energy to California's energy grid, although over the years all but one power plant have started their decommissioning process. Each power plant provides a unique perspective into how nuclear energy can be utilized safely, and how likely it is that California will continue to invest in nuclear energy generation based on reasons for closure. While new nuclear facilities are not likely, the energy that is currently supplied to California's energy grid from nuclear generation is irreplaceable if California wants to meet goals as soon as 2030.

The first power plant was *The Santa Susana Sodium Reactor Experiment* (SRE). It was short-lived, only connected to the electrical grid between July 1957 and February 1964. It began its decommissioning process due to an accident that resulted in a partial core meltdown, losing 13 of 43 fuel assemblies, and releasing radioactive contamination. *The Vallecitos Nuclear Power Plant* (VNC) was not a commercial power plant, but instead a private power plant run by Pacific Gas and Electric (PG&E) in conjunction with General Electric. It was mainly used as a research center for the Atomic Energy Commission's Nuclear Energy Program, and research continued past when the plant went into decommission in 1967. *Humboldt Bay Nuclear Power Plant* was the seventh licensed nuclear power plant in the United States, and had a capacity of 65 MW. This power plant was also owned and operated by PG&E from 1963 until 1976 when it was shut down to conduct seismic modifications and was declared not cost-effective. The decommissioning process for this plant concluded in 2019, and is now functioning as an

[36] *California Releases Report Charting Path to 100 Percent Clean Electricity*. (2021, March 15). California Energy Commission. Retrieved September 25, 2023, from https://www.energy.ca.gov/news/2021-03/california-releases-report-charting-path-100-percent-clean-electricity

unrestricted site, with the spent fuel stored in dry casks onsite[37]. *Rancho Seco Nuclear Generating Station* operated from 1975 until 1989, and was owned by Sacramento Utility District (SMUD), which contrary to PG&E is a publicly owned utility rather than investor owned. This plant was closed due to public referendum ten years before its operating license would expire, and had a much larger capacity of 913 MW. The vote was 53.4% voting to close the station, and 46.6% voting to keep the station active[38].

The San Onofre Nuclear Generating Station (SONGS) was the most recent nuclear power plant to enter into decommission in California. SONGS had three units; Unit 1 operated from 1968 until 1992, Unit 2 operated 1983 until 2013, and Unit 3 operated 1984 until 2013. The first unit had the smallest capacity at 436 MW, unit two had 1070 MW and unit 3 had 1080 MW power. Southern California Edison (SCE) owned 78.2% of SONGS, San Diego Gas and Electric (SDG&E) owned 20%, and the City of Riverside owned 1.8%. Decommissioning is planned to take 20 years and cost 4.4 billion dollars, with waste being held on site indefinitely. On January 31, 2012, unit 3 suffered a radioactive leak inside of the containment shell due to premature wear.

The only operational power plant in California is *Diablo Canyon Nuclear Power Plant.* This power plant has been operational since 1985, and is also owned by PG&E. It is a 2 unit generating station that uses water from the pacific ocean to cool its 4-loop pressurized water reactors. Both units have a capacity of 1,100 MW power, and create roughly 18,000 GWh of electricity annually. Originally, Diablo Canyon was slated to be decommissioned starting in 2024 and 2025 for each unit respectively, and this proposal was approved in 2018. However, with increasing energy demand and decreasing reliability, all coinciding with more emphasis on clean energy the proposal was re-examined in 2021 and Diablo Canyon’s lifetime was extended until 2029 and 2030 respectively, with the potential to be extended until 2035[39]. Diablo Canyon is the state's largest single source of electricity, generating 16,477 GWh in 2021. Without Diablo

---

[37] Radwaste Solutions. (2021, November 23). *Humboldt Bay officially decommissioned, site released for unrestricted use*. American Nuclear Society. Retrieved December 1, 2023, from https://www.ans.org/news/article-3456/humboldt-bay-officially-decommissioned-site-released-for-unrestricted-use/

[38] *Rancho Seco nuclear power station, closed down by referendum in ...* (2017, July 5). Environmental Justice Atlas. Retrieved May 8, 2023, from https://ejatlas.org/conflict/rancho-seco-nuclear-generating-station?translate=en

[39] *Nuclear Power Reactors in California*. (2020, March). California Energy Commission. Retrieved May 2, 2023, from https://www.energy.ca.gov/sites/default/files/2020-03/Nuclear_Power_Reactors_in_California_ada.pdf

Canyon's clean energy, California can expect an additional 6 million tons of CO2 emissions that will need to be accommodated for.

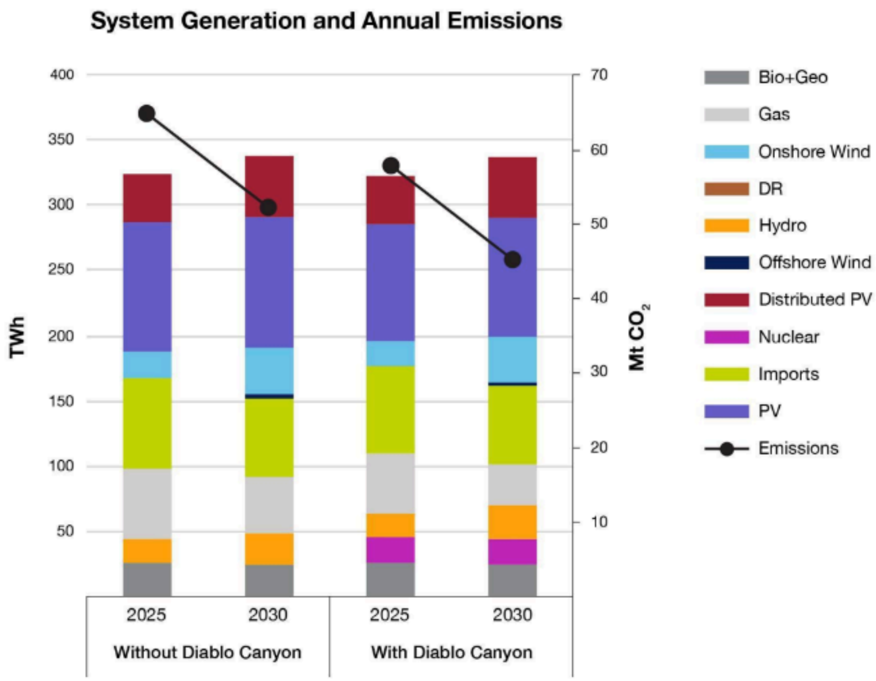


Figure: PG&E system generation and carbon dioxide reduction in 2025 and 2030 with and without Diablo Canyon Power Plant

However, California's heavy investment in nuclear energy was cut short by a policy proposed in 1976. A moratorium was passed by the state legislature, stating that no new nuclear power plants could be licensed to be built until the California Energy Resources Conservation and Development Commission, more commonly referred to as the California Energy Commission or CEC, determined that the federal government has identified and approved technology for two aspects of nuclear generation:

1. The construction and operation of nuclear fuel rod reprocessing plants
2. The permanent disposal of high-level nuclear waste

State laws exempted Diablo Canyon from this moratorium as it was already built by the time of this moratorium, even if it was not yet supplying energy to the electrical grid[40]. Two of the California reactors had closed because of partial core meltdowns, resulting in no deaths but instead in a general public distrust of California's nuclear system widespread enough to result in a shutdown of another nuclear power plant via public referendum. This new wave of public anti-nuclear sentiment would lay the groundwork for future policy decisions in California, such as the 1976 moratorium.

The moratorium was originally placed not as a way to strictly limit nuclear power plant stations, but instead as an alternative to a much harsher proposed bill. In June 1976, the Californian's for Nuclear Safeguards organization created Proposition 15, which stated that there would be a permanent ban on all new nuclear generating stations, and would also impose new restrictions on current nuclear power plants[41]. The moratorium was claimed to exist for more economic reasons than safety reasons as there are many financial issues that come with outlawing new energy production installations. Some of the listed economic impacts are increased costs for electricity, liability for investment losses, and loss of revenue. However, the avoidance of financial burden in the case of a potential nuclear incident cannot be discounted. In 35 years there have been no new nuclear power plants, as there has been progress but no federal approval in long term storage for nuclear waste. California is an agreement state which gives the California State Government the ability to self-regulate its nuclear industry, and the moratorium could be overturned if deemed necessary by the state government. This would take significant movement from California's voters to speak out in favor of nuclear energy generation, either for energy stability or for the desire to meet California's climate goals. The discussion will lie in whether or not California's voters have the same priorities in energy generation as the organizations in charge of planning for the future.

