Clean Coalition
Making Clean Local Energy Accessible Now

Cost and Engineering Study of Puente Power Project
Cost Effective PV Solar and Storage Capacity
Clean Coalition

Doug Karpa, Ph.D., J.D.
Policy Director
August 29, 2017

DECLARATION OF

Dr. Doug Karpa

I, **Dr. Doug Karpa**, declare as follows:

1. I am an environmental and energy attorney and a Ph.D. biologist with significant experience in modeling from population biology, traffic modeling, air quality modeling, and financial modeling using statistical, computer simulation, and spreadsheet approaches. I am employed by the Clean Coalition as Policy Director on whose behalf I prepared this model as primary author and this testimony initially.
2. I received a Ph.D. in Organismic and Evolutionary Biology from Harvard University in 2000 and a J.D. with a Certificate in Environmental Law from the University of California, Berkeley in 2009.
3. A copy of my professional qualifications and experience is attached and incorporated by reference.
4. I prepared the Testimony of Dr. Doug Karpa submitted by intervenors the Center for Biological Diversity. The basis for my testimony is set forth in the testimony itself and is incorporated by reference.
5. It is my professional opinion that the prepared testimony is valid and accurate with respect to the issues addressed therein.
6. I am personally familiar with the facts and conclusions related in the testimony and, if called as a witness, could testify competently thereto.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Dated: August 30, 2017

Signed: ___________________________

At: Mill Valley, CA

Summary

The Clean Coalition conducted a study of the costs of meeting the reliability requirements of the Puente Power Project and the Ellwood peaker following the same model approach used in the CAISO study, with improvements to the modeling of PV solar and energy storage dispatch.

The results of this study indicate that a combination of PV solar and energy storage can meet the defined reliability need of the Moorpark subarea that the Puente Power Project would meet and do so far more cost effectively than the Puente Power Project natural gas peaker.

This study demonstrates:

- A PV Solar and storage system of 120 MW of groundmount solar and 75 MW of energy storage with a total capacity of 220 MWh could meet the entirety of the capacity requirement.
- This system would cost approximately $267 million, compared to more than $299 million to install the Puente Power Project, based on component cost estimates from deployed systems, the National Renewable Energy Laboratory, and Lazard's analyses of costs of solar and storage. Developing an identically sized project using only built environment construction would raise costs to approximately $370 million. The installation $299 million cost does not include costs of natural gas, operations and maintenance of the natural gas plant, which are anticipated to add approximately $16 million per year.
- A PV solar and storage system of 210 MW solar and a 130 MW/560 MWH energy storage hybrid system could replace both the Puente Power Project and the Ellwood Peaker. This system would cost approximately $406 million with groundmount solar (or up to $575 million with 100% built-environment PV solar), rather than the $1.1 billion estimated by CAISO.

Qualifications

The Clean Coalition is an advocacy organization working on policy and demonstration pilot projects developing new approaches to deploying distributed renewable energy resources. In addition to our policy advocacy, we also consult with developers, energy providers and Community Choice aggregators to assess and develop on-the-ground projects demonstrating the potential and identifying the limitations of distributed energy resources. Among other projects, the Clean Coalition has been a partner in the development of the Valencia Gardens Energy Storage Project in San Francisco, the Hunter's Point Community Microgrid project in San Francisco, the Peninsula Advanced Energy Community Project, which addresses policy, permitting, and financing barriers impeding the development of Advanced Energy Communities, and the project analysis and staging for the AES Kaua'i PV Solar and storage project, which provides 11% of the island's energy at a cost of 11 cents per kWh. The Clean Coalition has legal, policy, economic and engineering expertise on staff, all of which was brought to bear in this study.

As the study's principal author, I relied on modeling expertise from having earned a Ph.D. in evolution, population biology and climate change biology at Harvard University. I have also trained in rate design and energy policy in the context of my law degree at the University of California at Berkeley. I have also represented energy clients on legal and technical issues with the national law firms Bingham McCutchen and Holland & Knight. My CV is attached to this testimony.

