

Personal statement of Amory B. Lovins
California Diablo Canyon Workshop
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Six years ago, I published a *Forbes* business article called “Closing Diablo Canyon Nuclear Plant Will Save Money and Carbon.”¹ It praised PG&E’s decision to phase out those twin reactors’ total 2.2 GW² of net capacity in November 2024 and late August 2025, after ample and timely carbon-free replacements were competitively procured.

This was foremost a rational *economic* choice, because the plant was cheaper to close than to run—by at least \$1 billion, NRDC calculated³, and plausibly by multiple billions⁴. PG&E also found that closing Diablo would help integrate more renewable power reliably into the grid by freeing up market space and grid capacity for cheaper carbon-free competitors to contest. In the modern grid dominated by nearly-free-to-run solar and windpower, reactors’ inflexibility and need to run nearly constantly make them unfit for purpose. Because renewables and efficiency cost less per kWh than Diablo’s forward levelized cost, they’d save more kWh per dollar, and thus displace more fossil-fueled electricity, than continued nuclear operation. Closure would also moot potentially costly seismic and cooling issues and broader safety concerns⁵. Finally, PG&E offered transitional help for workers and communities. This logic achieved a 2016 agreement among the stakeholders, later ratified by all three branches of California’s government. It was being routinely executed—until now.

When policy followup lagged, wildfires and grid-reliability concerns briskly refocused attention. The CPUC last year approved a massive 11.5-GW resource procurement by 2026. Another 4 GW came online in 2021 alone, including 2.4 GW (more than a Diablo’s worth) of ultrafast and reliable batteries⁶. Yet despite coherent policy refinements, this Workshop reflects some advocates’ ardor to reverse the agreed nuclear phaseout, whatever the unstated cost and risk.

Twenty days before the close of the 2022 legislative session, the Governor proposed⁷ a ten-year Diablo Canyon life extension, with exemption from bedrock environmental laws and marine protection, an unsupported legislative finding of cost-effectiveness, statewide socialization of unknown costs, and a forgivable \$1.4 billion state loan. This last-minute proposal reflects no utility’s proposal, no agency’s plan, no published analysis. It reverses but doesn’t even mention the all-parties orderly-phaseout agreement that almost every legislator voted for just four years ago. Sacramento may need to dispatch fleets of ambulances for victims of mass whiplash.

The apparent rationale is a sketchily based concern⁸ that without Diablo’s reactors, a combination of extreme heat, drought, and wildfires, plus supply-chain and tariff disruptions to planned supplies, might leave California short by ~1.8 GW in September 2025. This dark vision ignores lessons from California’s prolonged 2000–01 power emergency, when (despite already-exceptional energy efficiency) a statewide campaign led by the Governor’s office cut power demand by 12% (4.8 GW) in a few months. That’s more than double Diablo’s share of the latest heat-

driven 60+-GW demand estimate⁹. And if summertime demand *did* suffer brief but giant surges, inflexible reactors would be the least sensible way to meet them.

It's also almost certainly the costliest way. The Governor's proposal implausibly assumes that continued nuclear operation could meet the posited need more cheaply than other ways to do the same thing safely, securely, cleanly, flexibly, resiliently, and attractively—chiefly renewable supply plus efficient and timely use. Diablo Canyon's units are among the costlier to run among US reactors, which are generically so uneconomic that Congress just bailed them out with tens of billions of dollars in new subsidies. US nuclear operation has rarely if ever bid against the slate of carbon-free alternatives, let alone won. Diablo Canyon is especially unlikely to win.

But the proposal doesn't just *assume* cost-effectiveness. It mandates a nuclear solution *in place of* that amount of competitive procurement. At a stroke, this substitution of handwaving assumptions for market discipline—crowning a winner with no analysis of alternatives, no bids, and unknown prices—*would necessarily displace the same amount of efficiency and renewables already being competitively procured*. (Technically, either renewable or nuclear output would get curtailed, idling investments.) This would abandon every basic lesson California's energy policy has taught us in the past half-century. Reserves against contingencies should be procured and available, but just once, and at least cost.

