A Benefit-Cost Analysis of Fully Funding Residential Solar-Paired-Battery Storage Systems in California's High Fire-Threat Districts

By Camila Astorga, Adam Buchholz, Jack Chang and Juliet Flores Wilson

Public Policy 259

Fall 2019

Table of Contents

Methodology and Key Findings

This benefit cost analysis examines the "Batteries for Wildfire Resilience" program (subsequently referred to as "the Program"), which aims to increase energy resiliency statewide by covering 100% of solar-paired-battery storage system (hereinafter, also, "systems") costs for all households located in Tier 2 & 3 High Fire-Threat Districts (HFTD) throughout California.

The program would be funded by about $400 million in unused funds in the Self-Generation Incentive Program (SGIP) budget as of September 2019.

The analysis examines the costs of purchasing, installing, maintaining and disposing of the system after its 20-year operational life. It then weighs those costs against system benefits - avoided blackouts, electricity generation by the household systems, avoided electrical grid upgrades due to increased capacity and, finally, greenhouse gas emissions not produced by the grid due to energy generation displaced by the new household systems.

Our analysis found the implementation of the Program would yield a social net benefit of ≈$93.2 million within its budget constraints, which is enough to cover costs for ≈9,000 residential customers in California's HFTD's.

A Monte Carlo simulation of key parameters in this study returned positive results. Assuming a social discount rate of 3%, the simulation determined the Program would yield a mean net present value (NPV) at the household level of ≈$10,800 with a 95% confidence interval of approximately -$5000 to $27,000 per household.

Background

Public Safety Power Shutoff (PSPS) events have cut power to millions of households throughout the state of California in 2019. While researchers are working to determine the full economic cost of the shutoffs, initial estimates have pegged the cost of a single Oct. 9-12 Pacific Gas & Electric (PG&E) shutoff at $1 billion to $2.6 billion.[1] In October and November of 2019, additional shutoffs impacted customers of Southern California Edison and San Diego Gas & Electric.

As a result of those shutoffs, energy resiliency has become a priority for policymakers, advocates and residents throughout the state. Many households, particularly more affluent ones, are turning to renewable energy generation and battery storage as tools for riding out future PSPS events.[2] The state of California already offers subsidies for households of all income levels to purchase and install solar panels as well as energy storage through the California Public Utility Commission's (CPUC) SGIP program, which is funded by a flat fee

[1] Wolfram, C. (2019). "Measuring the Economic Costs of the PG&E Outages." Energy Institute Blog. Accessed at https://bit.ly/2PPToUK on December 11, 2019.
[2] Sylvia, T. (2019). "Power shutoffs cause a battery boom in California." *PV Magazine*. Accessed at https://bit.ly/36Ce21z on December 11, 2019.

charged to utility customers throughout the state. Current subsidy levels fund up to 80% of the purchase and installation costs for such energy systems, with different subsidy levels available based on household income.

Policy Description

The “Batteries for Wildfire Resilience” program provides a full subsidy for solar-paired battery storage systems to residential households located in Tier 2 & 3 HFTD[3] zones - an estimated 5 million people or 1.7 million households.

The program would subsidize the full cost of the purchase and installation of equipment (batteries, electrical system upgrades, permitting costs) as well as maintenance and end-of-life disposal costs of the system for residential customers. There is no income threshold designed into the program.

Program funding comes from the approximately $400,790,000 in SGIP funds that were unused as of September 18, 2019.[4] The majority of those unused funds come from generation, large-scale storage and non-residential storage equity budgets.

The program would be administered by utility companies and overseen by the CPUC.

Standing

Climate change impacts are global while its causes are often local. As a result, climate change represents a particularly consequential case of the free rider problem. States, nations and other actors can theoretically benefit from the carbon-saving actions of other actors without doing anything to reduce their own carbon emissions. At the same time, what other actors do can impact a state or nation regardless of that jurisdiction’s actions.

For this reason, the U.S. Environmental Protection Agency (EPA) adopted a global Social Cost of Carbon (SCC) under the Obama Administration. In its technical documentation, the EPA explained: “(E)missions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States—and conversely, greenhouse gases emitted elsewhere contribute to damages in the United States. Consequently, to address the global nature of the problem, the SC-CO2 must incorporate the full (global) damages caused by GHG emissions.”[5]

This report uses the U.S. EPA’s SCC estimate of $42 per ton of CO2 and defines standing to include everyone in the world. That said, this program is available only to people in California,