The study results were also reviewed by our Economics and Policy Director, Sahm White, who has over 20 years' experience in economic and environmental policy, with over 200 filings before public utility and energy commissions. Prior to joining the Clean Coalition, Mr. White held positions as a Senior Research Consultant to the Center for Ecoliteracy, and as Technical and Policy Analyst in the development of the Ecological Footprint. Subsequent to his graduate work in the Social Studies of Science and Technology at MIT, Mr. White completed coursework for an MS in Environmental Studies from San Jose State University. The study results were also reviewed by the Clean Coalition's Program Engineer, Bob O'Hagan. Mr. O'Hagan oversees the development of tools and processes that allow high penetrations of distributed generation while maintaining or improving distribution grid reliability. He started his career designing telecommunications and test equipment then transitioned into operations management for both public companies and startups. He has now moved into clean energy and power systems. Bob has an MS from Stanford in Electrical Engineering and an MBA from Santa Clara University. He received his BS in Electrical Engineering from Southern Methodist University.

Issues with the CAISO study

While the Clean Coalition commends CAISO for its willingness to prepare—and excellent work in presenting—a highly valuable study demonstrating that distributed renewables are technically capable of meeting the reliability needs of the Moorpark Subarea, we did identify a number of deficiencies in the study, particularly in the area of cost assessment.

1) CAISO failed to evaluate far more cost effective DER approaches to meeting reliability needs than the all-batteries scenarios developed in Scenarios 1 and 3. An all-battery approach is quite possibly the most expensive conceivable way to meet the reliability need using DER. Real-world applications have shown that PV solar and co-located storage represent far more financially viable approaches to meeting DER needs. The CAISO study suggest these "scenarios address a range of preferred resources including storage, and as the ISO added storage as necessary until reliability requirements were achieved, adding additional scenarios with increased storage in particular is redundant given the study methodology." While this is roughly true from an engineering perspective, from a real-world cost estimation perspective it is manifestly false. We therefore felt it necessary to evaluate the most cost-effective alternatives to fully evaluate the range of reasonable cost estimates for a DER replacement to the Puente Power Project and Ellwood Peaker.
2) The CAISO models employed an unrealistic profile of PV solar output that reduced the model dispatch by roughly half. CAISO modeled PV solar as producing no power before noon or after 4 pm, and producing full nameplate capacity between those hours, which is not remotely accurate. Furthermore, CAISO modeled battery dispatch as a binary profile of either zero or full nameplate dispatch. This has the result of overestimating the amount of battery

necessary to meet a given dispatch profile by up to 20%. Our load scenarios therefore adjust the CAISO study approach to incorporate more realistic PV solar and battery dispatch profiles.

3) The CAISO study dismisses using advanced inverters from PV solar or storage for any voltage support that could be provided in excess of the minimums required for those units. Thus, the voltage limits reported in the CAISO study should be viewed as overestimates, and the required DER as a maximum deployment needed. The Clean Coalition study does not evaluate the degree to which excess battery capacity in particular could reduce voltage limits.
4) The CAISO model also employed unrealistically high component costs, especially for battery storage. The CAISO study cites a Navigant study for its component costs, while ignoring industry standard sources, such as the National Renewable Energy Laboratory of the Department of Energy or Lazard's levelized cost reporting. In fact, the Navigant study reports a cost of $2.64 per watt based on solely commercial and residential installation, which is comparable to estimates in industry standard evaluations for built environment installed costs. However, this source ignores any potential for groundmount PV solar, which has average installed costs of $1.43 per watt. Any realistic development approach would certainly involve a combination of installation locations. Our study therefore updates the CAISO cost estimates to include the range from a 100% groundmount installation to a 100% built environment installation.
5) The Navigant study cited by CAISO also cites data from 2014 for Energy storage costs, which are wildly too high for any installation in 2018 or later. Battery costs have been falling by 11% a year or 40% since that time. We therefore felt it necessary to model costs using up to date cost estimates for installation in a 2018 time frame. On current trends, a 2020 installation may well see battery prices under half of what CAISO estimates. We update the CAISO study to use current battery prices and to adjust for price trends to 2018.
6) The CAISO study vastly overestimates the cost of implementing Demand Response. Typical Demand Response (DR) is deployed by load shedding contracts by shifting load to off peak hours, not by installing expensive behind the

meter battery installations. As a result, the typical costs estimated by the Lawrence Berkeley National Laboratories for the Moorpark area[1] would be a small fraction of the capacity costs used by CAISO. Although the LBNL study suggests costs between $50 and $100 per MW of DR, we use $100 in this study (in contrast to the effective cost of $485 used by CAISO).

