Union of Concerned Scientists

RESEARCH BRIEF

Countdown to Shutdown

California's Clean Energy Future after Diablo Canyon Closes

HIGHLIGHTS

The upcoming retirement of Diablo Canyon, California's last nuclear power plant, is a major milestone. State law requires the replacement of Diablo Canyon without increasing global warming emissions; however, to date, no action has been taken specifically to replace the zero-emissions energy from the power plant. Using grid modeling tools to analyze California's electricity sector emissions, the Union of Concerned Scientists found that, without further action, cumulative global warming and air pollution emissions will be significantly higher over the next decade due to the retirement and replacement of Diablo Canyon primarily with energy from existing natural gas power plants. To prevent an increase in emissions, the Union of Concerned Scientists recommends that California regulators and electricity providers pursue more ambitious electricity sector emissions reduction goals, which would both accelerate the deployment of renewables and energy storage and address the anticipated increase in cumulative emissions from the retirement of Diablo Canyon.

As California strives to decarbonize its economy, the state's electrical grid is rapidly evolving. The production of renewable electricity from sources like solar and wind continues to climb, while old natural gas and nuclear power plants continue to shut down. However, with the long-anticipated retirement of the Diablo Canyon nuclear power plant on the horizon, the transition to clean electricity is soon to encounter a speed bump: California will need to replace all of Diablo Canyon's output with clean energy. The state can overcome this obstacle and carry on toward its clean energy goals, but this will require careful, proactive planning.

California has long been a leader in decarbonizing its economy and transitioning to clean energy. Driving this transformation is the state law requiring global warming emissions reductions to 40 percent below 1990 levels by 2030 (California Legislature 2016) along with an executive order to achieve economy-wide carbon neutrality by 2045 (Brown 2018). To meet these ambitious goals, nearly every sector of California's economy will need to evolve, pursuing innovative strategies and new technologies to eliminate global warming emissions wherever feasible.

Decarbonizing California's electricity sector will be the key to success as other sectors of the economy, such as buildings and transportation, increasingly electrify. To ensure that the state's electricity sector rapidly transitions to clean

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Diablo Canyon, California's last nuclear power plant, is scheduled to retire mid-decade. State regulators are committed to replacing Diablo Canyon's energy without increasing global warming emissions, but current clean energy build-out plans are insufficient to achieve this goal.

electricity, California legislators and regulators have enacted many requirements. Foremost among them is the law requiring the state's electricity to be 60 percent renewable by 2030 and 100 percent zero-carbon by 2045 (California Legislature 2018a). State regulators at the California Public Utilities Commission have been tasked with overseeing a long-term electrical grid planning process—integrated resource planning (IRP)—which aims to ensure that the state's electricity sector reduces its emissions enough for California to achieve its economy-wide decarbonization goals.

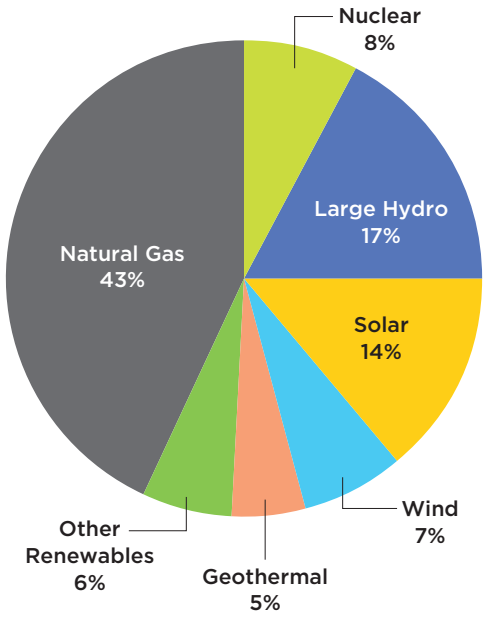
Taken together, this suite of policies and requirements is driving the transition to clean electricity in California. These policies can ensure that the retirement of Diablo Canyon does not stall, but rather accelerates the transition. However, current planning will not be sufficient to replace Diablo Canyon; without further action, cumulative global warming emissions will be higher over the next decade. In this analysis, the Union of Concerned Scientists (UCS) offers a comprehensive analytical approach that specifically examines the increase in cumulative global warming emissions from Diablo Canyon's retirement, along with solutions for replacing Diablo Canyon without increasing global warming emissions.