---

[40] *The California Nuclear Waste Act [Ballot]*. (2015, February). Legislative Analyst's Office. Retrieved April 25, 2023, from https://lao.ca.gov/BallotAnalysis/Initiative/2015-001

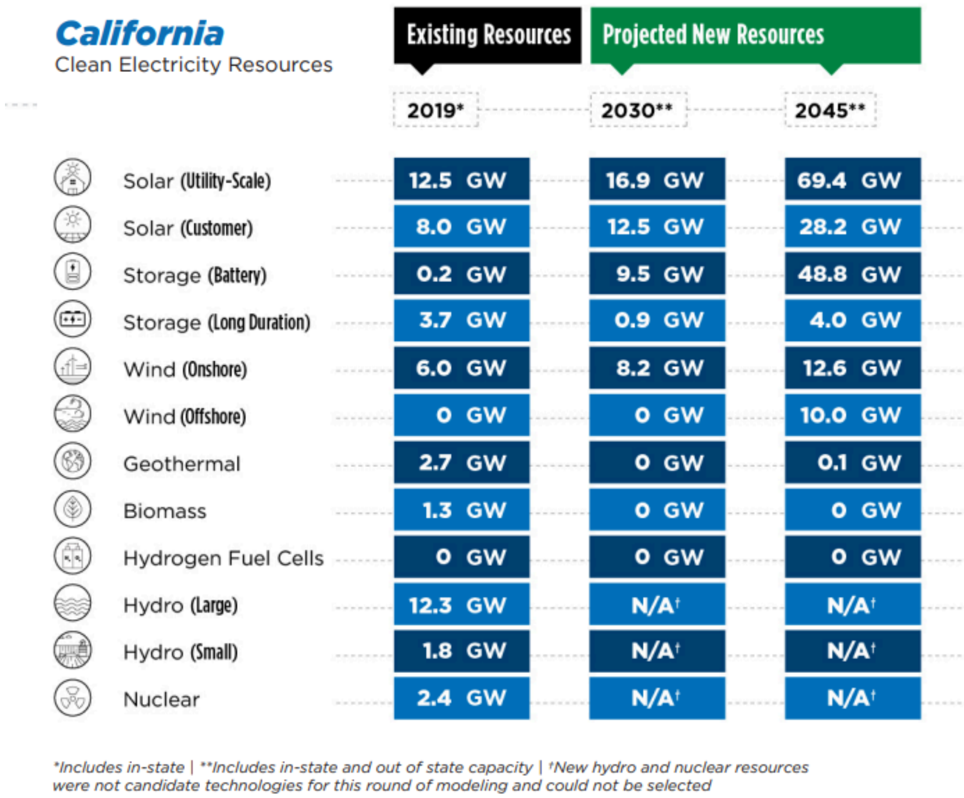
[41] Minnesota Law Review Editorial Board. (1982). *A Preemption Analysis of California 's Moratorium on Nuclear Plant Construction: Pacific Legal Foundation v. State Energy Resources Conservation and Development Commission*. University of Minnesota Law School. https://scholarship.law.umn.edu/cgi/viewcontent.cgi?article=4179&context=mlr

In the *Achieving 100% Clean Electricity in California* joint summary report, which details how California expects to reach its 2030 and 2045 goals, nuclear power is not listed in the potential resources. Instead, the report depicts an energy grid that functions off of solar and wind alone, with roughly 55 GW of storage. This report written by California Air and Resource Board (CARB), the California Energy Commission (CEC), and the California Public Utilities Commission is a policy projection of one route that California could take to meet climate goals, but it is the path that the state currently utilizes. Currently, California only has 5.6 GW of storage capacity integrated into the grid, a project that took three years to complete[42]. In the summary report, the agencies state that California will need to build an average of 6 GW of new solar, wind, and battery storage per year. In the last decade, California has built an average of 1.3 GW new solar and wind per year[43].

---

[42] *ICYMI: California Grid Reaches 5,600 MW of Battery Storage Capacity, a 1020% Increase Since 2020 | California Governor*. (2023, July 12). Gavin Newsom. Retrieved September 26, 2023, from https://www.gov.ca.gov/2023/07/12/icymi-california-grid-reaches-5600-mw-of-battery-storage-capacity-a-1020-increase-since-2020/

[43] *California Releases Report Charting Path to 100 Percent Clean Electricity*. (2021, March 15). California Energy Commission. Retrieved September 6, 2023, from https://www.energy.ca.gov/news/2021-03/california-releases-report-charting-path-100-percent-clean-electricity


California
Clean Electricity Resources

	Existing Resources	Projected New Resources	
	2019*	2030**	2045**
Solar (Utility-Scale)	12.5 GW	16.9 GW	69.4 GW
Solar (Customer)	8.0 GW	12.5 GW	28.2 GW
Storage (Battery)	0.2 GW	9.5 GW	48.8 GW
Storage (Long Duration)	3.7 GW	0.9 GW	4.0 GW
Wind (Onshore)	6.0 GW	8.2 GW	12.6 GW
Wind (Offshore)	0 GW	0 GW	10.0 GW
Geothermal	2.7 GW	0 GW	0.1 GW
Biomass	1.3 GW	0 GW	0 GW
Hydrogen Fuel Cells	0 GW	0 GW	0 GW
Hydro (Large)	12.3 GW	N/A†	N/A†
Hydro (Small)	1.8 GW	N/A†	N/A†
Nuclear	2.4 GW	N/A†	N/A†

**Includes in-state | **Includes in-state and out of state capacity | †New hydro and nuclear resources were not candidate technologies for this round of modeling and could not be selected*

Figure: SB 100 Projected Energy Sources to meet Climate Goals

At the current rate, obtained by averaging the storage building rate from 2020-2023 and applying it to meet storage goals, California will meet said storage plans between 2048 and 2061, neither of which align with the state's goals. Even with these additions, California will need to triple its energy grid capacity to meet the climate goals and needs of its population, as well as find solutions to intermittency problems until the storage goals can be met. However, this study performed by the SB 100 agencies (CEC, CPUC, and CARB) is still designed to be a discussion of how California can reach 100% clean energy, leaving no clear roadmap or implementable strategies.

In 2021, California was the fourth electricity producer in the nation, supplying about 5% of utility scale generation. However, California consumes more energy than it produces. The state ranked 2nd in terms of consumption from all 50 states, requiring roughly 7,300 trillion Btu in energy supply[44]. This data is not surprising given that 11.7% of the United States Population lives in California, and when consumption is measured by how much an individual consumer uses on average California ranks lower than all but two states in energy usage. Due to the large population and sheer state size most of the state's energy use occurs in transportation, with more registered motor vehicles and more vehicle miles than any other state. Roughly ⅓ of the state's share of energy is directed to the transportation sector. The industrial sector takes the second largest share, followed by residential and commercial tied for third. There is already movement in legislation to decrease the carbon emissions from the transportation sector by requiring that all new cars sold after 2035 are zero emission vehicles, but as of September 18th, 2023 the House of Representatives has passed the *Preserving Choice in Vehicle Purchases Act*, targeting the California phaseout in all but name by outlawing the 2035 regulations. [45]. This legislation is currently waiting to be assessed by the Senate, but could have a drastic impact on moving California industries to operate off of clean energy. Furthermore, this is an example of why energy policy can be so difficult to manage, since federal and state laws or goals do not often align. This discussion only gets more complicated with the introduction of imports.

More energy is imported to California than any other state, and while some of it is exported to Mexico, almost all of it is used in the state. Most consumption comes in the form of natural gas, making up 42% of the energy generation profile according to the Energy Information Administration. In 2021, solar generation provided 19% of energy generation at a utility scale, at 27% if small solar generation is included. Nuclear energy generation created 8% of California's energy generation, wind power and hydropower added 7% each, and 6% came from geothermal generation in the Salton Sea. This data only includes that which was generated in state, but out of state natural gas, California's main energy source and non-renewable, is still the top imported from states including Arizona, Nevada, and Oregon. Once in the state roughly 33% of natural gas is directed to the industrial sector, and 31% was directed to the state's electricity sector. 22% is moved to homes and 12% is supplied to the commercial sector. The California Energy

[44] *California Profile*. (2023, April 20). EIA. Retrieved September 26, 2023, from https://www.eia.gov/state/print.php?sid=CA

[45] .*H.R.1435- Preserving Choice in Vehicle Purchases Act*. (2023, September 18). Congress.gov. Retrieved September 26, 2023, from https://www.congress.gov/bill/118th-congress/house-bill/1435/text

Commission records 66.4% of its energy mix comes from thermal and non-renewables[46]. This is the area of most concern to meet California's climate goals, and natural gas consumption has only grown over the last few decades to fill the gap left by decommissioning nuclear facilities despite said climate goals.

With the decommissioning of all but one nuclear facility, Diablo Canyon, California imports roughly 36% of its nuclear energy from two facilities: Palo Verde Generating Station in Arizona, and Columbia Generating Station located in Washington[47]. When including imported nuclear, these three facilities supply 10% of California's energy, and are clean energy resources. 34% of the nuclear generation is imported from Palo Verde, which also supplies Arizona, New Mexico, and Texas with nuclear energy. This facility is located roughly 55 miles outside of Phoenix, and has a combined capacity of 3.8 GW. Currently the facility has an approved license through 2047 with no discussion of closure. The remaining 2% of imported nuclear energy is from Columbia Generating Station near Richland, Washington. This reactor has a capacity of 1.8 GW, and has an active license until 2043 with no plans to decommission. Columbia Generating Station is the 3rd largest electricity generator in the state of Washington, and the Pacific Northwest's only commercial nuclear reactor. If California looks to follow the path set forth by the SB 100 agencies to meet the climate goals, it will need to replace the 10% of energy supplied by nuclear facilities, rather than adding it to the energy portfolio and decreasing the pressure to evolve solar and wind capacity so quickly. California is already off track to meet 60% clean energy by 2030, and this is currently including nuclear generation as a clean energy source. There is no reliable opportunity to transition away from nuclear power at the moment without putting unnecessary stress on the electricity grid and putting Californian citizens at risk of increased blackouts or rises in energy costs.

[46] *2021 Total System Electric Generation*. (n.d.). California Energy Commission. Retrieved September 27, 2023, from https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation

[47] *U.S. Energy Information Administration*. (2022, September 19). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved September 26, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=53899#

Diablo Canyon Power Plant is the largest single supplier of electricity to California, and accounts for 39% of Pacific Gas and Electric's 2021 energy mix[48]. Renewables make up another 50% of the energy mix, 4% comes from large zero-emissions hydropower, and the remaining 7% is PG&E's only emissions source- natural gas. PG&E is the largest energy provider in California, as well as one of the largest in the nation. With its energy profile, it services a 70,000 square mile area in Northern California to approximately 16 million people, just under half of the total population of the State[49]. Diablo Canyon Power Plant has positioned PG&E in a great position to meet the 2045 state goals from clean energy. If Diablo Canyon had begun its decommissioning process in 2024 as it was originally slated, it is unlikely that PG&E would be able to recover that generation in time to meet the goals set forth. Diablo Canyon is not just useful as a clean energy resource, but is also a crucial provider to California's citizens that already experience high levels of energy instability.