Supply-chain concerns

That said, concerns about timely implementation are not frivolous. As disruptions from COVID-19 and Putin's War continue to reverberate through the global economy, it's fair to ask if strained supply chains can be relied upon for timely delivery of equipment to replace Diablo's 2.2 GW in the next three years.

For perspective, renewable power is adding about 300 GW of global supply each year¹⁰, and industry expects solar photovoltaic (PV) power alone to add that much in 2025¹¹. California added 3.0 GW of PV capacity just in 2021—a Diablo's worth of capacity every nine months, shiftable into evening peak hours by the hybrid storage that now dominates new California PV projects. By year-end, about 70 GW of PVs (95% combined with batteries), and nearly twice that much in total battery projects, had been queued for connection to the California grid.¹²

The complex PV supply chain¹³ has been especially stressed of late by extraordinary growth plus geopolitical, tariff, and Uighur-forced-labor disputes. Nonetheless, in 2021 it shipped 194 GWdc (47% above 2020)¹⁴, installed 172 GWdc, and continued to accelerate. Supplying an extra 0.9 GWdc per year, a small fraction of current US domestic module production, to replace Diablo¹⁵ is thus a rounding error. But the replacement wouldn't be all-PV: competitive procurement would also elicit many other renewables, plus major demand-side resources. Their diversity in technology, sourcing, location, and constraints is a vital hedge against completion risks.

It's true that US federal solar tariff disputes are particularly tangled at the moment, but the Biden Administration is strongly motivated to resolve them quickly; it's inconceivable that the

present mess¹⁶ would be allowed to persist for another three years. Workarounds are also widespread, such as bifacial modules, currently exempt from tariffs; they're used mainly in utility-scale projects, but also in a fast-growing 9% of California's strong 2021 rooftop solar market. Moreover, California has some attractive rural windpower sites, and the nation's best business case for behind-the-meter distributed windpower¹⁷.

What has changed since PG&E agreed in 2016 to phase out Diablo Canyon?

To assess the reasonableness and urgency of the Governor's radical proposal, it helps to ask what has changed since PG&E's 2016 analysis and decision. Spoiler alert: nothing that would materially support it, but a great deal that makes it clearly ill-advised. Here are the details:

1. The business case, speed, risk profile, and grid-reliability case for demand-side and renewable competitors have all greatly improved. Globally, renewables now provide about 95% of the world's net additions of generating capacity¹⁸. They're consistently adding hundreds of times more capacity and annual output than nuclear power does (though in most years it's shrinking)¹⁹. Renewables' cost continues to trend down and their performance up—the opposite of nuclear trends. Nuclear power is decades into a slow-motion commercial collapse, both in the US²⁰ and abroad²¹, while renewables took over: PV was 44% and wind was 33% of 2021 US capacity additions²², despite cheap gas.
2. The energy-efficiency resource—already half the historic (IEA) and prospective (IPCC) global climate solution—is now known to be far larger than California's or others' standard analyses assume, yet at even lower cost, and often with increasing returns²³. The demand-response resource is also now known to be much larger than was assumed or is being captured²⁴.
3. Climate concerns have intensified. Does that shift mean we must buy every possible solution? On the contrary, it reinforces the need to invest judiciously rather than indiscriminately: to buy fast, cheap, sure resources rather than slow, costly, speculative ones²⁵. (California's deep drought, by making hydropower erratic, does expand the need for planned solar and windpower, which drought doesn't affect, or for efficient and timely electricity use, or both. So does hotter weather. Current plans include all this, and can scale to meet greater needs. The question is not whether but when and how surely.)
4. Many operators have closed operating nuclear reactors that are licensed but uneconomic to run—and therefore not climate-effective either, making climate change worse than if the cheapest carbon-free sources were bought instead²⁶. State-level data²⁷ confirm (even when the operators gives little or no notice) that within typically a year from nuclear closure, or virtually always within two years, the lost nuclear output is replaced by demand-side and renewable resources, so power-sector CO₂ emissions resume their decline. Thus claims that nuclear closure means lastingly burning more gas or coal are not empirically validated; any such blips are transient. After a year or two, the carbon-free replacement resources substituted for lost nuclear output begin to save

more carbon than the closed plant did, because they're cheaper than nuclear operating cost and thus save more carbon per dollar. They also continue to save carbon over far more future years²⁸. The result is a greater climate win than keeping old reactors open. The nuclear industry is anxious that this climate opportunity cost not be discussed or understood.