The Upcoming Retirement of California's Last Nuclear Power Plant

After a long and fraught history of seismic safety concerns due to the discovery of fault lines very close to Diablo Canyon (Lochbaum 2013), in 2018 California regulators approved the request to shut down both of Diablo Canyon's nuclear reactors, totaling 2,240 megawatts (MW), when their operating licenses expire in 2024 and 2025 (CPUC 2018). The decision to retire Diablo Canyon, California's last nuclear power plant, marked the beginning of the end for the era of nuclear power in California.

Ultimately, the decision to retire Diablo Canyon was made largely for economic reasons—it would not have been cost-effective to make the investments necessary to keep the power plant running beyond 2025. At the same time, California regulators also made a commitment to prevent an increase in global warming emissions due to Diablo Canyon's closure (CPUC 2018). Shortly afterward, California legislators codified that commitment into law (California Legislature 2018b).

FIGURE 1. California In-State Electricity Generation



The Diablo Canyon nuclear power plant provided 8 percent of electricity generated inside California in 2019.

Note: Approximately 72 percent of California's electricity is generated in-state—the rest is imported from other states.

SOURCE: CEC 2020.

Replacing the massive Diablo Canyon nuclear power plant without increasing global warming emissions will be no easy feat. By itself, Diablo Canyon accounted for 8 percent of California's in-state electricity generation in 2019 (CEC 2020) (Figure 1). When the similarly sized San Onofre nuclear generating station unexpectedly and permanently went offline in 2012, natural gas power plants initially filled the gap. As a result, there was a notable uptick not only in global warming emissions from gas plants, but also in air pollution emissions like nitrogen oxides (NOx), which disproportionately affect the health of California's disadvantaged communities (PSE Healthy Energy 2017). To avoid a similar uptick in global warming and air pollution emissions when Diablo Canyon closes, California regulators and electricity providers must take action now.

Replacing the massive Diablo Canyon nuclear power plant without increasing global warming emissions will be no easy feat.

> ***Regulators expressed a commitment to replace Diablo Canyon without increasing global warming emissions but only offered a loose interpretation of this requirement.***

The Existing Approach to Replacing Diablo Canyon That Falls Short

California regulators have indicated that any Diablo Canyon replacement plans should be assessed as part of the IRP process (CPUC 2018). One of the overall drivers of the IRP process is to plan for reductions in electricity sector emissions that are consistent with the California Air Resources Board scoping plan. The most recent scoping plan suggests that annual global warming emissions from the electricity sector will need to be reduced from their current level of 63 million metric tons (MMT) down to 30–53 MMT by 2030 (CARB 2017). California regulators must select a 2030 emissions target within this range. In 2020, these regulators chose to pursue a pathway that reduces electricity sector emissions to 46 MMT by 2030 (CPUC 2020), but they have also considered more ambitious emissions pathways that reduce emissions further, to 38 MMT and 30 MMT. California regulators have thus far declined to pursue one of these more ambitious targets despite overwhelming support from companies and organizations across California, including UCS (CPUC 2020).

When California regulators approved the retirement of the Diablo Canyon nuclear power plant, they expressed a commitment to replace it without increasing global warming emissions but did not specify how that goal would be achieved (CPUC 2018). (While the current IRP process does include measures to replace the *capacity* of Diablo Canyon, and therefore the grid reliability contribution, there are no safeguards in place to ensure that all the zero-emissions *energy* from Diablo Canyon is replaced as well.)[1] Since then, the regulators have only offered a loose interpretation of this requirement, stating that as long as California's electricity sector overall meets its global warming emissions reduction goals over the next decade and especially in 2030, then the emissions requirement for Diablo Canyon's replacement has been met (CPUC 2019).

However, this interpretation ignores the reality that the state's electricity sector may have surpassed its emissions goals by an even wider margin if Diablo Canyon were to remain online—an indication that too little is being done to replace Diablo Canyon. This approach also focuses too narrowly on emissions in 2030, a single snapshot in time, and it overlooks the cumulative emissions that will occur throughout the next decade. In addition, California regulators have argued that, because the IRP includes the early build-out of clean resources to take advantage of soon-to-expire tax credits, this early build-out more than replaces the energy from Diablo Canyon (CPUC 2019). But this too ignores the reality that much of this procurement likely would have happened even if Diablo Canyon were to remain online.