7) The CAISO cost estimates also ignore critical financial aspects of DER development. In particular, PV solar and storage facilities receive a 30% investment tax credit which is a fundamentally important aspect of the installed cost and Power Purchase Agreement (PPA) price. This represents not only a substantial reduction in cost to ratepayers, but also presents a key engineering constraint in that some 70% of the charging of the energy storage must come from the co-located PV to qualify for the tax credit. In addition, depreciation scheduling and other financial approaches can reduce effective installed costs further. Our update of the CAISO model only includes the impact of the ITC here.

8) The CAISO cost estimates also fail to include the costs of fuel and operations and maintenance of the natural gas peaker plants in comparing the cost of peakers with the costs of DER. These additional costs would run on the order of $16 million per year, and would raise the costs of the Puente Power Project by some $870 million in nominal terms over thirty years (*i.e.*, before applying inflation, fuel cost projections, or discounting to estimate net present value). The comparable calculation for the PV Solar and Storage facility would run between $430 million and $530 million. We provide a summary of these additional costs as a supplement to the CAISO Study.

Study Methodology

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[1] Alstone, P, *et* al (2017) Demand Response Potential for California SubLAPs and Local Capacity Planning Areas An Addendum to the 2025 California Demand Response Potential Study, Lawrence Berkeley Labs, available at www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442453027. Note: the Demand Response Auction Mechanism pilot also appears to be delivering demand response at approximately $100/kw-year. See, St. John, "Ohmconnect wins deal to supply 4.5MW of behavioral demand Response to SDG&E," Green Tech Media, May 7, 2017, *https://www.greentechmedia.com/articles/read/inside-ohmconnects-4-5mw-behavioral-demand-response-contract-with-sdge*

The Clean Coalition study is designed to add two additional scenarios to the CAISO study to model the required size of a PV solar and storage system to meet the reliability needs identified in the CAISO study. Our scenario *4* represents replacing only the Puente Power Project and uses the voltage limits and “Remaining Load to Serve” profiles taken from Scenario 1 of the CAISO study. Our Scenario 5 represents replacing both the Puente Power Project and the Ellwood Peaker and uses the voltage limits and “remaining Load to Serve” from CAISO’s scenario 3. In effect, our study merely replicated Scenarios 1 and 3, but did so using PV solar and Storage as incremental resources instead of the IFOM batteries modeled in the Appendix of the CAISO study. The methodology of the model construction is as follows:

1) This model deploys PV solar and storage to meet the load required to meet the reliability requirements defined by voltage support limits and power flow analyses identified in the CAISO study. These CAISO identified limits represent extrapolations of needed load to serve in 2022 from 2014, 2015, and 2016 load profile as the basis for each scenario. This study uses the same set of load profiles. Our model of using PV solar and storage takes the "Remaining Load to Serve" profile from CAISO’s Scenario 1 to model a replacement for the Puente Power Project alone (Scenario 4), and the profile from Scenario 3 to model a replacement for Puente and Ellwood jointly (Scenario 5).
2) Scenarios 4 and 5 both deploy an identical package of “base incremental distributed resources” (PV solar, energy storage and Demand Response) as assumed in the CAISO study.
3) Unlike in the CAISO study, the PV component for both the “base incremental distribute resources” and the incremental PV solar follows a daily profile based on CAISO data to deliver generation factors profiles. Thus, in our model, PV solar dispatches some fraction of nameplate capacity throughout daylight hours.
4) The model is designed to allow a range of total PV solar sizing in order to optimize the cost of a PV solar and storage system under various component costs.