5. Operating reactors increasingly exhibit costly geriatric problems in older fleets like those of the US (average age 42 years) and France (37). Some combination of commendable operational improvements, closure of underperforming units, and laxer regulation has sustained high US fleet capacity factors, but in even more nuclear-centric France, only about 25 GW of the 63-GW nuclear fleet is now operating, turning France from a major power exporter to a major power importer (even at times of minimum load) and threatening serious power shortages in the coming winter²⁹. The standardized designs used to moderate cost increases (neither France³⁰ nor anyplace else has demonstrated *falling* nuclear costs with higher volumes) also standardized costly flaws—in this case, serious corrosion³¹. France now has more nuclear capacity closed for repairs or safety checks than Germany closed cumulatively during 2000–21. French nuclear shortfalls since 2019, if displaced by gas-fired generation, could far more than account for Europe's total gas-storage deficit as Putin's War began—a major blow to European energy security. Indeed, comparing the French and German power system suggests that an open and competitive grid where all technologies, sizes, ownerships, and locations can compete fairly yields greater energy security and lower wholesale power prices than a closed, central-plant-based, nuclear-centric grid³².
6. Smaller and different kinds of reactors have lately been vigorously proposed and heavily subsidized. Even at this early stage, they are turning out to have unpromising economics³³, unattractive business risks, no material ability to help with climate (the US grid will be decarbonized before they could scale), and worrisome new safety³⁴, waste³⁵, and proliferation³⁶ issues. Vendors seem unwilling to bear the cost and performance risks³⁷.
7. The already-weak, though still widespread, belief that keeping the grid reliable as it becomes renewable requires “clean firm” thermal generation—nuclear or fossil-fueled power plants—has become technically unworkable³⁸. Contrary analysis and experience demonstrate highly reliable performance in largely or wholly renewable grids³⁹. Synchronous condensers and grid-forming inverters can now provide all ancillary services needed for grid stability, more quickly and precisely than traditional rotating machines, even at multi-GW scale⁴⁰. Counting grid integration costs, not just bare leveled costs of electricity, makes nuclear power even *less* competitive with variable renewables (let alone energy efficiency), because central thermal plants' forced outages tend to be larger, longer, more abrupt, and less predictable than those of solar and windfarms, thus requiring more and costlier backup or firming resources⁴¹. California's pioneering commitment to all-renewable electricity is now becoming mainstream⁴².