While California's electricity providers are currently required to plan for Diablo Canyon's retirement in their IRPs, these plans contain very few specific actions to ensure that global warming emissions do not increase due to Diablo Canyon's retirement. Furthermore, to date, no actions have been taken *specifically* to replace Diablo Canyon with clean electricity.

Analysis of the Increase in Emissions from Diablo Canyon's Retirement

To understand the actions that California must take in order to replace Diablo Canyon's generation without increasing global warming emissions, UCS undertook a comprehensive analysis that examines cumulative emissions from the electricity sector in the "what if" scenario where Diablo Canyon remains online. In particular, this analysis rests on the assumption that replacing Diablo Canyon without increasing global warming emissions requires *cumulative* global warming emissions not to exceed the levels that would occur if Diablo Canyon had remained online. In addition, because there has been no specific planning and no specific actions to replace Diablo Canyon's energy to date, this analytical approach also assumes that none of the resources already operating on the grid were brought online specifically to replace Diablo Canyon.

Using the same electrical grid planning tool used by California regulators (the RESOLVE model)[2] along with the most recent IRP planning assumptions (CPUC 2020), UCS analyzed a range of California electricity sector scenarios with and without Diablo Canyon remaining online beyond 2025. By comparing the results of scenarios with and without Diablo Canyon, we determined the effect of Diablo Canyon's impending retirement on cumulative global warming emissions.

This analysis focused on the three global warming emissions pathways that California regulators have been considering in the IRP process: statewide electricity sector emissions reductions to 46 MMT, 38 MMT, and 30 MMT by 2030. Specifically, we identified the new grid resources required to achieve electricity sector emissions reductions in the California Independent System Operator (CAISO) territory between 2020 and 2030, studying each of the three pathways with and without Diablo Canyon remaining online beyond 2025.[3] In all scenarios, the RESOLVE model optimized investments in new electrical grid resources to fulfill clean energy and reliability requirements at the lowest cost.