---

[48] *Exploring clean energy solutions*. (n.d.). PGE. Retrieved May 27, 2023, from https://www.pge.com/en_US/about-pge/environment/what-we-are-doing/clean-energy-solutions/clean-energy-solutions.page?WT.mc_id=Vanity_cleanenergy

[49] *Company profile*. (n.d.). PGE. Retrieved May 27, 2023, from https://www.pge.com/en_US/about-pge/company-information/profile/profile.page

Part 4: Potential Challenges and Opportunities

While transitioning to clean or renewable energy sources is crucial in the fight against climate change impacts, California's reliance on solar and wind as the only energy sources can cause a variety of issues for the state's consumers. The intermittency issue of both sources has not yet been solved, which could lead to increased rolling blackouts and no back up energy generation. Secondly, the expansion necessary to meet energy demand can cause huge increases in energy prices for consumers in a state that already has the highest retail energy price in the continental United States[50]. Californians cannot afford the 6% residential price increase that accompanies the transition to solar and wind without nuclear power.

Climate change impacts can be felt in almost any sector, and the California energy sector struggles with two main issues: drought and wildfires. Over the past several decades, average temperatures have increased which has led to less snowfall and overall precipitation. This has damaged the potential capacity for hydropower, but also made conditions drier for any plant life growing. These organisms are then more susceptible to fires, and the fires that occur are more destructive and widespread than they have been historically. These fires can occur for a variety of reasons, one of which being a failure of electric utility infrastructure. This cause is responsible for roughly 10% of wildfires, which caused investor owned utility companies (IOUs) to create a solution that involved proactively cutting power to electrical lines before a fire might occur. These events are called Public Safety Power Shutoffs, and can last up to several weeks, leaving communities and essential facilities without power[51]. The suggestions from IOUs to combat this issue is for homes and buildings to install backup generators that are able to be turned on during PSPS events, however these increase emissions greatly compared to an average day, with one report by the California Air Resources Board (CARB) estimated that in just one 50 hour PSPS event 24.3 excess tons of NOx were released, along with 101.5 tons of THC and 10.6 tons of PM[52]. As long as climate change is exacerbating the effects of seasonal wildfires, PSPS events

[50] *US Electricity Profile 2021 - U.S. Energy Information Administration*. (2022, November 10). EIA. Retrieved September 27, 2023, from https://www.eia.gov/electricity/state/
[51] *Public Safety Power Shutoffs*. (n.d.). California Public Utilities Commission. Retrieved September 27, 2023, from https://www.cpuc.ca.gov/psps/
[52] *Potential Emissions Impact of Public Safety Power Shutoff (PSPS) Draft – Deliberative*. (2020, January 30). California Air Resources Board. Retrieved September 27, 2023, from https://ww2.arb.ca.gov/sites/default/files/2020-01/Emissions_Inventory_Generator_Demand%20Usage_During_Power_Outage_01_30_20.pdf

will continue to occur and backup generators will be run, releasing more greenhouse gasses into the atmosphere. This positive feedback loop must be dealt with at the source, by decreasing carbon emissions and utilizing the full potential of clean energy. This must also be done in a way that allows for California's constituents to have reliable energy and have actionable plans instead of relying on potential technological innovation.

Another important discussion item of the transition to 100% clean energy is the cost to California residents. The report released by the SB 100 agencies indicates that meeting the 2045 goals will increase annual electricity system costs by $4.6 billion. Californians are already feeling the cost of implementing new technology so quickly, with the 2021 average retail price of 19.65 cents/kWh, 5 cents above the United States Average. According to the Bureau of Labor Statistics, California has 4 of the top 6 cities with the highest energy prices in the nation, updated through August 2023[53]. Total expenditure per capita for energy consumption totals $3,837 annually, but the United States Census has per capita income annually at $41,276, indicating that currently before any price increases California residents already spend 10% of their income on energy costs[54]. Decreased energy flexibility by limiting the resources used would increase the average price point, due to the current intermittency issues as well as solar PV prices. Building new wind and solar facilities are still more expensive that utilizing the current nuclear facilities available[55]. Movement to clean energy must occur without jeopardizing the livelihood of those that use the energy, and there is a current nuclear facility that, if continued to remain licensed, could ease the burden of excess costs from building new solar facilities and investing in the potential developments of storage and wind.

The reason that California cannot afford to give up any clean energy source, nuclear or otherwise is due to the sheer amount of greenhouse gasses that California emits every year in its energy use. In 2021, California emitted 324 million metric tons of carbon dioxide that were energy

---

[53] *Average energy prices for the United States, regions, census divisions, and selected metropolitan areas : Midwest Information Office : U.S.* (n.d.). Bureau of Labor Statistics. Retrieved September 27, 2023, from https://www.bls.gov/regions/midwest/data/averageenergyprices_selectedareas_table.htm
[54] *California*. (n.d.). U.S. Census Bureau QuickFacts: California. Retrieved September 27, 2023, from https://www.census.gov/quickfacts/fact/table/CA/BZA210221
[55] *Levelized Cost of Energy and Levelized Cost of Storage 2019 | Lazard*. (2019, November 07). Lazard. Retrieved September 27, 2023, from https://www.lazard.com/research-insights/levelized-cost-of-energy-and-levelized-cost-of-storage-2019/

related[56]. In just 2021 electric power emissions California produced 35.3 million metric tons of Carbon Dioxide. Even in commercial power emissions California produced 19.4 million metric tons of CO_2. One of California's 2030 climate goals is to drop greenhouse gas emissions by 40% below the 1990 emissions amount legally, or 48% by the advanced goal. If California were going to meet these deadlines, the state would need to drop 144.08 million metric tons of emissions by 2030, emitting only 216 million metric tons just to meet the 40% requirement. In the past 33 years, California has only dropped 10% below 1990 levels of emissions. Emitting 214 million metric tons would place California emitting less than it did in 1970 by roughly 80 million metric tons. In order to meet this criteria in the next seven years, no clean energy source can be discounted.

Nuclear energy generation, and the Diablo Canyon Power Plant in particular, offers unique benefits that are hard to match with other resources, especially with the current level of technology in those fields. The SB 100 report focuses on goals for solar, wind, and storage as the only technology that will be used by 2030. While all three of these technologies need to be implemented, they are unable to provide everything that the California grid requires, specifically there is no baseload energy system. Solar energy on a utility scale is thought to be the primary provider for California's energy grid, followed by battery storage. From 2019 to 2023 California increased its storage capacity from 250 MW to 5,000 MW[57], but the projected need for battery storage by 2030 is 9,500 MW, and 48,800 by 2045. This goal is not unachievable, but the current 5,000 MW storage is limited due to the high price of new storage systems installation for citizens, leading to only 15% of current rooftop solar systems having storage. The SB 100 report shows 4.0 GW of energy generation from long duration storage to help solve the issue of when peak demand occurs, but the technology is still in a developmental phase, with grants available for research and development. The timescale for storage creation and implementation does not give California room for mistakes, or even to not have mistakes and still produce 8 times what is currently in use as the report suggests. By no means should it be discontinued, but in order for

[56] *State Carbon Dioxide Emissions Data - U.S. Energy Information Administration*. (2023, 12th July). EIA. Retrieved September 28, 2023, from https://www.eia.gov/environment/emissions/state/
[57] *New Data Shows Growth in California's Clean Electricity Portfolio and Battery Storage Capacity*. (2023, May 25). California Energy Commission. Retrieved September 28, 2023, from https://www.energy.ca.gov/news/2023-05/new-data-shows-growth-californias-clean-electricity-portfolio-and-battery

storage to develop at the rate necessary there can be little adaptations to the current clean energy sources that California employs.

Solar power as well must continue to be expanded upon, but will not be able to offer the level of security that a non-intermittent clean energy source can. Solar is only able to provide energy to the grid when sun is available, leaving large amounts of time where it cannot be a provider without storage. As stated above, only 15% of rooftop solar facilities have storage that allows them to redirect energy back to the grid, but it is nowhere near enough to solve the reliability issues. Solar supplies energy to the grid during non peak hours for homeowners, and demand spikes in the early evening when Californians arrive home and plug in electronic devices, or use the air conditioning now that they are home. In a yearly trend, peak demand occurs in the late summer months when the weather is hotter, which coincides with peak CO2 emissions[58]. Even though the days are longer and the potential for solar is increased, peak demand exceeds available resources, both renewable and fossil fuels. This issue has exacerbated the climate extremes that California feels keenly in the late summer, leading to rolling blackouts and brownouts, as well as increased PSPS events. California has attempted to solve this problem currently by increasing natural gas usage, while continuing to encourage homeowners to install solar panels in their homes. However, much of the draw to residential solar may decrease as California has changed regulations surrounding rooftop solar, opting to pay customers less for excess power by roughly 75%, as well as set rates that push consumers to use power at times that functions better for the grid[59]. This policy has the potential to raise costs of operating panels on homes, and could slow the growth of clean energy, as well as making solar panels less accessible to middle and lower income households. Finally, in order to install enough solar panels to reach the power generation necessary, roughly 90,000 acres of land would be necessary to develop into solar farms[60]. Since climate change mitigation requires many different methods to adapt and

[58] *Emissions, Today's Outlook*. (n.d.). California ISO. Retrieved September 29, 2023, from https://www.caiso.com/TodaysOutlook/Pages/emissions.html

[59] Cart, J. (2022, December 15). *California's residential solar rules overhauled after highly charged debate*. CalMatters. Retrieved September 30, 2023, from https://calmatters.org/environment/2022/12/california-solar-rules-overhauled/

[60] Aborn, J., Baik, E., Benson, S., Bouma, A. T., Buongiorno, J., Leinhard V, J. H., Parsons, J., & Wei, Q. J. (2021, November). An Assessment of the Diablo Canyon Nuclear Plant for Zero-Carbon Electricity, Desalination, and Hydrogen Production. https://energy.stanford.edu/news/extending-diablo-canyon-nuclear-plant-would-help-california-meet-its-climate-goals-new-study

mitigate, California has passed stringent land protection policies, such as the need to preserve 30% of its natural and coastal lands by 2030. This offers increased protection for at-risk species, as well as slows development, but also limits the ability to expand solar farms to the extent necessary. The likelihood of implementing the correct technology after development to control the intermittency issues, as well as make solar affordable enough to continue to have citizens install it on rooftops is unlikely. Diablo Canyon Power Plant offers the opportunity of decreasing stress on the energy grid as a baseload provider and offering solar to operate during the day as needed, as well as only occupying 900 acres.