8. The supposed need for continued thermal generation can be modeled only by excluding most of the ten carbon-free grid-balancing resource categories⁴³—as the prevalent MIT, IEA, and most other models still do. Most or all energy models now driving climate and electricity policy have other grave structural flaws too, such as not competing or comparing demand-side with supply-side resources, and not using renewables' observed market prices⁴⁴ and price behaviors (including actual learning curves⁴⁵). But a few recent models⁴⁶ that start to count the full portfolio of grid-balancing resources confirm stable grids with little or no long-duration storage, even in severe conditions.
9. It was already clear well before 2016 that neither new nor existing nuclear plants have a business case or an operational need. That is far more obviously true in 2022—most of all from the excellent international performance of high-variable-renewable grids, even without adding bulk storage⁴⁷. No responsible party in California, therefore, thought it worth analyzing or suggesting an extension in Diablo Canyon's planned phaseout when the initial 40-year licenses expire. Tellingly, none of the five main California utilities' post-2016 decarbonization plans—the most ambitious published by PG&E itself in June 2022⁴⁸—recommended extending Diablo Canyon's operating life. Neither did the latest plans by any of California's grid, electricity, or energy regulatory agencies. Neither did a major independent analysis, published in May 2022 as a roadmap for 85% carbon-free electricity by 2030 with stress-tested reliability⁴⁹. Instead, it found that despite planned Diablo Canyon and gas-plant retirements, California could meet an August 2030 peak load 22%, or more than 10 GW, above the equivalent 2020 peak. A few PowerPoint slides sketched for this hearing do not a real analysis make. After decades of contrary evidence, the burden of proof that there's a dangerous capacity gap and that Diablo life extension could cost-effectively, practically, and reliably fill it seems impossible to bear.
10. Meanwhile and in contrast, the nuclear industry and its allies have conducted an impressively powerful and effective lobbying and publicity campaign to deny and obfuscate these facts, and in California, to create the illusion that resource adequacy or climate goals or both require Diablo Canyon's operating life to be extended beyond 2024/25. A nuclear advocate's gubernatorial candidacy has added political overtones. This campaign, backed by prominent but seemingly misguided allies⁵⁰, has triggered a reexamination of Diablo's closure schedule, including this Workshop. The federal Administration—the most pro-nuclear in history—has also added vast new subsidies for existing nuclear plants (and massive grants for new ones), plus special subsidies that might (under rules already fudged) apply to keeping Diablo open. Thus some but far from all of the unknown cost of extending Diablo's operating life would be socialized to US taxpayers rather than borne solely by California tax- and ratepayers—those served by all private and community-choice providers, not just PG&E customers. This distorts California's economic incentives, encouraging irrational choices. It's a high price to pay to give the nuclear industry and its allies a political trophy they desperately crave to distract from their tottering enterprise's commercial collapse.

Conclusions

If California policymakers soberly weigh all these factors with their usual sophistication, I think they will draw five conclusions:

- A. There is no sound, let alone compelling, reason to disturb the existing Diablo phaseout agreement. Keep calm and carry on.
- B. If there are real concerns about the timely substitution of competitively procured, carbon-free demand- and supply-side resources for Diablo's output after 2024/25, resolve those concerns by improving existing procurement, approval, and deployment processes—not by upending, diluting, or displacing them. If an “insurance policy” were desired in case currently robust resource acquisitions faltered, it's hard to imagine that Diablo extension could seriously contend for that role. However, it could be interesting to see what total payment PG&E would require to cover the resulting costs and risks, i.e. what the firm would bid in a competitive process if it had to deliver results, without the heavy hand of state regulators on the scales.
- C. California does not need and cannot afford all obtainable resources. Choosing one resource excludes others, due to the economic principle of “opportunity cost” (which means you can't spend the same dollar on two different things at the same time) and because no generator can serve a load that another resource is already serving. So forcing Diablo's 2.2 GW of net output to stay on the grid beyond its planned closure means that either Diablo will run less (worsening its operating economics) because the added renewables and demand-side resources being installed to replace it are allowed to the job cheaper, or Diablo will somehow gain priority over and displace⁵¹ those resources that could serve customers at much lower cost. Either outcome would waste money, because if there is a supply/demand gap, it must be filled only once, not twice. Nor could proposed new uses of Diablo Canyon electricity, such as desalination or hydrogen production, make its electricity competitive with new carbon-free resources: the advantage of using waste-heat-warmed seawater can't bridge the basic cost gap⁵².
- D. Extending Diablo's life would be such a nightmarishly complex process, with so many moving parts—many dependent on parties and choices not under California's control, and some completely unpredictable due to unforeseeable technical or natural events—that it must be considered a speculative resource. Rationally considered, it is far more speculative than the non-nuclear, non-fossil resources of which California has uniquely deep and favorable experience. This all-or-nothing 2.2-GW chunk is utterly dependent on many complex steps, known and unknown, so it cannot be confidently substituted for diverse portfolios of proven, widely available resources. California should therefore devote its focus, attention, and budgets not to exploring the least attractive and least commercially viable electricity solutions but to implementing the most attractive and competitive ones already in hand—and adding more like them, especially for superefficient electricity use.
- E. Just this conversation about Diablo also has an opportunity cost. It has already consumed a great deal of the precious time and attention of California's political leaders and energy-policy institutions, diverting them from getting on with their vital and challenging jobs. Continuing this distraction would only delay solutions that are cheaper,

surer, and working, in favor of a hypothetical resource that is costlier, riskier, and propelled more by ideological fervor than by pragmatism or logic. Doing so in haste would further heighten the risk of costly errors. That's not smart policy. Those advocating it have had their say. California got this choice right the first time in 2016–18. Nothing important has tipped the balance; instead, the case for gracefully retiring Diablo Canyon as agreed then is even stronger today. There the matter should rest.