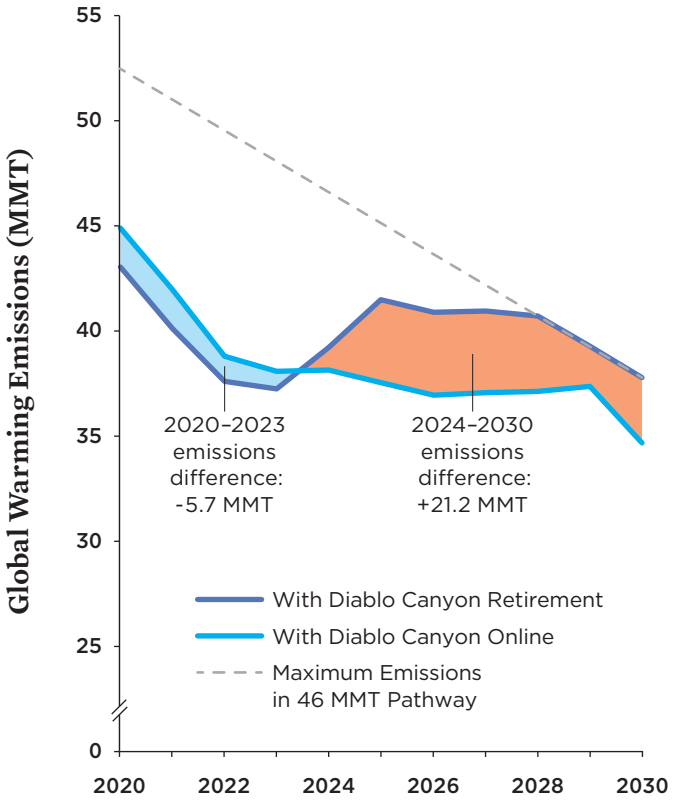
EMISSIONS IN THE 46 MMT PATHWAY WITH AND WITHOUT DIABLO CANYON ONLINE

The first pathway is the least ambitious; it reduces statewide electricity sector global warming emissions to 46 MMT by 2030. We compared the results of the 46 MMT pathway with and without Diablo Canyon remaining online to determine the effect of Diablo Canyon's retirement on global warming emissions over the next decade. Analysis of this pathway showed that, to prepare for Diablo Canyon's retirement, some additional clean resources will be built early in the decade, which will reduce total global warming emissions by 5.7 MMT in the 2020–2023 time frame before Diablo Canyon shuts down (Figure 2). However, because too few clean resources will be built to fully replace Diablo Canyon's energy, global warming emissions will be 21.2 MMT higher in the 2024–2030 time frame after Diablo Canyon retires. As a result, with Diablo Canyon's retirement, cumulative global warming emissions from the electricity sector over the next decade will be 15.5 MMT higher (21.2 MMT minus 5.7 MMT) unless further actions are taken to replace Diablo Canyon (see the table). To put this in context, 15.5 MMT is roughly equivalent to the global warming emissions that 306,000 typical gasoline-powered passenger vehicles would emit over the next decade.[4]

In addition, because existing natural gas power plants would operate more frequently to fill the gap left by Diablo Canyon's retirement, air pollution emissions would increase in tandem with global warming emissions, with an estimated cumulative increase of 1,890 metric tons of NOx over the next decade (see the table).[5] This is approximately equivalent to the NOx emissions from 1,750 diesel school buses operating over the next decade.[6]

Another significant finding from this analysis is that, in the 46 MMT pathway, global warming emissions in 2030 fall below the 2030 emissions target when Diablo Canyon remains online (Figure 2); this scenario produces 34.8 MMT of emissions in the CAISO, which roughly corresponds to 43 MMT statewide.[7] This finding suggests that the 46 MMT by 2030 pathway is incompatible with state law since it would not reduce 2030 electricity sector emissions enough to replace Diablo Canyon *in addition to* meeting the state's renewable energy goals.[8] To ensure the replacement of Diablo Canyon without increasing global warming emissions, the obligation to replace Diablo Canyon with clean energy must be considered *separately and in addition to* the state's Renewable Portfolio Standard mandates. Therefore, UCS analysis indicates that the 2030 electricity sector emissions target must be at most 43 MMT to ensure full replacement of Diablo Canyon in 2030.

FIGURE 2. Annual Emissions and Cumulative Emissions Difference with 46 MMT Target



Under the 46 MMT pathway, the early build-out of clean resources when planning for Diablo Canyon's retirement reduces cumulative global warming emissions by 5.7 MMT at the beginning of the decade. However, Diablo Canyon's retirement, in combination with insufficient additional clean resources, increases cumulative global warming emissions by 21.2 MMT in the latter half of the decade. Therefore, without further action, Diablo Canyon's retirement will increase cumulative global warming emissions by 15.5 MMT over the next decade.

Note: This figure shows CAISO emissions only. Because the CAISO encompasses roughly 81 percent of the state's electricity sector, the CAISO-specific emissions targets displayed on the chart are 81 percent of the statewide 46 MMT emissions goal.

UCS findings suggest that the state's 46 MMT by 2030 pathway would not reduce emissions enough to replace Diablo Canyon, making it incompatible with state law.

EMISSIONS IN THE MORE AMBITIOUS PATHWAYS WITH AND WITHOUT DIABLO CANYON ONLINE

The second pathway examined was the moderately ambitious 38 MMT pathway. UCS compared the results of the 38 MMT pathway with and without Diablo Canyon, and the comparison showed that Diablo Canyon's retirement leads to a cumulative increase of just 5.1 MMT of global warming emissions and an estimated 938 metric tons of NOx emissions over the next decade (see the table). The cumulative excess emissions are lower in this pathway because the lower, 38 MMT target requires additional investments in clean electricity resources, especially when Diablo Canyon shuts down mid-decade.

Finally, UCS compared the results with and without Diablo Canyon while using a 30 MMT emissions target, the most ambitious one being considered by state regulators. The 30 MMT pathway produced no excess global warming emissions even when Diablo Canyon shuts down; instead, this pathway *reduces* cumulative emissions over the next decade by 1.3 MMT (see the table). The more ambitious 30 MMT pathway inherently addresses the retirement of Diablo Canyon because the much more stringent emissions target requires a larger build-out of clean resources early in the 2020s to ensure that global warming emissions do not spike when Diablo Canyon retires.

