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Introductory toolkit for clean reliability: What does California need to ensure grid reliability while reducing fossil fuels?

California's grid is predicted to be vulnerable to outages this summer and in coming years, if California experiences extreme heat conditions or wildfire-related transmission disruptions. With regional heatwaves, imports from neighboring states might be more expensive and strained.

The added risks from climate change to the energy grid will continue to aggravate into the future, as it is predicted to widely stress or damage energy output, and will bring increasingly challenging weather conditions for which to plan. As California transitions its electricity generation to be 100% zero-carbon by 2045 per the directive of Senate Bill 100, relevant decision-makers have the opportunity to plan and prepare for these elevated risks in future summers.

To achieve past standards of reliability while transitioning the grid to be 100% renewable, California must deploy additional resources quicker. CAISO’s 2022 Summer Readiness report concludes with a requirement for future reliability, stating “additional resources are needed to ultimately achieve long-term reliability margins.”[1]

These constraints and risks pose the puzzle: How can California ensure clean and renewable grid reliability? Which resources and processes can be improved to quicken and support existing agency and government plans? Can California prevent the repetition of summer extreme heatwave risks?

This hearing and report aims to explore information for an initial policy toolkit of renewable solutions to maintain grid reliability, which can help to withstand future unpredictable weather conditions aggravated by climate change. The report begins with

[1] CAISO, “2022 Summer Loads and Resources Assessment” (Folsom, CA, 2022), pp. 1-67. www.caiso.com/Documents/2022-Summer-Loads-and-Resources-Assessment.pdf , pg. 20.

a recap of Summer Readiness modeling by two key groups and overviews two main crises that led to this summer's conditions, climate change and supply chain delays. Subsequently, the report gathers a list of various firm or flexible resources that serve to strengthen reliability by discussing their current role in California's grid planning and potential current bottlenecks in their deployment.

Summer reliability reports forecast shortfall risks during extreme heat waves

The California Independent System Operator (CAISO)'s annual Summer Load and Resource Assessment[2] warns that extreme heat waves would likely make California's electric grid prone to outages in the case of extreme heat conditions and transmission damage from wildfires.

Extreme heat waves across the western region would introduce a nexus of electricity grid risks, threatening to leave some Californians without electricity. Lower-than-normal hydro power[3] and increases in demand during the summer[4] have increasingly strained the balance of the grid, particularly recently. Many unpredictable factors could further threaten the grid, including unpredictably hot temperatures, wildfire damage to key transmission lines, smoke cover reducing solar production, and delays in project development.[5] The interplay of these conditions on an extremely hot evening could mean that a certain percent of homes aren't able to be served with electricity. California would therefore be at its highest risk of blackouts with a combination of decreased imports from neighboring states, paired with low solar and hydro generation, at peak hour, CASIO's assessment finds.

As a consequence of these elevated summer risks, California isn't meeting industry reliability standards. This means the state is currently 1,700 megawatts (MW) of capacity short of the traditional reliability metric of only one load-shedding event per every 10 years.[6]

California might not be able to rely on energy imports from neighboring states, either. The North American Reliability Corporation (NERC)'s Summer Reliability Assessment[7] similarly finds that the Western Interconnection is at an elevated risk this summer. Critical imports from other states in the Western Interconnection could become

[2] Ibid.
[3] Ibid, pg. 5
[4] Ibid, pg. 23
[5] Ibid, pg. 13
[6] Ibid, pg. 20
[7] NERC, "2022 Summer Reliability Assessment" (Atlanta, GA, May 2022), pp. 1-46.
www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2022.pdf

unavailable from low hydro generation, wildfire threats, and supply chain delays[8]. This means that there could be insufficient electricity imports, and spiking prices of imports, to meet extreme heat peak conditions.

It is important to understand that these predictions exclude the use of "extraordinary and voluntary" energy conservation measures, which should be considered an additional policy tool for extreme heat conditions. CAISO's report suggests that the risks of shortfalls this summer will be met by other voluntary conservation measures this summer. CAISO's updated Flex Alert system and the CPUC's Emergency Load Reduction Program are an example of effective tools that have been previously used to reduce tight grid conditions, which aren't included in these predictions.[9]

Aggravating crises: Climate change and COVID-19 supply chain delays
Two main crises have aggregated these conditions: the unpredictability of climate change, and supply chain delays from the pandemic. In other words, extreme weather is changing the way that California can predict energy supply and demand, as supply chain complications are making it more difficult for resources to come online.