Wind potential is also included in the SB 100 report, and will continue to be crucial in achieving 100% clean energy regardless of any base load source decided upon. Yet wind is not able to serve as a base load source itself, due to a myriad of issues that mirror solar power. Wind generation is also an intermittent energy source, as well as it also requires a significant amount of space. Estimates show that the average power density for onshore wind turbines ranges between 3.5 and 7.0 W/m^2, and the SB 100 report is demonstrates that at least 6 GW of onshore wind energy must be constructed before 2045, which would require an incredible amount of land to generate the necessary production[61]. The same limitations of California's goals to protect its natural land will create barriers for this level of construction, especially since building large scale wind farms can potentially displace or harm natural ecosystems and biodiversity. Offshore wind does not provide much better alternatives. While there is increased space to build projects, California does not currently have any existing offshore wind to build off of, and instead must create a framework for a whole new type of energy source. Offshore wind is the most expensive renewable energy source, according to the LCOE analysis from 2023. Offshore wind is also more expensive to build than to utilize current nuclear facilities. The sites proposed for California's offshore wind are located roughly 20 miles off of Humboldt County, and 20 miles off of Morro Bay[62]. This would put the northern location between the open ocean and the Samoa State Marine Conservation Area, and place the southern location between open ocean and both the Cambria State Marine Conservation Area and the Piedras Blancas State Marine Reserve. The

---

[61] Miller, L. M., & Keith, D. W. (2018, October 4). Observation-based solar and wind power capacity factors and power densities. *Environmental Research Letters*, *13*(10). IOP Science. 10.1088/1748-9326/aae102
[62] *California Activities*. (n.d.). Bureau of Ocean Energy Management. Retrieved October 2, 2023, from https://www.boem.gov/renewable-energy/state-activities/california

Monterey Bay National Marine Sanctuary is also located nearby, if not overlapping the location for the offshore wind farm[63]. Placing wind farms to the scale necessary in these locations could create incredible damage not just on the ecosystems, but also by blocking reserves that are limited take only, the damage to the ecosystem could lead to direct impacts on the fish populations and potentially fishermen in those areas. Overall, offshore wind is unlikely to be scalable enough to solve the intermittency problem in the time frame available, and even if it were able to be, there are many other potential issues with the source that could be avoided if current nuclear generation was kept intact, at the very least through 2045.

Many proponents of solar and wind power generation feel that long duration storage allows for flexibility to decide when to add stored solar and wind back into the grid to accommodate peak demand, however that technology is still far off from being developed on a scalable level. Global carbon emissions are at an all time high, and there is not time available to wait for technologies to develop before switching to clean energy. Cutting carbon emissions will help decrease the amount of latent greenhouse gasses in the atmosphere, which in turn will help to mitigate the increased warming that is occurring. Unfortunately, as California has worked to decommission nuclear reactors that supplied clean energy the state has turned to increased natural gas consumption rather than additional clean energy sources. If California were to decommission Diablo Canyon by 2030 as originally planned in the SB 100 report there would be little to no clean energy options to provide the additional 10% of energy generation that Diablo Canyon currently supplies. Rather than writing off this energy source due to the potential that a nuclear incident could occur, California should invest in the safety of Diablo Canyon and ensure that it can continue to meet new safety standards and remain a part of California's energy portfolio.

Even if California decides to keep Diablo Canyon open, it will be difficult to accommodate for the increase in demand over the coming years. The EIA predicts that energy consumption in the United States will grow anywhere from 0%-15% by 2050 due to factors such as economic growth, population growth, and increased travel that all have the potential to negate the positive

[63] *Maps – California MPAS*. (n.d.). California MPAS. Retrieved October 2, 2023, from https://californiampas.org/outreach-toolkit/printed-materials/maps

impact brought on by increased energy efficiency[64]. The organizations that will need to be handling this increase in energy demand are mostly investor owned utilities (IOU's), as they service nearly 72% of the nation[65]. In state, 88% of California's population is serviced by 3 utility providers, all investor owned: Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E). PG&E and SCE are the two largest IOU's in the country, with over 10 million accounts between them. Each of these organizations has created their own path to clean energy, each one utilizing a different energy makeup.

PG&E has several goals marked in the climate strategy report, starting with "continuing to green the power sector towards delivering decarbonized electricity 24/7/365". Included in the statement of this goal is that PG&E will use Diablo Canyon Power Plant infrastructure to support new carbon free generation, rather than decommissioning the plant[66]. This first goal is the foundation to the electrification program that PG&E develops the rest of its energy decisions on. It also includes the ability to modify Diablo Canyon to fit the needs of both PG&E and the necessary commitment to clean energy. On top of this, PG&E already provides 93% of its electricity as clean energy, with the remaining 7% supplied by natural gas (figure).

---

[64] *U.S. Energy Information Administration*. (2023, April 3). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved October 3, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=56040

[65] *Investor owned utilities served 72% of U.S. electricity customers in 2017*. (2019, August 15). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved October 3, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=40913

[66] Pacific Gas and Electric. (2022, June). *PG&E Climate Strategy Report*. Pacific Gas and Electric. Retrieved May 5, 2023, from https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/pge-climate-goals/PGE-Climate-Strategy-Report.pdf

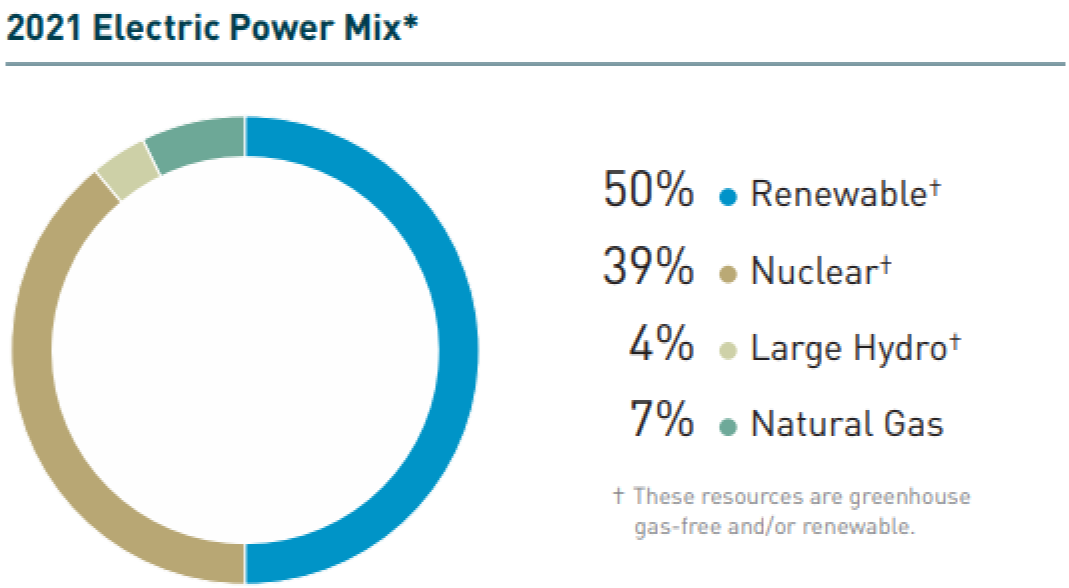


Figure : Pacific Gas and Electric's 2021 Power Mix

For this remaining 7%, PG&E intends to transition to 15% supplied by renewable natural gas, an energy source that is both more expensive and less clean than other renewable resources. Since renewable natural gas is chemically identical to natural gas, it produces the same carbon emissions[67]. This source can be considered renewable as it is found in sources that would usually emit methane into the atmosphere, but while it would not emit methane it will still emit other greenhouse gasses into the atmosphere. Renewable natural gas (RNG) is not a realistic strategy that can mitigate climate change in the long term. PG&E must base its climate strategy on other sources, most likely the clean energy that comes from Diablo Canyon as stated in other goals of the climate strategy report.

Southern California Edison relies on natural gas as its current largest single supplier of energy. Roughly 45% of the energy supplied to SCE customers is clean, with 8% of that energy provided by imported nuclear power[68]. SCE's focus for decarbonization relies on increased storage and grid modernization as the key element moving forward. Currently, there are three storage

[67] Desai, M. (2020, April 13). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 – Main Text*. Environmental Protection Agency. Retrieved October 3, 2023, from https://www.epa.gov/sites/default/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

[68] Southern California Edison. (n.d.). *Sustainability Report*. Edison International. Retrieved October 3, 2023, from https://www.edison.com/sustainability/sustainability-report

facilities that SCE is constructing, totaling 535 MW additional storage. Through these three new storage facilities, SCE plans to build co-located storage on existing and new solar facilities. However, increased storage is only one part of the solution when it comes to a diverse energy profile. While 25% of power in the SCE service area comes from natural gas, but a larger 30% comes from what SCE calls an "unspecified source", meaning that they are unable to trace the energy to a specific facility or source, but is likely dominated by natural gas. As long as SCE is using unspecified power they will not be able to provide reliable 100% clean energy to its customers. SCE will need to focus on multiple goals at once: creating additional storage, and if not supplying its own renewables, then understanding where their energy profile is sourced from to ensure that it is renewable, sustainable, and reliable. If SCE does not have its own baseload power source, then it becomes more important to understand how reliable the other energy sources are in case of an issue of intermittency. The sustainability report from SCE did not discuss what the predicted energy profile in future years will be.