---

[3] HFTD areas identified as at extreme risk (Tier 3) and elevated risk (Tier 2) for wildfires by CPUC Decision 17-12-024 December 14, 2017. Accessed at https://bit.ly/2E0p6t7 on December 8, 2019.
[4] CPUC. (2019). “Decision Establishing a Self-Generation Incentive Program Equity Resiliency Budget, Modifying Existing Equity Budget Incentives, Approving Carry-Over of Accumulated Unspent Funds, and Approving $10 Million to Support the San Joaquin Valley Disadvantaged Community Pilot Programs.” California Public Utilities Commission. Accessed at https://bit.ly/2Psk9yq on December 8, 2019.
[5] US EPA. (2017). “Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis.”

and the majority of the program's costs and benefits affect Californian ratepayers and program participants. The global definition of standing used here does not significantly affect the final economic costs and benefits of this program.

Description of Costs and Benefits

Summary of Costs and Benefits

This analysis attempts to explore all significant negative and positive impacts of the "Batteries for Wildfire Resilience" program. Using parameters for each of these impacts, we monetized them in present dollars as shown below in Table 1.

Table 1. Benefits and Costs

Benefits	USD in millions[6]	Costs		Net Value
Avoided Blackouts	$108.4	*Battery and Solar Panels*[7]	$314.3	
Generated Electricity	$355.8	*Operations and Maintenance Costs*	$24.2	
Grid Benefits of Battery Installation	$8.5			
Avoided CO_2 Emissions	$14.5	*Disposal Costs*	$53.3	
		CO_2 Emissions from Disposal	$2.42	
Total	$487.2		($394.2)	**$93**

The costs and benefits shown here are described in detail in the following section.

Benefits

Avoided blackouts - reduction in the loss of earnings, material damages and immaterial damages

Avoiding power outages can decrease both material and immaterial harm caused by losing electricity for extended periods. For example, power outages can result in lost wages for employees and lost productivity for employers. Power outages can also damage material goods such as food and medication that need to be refrigerated.

[6] 3% discount rate, $42/ton social cost of carbon
[7] Purchase and installation costs.

Power outages can also inflict intangible harm such as increasing the mental burden of navigating daily tasks without electricity. The value of these damages is by definition resistant to exact estimates and usually must be inferred through contingent valuation or shadow prices. In this analysis, we estimate a consumer's Willingness to Accept (WTA) amount to avoid a power interruption by using figures from a national opinion survey of more than 500 U.S. residents about consumers' attitudes toward power outages conducted by Bates White Economic Consulting.[8] The survey included questions about customers' willingness to pay to avoid outages and their willingness to be paid to volunteer for lengthy power interruptions.

Extra energy generated

The Program will incentivize the installation of more solar-paired-battery storage systems that will add energy to the state's total generation system. The unknown factor is whether curtailment of electricity will occur elsewhere if electricity is generated by hundreds of newly installed systems subsidized by the Program. Without curtailment elsewhere, the addition of electricity would represent added value to the state. Even with curtailment, society would exchange potentially lower cost and cleaner solar energy for higher cost and dirtier fossil fuel-based electricity. Either scenario, with or without curtailment, would benefit society over the residential systems' 20-year lifetime.

Avoided costs for the electrical system

Batteries and solar panels provide a variety of benefits to the grid in addition to the clean energy they produce and store. That added energy, especially if dispatched during peak-use times, can help system operators avoid adding generation capacity such as peaker-plants as well as maintenance to distribution and transmission networks. Such household systems also can help maintain grid frequency and other ancillary services to the electrical grid. We monetize this benefit by introducing estimates from a "2017 Advanced Energy Storage Impact Evaluation" ITRON report commissioned by the CPUC.[9] This analysis assumes that this impact generates one-time savings in avoided grid capacity costs.

Reduction in CO_2 emissions

"Batteries for Wildfire Resilience" would help thousands of households produce clean energy that could replace grid electricity generated from fossil fuel sources such as natural gas and coal. This replacement would help the system reduce overall emissions of CO_2 and other greenhouse gases. This report monetizes emissions savings by focusing on carbon dioxide since economists have most commonly assigned a dollar value to tons of carbon dioxide.

---

[8] King, Kathleen. (2012). "Willingness to Pay to Avoid Outages: Reliability Demand Survey." Bates White Economic Consulting.
[9] ITRON, "2017 Advanced Energy Storage Impact Evaluation," Figure 1-17.

Costs

Battery and solar panels

Our analysis includes the cost of purchasing and installing solar-paired-battery storage systems, electrical system upgrades and permitting costs. The Program would subsidize the up-front purchase of the system from a vendor of the participant's choice. The analysis monetizes this cost by using the market value of such equipment and services.