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¹ *Forbes*, 22 June 2016, <https://www.forbes.com/sites/amorylovins/2016/06/22/close-a-nuclear-plant-save-money-and-carbon-improve-the-grid-says-pge/>.

² 1 GW = 1 gigawatt = 1 billion watts = 1,000 megawatts = 1,000,000 kilowatts. The International Atomic Energy Agency lists design net capacity as 1,084 MW for unit 1 and 1,106 MW for unit 2, a total of 2.190 GW.

³ <https://www.nrdc.org/experts/diablo-canyon-update-one-year-after-historic-joint-proposal>.

⁴ E.g. the consultants' 2017 report at <https://foe.org/wp-content/uploads/2017/legacy/PlanBfinal.pdf>, assuming renewable costs that now look conservatively high.

⁵ <https://www.newyorker.com/science/elements/how-safe-are-nuclear-power-plants>.

⁶ <http://www.caiso.com/about/Pages/Blog/Posts/Storage-was-the-compelling-story-of-2021-according-to-our-newly-published-Annual-Stats.aspx>

⁷ <https://www.latimes.com/business/story/2022-08-12/california-could-lend-pg-e-1-4-billion-to-save-the-diablo-canyon-nuclear-plant>

⁸ <https://efiling.energy.ca.gov/GetDocument.aspx?tn=244871>.

⁹ <https://www.nrdc.org/media/2001/010823>.

¹⁰ <https://www.iea.org/reports/renewable-energy-market-update-may-2022>.

¹¹ <https://www.nrel.gov/docs/fy22osti/82854.pdf>.

¹² https://emp.lbl.gov/sites/default/files/queued_up_2021_04-13-2022.pdf, which also explains why it is impossible to predict how many of the queued projects will be completed—a strong function of state and local approvals, which presumably might merit the same sense of urgency that the Governor proposes for waiving any regulation that might interfere with Diablo Canyon's life extension.

¹³ <https://iea.blob.core.windows.net/assets/d2ee601d-6b1a-4cd2-a0e8-db02dc64332c/SpecialReportonSolarPVGlobalSupplyChains.pdf>.

¹⁴ <https://www.nrel.gov/docs/fy22osti/82854.pdf>. In 2021, photovoltaics added 172 GWdc of installed capacity in the world (+19% y/y, with 27% projected in 2022), 23.6 GWdc in the US (+25% y/y, or 44% of total capacity additions), and 3.0 GWac in California (whose PVs led the nation with 24% of total generation and 26.6 GWac of capacity). In round numbers, 1 GWdc (direct current) gets converted into about 0.8 GWac (alternating current).

¹⁵ I.e. the plant's peak rated net output of 2.2 GW, times 1.25 to convert from AC to DC capacity, replaced over 3 y.

¹⁶ <https://www.washingtonpost.com/business/2022/05/07/auxin-solar-projects-frozen/>.

¹⁷ <https://www.nrel.gov/analysis/distributed-wind-futures.html>.

¹⁸ <https://www.iea.org/reports/renewable-energy-market-update-may-2022>.

¹⁹ <https://doi.org/10.1016/j.tej.2022.107122>, <https://news.bloomberglaw.com/environment-and-energy/why-nuclear-power-is-bad-for-your-wallet-and-the-climate>.

²⁰ <https://doi.org/10.1016/j.tej.2022.107122>.

²¹ <https://worldnuclearreport.org>; <https://www.bloomberg.com/news/articles/2022-06-30/renewable-power-costs-rise-just-not-as-much-as-fossil-fuels>; <https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/>.