The Path Forward to Replace Diablo Canyon

This analysis demonstrates that California's current electricity sector emissions pathway fails to meet the requirements of state law because cumulative global warming emissions will be higher over the next decade due to the retirement of Diablo Canyon. Additional action is required to replace Diablo Canyon without significantly increasing global warming and air pollution emissions. Here we outline the types of resources that California will need to deploy to replace Diablo Canyon, as well as specific recommendations for moving forward.

TYPES OF RESOURCES REQUIRED TO REPLACE DIABLO CANYON

Our analysis estimated the incremental resources required to fill the 15.5 MMT cumulative emissions gap in the 46 MMT pathway. In addition, we assessed the *overall* resources required to replace Diablo Canyon in the 46 MMT, 38 MMT, and 30 MMT pathways.

First, our analysis examined the type and quantity of incremental grid resources required specifically to close the 15.5 MMT cumulative emissions gap in the 46 MMT pathway.[9] Closing this emissions gap also included the reduction of 2030 emissions below 46 MMT to 43 MMT (in order to satisfy Renewable Portfolio Standard requirements in addition to fully replacing Diablo Canyon with clean energy). Our findings suggest that, over the course of the next decade, the most cost-effective way to fill this emissions gap is to increase the wind build-out by 3,000 MW while slightly decreasing the solar and battery storage build-out by 600 MW and 300 MW, respectively.[10] (The reduction in the total build-out of new solar and battery storage by 2030 is very small, and the total build-out still exceeds 10,000 MW and 8,000 MW, respectively.)

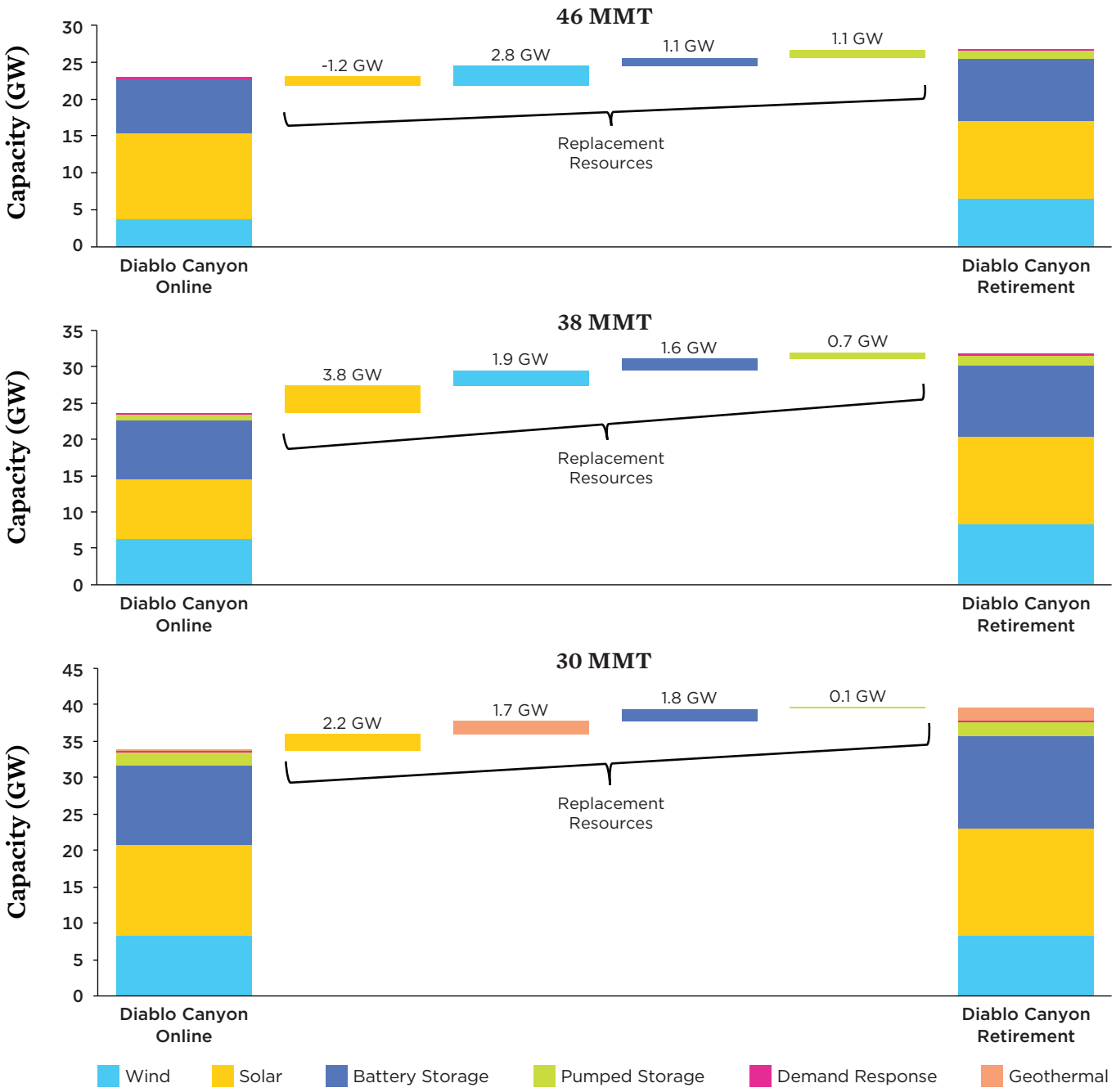
Cumulative Increase in Emissions from Diablo Canyon Retirement