Climate change is predicted to spike costs and risks for energy grids around the globe. The UN's IPCC report considers the energy sector to be one of the impacted sectors from climate change, with greater risk of the infrastructure being damaged by natural disasters, and decreasing the efficiency of solar, hydro, and other generation.[10] Energy costs in the United States will rise by 14 percent without new methods of planning.[11]

In California, heat waves, in particular, will make planning more difficult, and will also degrade and threaten existing infrastructure. Extreme heat is anticipated to elevate the risk to energy planning by significantly increasing energy use to cool buildings; impacting the availability of imports from neighboring states; compromising the performance of generation, transmission and distribution; and increasing the risk of wildfires damaging critical transmission and distribution lines.[12] The heatwaves in

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[8] Ibid, pg. 32.
[9] CAISO, pg. 3
[10] Dodman, D., et al., 2022: Cities, Settlements and Key Infrastructure. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA,, pg. 931
[11] Wendy S. Jaglom et al., "Assessment of Projected Temperature Impacts from Climate Change on the U.S. Electric Power Sector Using the Integrated Planning Model," *Energy Policy* 73 (2014): pp. 524-539, https://doi.org/10.1016/j.enpol.2014.04.032.
[12] Liz Gill, Aleecia Gutierrez, and Terra Weeks, "2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment" (Sacramento, CA: CEC, 2021), pp. 1-179., energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity

mid-August of 2020 was an example of how climate change risks can converge into rolling blackouts: Demand spiked from cooling needs and exceeded Resource Adequacy predictions, and highly stressed import markets were not able to make up for these shortfalls.[13]

Constraints from the COVID-19 pandemic have also delayed new capacity in the last few years. Other development logistics are also predicted to slow development in the near term. Many solar farms and energy storage commissions by California have been delayed in the past two years because of supply chain challenges.[14] While some indicators have suggested modest improvements relative to 2021,[15] experts still point to various issues remaining in renewable markets, including labor shortages, transportation and shipping backlogs, and shortages to access of lithium-ion batteries.[16] Looking forward, forecasts for the global renewable market until 2026 predict that rising commodity prices and price shocks, permitting delays, and grid interconnection projects will also serve to delay renewable projects.[17]

The response to summer 2022 potential emergency energy risks

Agencies, energy entities, and the Governor's office have all been taking swift leadership to bolster reliability for this summer. The most recent budget includes $2.2 billion to deploy a strategic energy reserve for stressed grid conditions to maintain reliability, which would identify an additional 5,000 MW of energy only allowed to be used during emergency grid conditions.[18] In addition, $550 million for distributed energy resources and $140 million for long duration storage which will both assist with flexibly meeting peak load. The CPUC, CEC and CAISO have similarly introduced a plethora of reliability solutions in the past year, such approving the procurement of over 4,000 MWs of qualifying capacity, adjusted demand reduction programs, added funding for a Smart Thermostat program, and more.[19]

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[13] CAISO, 2022.
[14] Nichola Groom, "California Says It Needs More Power to Keep the Lights On," Reuters (Thomson Reuters, May 6, 2022), reuters.com/world/us/california-says-it-needs-more-power-keep-lights-2022-05-06
[15] Brendon Murray, Bloomberg.com (Bloomberg, July 16, 2022), .bloomberg.com/news/articles/2022-07-17/when-will-supply-chains-return-to-normal
[16] Kavya Balaraman, "Supply-Chain Squeeze: Solar, Storage Industries Grapple with Delays, Price Spikes as Demand Continues to Grow," Utility Dive, March 31, 2022, utilitydive.com/news/solar-storage-delays-price-supply-chain/620537
[17] "Renewables 2021: Analysis and Forecast to 2026," 2021, pp. 1-175. iea.blob.core.windows.net/assets/5ae32253-7409-4f9a-a91d-1493ffb9777a/Renewables2021-Analysisandforecastto2026.pdf
[18]"California State Budget, Full Summary" (Sacramento, CA, 2022), pp. 1-153, ebudget.ca.gov/FullBudgetSummary.pdf
[19] CPUC, "CPUC Ensures Electricity Reliability during Extreme Weather for Summers 2022 and 2023," California Public Utilities Commission, December 2, 2021.