San Diego Gas and Electric states in their decarbonization roadmap that their priorities are maintaining affordability and reliability. Unlike PG&E and SCE, SDG&E also includes carbon removal to address the limitations of the timeline, as well as clean hydrogen in production. SDG&E expects to have 68 million metric tons of CO_2 emissions residually by 2045, and will handle that by adding in carbon removal frameworks[69]. SDG&E provides future predictions of the electricity profile expectations in the decarbonization report. For the scale up to 2030, the majority of energy is sourced from solar, followed closely by natural gas and imports. By 2045, solar will provide almost 50% of the energy, with imports and wind generation also contributing large portions of generation. However, there is an additional category in the energy mix that is defined as "other", which includes oil, gas, geothermal, biomass, hydroelectric, and nuclear. Most of these sources are meant to be balances by the Carbon Capture Storage (CCS) that SDG&E will invest in, but the continued use of coal and oil does not state specifically that it will be used with CCS the same way that natural gas is, and any form of fossil fuel energy poses dangers to the environment. Lastly, nuclear energy is included in the other category, but not in the import category. SDG&E's nuclear power plant, San Onofre Generating Station, has been in

---

[69] San Diego Gas and Electric, Boston Consulting Group, Black and Veatch, & Victor, D. G. (2022, April). *The Path to Net Zero - A Decarbonization Roadmap for California*. SDGE. Retrieved May 10, 2023, from https://www.sdge.com/sites/default/files/documents/netzero2.pdf

the decommissioning process since 2018, so there is no nuclear generation currently run by SDG&E, and there will not be with the continued California moratorium on new nuclear facilities.

These futures from all three IOU's rely on developing technology and infrastructure that does not yet exist. However, nuclear power generation in California has not hit a standstill as previously thought and can provide either a baseload energy source to establish reliability, or at least if Diablo Canyon Power Plant is kept active through at least 2045 then it can act as a transition energy source. While nuclear generation in California may not ever be able to overcome the amount of decommissioning that has already occurred due to a variety of reasons such as start-up cost and strict regulations, Diablo Canyon has momentum with its extension to provide reliable energy and become a staple in the clean energy transition.

Part 5: Recommendations

The Diablo Canyon Power Plant extension shows promise for the future of nuclear energy in California. The current license is set to expire in 2029 for Unit 1, and 2030 for Unit 2 as a part of an exemption from the NRC to continue reliability of the grid. California has the option, and PG&E intends to, file for a full license renewal of up to 20 years as is the standard by the end of 2023[70]. Additionally, one unexpected benefit of continuing to operate Diablo Canyon is that the beach it is located on is closed to the public, which has allowed for many species to thrive in the rocky intertidal zone. If Diablo Canyon is closed, then it may see increased tourism that threatens the livelihood of the organisms that reside there. Keeping Diablo Canyon open at least through 2045 relieves pressure that California's energy grid will feel from rapidly switching to new resources with new grid integration that has a myriad of potential issues. No other proposed energy sources offer the reliability to provide energy during peak hours that nuclear power generation does, and Diablo Canyon is the only remaining in-state nuclear reactor facility. If California wants to be able to provide reliable and cost effective energy to its constituents that already pay some of the highest prices in the nation, then applying for the full license extension will be a smart move. California will already have trouble reaching its climate goals with the current foundation, let alone if an additional 10% of clean energy needs to be provided.

However Diablo Canyon offers untapped potential to be a source of multiple outlets of clean energy, not just nuclear power. Much of the fear with continuing to operate Diablo Canyon surrounds cost effectiveness and whether solar could be more cost effective than nuclear generation. Cost effectiveness is not the only important factor in choosing energy mixes, but first it is crucial that the grid is designed to support the energy integration and that customers are taken care of. A research study from MIT and Stanford proposes a solution that makes Diablo Canyon Power Plant more lucrative as well as meeting California regulations setting reduced water intake rates for nuclear generation plants by building a desalination plant onto the existing facility. California is consistently struggling to meet water supply demand from large scale agriculture and residential use that have been exacerbated by climate change. Sea water is pulled

[70] Lopez, N. (2023, March 2). *Feds allow Diablo Canyon to stay open while seeking 20-year extension*. CalMatters. Retrieved April 29, 2023, from https://calmatters.org/environment/2023/03/diablo-canyon-nuclear-power-plant/

in through filters in the nuclear power plants cooling system to prevent debris and organisms from entering the plant. This cooling system could be adapted in a variety of ways to introduce additional resources.

There are four proposed desalination plants programs that could be attached to Diablo Canyon such as large scale desalination plants similar to current models, using half of the cooling water from the power plant as feedwater, using all of the cooling water as feedwater, or using all electricity from the power plant to produce water[71]. The first option requires a desalination brine to be mixed with the cooling water, which takes away the need for high-energy diffusers and instead relies on the current condensers that are already in place. Power would still be primarily available to the California grid, with a small amount being redirected into the desalination plant. This option also has the potential to meet the annual needs of the Coastal Branch delivery shortfall, as well as provide additional water to accommodate the Central Coast groundwater overdraft, providing an anticipated 55,941 acre feet/year. The second option works within the bounds of strict California regulation, emphasizing meeting environmental requirements without new large investments. Diablo Canyon will operate as it has been, with the desalination plant taking in half the water, while the other half is dilating the brine discharge. The shining moment of this option is that it will function well if there is not enough water demand to justify new resources. Additionally, this option can function as a stepping stone towards other designs if it works well. The third option that uses all the cooling water requires more power, resulting in almost a flipped energy production from option one with the majority of energy produced by Diablo Canyon used by the desalination plant, and any excess can be sold back into the grid. This option will not increase water intake, but optimizes all of the existing framework to produce the most water possible without extensive adjustments. The final option separates Diablo Canyon entirely from the California energy grid with the excess energy produced past what it takes to desalinate the cooling water used to draw in and desalinate additional seawater. This configuration would not help reduce carbon emissions from electricity generation, but would provide water to much needed areas of California, such as the agriculturally focused central

[71] Aborn, J., Baik, E., Benson, S., Bouma, A. T., Buongiorno, J., Leinhard V, J. H., Parsons, J., & Wei, Q. J. (2021, November). An Assessment of the Diablo Canyon Nuclear Plant for Zero-Carbon Electricity, Desalination, and Hydrogen Production.
https://energy.stanford.edu/news/extending-diablo-canyon-nuclear-plant-would-help-california-meet-its-climate-goals-new-study

valley. Options 2, 3, and 4 offer a higher yield than that of current water export projects, as well as building upon Diablo Canyon saving upwards of 9 billion dollars for option 2, and 4 billion dollars with option 3. These projects provide the opportunity for Diablo Canyon to become multi-faceted, and provide several different crucial resources to Californians that otherwise they may not have access to. One of the recurring issues heard about Diablo Canyon is that it is expensive to continue to run. Putting aside the need for clean energy, especially reliable baseload energy, this is one option that allows for investors to see additional needs that can be fulfilled by Diablo Canyon, as well as potentially boost the California economy by cutting water costs either residential or agricultural before exports. This will not require any large changes in the operation of the plant, and co-location makes both facilities function more efficiently than either on their own, as well as within regulation. This water will be a carbon free resource and is not dependent on rainfall or weather patterns that are highly variable due to climate change.

A desalination plant is only one option for building a co-located clean energy resource as a new part of Diablo Canyon Power Plant. An alternative proposal is to construct a clean hydrogen plant that functions in tandem with Diablo Canyon. This clean hydrogen plant can also function with the addition of the desalination plant, allowing one location to provide a variety of clean energy and water. A facility attached to the current plant infrastructure could produce up to 110 million kilograms of hydrogen a year, at a price of $2-$2.50 per kilogram[72]. The energy supplied by Diablo Canyon can be used to provide low cost energy to the hydrogen plant, and utilize the steam that the nuclear power plant produces to increase efficiency of the hydrogen electrolysis process. Additionally, constructing the hydrogen facility and desalination facility allow the two projects to share capital costs, reducing the overall investment necessary to produce additional clean energy. With this addition, 500 MW of energy generation from the nuclear power plant are allocated towards the hydrogen production, totalling to roughly 22% of the overall Diablo Canyon available energy. The 2035 potential hydrogen demand ranges from 1,200 million kilograms to 4,250 million kilograms. The production from Diablo Canyon hydrogen could make a significant impact in this demand from a resource that is just beginning to be developed. The

[72]Aborn, J., Baik, E., Benson, S., Bouma, A. T., Buongiorno, J., Leinhard V, J. H., Parsons, J., & Wei, Q. J. (2021, November). An Assessment of the Diablo Canyon Nuclear Plant for Zero-Carbon Electricity, Desalination, and Hydrogen Production.
https://energy.stanford.edu/news/extending-diablo-canyon-nuclear-plant-would-help-california-meet-its-climate-goals-new-study

hydrogen plant will also receive water from the desalination plant, requiring less than .15% of the output. The hydrogen addition will only require 20 acres of land, significantly less than either wind or solar would require.

Utilizing Diablo Canyon as a multi-source energy producer serves only to diversify California's energy profile and increase reliability. In the fight against climate change clean energy sources are not competing in their entirety, but instead they can be complimentary suppliers. As California struggles with energy reliability in 2023 due to climate change, this can only be expected to worsen over the coming years. If California seeks to take out firm energy sources- sources that are always available- then it risks a rigid and unadaptable grid. These resources must be utilized together to create energy systems that are as affordable as possible to Californians, but still prioritize clean energy and the existing environmental systems. The resources that could be provided by a co-located plant, like the one proposed for Diablo Canyon, satisfy diverse needs from the population, and keep in mind realistic goals and expectations for clean energy and available land space. Similarly, the proposed plan keeps in mind that construction costs for new clean energy projects are often high, and it is crucial to have strong investments in the programs taking place. Nuclear has previously been considered an expensive energy producer, but there are many ways to decrease the costs and make new markets. Continued investment in this resource is crucial to continuing to supply reliable clean energy.