Emissions Pathway by 2030	Bare Minimum (46 MMT)	Moderate (38 MMT)	Ambitious (30 MMT)
Cumulative Global Warming Emissions Difference	15.5 MMT	5.1 MMT	-1.3 MMT
Cumulative NOx Emissions Difference	1,890 metric tons	938 metric tons	NA

Without further action, Diablo Canyon's retirement will result in an additional 15.5 MMT of global warming emissions and 1,890 metric tons of NOx emissions over the next decade. However, California regulators could close that gap by selecting a lower global warming emissions pathway for California's electricity sector.

Note: There are no data for NOx emissions in the 30 MMT pathway because the tool used to calculate NOx emissions (the Clean System Power calculator) did not have the capability to calculate NOx emissions for that pathway.

FIGURE 3. Clean Resources That Replace Diablo Canyon in 2030



The mix of new clean resources required to replace Diablo Canyon depends heavily on the 2030 decarbonization target being pursued. Resources like wind and pumped storage can replace Diablo Canyon when planning for relatively less ambitious emissions targets. However, for more ambitious electricity sector decarbonization, geothermal, solar, and battery storage are the only types of resources available that can be built out further to fill the gap left by Diablo Canyon's retirement.

Notes: Data in the chart show the resource build-out with Diablo Canyon retirement and the resource build-out with Diablo Canyon remaining online. The difference between these two build-outs represents the Diablo Canyon replacement resources. There is a negative amount of solar capacity replacing Diablo Canyon in the 46 MMT pathway because the model selects a larger amount of wind and energy storage resources, which negates the need for some solar capacity. In addition, since the original 46 MMT emissions pathway does not necessitate full replacement of Diablo Canyon by 2030, the 46 MMT pathway shown here includes the resources required to close the 15.5 MMT emissions gap, which actually results in lower 2030 emissions of 43 MMT.

> ***Adopting the 30 MMT pathway for California's electricity sector guarantees the full replacement of Diablo Canyon while also helping the state achieve its economy-wide decarbonization goals.***

Next, we examined the *overall* amount of grid resources required to replace Diablo Canyon's capacity and zero-emissions energy in 2030 in all three emissions pathways (Figure 3). The results show that, generally, a diverse combination of renewable energy and energy storage is the most economic approach to replacing Diablo Canyon, regardless of the 2030 emissions target.

Wind and energy storage are the most cost-effective resources for replacing Diablo Canyon, likely due to their relatively low costs and high grid reliability contributions. However, the quantity and type of Diablo Canyon replacement resources vary based on the 2030 emissions target in large part due to the limited availability of the most cost-effective resources. For instance, wind and energy storage are the main resources that replace Diablo Canyon in the 46 MMT pathway, but there are real-world limitations on the amount of wind and pumped storage (one type of energy storage using reservoirs of water) facilities that can be built. To decarbonize the electricity sector down to the 30 MMT target, essentially all of the available wind and pumped storage must be built regardless of whether or not Diablo Canyon remains online. Therefore, no additional wind or pumped storage resources are available to replace Diablo Canyon in the 30 MMT pathway, and geothermal, battery storage, and solar would be used instead.