Despite widespread efforts, the aforementioned summer reliability reports still find that California requires more resources and solutions to maintain reliability and meet its carbon emissions goals in the long run, without bumping into the need to deploy last-minute resources every summer. Some have raised concerns about the limitations of summer's grid patchwork approach, for example, citing issues with continued fossil fuel deployment for reliability[20] and the need to sidestep existing environmental and coastal protections.[21]

Existing opportunities for clean reliability

Many innovative and existing policy solutions exist to improve grid reliability, and California is already planning to deploy some of them up to 2045. This portion of the grid report provides an introductory toolkit of clean, renewable resources that can improve reliability in California. Each section aims to touch on the current planning targets for each technology, as well as bottlenecks to their deployment and potential near-term innovation in their deployment.

1. Battery and storage

California's energy resource plans aim for a wide buildout of both long and short duration storage, identifying them as a critical resource to replacing natural gas peaking capacity. The most recent 2021 SB 100 joint agency report[22] plans for an additional need of 53 GWs of energy storage by 2045, with 4 GW from long duration storage and the rest from battery storage.[23] The report notes that innovation and decreases in costs of storage are anticipated to replace the need for natural gas capacity used for reliability.[24] Similarly, California's Integrated Resource Plan this year approved the addition of 15 GWs of new battery storage by 2032.[25]

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[20] Borgeson, Merrian, and Victoria Rome. Letter to Gavin Newsom, Toni Atkins. "Re: Oppose Unless Amended: Opposition to DWR Investments and Project 'Certification' in the Energy Trailer Bills (AB 205/SB 122)." San Francisco, California, June 29, 2022. drive.google.com/file/d/1t2pKMs3ZZdC_QuLqZ_RhPve29LKCiqRM/view

[21] Sierra Club, CEJA, Defenders of Wildlife, CA Coastal Protection Network, Environment California, NALC, Food & Water Watch, et al. "OPPOSE THE ENERGY TRAILER BILLS (AB 205/SB 122) Clean and Reliable Energy Doesn't Mean Cutting Out Community or Environmental Protections," June 28, 2022. https://s3.documentcloud.org/documents/22073680/environmental-oppose-letter-ab-205.pdf

[22] Gill et al., 2021

[23] Ibid.

[24] Ibid, pg. 17

[25] CPUC, "CPUC Approves Long Term Plans To Meet Electricity Reliability and Climate Goals" (Public Utilities Commission Feb. 10, 2022). cpuc.ca.gov/news-and-updates/all-news/cpuc-approves-long-term-plans-to-meet-electricity-reliability-and-climate-goals

Both the IRP and joint-agency report only consider three more commercialized forms of storage types: lithium-ion batteries, flow batteries, and pumped storage.[26] The status of projects and use of other types of storage are gathered and explained in the CEC's 2018 Tracking Progress report.[27]

Storage serves a critical role in avoiding fossil fuel resource needs for peak hours and ensuring local reliability needs. Additional storage is predicted to help to reduce generation peak demand, replacing or complementing the use of peaker plants and transmission/distribution lines.[28] Local deployment of battery storage programs can also provide for local reliability with less associated emissions. For example, an upcoming community reliability program is set to provide backup power for 38 critical facilities in disadvantaged communities, as a pilot program through EPIC.[29]

Storage deployed throughout the past year and currently will be critical to this summer's reliability. Around half of the total installed capacity in the past year, 3124 MW, comes from battery energy storage systems, CAISO's summer readiness report notes.[30] This newly deployed storage will critically capture surplus solar and low-cost energy production, and will be able to help meet peak energy use periods this summer. Moreover, this year's budget allocations build upon this deployment by allocating $140 million toward long-duration energy storage.[31]

2. Demand Response

Demand response programs reduce energy use during peak demand periods through setting higher rates or providing payments to participants.[32] These programs serve as a critical reliability resource, both for every-day evening periods and in extreme heat conditions. They provide a more immediate, cost-competitive alternative than increasing generationin the near term.

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[26] A quick overview of other existing storage technologies which haven't been widespread commercialized in California can be found at the Environmental and Energy Study Institute webpage "Energy Storage Factsheet (2019)": eesi.org/papers/view/energy-storage-2019
[27] CEC, "Tracking Progress - Energy Storage," California Energy Commission, August 2018, energy.ca.gov/sites/default/files/2019-12/energy_storage_ada.pdf
[28] CEC, 2018
[29] CEC, "Optimizing Long-Duration Energy Storage to Improve Grid Resiliency and Reliability in Under-resourced Communities)," California Energy Commission, 2022, energy.ca.gov/solicitations/2021-12/optimizing-long-duration-energy-storage-improve-grid-resiliency-and
[30] CAISO, 2022
[31] "California State Budget, Full Summary", 2022
[32] CPUC, "Demand Response (DR)," California Public Utilities Commission, 2022, cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr

Adjustments made to demand response participation and additional budget allocation aim to expand the types and number of participants responding during critical emergency grid conditions. The CPUC raised the payment amount in their developed Emergency Load Reduction Program to pay participating customers $2 per kWh of energy during alerted emergency conditions.[33] The program was further modified to create another opportunity for electric vehicle owners to participate.[34]

3. Nuclear Power and Diablo Canyon

California's last nuclear plant, Diablo Canyon, has been approved to be shut down and decommissioned after its federal Nuclear Regulatory Commission licenses expire between 2024 and 2025.[35] The zero-carbon energy generated by the plant, which accounted for 8.5% of total in-state generation last year,[36] is planned to be replaced with other sources of zero-carbon resources with equal output. The CPUC has approved 5.5 GWs of qualifying capacity — with at least 1 GW of geothermal and 1 GW of long duration storage — to replace the capacity from both Diablo Canyon's and several once-through-cooling facilities set to retire.[37]

Some research has evaluated the reliability benefits of delaying the facility's closure. The Brattle Group's analysis of delaying Diablo Canyon[38] found that delaying the facility's closure would provide assurance to meeting grid reliability standards, in the case that renewables or new, dispatchable clean technologies aren't able to scale as needed. The authors find this is because maintenance of the facility's output would displace gas-fire generation and imports, particularly during night periods. The joint

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[33] CPUC, "Emergency Load Reduction Program," California Public Utilities Commission, 2022, cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr/emergency-load-reduction-program

[34] CPUC, "CPUC Ensures Electricity Reliability during Extreme Weather for Summers 2022 and 2023," California Public Utilities Commission, 2022, cpuc.ca.gov/news-and-updates/all-news/cpuc-ensures-electricity-reliability-during-extreme-weather-for-summers-2022-and-2023

[35] Decision Approving Retirement Of Diablo Canyon Nuclear Power Plant (Public Utilities Commission November 1, 2018), https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M205/K090/205090240.PDF

[36]CEC, "2021 Total System Electric Generation," California Energy Commission (California Energy Commission), energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

[37] Administrative Law Judge's Ruling Seeking Feedback On Mid-term Reliability Analysis And Proposed Procurement Requirements (Public Utilities Commission February 22, 2021), https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M367/K037/367037415.PDF

[38] Samuel Newell, Dean Murphy, and Wonjun Chang, "How Could Diablo Canyon Help Meet California's Climate and Reliability Goals?," Brattle, July 28, 2022, 2021).brattle.com/insights-events/publications/how-could-diablo-canyon-help-meet-californias-climate-and-reliability-goals-brattle-consultants-explore-in-a-new-report

MIT-Stanford study[39] similarly found that delaying the closure of the facility until 2035 would increase reliability. While the study itself didn't focus on reliability, the authors find that delaying the plant's closure until 2035 would provide the same total generation created by all of the state's peaker and once-through cooling facilities.

4. Geothermal

The SB 100 core scenario plans for the addition of 135 MW of geothermal power by 2045 (this is likely an underestimate, given the PUC's more recent procurement order; see footnote).[40,41] California has currently installed 2.6 GW of installed capacity geothermal.[42]

Geothermal energy provides uninterrupted power, unlike other variable renewables, with minimal emissions.[43] While geothermal energy does emit more carbon dioxide than other renewables over its lifespan (i.e. 91 grams per kWh compared to 10 for wind, 40 for solar, and 16-74 for biomass), they still produce relatively little compared to their fossil fuel counterparts (with 549 grams per kWh for natural gas plants).

Geothermal also potentially has an untapped opportunity to scale its dual-use to produce lithium from geothermal brines, as well. First, geothermal could be coordinated to simultaneously extract lithium in certain circumstances. Pilot projects in California are testing cost-effective lithium extraction, which could provide a critical resource for clean energy products, from geothermal brines, funded as part of the CEC's Electric Program Investment Charge.[44,45] If combined with current geothermal production, this modification could allow for geothermal facilities to be even more cost-effective and cheaper for ratepayers, the report suggests.[46]

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[39] Justin Aborn et al., "An Assessment of the Diablo Canyon Nuclear Plant for Zero-Carbon Electricity, Desalination, and Hydrogen Production" (Stanford, CA, 2021), https://energy.stanford.edu/sites/g/files/sbiybj9971/f/diablocanyonnuclearplant_report_11.19.21.pdf

[40] Gill et al., 2021

[41] The costs of geothermal dropped 30 percent since the creation of the joint agency report model, and may therefore under-identify the advantage of deploying additional geothermal capacity. The decrease in the costs drops the levelized cost of electricity for geothermal to be under some of the other resources and could have otherwise been selected for more often. Additional explanation can be found on page 92 of the report.