5) Demand response resources are deployed to the highest loads in consecutive hours after PV solar dispatch is deployed, as CAISO appears to have done. Typically, these fall within the hours of 3 to 9 p.m., much as in the CAISO study.
6) Once PV solar and Demand Response resources are deployed, energy storage discharge required is calculated to meet the full remaining load plus an additional 15 MW. The 15 MW margin is set based on the maximum increment needed for the Power Dispatch validation in Iteration 2 (see CAISO study, Appendix, Table A-2b, page 33). This means the ES should meet all power dispatch requirements (even if it's significantly overbuilt). However, a full power flow analysis is beyond the scope of this study, so we assume that the load limits identified by CAISO hold independent of the technology dispatching power into the grid.
7) The total Energy Storage dispatch, rounded up to the nearest 5 MWH is taken as the total size of the battery storage component. The highest energy storage dispatch rounded up to the nearest 5 MW is taken as the required dispatch capacity. PV solar in excess of "Remaining Load to Serve" is assigned to energy storage charging. Total PV charging is calculated as a check that the system in fact charges the Energy Storage at least 70% from PV solar to allow for application of the federal Investment Tax Credit. Note, where the total PV charging is less than the discharge, the energy storage system could also charge during night time hours or with larger PV installations at marginal cost. Given that the load to serve during nighttime hours is generally negative, nighttime charging was not modeled.
8) The Component Cost model uses the same approach to cost estimation as the CAISO model, albeit with improved cost estimates derived from Lazard[2] and Department of Energy[3] Estimates. Also, improved demand response costs were included as described above. The Cost component model calculates the total system cost based on the PV solar and storage components sized to meet the

[2] Lazard's Levelized Cost of Energy Analysis, v. 10.0 (December 2016). https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf; Lazard's Levelized Cost of Storage, v. 2.0 (December 2016) https://www.lazard.com/media/438042/lazard-levelized-cost-of-storage-v20.pdf.

[3] National Renewable Energy Research Laboratory, U.S. Solar Photovoltaic System Cost Benchmark Q1 2016, https://www.nrel.gov/docs/fy16osti/67142.pdf, National Renewable Energy Research Laboratory, Economic Analysis Case Studies of Bwettery Energy Storage with SAM, https://www.nrel.gov/docs/fy16osti/64987.pdf.

Remaining Load to Serve. Component costs are $1.43 per watt for PV and $400 per MWH for Energy Storage, based on published 2016 estimates from the National Renewable Energy Laboratories and Lazard's levelized costs for PV and storage. The cost of demand response was taken as $100 per kw-yr. The 30% ITC is taken and continued cost declines of 11% a year for energy storage from 2016 to 2018 are taken to account based on trends over the last five years.

9) The smallest system that could meet the requirements of all three load profiles (typically based on the 2015 profile) was selected and the lowest cost system configuration was selected as the least cost estimate for a PV solar and storage system to meet the configuration needs.
10) In addition, a calculation of the fuel and operations and maintenance costs was included. Based on the 2016 costs of fuel and maintenance from Department of Energy outlooks, the annual costs of Puente were estimated at $16 million per year. The maintenance costs of the PV solar and storage system were estimated to be $6 million per year, although cost estimates for system maintenance are considerably more variable and more anecdotal for solar and storage maintenance.

<u>Conclusion.</u>

Realistic cost estimates of DER systems to meet the needs of Puente Power Project and the Ellwood Peaker are vastly lower than the estimates provided by CAISO using comparable methodologies. In fact, it appears that a PV solar and storage system would have a lower installed cost than the Puente Power Project even before incorporating the costs of fuel, operations, and maintenance. Our findings are:

- A PV Solar and storage system of 120 MW of groundmount solar and 75 MW of energy storage with a total capacity of 255 MWh could meet the entirety of the capacity requirement.
- This system would cost approximately $267 million, compared to more than $299 million to install the Puente Power Project, based on component cost estimates from deployed systems, the National Renewable Energy Laboratory, and Lazard's analyses of costs of solar and storage. Developing an identically-sized project using only built environment construction would

raise costs to approximately $370 million. The installation $299 million cost of the Puente Power Project does not include costs of natural gas, operations and maintenance of the natural gas plant, which are anticipated to add approximately $16 million per year.

- A PV solar and storage system of 210 MW solar and a 130 MW/560 MWH energy storage hybrid system could replace both the Puente Power Project and the Ellwood Peaker. This system would cost approximately $406 million with groundmount solar (or up to $575 million with 100% built-environment PV solar), rather than the $1.1 billion estimated by CAISO.
- The nominal cost of the Puente Power Project, including 30 years of fuel, operations and maintenance would be $866 million, compared to $430 million for the PV solar and storage system modeled here. (Note: This estimate takes 2016 costs and does not incorporate inflation, price forecasts, or discount rates, and so represents a heuristic for evaluating relative costs rather than a robust cost forecast.)