One innovative proposal creates a market for spent fuel, which both increases the available money in nuclear energy, as well as assists in solving the spent fuel issue after Yucca Mountain construction has stalled. This could provide crucial economic benefits to what has otherwise been considered an outdated energy producer in California. Interim Storage Partners (ISP), a private LLC, as well as Holtec International have submitted applications for private interim storage facilities in Carlsbad, New Mexico and Andrews, Texas. Holding nuclear spent fuel privately utilizes the loophole in the Continued Storage Act that states that no interim storage facilities can be federally created while Yucca Mountain is in development[73]. The Department of Energy is unable to accept spent fuel, but has been paying into the federal Judgement Fund to

---

[73] Bell, M. Z., & Macfarlane, A. (2022, September). "Fixing" the nuclear waste problem? The new political economy of spent fuel management in the United States. *Energy Research and Social Science*, *91*. ScienceDirect. https://doi.org/10.1016/j.erss.2022.102728

pay nuclear companies for their storage expenses. These funds, totalling $8.6 billion, are accessible by private organizations if they can create storage solutions, which has greatly incentive groups to find temporary solutions that can be turned into permanent solutions if Yucca Mountain Repository is ultimately unsuccessful. Both companies included an environmental impact statement in their 2022 applications that state there are no adverse impacts of the facilities. ISP's parent company already operates a low-level waste storage facility located at the site where they also plan to handle spent fuel storage. While this so-called organizational fix will not provide a secure long-term future, it can concretely provide a temporary solution until there is a regulatory fix, or the proposed solution is accepted as the final solution, besides the current solution of Diablo Canyon Power Plant which stores its waste on site.

Creating new markets for spent fuel is not the only solution, and there have been several successful technological advances that have been proposed or even successfully implemented in other nuclear facilities. These technologies could either be added to Diablo Canyon to improve efficiency, or they could function as stand alone clean energy solutions if California worked to overturn the moratorium. One of the potential new technologies is the Small Modular Reactor (SMR). These nuclear reactors only provide about 30% of the generating capacity as current nuclear reactors, but can be transported as systems or components to be installed at a different location. The benefits of these reactors are that they can be adapted to locations with less available land space that cannot house large scale nuclear reactors, as well as less capital cost. These SMRs also fit into a niche in rural electricity grids, providing opportunities where there is limited grid coverage and the inability to cover the cost of installing a large grid connection. Even if these SMRs are not used as consistent grid generation, they can replace the backup generators that spike CO2 emissions in times of grid blackouts by providing clean energy where natural gas generators are currently being utilized[74]. Safety concepts for SMRs rely more on inherent safety catches rather than human power in dangerous instances, making them more in line with current safety regulations and removing the potential for nuclear reactor meltdowns. Lastly, these small reactors will require less fuel input, and produce less spent fuel to regulate or transport to uncertain facilities. These technologies are not currently available to integrate, but

[74] Liou, J. (2023, September 13). *What are Small Modular Reactors (SMRs)? | IAEA*. International Atomic Energy Agency. Retrieved October 6, 2023, from https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs

would be a thoughtful and effective investment into equitable clean energy for the future if California is unable to meet its climate goals.

While the SMRs are still in development, there is another technology that could be beneficial for Diablo Canyon, and has been proven effective in many other nuclear reactors globally. Nuclear energy, once processed, is able to be reprocessed to provide new fuel such as plutonium to increase the efficiency of the power plant. Closing the fuel cycle, this reprocessing allows for 25-30% more energy generation from the plant, as well as slicing the amount of spent fuel waste to roughly one fifth of what is currently produced[75]. Several other countries with large nuclear programs such as France, Germany, Russia, and China have regulatory practices that have developed robust programs that have led to a far greater nuclear generation capacity. In the United States, nuclear generation accounts for roughly 20% of energy generation, but in France nuclear generation accounted for 68% of total energy generation, despite having roughly half of the nuclear generators that the United States has[76]. Because of how much nuclear energy France generates, the country has become the largest energy exporter in Europe, additionally allowing France to step away from reliance on natural gas from Russia. The United States currently has no recycling plans, but investing in reactors that are able to reprocess used fuel would decrease the amount of uranium necessary, decreasing the need to mine uranium as well as the emissions from mining. Additionally, it would turn the spent fuel that has already been used and is struggling to find a permanent location into a resource that can be reprocessed into increased clean energy output, and the spent fuel that is produced has a shorter half life. Recycling is a solution that can fix many issues that investors have with nuclear generation such as spent fuel management, uranium mining, and overall generation capacity.

Unfortunately, new technologies are not the sole tactic that needs to be employed to ensure that nuclear generation is able to continue to provide clean energy. In the LCOE report, many of the renewable technologies had significant drops in price when they were in a field with potential

---

[75] *Processing of Used Nuclear Fuel*. (2020, December). World Nuclear Association. Retrieved October 6, 2023, from
https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx
[76]Fasching, E. (2023, January 23). *Nuclear power plants generated 68% of France's electricity in 2021*. U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved October 6, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=55259

subsidiaries. Nuclear energy was not offered the same options as other clean energy technologies that could assist in making it equitable and achievable for nuclear facilities to continue to operate, especially if they will need to operate at the same scale as projected wind and solar farms. In a forward move towards protecting nuclear power, the Bipartisan Infrastructure Law established a Civil Nuclear Credit Program that opened up six billion dollars of available funds to assist nuclear power plant owners with operating costs. Organizations would apply for these funds, just as Diablo Canyon Power Plant intends to by the end of 2023[77]. In their application, nuclear generation plants must demonstrate that they will continue to operate safely under the NRC guidelines, as well as prove that the reactor will be shut down due to economic reasons to ensure that the funds go to plants that truly need the funds. Nuclear generation supplies 52% of the United State's clean energy, and as such it is easier to build on existing frameworks than create new ones. The Inflation Reduction Act included a production tax credit for clean hydrogen that provides up to $3 per kilogram of hydrogen that is produced without greenhouse gas emissions[78]. Luckily, there are already proposed plans for a Diablo Canyon hydrogen plant that could apply for the tax credit and drop the production prices of energy for the whole facility, making it more accessible and cheaper than other intermittent renewables. These monetary investments show a real possibility that nuclear generation is still crucial to not only California's clean energy generation, but the nation's as a whole. If Diablo Canyon is able to secure these funds, then it will have one less barrier to overcome with the goal of continuing to operate and provide firm energy to California's population. These recommendations are used to evaluate how Diablo Canyon can continue to function, or how it can sway public perception by decreasing costs and increasing output

---

[77] *DOE Establishes $6 Billion Program to Preserve America's Clean Nuclear Energy Infrastructure*. (2022, February 11). Department of Energy. Retrieved October 6, 2023, from https://www.energy.gov/articles/doe-establishes-6-billion-program-preserve-americas-clean-nuclear-energy-infrastructure

[78] *What the climate bill does for the nuclear industry*. (2022, August 22). CNBC. Retrieved October 6, 2023, from https://www.cnbc.com/2022/08/22/what-the-climate-bill-does-for-the-nuclear-industry.html

Conclusion:

This paper set out with the goal of establishing whether or not Diablo Canyon has such negative public perception that it is affecting the regulatory structure around the last nuclear power plant in California to the point that in the next few years the power plant could close, rendering nuclear power outdated in the state's energy profile. While there are many factors that have led to the regulatory structure around nuclear generation in California such as the spent fuel issue, or the high capital costs, it is public perception that has led to the decommissioning of so many reactors and the moratorium passed prohibiting the construction of more. This perception has been defined by discrete events like the Three Mile Island nuclear accident, but also by underlying continual fears that nuclear power will do more damage to the environment than it will save by producing clean energy. This research has found that if nuclear generation is going to continue in California, the best thing that the state can do is invest in educating the public about nuclear generation and the steps that can be taken to remedy their fears. Diablo Canyon has untapped potential, and has rapidly shifted even in the past few years from being thought of as an energy source that needs to be phased out, to potentially being the biggest contributor to California's clean energy fight.

Public perception is rapidly shifting, and PG&E in operating Diablo Canyon needs to lean into the current atmosphere to make movements that will only continue to increase the efficiency of Diablo Canyon, like applying for the federal operating funds and building a desalination plant. In a survey conducted in 2022, nuclear energy had an overall approval rating of 54%, with 32% of interviewees stating definite approval. When the residents of San Luis Obispo county where Diablo Canyon Power Plant is located, there was a total approval rating of 73%. In less than a decade, approval of nuclear energy has doubled, and a majority of voters support continuing to operate Diablo Canyon. Overall, the study found that when voters were educated about the positives and drawbacks of nuclear power, majorities approved and stated that the benefits outweighed the risks[79]. The early 2020's held much uncertainty in power reliability for

[79] Mertz, D., Everitt, M., & FM3 Research. (2022). *California Voter Views of Nuclear Energy for Electricity*. Carbon Free California. Retrieved September 25, 2023, from https://carbonfreeca.org/wp-content/uploads/2022/05/CA-Nuclear-Energy-Issues-Survey-Analysis.pdf

Californians, and Diablo Canyon has the potential to satisfy the need for firm energy that meets the clean energy criteria.

This shift in public perception has given Diablo Canyon the opportunity to extend its license, as no other energy is able to satisfy the potential that it has, regardless of risks. As an existing infrastructure it is easier to operate than offshore wind, it can provide energy at peak hours unlike solar, it takes up less land space than onshore wind farms, it is not subject to risks of climate change like hydropower is, and it is a clean energy source unlike natural gas. These unique qualities make it an optimal source for the energy requirements of California's grid at least until the technological developments of other renewable energy sources catch up. The momentum that Diablo Canyon has gained is proven through the surveys that have been conducted, the temporary license extension, and the proposals that would make Diablo Canyon an even more attractive and lucrative resource. If California intends to capitalize on this movement in order to meet its climate goals, then it must apply for the federal funds, discuss and implement a desalination plant, evaluate the likelihood of an additional clean hydrogen plant, and demonstrate why spent fuel recycling is so vital to continued production. But most of all, California must continue to educate its population about the facts of nuclear energy generation and the reality of what can be done to optimize the resource that is already available with spent fuel. In conclusion, there is not a better time to invest in the clean energy supplied by nuclear generation in California, and if California chooses to let Diablo Canyon's license expire in 2030 it will be incredibly difficult, if not impossible to meet the set climate goal of providing 100% clean energy by 2045.