[42] Ibid, pg. 75

[43] John Lofthouse, Randy Simmons, and Ryan Yonk, "Reliability Of Renewable Energy: Geothermal," n.d. heartland.org/_template-assets/documents/publications/reliability-geothermal-fullreport.pdf

[44] Julie Chao, "Geothermal Brines Could Propel California's Green Economy," News Center, August 3, 2020, newscenter.lbl.gov/2020/08/05/geothermal-brines-could-propel-californias-green-economy/

[45] Susanna Ventura et al., "Selective Recovery of Lithium from Geothermal Brines," Selective Recovery of Lithium from Geothermal Brines, March 2020, energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-020.pdf

[46] Ibid, pg. 26

One of the main limitations for geothermal has previously been its higher costs of production.[47] However, in recent years, its costs have been from innovation and its baseload quality could raise the resource's economic and planning value.[48]

5. Dispatchable generation using low-carbon or zero-carbon fuels

Certain Dispatchable zero-carbon fuels can provide unique reliability potential, given their abilities to be immediately deployed and flexibly used in the grid. If paired and planned for, the electricity produced from both of these technologies can be powered using forms of lower carbon fuels.

On a larger scale, dispatchable fuels can be added on a utility grid scale to support The meeting peak load, as well as high demand during emergency conditions. Lodi Energy Center in California, as a pilot program example, will be reconfigured to burn a mixture of hydrogen gas and natural gas, reducing the overall emissions from the facility.[49]

Linear generators and fuel cells can be powered with zero-carbon fuels and used to help support local reliability. Linear generators can also provide deployable, flexible energy that can either be powered by ammonia or renewable hydrogen power, for example.[50] These generators can serve local reliability needs, similar to that of a diesel generator, but could use lower-carbon, interchangeable fuels, and have already been tested in various commercial buildings and microgrids.[51] As they have flexible and instant abilities of deployment, they similarly can be used to drive down costs or meet peak hour demand. Similarly, but with different technology and inputs, fuel cells can be powered by gas produced from biomass of various forms of renewable hydrogen technology.[52] Fuel cells also tend to have greater efficiency compared to combustible engines and can use lower-carbon fuels to provide local reliability.[53]

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[47] Herman K. Trabish, "Geothermal's Surprise: Cheap Renewables Could Keep States from Achieving Climate Goals," Utility Dive, January 27, 2020.
[48] Ibid.
[49] Wes Bowers, "Lodi to be base for hydrogen pilot program providing power to NorCal," lodine News, June 9, 2022, lodinews.com/news/article_a18bc96e-e788-11ec-80fa-7730df49a97e.html
[50] Jeff St. John, "These Generators Can Switch from Running on Fossil Fuels to Clean...," Canary Media, June 23, 2022, canarymedia.com/articles/clean-energy/these-generators-can-switch-from-running-on-fossil-fuels-to-clean-fuels
[51] PG&E, "Imagining a Cleaner Mobile Power Solution: PG&E and NextEra Energy Resources Pilot Mainspring Linear Generator at Napa County Microgrid," Business Wire, August 30, 2021, businesswire.com/news/home/20210830005457/en/Imagining-a-Cleaner-Mobile-Power-Solution-PGE-and-NextEra-Energy-Resources-Pilot-Mainspring-Linear-Generator-at-Napa-County-Microgrid.
[52] Department of Energy, "Fuel Cells," Energy.gov, accessed August 5, 2022, energy.gov/eere/fuelcells/fuel-cells.
[53] Ibid.

Conclusion

After summarizing the existing identified risk to California's grid, and identifying climate change and supply chain delay as two critical problems for California's grid buildout, this report presents a policy toolkit of reliable resources that could be served to improve demand in the near future. The technologies identified in this report — energy storage, nuclear, geothermal, demand response, and various technologies that rely on zero-carbon fuels — are not comprehensive and only begin to preview policy opportunities to improve grid reliability. Other elements, which are beyond the scope of this initial toolkit, include the deployment of renewable resources, including administrative and permitting processes, manufacturing and supply chains, data and modeling, and resources that will take longer to install, such as offshore wind and other renewables.