Supplemental Testimony regarding battery operations and maintenance costs and costs of addressing battery degredation.

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Clean Coalition

September 7, 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: September 7, 2017

Signed: ______________________________

At: San Francisco, CA

1. **Operations and Maintenance costs of batteries are low and would add approximately $35 million over 30 years.**

Since industrial lithium battery deployments are relatively new, operational experience with operations and maintenance cost over a 30 year period do not entirely exist. However, several reliable estimates have been made based on our understanding of the requirements of battery systems generally. Generally, operations and maintenance costs are comprised mostly of maintenance of HVAC systems to maintain operational temperatures, maintenances of mechanical and electrical connections, and cabinet maintenance. Based on a 2017 survey by PacificCorps for the 2017 Integrated Resources Planning Process, these are estimated to fall within the range of $6-$11 per kW per year.[1]

Based on these costs, our estimate of the total operations and maintenance costs would be increased by approximately $20 million in real dollars (assuming a discount rate equal to inflation to represent the ratepayer discount rate) for the Puente Replacement system and by some $35 million for the Puente and Ellwood replacement projects.

Table 1 – Operations, maintenance, and fuel costs for Puente Power Project and the Puente Replacement solar+storage alternative (Scenario 4) and the Puente and Ellwood Replacement solar+storage alternative (Scenario 5)

	Puente Power Project	**Solar+storage (Puente Only)**	**Solar+storage (Puente + Ellwood)**
Operations & Maintenance ($/MWH (gas) $/kW (solar))	$4.72	$50.00	$50.00
Fuel Costs ($/MWH)	$28.22	$0.00	$0.00
Nameplate (MW) (natural gas, solar)	262	130	220
Operating Hours per year	2,190		
MWH/ year	573,780		
Annual O&M and Fuel	$18,900,313	$6,500,000	$11,000,000
Battery Capacity (MW)		75	130
O&M Cost per kw		$9	$9
Annual battery O&M	$18,900,313	$675,000	$1,170,000
Installed cost	**$299,000,000**	**$267,619,333**	**$406,458,621**
Total 30 year cost	**$567,009,396**	**$215,250,000**	**$365,100,000**
Total cost	**$866,009,396**	**$482,869,333**	**$771,558,621**

[1] M. Kleinberg, KEMA, Inc. (2017) Battery Energy Storage Study for the 2017 IRP, at 19, available at http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Integrated_Resource_Plan/2017_IRP/10018304_R-01-D_PacifiCorp_Battery_Energy_Storage_Study.pdf

Including the more than $550 million in fuel, operations, and maintenance costs (without accounting for finance costs) associated with Puente alone, clearly the lifetime costs including installation costs, the solar+storage facility to replace Puente would cost roughly $483 million, compared to the more than $860 million for Puente. Replacing Ellwood and Puente together would cost some $771 million over 30 years, which is less than the cost for Puente alone. We do not have costs estimates for the Ellwood installation or the operations and maintenance costs of Ellwood in addition to those of Puente.

2. Battery degradation can be addressed through oversizing batteries by 40%

Engineering studies of the lifetime of industrial lithium-ion batteries suggest that at 25C, 4 cycles per day suggest a 30% capacity loss after 15 years.[2] These conditions represent more intensive use than the batteries in this application where many days, including winter days, may not require any battery discharge whatsoever and so represent the maximal capacity degradation rate.

Although parties have suggested a complete replacement at the end of the 15 year minimum lifetime, this ignores the substantial residual capacity that would be present in the batteries at that time. Instead, a more cost-effective approach would be to oversize the batteries by 40%, adding some $22,600,000 to the installed cost of the Puente Power Project replacement (for a total of $290 million, or still less than the installed cost of the Puente Power Project. Restoring the overall capacity to 140% to allow degradation to 100% by the end of the 30 year window would require installation of additional capacity, rather than complete replacement. If costs continue their long term decline this additional capacity would add under $5 million in 2017 dollars to the total 30 year project costs. For the replacement for Ellwood and Puente together, a similar strategy of battery oversizing and supplementation would add $50 million to the installed cost and another $9 million in 15 years time to supplement the existing battery capacity. Even with this additional $59 million in costs, the 30 year cost of the Ellwood and Puente replacement would still cost ratepayers less than the Puente Power Project alone. These of course do not account for the development of entirely new battery technologies leading to more cost effective and efficient replacement technologies in 15 years' time.

3. 30-year mortality and disease costs

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[2] M. Abe, *et al.* (2012) Lifetime Prediction for Heavy-duty Industrial Lithium-ion Batteries that Enables Highly Reliable System Design. *Hitachi Review* **61**: 259-263

The full costs of natural gas plants over 30 years must of course include the additional burden of mortality and disease borne by ratepayers in the vicinity of the project. Although costs vary according to technology and conditions, one can develop at least a qualitative assessment of the likely costs from using a polluting power source over a non-polluting source. In addition to the O&M and Fuel costs, natural gas plants also incur substantial mortality and disease costs that must also be incorporated in to cost accounting of the costs comparisons of the Puente Power Project and Ellwood refurbishment with solar+storage alternatives. Recent studies indicate that natural gas plants cause approximately at 2.8 deaths, 30 serious illnesses, and 700 minor illnesses per TWh.[3] Assessing a mortality cost of $7,000,000 per mortality, this would add some $337 million in costs to the Puente Power Project and some $12,700,800 to the costs of Ellwood, bringing the costs of Puente Power Project to over $1.2 billion dollars. Although the per patient cost of serious and minor illness is variable, these total costs are likely lower per patient year. (Assuming an average of $3,100 per patient per year,[4] the total illness costs would add approximately $40 million to the costs of Puente.)

Table 2 – Additional mortality and illness costs from Puente and Ellwood.

	Puente	Ellwood
Nameplate (MW)	262	54
Operating Hours per year	2,190	400
MWH/ year	573,780	21,600
30 years (TWH)	17.21	0.65
Additional deaths	48	2
Additional serious illnesses	516	19
Additional minor illnesses	12,049	454
Mortality costs	$337,382,640	$12,700,800

4. Conclusion

Our initial testimony model compared solar+storage options to the Puente Power Project and Ellwood Peaker under the same set of installed cost assumptions as that used by CAISO. Employing a more rigorous analysis of the 30 year real costs, including O&M costs, fuel, battery degradation costs, and mortality and illness costs over 30 years indicates that not only would a solar+storage option have a lower installed cost, but would have a sharply lower total cost than the Puente Power Project.

Attachments include all cited studies.

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[3] A. Markandya, P. Wilkinson (2007) Electricity Generation and Health. *Lancet* **370**:979-90

[4] C. Nunes, Pereira, and Morais-Almeida (2017) Asthma costs and social impact *Asthma Res Pract.* **3**: 1.

1) M. Kleinberg, KEMA, Inc. (2017) Battery Energy Storage Study for the 2017 IRP

2) M. Abe, *et al.* (2012) Lifetime Prediction for Heavy-duty Industrial Lithium-ion Batteries that Enables Highly Reliable System Design. *Hitachi Review* **61**: 259-263

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4) C. Nunes, Pereira, and Morais-Almeida (2017) Asthma costs and social impact *Asthma Res Pract*. **3**: 1.