ADDITIONAL ACTION REQUIRED TO REPLACE DIABLO CANYON

California regulators could take action in a couple of different ways to ensure that Diablo Canyon's retirement does not result in increased global warming emissions. One option is to select a lower-emissions pathway than the one the state is currently on, which would address Diablo Canyon's retirement automatically. Alternatively, regulators could stick with the current pathway and order procurement of clean resources specifically to replace Diablo Canyon, which would necessarily go over and above the procurement that is already required to reach California's renewable electricity goals. UCS recommends the former option—specifically the adoption of the 30 MMT pathway for California's electricity sector—because this pathway guarantees the full replacement of Diablo Canyon while also accelerating the decarbonization of the electricity sector, helping to ensure that California achieves its economy-wide decarbonization goals.

With the transition to clean electricity being the linchpin of decarbonizing California's entire economy, the retirement and replacement of Diablo Canyon is a prime opportunity to accelerate the state's clean energy progress. By utilizing an analytical approach and taking the actions necessary to fully replace Diablo Canyon by 2030, California can keep its momentum toward a decarbonized economy, setting an example for how to manage the clean energy transition no matter the challenges along the way.

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ENDNOTES

1. Capacity is the maximum power output that an electricity generator is capable of producing, typically measured in megawatts (MW); energy is the actual amount of electricity produced over a certain time period, typically measured in megawatt-hours (MWh). For a more in-depth explanation, see https://www.iso-ne.com/about/what-we-do/in-depth/capacity-vs-energy-primer.
2. The RESOLVE model is an electrical grid capacity expansion model used by the California Public Utilities Commission in the IRP proceeding. For more information about the RESOLVE model, see https://www.cpuc.ca.gov/General.aspx?id=6442464143.
3. In general, this modeling used identical inputs and assumptions as the California Public Utilities Commission modeling conducted for the 2019–2020 Reference System Plan. However, some changes were required to perform this analysis. For example, UCS ran the RESOLVE model for every year in the 2020s to accurately calculate cumulative global warming emissions. Furthermore, in scenarios where Diablo Canyon remained online, UCS gave each unit of Diablo Canyon a 20-year retirement extension. For more information on the modeling inputs, assumptions, and results, please see our technical appendix at at www.ucsusa.org/resources/countdown-shutdown.
4. This calculation assumes the typical passenger vehicle emits 4.6 metric tons of carbon dioxide per year and operates for 11 years (from 2020 through 2030).
5. UCS calculated cumulative NOx emissions by entering RESOLVE model outputs into the California Public Utilities Commission's Clean System Power Calculators for the 46 MMT and 38 MMT pathways. Since there is no calculator for the 30 MMT pathway, UCS did not calculate NOx emissions for that pathway. For more information on the calculators, see https://www.cpuc.ca.gov/General.aspx?id=6442459770.
6. This calculation assumes that diesel school buses emit 8.18 grams of NOx per mile and travel 12,000 miles per year for 11 years (from 2020 through 2030).

7. Throughout this modeling, in-CAISO emissions are assumed to be 81 percent of statewide emissions. Therefore, 34.8 MMT of CAISO emissions corresponds to 43 MMT.
8. In the 46 MMT pathway with Diablo Canyon remaining online, the 60 percent Renewable Portfolio Standard (RPS) requires additional renewable energy build-out that reduces 2030 emissions below the 46 MMT target. This suggests that both meeting the 60 percent RPS in 2030 and replacing Diablo Canyon without increasing global warming emissions requires a 2030 emissions target below 46 MMT.
9. To determine the incremental resources required to fill the 15.5 MMT emissions gap, UCS constructed a new emissions pathway by adjusting annual global warming emissions targets to ensure that 2030 cumulative emissions do not exceed emissions when Diablo Canyon remains online in the 46 MMT pathway. We then compared the resource build-out in this new pathway with the resource build-out in the original 46 MMT pathway (with Diablo Canyon retirement) that resulted in 15.5 MMT excess emissions.
10. To maintain consistency with the modeling conducted by the California Public Utilities Commission in the 2019–2020 IRP, this modeling only included in-state and out-of-state wind as potential new resources—offshore wind was not considered an option.

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