Glossary

- **Clean Energy**- energy that is created from renewable, zero emission sources that do not pollute the atmosphere
- **Green Energy**- energy derived from natural resources, such as sunlight, wind, or water. There is no harm to the environment through factors such as greenhouse gasses
- **SAFSTOR**- A long-term storage condition for a permanently shutdown nuclear power plant. During SAFSTOR, radioactive contamination decreases substantially, making subsequent decontamination and demolition easier and reducing the amount of Low Level Waste requiring disposal
- **ENTOMB**- where radioactive contaminants are encased in long-lived material such as concrete. The structure is surveyed and maintained until the radioactive waste decays to an appropriate level that allows for the termination of the license and release of the property (*Glossary | NRC.gov*, n.d.)
- **ISFSI-** Independent Spent Fuel Storage Installation. ISFSI occurs when the spent fuel from a nuclear reactor is kept on site in dry casks or pools.
- **DECON-** the phase of reactor decommissioning in which components that contain radioactive contamination are removed from a site and disposed of at a commercially operated waste- disposal facility, or it is decontaminated to a level that allows the site to be released for unrestricted use (*Glossary | NRC.gov*, n.d.)
- **PWR-** a nuclear power reactor design in which very pure water is heated to a very high temperature by fission, kept under high pressure to prevent it from boiling, and converted to steam by a steam generator. The resulting steam drives turbines, which activate generators to produce electrical power.
- **SMR-** advanced small modular reactors
- **WIPP-** Waste Isolation Pilot Plant. Located southeast of Carlsbad, New Mexico, this site stores radioactive waste in salt deposits. Used for nuclear defense materials
- **NRC-** Nuclear Regulatory Committee. The current federal regulatory agency for the nuclear industry
- **AEC-** Atomic Energy Commission. The government agency that would transform into the NRC
- **EIA-** U.S. Energy Administration Agency
- Baseload- The minimum amount of electric power delivered or required over a given period of time at a steady rate.
- **California Energy Mix-** Total in-state electric generation plus Northwest and Southwest energy imports
- **California Power Mix-** Percentage of specified fuel types derived from the California Energy Mix for use on the annual Power Content Label
- **In-State Generation-** Energy from power plants physically located in the state of California
- **Total System Electric Generation-** Used interchangeably with California Energy Mix

- **Total System Power-** Original terminology used to describe California's annual electric generation
- **POU-** public owned utility (SMUD, LADWP, SFPUC, etc)
- **IOU-** Investor Owned Utility (PG&E, SDG&E, SCE)
- **Northwest Imports**- Energy imports from Alberta, British Columbia, Idaho, Montana, Oregon,South Dakota, Washington, and Wyoming
- **Southwest Imports-** Energy imports from Arizona, Baja California, Colorado, Mexico, Nevada, New Mexico, Texas, and Utah
- **LLW-** Low level waste, radioactively contaminated protective clothing, tools, filters, rags, medical tubes. Occurs at commercially operated disposal facilities licensed under the NRC
- **Waste incidental to reprocessing-** waste by products that result from reprocessing spent nuclear fuel
- **HLW-** High level waste, irradiated or used nuclear reactor fuel
- **Uranium mill tailings-** the residuals remaining after the processing of natural ore to extract uranium and thorium
- **PSPS Event-** Public Safety Power Shutoff Event

References

Aborn, J., Baik, E., Benson, S., Bouma, A. T., Buongiorno, J., Leinhard V, J. H., Parsons, J., & Wei, Q. J. (2021, November). An Assessment of the Diablo Canyon Nuclear Plant for Zero-Carbon Electricity, Desalination, and Hydrogen Production. https://energy.stanford.edu/news/extending-diablo-canyon-nuclear-plant-would-help-california-meet-its-climate-goals-new-study

About. (n.d.). Waste Isolation Pilot Plant. Retrieved September 13, 2023, from https://wipp.energy.gov/index.asp

Average energy prices for the United States, regions, census divisions, and selected metropolitan areas : Midwest Information Office : U.S. (n.d.). Bureau of Labor Statistics. Retrieved September 27, 2023, from https://www.bls.gov/regions/midwest/data/averageenergyprices_selectedareas_table.htm

Baron, J., & Herzog, S. (2020, October). Public opinion on nuclear energy and nuclear weapons: the attitudinal nexus in the United States. *Energy Research and Social Science*, *68*. ScienceDirect. https://doi.org/10.1016/j.erss.2020.101567

Bell, M. Z., & Macfarlane, A. (2022, September). "Fixing" the nuclear waste problem? The new political economy of spent fuel management in the United States. *Energy Research and Social Science*, *91*. ScienceDirect. https://doi.org/10.1016/j.erss.2022.102728

Butler, C. D. (2018, October 16). *Climate Change, Health and Existential Risks to Civilization: A Comprehensive Review (1989–2013)*. NCBI. Retrieved November 5, 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6210172/

California. (n.d.). U.S. Census Bureau QuickFacts: California. Retrieved September 27, 2023, from https://www.census.gov/quickfacts/fact/table/CA/BZA210221

California Activities. (n.d.). Bureau of Ocean Energy Management. Retrieved October 2, 2023, from https://www.boem.gov/renewable-energy/state-activities/california

California: Agreement State | NRC.gov. (2023, August 21). Nuclear Regulatory Commission. Retrieved September 25, 2023, from https://www.nrc.gov/agreement-states/california.html

California Energy Commission. (2018, February). *California Energy Demand 2018-2030 Revised Forecast*. California Energy Commission. Retrieved November 06, 2023, from https://www.energy.ca.gov/publications/2018/california-energy-demand-2018-2030-revised-forecast

The California Nuclear Waste Act [Ballot]. (2015, February). Legislative Analyst's Office. Retrieved April 25, 2023, from https://lao.ca.gov/BallotAnalysis/Initiative/2015-001

California Profile. (2023, April 20). EIA. Retrieved September 26, 2023, from https://www.eia.gov/state/print.php?sid=CA

California Releases Report Charting Path to 100 Percent Clean Electricity. (2021, March 15). California Energy Commission. Retrieved September 6, 2023, from https://www.energy.ca.gov/news/2021-03/california-releases-report-charting-path-100-percent-clean-electricity

California Releases World's First Plan to Achieve Net Zero Carbon Pollution | California Governor. (2022, November 16). Gavin Newsom. Retrieved August 18, 2023, from https://www.gov.ca.gov/2022/11/16/california-releases-worlds-first-plan-to-achieve-net-zero-carbon-pollution/

California State Energy Profile. (2023, April 20). EIA. Retrieved September 6, 2023, from https://www.eia.gov/state/print.php?sid=CA

Cart, J. (2022, December 15). *California's residential solar rules overhauled after highly charged debate*. CalMatters. Retrieved September 30, 2023, from https://calmatters.org/environment/2022/12/california-solar-rules-overhauled/

Chen, C.-H., & Su, N.-J. (2022, September 21). *Global Trends and Characteristics of Offshore Wind Farm Research over the Past Three Decades: A Bibliometric Analysis*. MDPI. Retrieved August 31, 2023, from https://www.mdpi.com/2077-1312/10/10/1339

Company profile. (n.d.). PGE. Retrieved May 27, 2023, from https://www.pge.com/en_US/about-pge/company-information/profile/profile.page

Desai, M. (2020, April 13). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 – Main Text*. Environmental Protection Agency. Retrieved October 3, 2023, from https://www.epa.gov/sites/default/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

Diablo Canyon Decommissioning Engagement Panel. (n.d.). *Spent Fuel Management – Diablo Canyon Decommissioning Engagement Panel*. Diablo Canyon Decommissioning Engagement Panel. Retrieved October 6, 2023, from https://diablocanyonpanel.org/decom-topics/spent-fuel-management/

DOE Establishes $6 Billion Program to Preserve America's Clean Nuclear Energy Infrastructure. (2022, February 11). Department of Energy. Retrieved October 6, 2023, from https://www.energy.gov/articles/doe-establishes-6-billion-program-preserve-americas-clean-nuclear-energy-infrastructure

Downey, G. L. (1986, November). Risk in Culture: The American Conflict over Nuclear Power. *Cultural Anthropology*, *1*(4), 388-412. JSTOR. https://www.jstor.org/stable/656378

Emissions, Today's Outlook. (n.d.). California ISO. Retrieved September 29, 2023, from https://www.caiso.com/TodaysOutlook/Pages/emissions.html

Energy Information Administration. (n.d.). *Electricity Data Browser*. EIA. Retrieved November 6, 2023, from https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=vvvvu&geo=g00000000004&sec=g&freq=A&start=2001&end=2022&ctype=linechart&ltype=pin&rtype=s&maptype=0&rse=0&pin=

Energy Information Administration. (n.d.). *Frequently Asked Questions (FAQs) - U.S. Energy Information Administration*. Energy Information Administration (EIA). Retrieved November 8, 2023, from https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

Exploring clean energy solutions. (n.d.). PGE. Retrieved May 27, 2023, from https://www.pge.com/en_US/about-pge/environment/what-we-are-doing/clean-energy-solutions/clean-energy-solutions.page?WT.mc_id=Vanity_cleanenergy

Fasching, E. (2023, January 23). *Nuclear power plants generated 68% of France's electricity in 2021*. U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved October 6, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=55259

Ferguson, C. (2011). Do not phase out nuclear power- yet. *Nature*, *471*(411). https://www.nature.com/articles/471411a

Galindo, A. (2022, November 15). *What is Nuclear Energy? The Science of Nuclear Power*. International Atomic Energy Agency. Retrieved August 30, 2023, from https://www.iaea.org/newscenter/news/what-is-nuclear-energy-the-science-of-nuclear-power

GE Hitachi Announces Intent to Transfer Ownership of Vallecitos Nuclear Center | GE News. (2023, May 9). General Electric. Retrieved May 12, 2023, from https://www.ge.com/news/press-releases/ge-hitachi-announces-intent-to-transfer-ownership-of-vallecitos-nuclear-center