²² <https://www.nrel.gov/docs/fy22osti/82854.pdf>.

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- ²³ <https://doi.org/10.1088/1748-9326/aad965>.
- ²⁴ <https://www.raponline.org/knowledge-center/time-varying-and-dynamic-rate-design/>, https://rmi.org/wp-content/uploads/2018/02/Insight_Brief_Demand_Flexibility_2018.pdf.
- ²⁵ <https://www.youtube.com/watch?v=kgCBLG4ci9g&t=3321s>.
- ²⁶ <https://climatenow.com/podcast/nuclear-power-does-it-have-a-role-to-play-in-the-clean-energy-future/>.
- ²⁷ <https://www.worldnuclearreport.org/-World-Nuclear-Industry-Status-Report-2019-.htm>, and a forthcoming update by another author.
- ²⁸ <https://www.forbes.com/sites/amorylovins/2019/11/18/does-nuclear-power-slow-or-speed-climate-change/>.
- ²⁹ <https://www.bloomberg.com/news/articles/2022-01-23/french-nuclear-giant-s-fall-risks-energy-security-for-all-europe>.
- ³⁰ <https://doi.org/10.1017/CBO9781139150880.015>.
- ³¹ <https://www.neimagazine.com/news/newseof-provides-update-on-corrosion-in-french-reactor-fleet-9722516>.
- ³² <https://doi.org/10.1016/j.tej.2022.107122>.
- ³³ <https://ieeexplore.ieee.org/document/9374057>.
- ³⁴ <https://www.ucsusa.org/resources/advanced-isnt-always-better>.
- ³⁵ <https://www.pnas.org/doi/10.1073/pnas.2111833119>.
- ³⁶ <https://www.tandfonline.com/doi/abs/10.13182/NT13-A19873> and <https://www.energyintel.com/0000017e-ff91-df96-a1fe-ffffdf990000>.
- ³⁷ <https://ieefa.org/articles/ieefa-us-small-modular-reactor-too-late-too-expensive-too-risky-and-too-uncertain>.
- ³⁸ <https://doi.org/10.1016/j.tej.2017.11.006>.
- ³⁹ <https://doi.org/10.1016/j.tej.2022.107122>.
- ⁴⁰ <https://reneweconomy.com.au/world-first-hornsdale-battery-gets-approval-to-deliver-critical-inertia-services-to-grid/>.
- ⁴¹ <https://www.utilitydive.com/news/nuclear-energy-should-not-be-part-of-the-global-solution-to-climate-change/620392/>.
- ⁴² <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9837910>.
- ⁴³ <https://doi.org/10.1016/j.tej.2020.106827>.
- ⁴⁴ [https://www.cell.com/joule/pdfExtended/S2542-4351\(21\)00100-8](https://www.cell.com/joule/pdfExtended/S2542-4351(21)00100-8).
- ⁴⁵ <https://www.oxfordmartin.ox.ac.uk/publications/empirically-grounded-technology-forecasts-and-the-energy-transition/>.
- ⁴⁶ https://www.eliagroup.eu/en/news/press-releases/2021/11/20211119_elia-group-publishes-roadmap-to-net-zero, <https://doi.org/10.1063/5.0064570>.
- ⁴⁷ <https://www.utilitydive.com/news/nuclear-energy-should-not-be-part-of-the-global-solution-to-climate-change/620392/>.
- ⁴⁸ https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/pge-climate-goals/PGE-Climate-Strategy-Report.pdf
- ⁴⁹ <https://energyinnovation.org/publication/85-percent-clean-electricity-by-2030-in-california/>, https://gridlab.org/wp-content/uploads/2022/05/GridLab_California-2030-Study-Technical-Report-5-9-22-Update1.pdf
- ⁵⁰ Including two former US Secretaries of Energy, neither of whom seemed familiar with the analytic basis of the 2018 agreement, and one of whom declined to correct his misstatements about German phaseout experience.
- ⁵¹ <http://www.aiso.com/informed/Pages/ManagingOversupply.aspx>.
- ⁵² <https://doi.org/10.1073/pnas.1804655115>.