Glossary - U.S. Energy Information Administration. (n.d.). Glossary - U.S. Energy Information Administration (EIA). Retrieved September 6, 2023, from https://www.eia.gov/tools/glossary/?id=B

Governing Legislation | NRC.gov. (2021, September 10). Nuclear Regulatory Commission. Retrieved September 22, 2023, from https://www.nrc.gov/about-nrc/governing-laws.html

History | NRC.gov. (2021, September 10). Nuclear Regulatory Commission. Retrieved August 31, 2023, from https://www.nrc.gov/about-nrc/history.html

.H.R.1435- Preserving Choice in Vehicle Purchases Act. (2023, September 18). Congress.gov. Retrieved September 26, 2023, from https://www.congress.gov/bill/118th-congress/house-bill/1435/text

ICYMI: California Grid Reaches 5,600 MW of Battery Storage Capacity, a 1020% Increase Since 2020 | California Governor. (2023, July 12). Gavin Newsom. Retrieved September 26, 2023, from https://www.gov.ca.gov/2023/07/12/icymi-california-grid-reaches-5600-mw-of-battery-storage-capacity-a-1020-increase-since-2020/

Investor owned utilities served 72% of U.S. electricity customers in 2017. (2019, August 15). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved October 3, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=40913

Levelized Cost of Energy and Levelized Cost of Storage 2019 | Lazard. (2019, November 07). Lazard. Retrieved September 27, 2023, from https://www.lazard.com/research-insights/levelized-cost-of-energy-and-levelized-cost-of-storage-2019/

Liou, J. (2023, September 13). *What are Small Modular Reactors (SMRs)? | IAEA*. International Atomic Energy Agency. Retrieved October 6, 2023, from https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs

Lopez, N. (2023, March 2). *Feds allow Diablo Canyon to stay open while seeking 20-year extension*. CalMatters. Retrieved April 29, 2023, from https://calmatters.org/environment/2023/03/diablo-canyon-nuclear-power-plant/

Maps – California MPAS. (n.d.). California MPAS. Retrieved October 2, 2023, from https://californiampas.org/outreach-toolkit/printed-materials/maps

Melber, B., Nealey, S., Hammersla, J., & Rankin, W. (1977, November 1). *Nuclear power and the public: analysis of collected survey research (Technical Report)*. OSTI.GOV. Retrieved September 5, 2023, from https://www.osti.gov/biblio/5234344

Mertz, D., Everitt, M., & FM3 Research. (2022). *California Voter Views of Nuclear Energy for Electricity*. Carbon Free California. Retrieved September 25, 2023, from https://carbonfreeca.org/wp-content/uploads/2022/05/CA-Nuclear-Energy-Issues-Survey-Analysis.pdf

Miller, L. M., & Keith, D. W. (2018, October 4). Observation-based solar and wind power capacity factors and power densities. *Environmental Research Letters*, *13*(10). IOP Science. 10.1088/1748-9326/aae102

Minnesota Law Review Editorial Board. (1982). *A Preemption Analysis of California's Moratorium on Nuclear Plant Construction: Pacific Legal Foundation v. State Energy Resources Conservation and Development Commission*. University of Minnesota Law School. Retrieved September 25, 2023, from https://scholarship.law.umn.edu/cgi/viewcontent.cgi?article=4179&context=mlr

Moments in NRC History: Founding of the NRC-- January 19th, 1975. (2014, February 4). YouTube. Retrieved September 21, 2023, from https://www.youtube.com/watch?v=uhijG_aLd-8&list=PL27FC68CD5516246D&index=7

New Data Shows Growth in California's Clean Electricity Portfolio and Battery Storage Capacity. (2023, May 25). California Energy Commission. Retrieved September 28, 2023, from https://www.energy.ca.gov/news/2023-05/new-data-shows-growth-californias-clean-electricity-portfolio-and-battery

The nuclear fuel cycle - U.S. Energy Information Administration. (2022, July 12). EIA. Retrieved September 6, 2023, from https://www.eia.gov/energyexplained/nuclear/the-nuclear-fuel-cycle.php

Nuclear Power Reactors in California. (2020, March). California Energy Commission. Retrieved May 2, 2023, from https://www.energy.ca.gov/sites/default/files/2020-03/Nuclear_Power_Reactors_in_California_ada.pdf

Nuclear Power Today | Nuclear Energy. (2023, November 15). World Nuclear Association. Retrieved December 5, 2023, from https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

NUREG BR-0121, Regulating the Disposal of Low-Level Radioactive Waste, A Guide to The Nuclear Regulatory Commission's 10 CFR. (1989, August). Nuclear Regulatory Commission. Retrieved September 22, 2023, from https://www.nrc.gov/docs/ML1207/ML120720225.pdf

Outline History of Nuclear Energy. (2020, November). World Nuclear Association. Retrieved November 8, 2023, from https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx

Pacific Gas and Electric. (2022, June). *PG&E Climate Strategy Report*. Pacific Gas and Electric. Retrieved May 5, 2023, from https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/pge-climate-goals/PGE-Climate-Strategy-Report.pdf

Potential Emissions Impact of Public Safety Power Shutoff (PSPS) Draft – Deliberative. (2020, January 30). California Air Resources Board. Retrieved September 27, 2023, from https://ww2.arb.ca.gov/sites/default/files/2020-01/Emissions_Inventory_Generator_Demand%20Usage_During_Power_Outage_01_30_20.pdf

Processing of Used Nuclear Fuel. (2020, December). World Nuclear Association. Retrieved October 6, 2023, from https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx

Public Safety Power Shutoffs. (n.d.). California Public Utilities Commission. Retrieved September 27, 2023, from https://www.cpuc.ca.gov/psps/

Radwaste Solutions. (2021, November 23). *Humboldt Bay officially decommissioned, site released for unrestricted use*. American Nuclear Society. Retrieved December 1, 2023, from https://www.ans.org/news/article-3456/humboldt-bay-officially-decommissioned-site-released-for-unrestricted-use/

Ramana, M. V. (2018, February 27). Technical and Social Problems of Nuclear Waste. *WIREs Energy and Environment*. Wiley Online Library. https://doi.org/10.1002/wene.289

Rancho Seco nuclear power station, closed down by referendum in 1989, California, United States | EJAtlas. (2017, July 5). Environmental Justice Atlas. Retrieved May 8, 2023, from https://ejatlas.org/conflict/rancho-seco-nuclear-generating-station?translate=en

Rosa, E. A., & Dunlap, R. E. (1994, January 1). The Polls- Poll Trends: Nuclear Power: Three Decades of Public Opinion. *Public Opinion Quarterly*, *58*(2), 295-324. https://doi.org/10.1086/269425

San Diego Gas and Electric, Boston Consulting Group, Black and Veatch, & Victor, D. G. (2022, April). *The Path to Net Zero - A Decarbonization Roadmap for California*. SDGE. Retrieved May 10, 2023, from https://www.sdge.com/sites/default/files/documents/netzero2.pdf

Southern California Edison. (n.d.). *Sustainability Report*. Edison International. Retrieved October 3, 2023, from https://www.edison.com/sustainability/sustainability-report

State Carbon Dioxide Emissions Data - U.S. Energy Information Administration. (2023, 12th July). EIA. Retrieved September 28, 2023, from https://www.eia.gov/environment/emissions/state/

Tabassum, S., Rahman, T., Islam, A. U., Rahman, S., Dipta, D. R., Roy, S., Mohammad, N., Nawar, N., & Hossain, E. (2021, December 04). *Solar Energy in the United States: Development, Challenges and Future Prospects*. MDPI. Retrieved August 31, 2023, from https://www.mdpi.com/1996-1073/14/23/8142

Three Mile Island | TMI 2 |Three Mile Island Accident. (2022, April). World Nuclear Association. Retrieved September 13, 2023, from https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx

Twelve U.S. States generate more than 30% of their electricity from nuclear power. (2020, March 26). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved September 22, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=43256

2021 Total System Electric Generation. (n.d.). California Energy Commission. Retrieved September 27, 2023, from https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation

2023 Levelized Cost Of Energy+. (2023, April 12). Lazard. Retrieved September 6, 2023, from https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/

Understanding electricity. (n.d.). California ISO. Retrieved November 16, 2023, from https://www.caiso.com/about/Pages/OurBusiness/Understanding-electricity.aspx

URAM-2018: Ebb and Flow — the Economics of Uranium Mining. (2018, June 22). International Atomic Energy Agency. Retrieved September 6, 2023, from https://www.iaea.org/newscenter/news/uram-2018-ebb-and-flow-the-economics-of-uranium-mining

Uranium Mining Overview. (2023, August). World Nuclear Association. Retrieved September 6, 2023, from https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview.aspx

US Electricity Profile 2021 - U.S. Energy Information Administration. (2022, November 10). EIA. Retrieved September 27, 2023, from https://www.eia.gov/electricity/state/

U.S. Energy Information Administration. (2022, September 19). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved September 26, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=53899#

U.S. Energy Information Administration. (2023, April 3). U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. Retrieved October 3, 2023, from https://www.eia.gov/todayinenergy/detail.php?id=56040

U.S. nuclear industry - U.S. Energy Information Administration. (2023, August 24). EIA. Retrieved August 31, 2023, from https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php

Vaish, A., Grossmann, T., & Woodward, A. (2008, May). Not all emotions are created equal: The negativity bias in social-emotional development. *National Library of Medicine*. PubMed Central. 10.1037/0033-2909.134.3.383

What the climate bill does for the nuclear industry. (2022, August 22). CNBC. Retrieved October 6, 2023, from https://www.cnbc.com/2022/08/22/what-the-climate-bill-does-for-the-nuclear-industry.html

Wheatley, S., Sovacool, B. K., & Sornette, D. (2016, May). Reassessing the Safety of Nuclear Power. *Energy Research and Social Science*, *15*, 96-100. Elsevier. https://doi.org/10.1016/j.erss.2015.12.026

WINDExchange: Offshore Wind Energy. (n.d.). WINDExchange. Retrieved August 31, 2023, from https://windexchange.energy.gov/markets/offshore