Operations and maintenance costs

The Program subsidizes annual maintenance costs for the system over its estimated 20-year operational life. These costs include cleaning the solar panels and repairing common wear-and-tear to the PV system.

Direct costs and negative externalities produced by the end of life disposal of batteries and panels

The subsidy program provides a one-time disbursement of funds covering the cost of disposing of the system, which generates direct costs and negative externalities. The main cost comes from recycling the solar panels and batteries. The one-time recycling and disposal process also generates approximately the same amount of greenhouse gas emissions as operating the system over its lifetime.[10]

Impacts Not Included

This analysis does not include the impacts of non-greenhouse gas emissions such as fine particulate matter or nitrogen oxide produced by fossil fuel-powered energy generation displaced by renewable energy systems. Such pollutants are not typically monetized, unlike carbon dioxide. And while these costs could be calculated via health impacts to neighboring populations, those effects are highly dependent on the location of the energy generation facilities and the proximity and types of populations living nearby.

Quantification and Monetization of Benefits and Costs

Summary of Costs and Benefits Monetization

The table below summarizes the parameters and values ranges used to monetize each of the benefits and costs previously described. The table also specifies the distribution used to predict their impacts through a Monte Carlo simulation.

[10] Li, X., Chalvatzis, K., Stephanides, Ph., "*Innovative Energy Islands: Life-Cycle Cost-Benefit Analysis for Battery Energy Storage*" in Sustainability 2018, 10, 3371. Accessed at https://www.mdpi.com/2071-1050/10/10/3371 on December 14, 2019.

Table 2. Parameters, value ranges, and distributions used for the Monte Carlo simulation

Benefits	Low	High	Midpoint / Mode	Distribution
Avoided Blackouts	$183	$1,500	$841	Triangular
Grid benefits of Battery installation[11]	$540	$1,485	$1,013	Triangular
Value of Generated Electricity[12]			$2,400	Uniform
Avoided CO_2 Emissions[13]	$74	$148	$111	Triangular
Costs	**Low**	**High**	**Midpoint / Mode**	**Distribution**
Battery and Solar Panels[14]	$26,900	$47,490	$37,365[15]	Triangular /Uniform[16]
Maintenance per kW of installed solar capacity	$20	$30	$25	Triangular
Disposal costs			$11,120	Uniform
CO_2 Emissions from Disposal[17]			$517	Uniform

Discounting

The program has a finite time horizon of 24 years. Subsidies will only be allocated and batteries will only be distributed during the first four years of the program, although impacts will be distributed throughout the 20-year operational life of a typical residential solar-paired-battery

---

[11] Including reduced need for transmission upgrades and maintenance.
[12] Generation ranges from 8000 to 16,000 kWh per year, for a mean of 12,000 kWh valued at $0.23 per kWh
[13] Annual, valued at $42 per ton in this table
[14] Purchase and installation costs.
[15] Note that this number includes the average cost of a 14kW battery ($9,240) plus the cost of an average 7.5kW solar panel system (7.5 kW*$3,750/kW).
[16] Note that different sub-parameters compound the cost of batteries and solar panels. The cost of a battery will be uniform since all solar systems (independently if they are 5 or 10 kW) will use the same 14kW battery for storage. Likewise, the cost of purchasing and installing a PV system will be uniform per panel. However, the size of the system may vary from 5 to 10 kW per household. It is for this last sub-parameter that we allow for variation in the Monte Carlo simulation.
[17] Valued at $42 per ton in this table.

storage system. Thus, the full impacts caused by a system installed on year 4 of the implementation phase could be observed only 20 years from its installation or 24 years into the program.

This analysis calculates the net value of the program at the household level since all observed impacts are produced by a single solar-paired-battery storage system. As a result, the analysis calculates a net present value (NPV) that comprises each of the following impacts in today's dollar value per household, based on the following schedules.

1. Initial costs - occur only when the system is purchased and installed by a household.
2. Disposal costs - occur only at the end of the 20-year operational life of the solar-paired-battery storage system when it is to be removed from a household.
3. Yearly costs - constant costs that occur annually.
4. One-time benefits - occur only at the time the system is purchased and installed by a household.
5. Yearly benefits - constant benefits that occur annually.

Benefits

Avoided blackouts - reduction in the loss of earnings, material damages and immaterial damages

The analysis addresses loss of earnings, material damages and immaterial damages as one category to align with most of the literature on this topic, which does not distinguish among them as separate parameters.

Costs of power outages vary by the number of customers impacted and the duration of the outage. The relationship between outage length and damages caused is likely not linear — for example, a family may be willing to pay more than twice as much to avoid a 48-hour outage than a 24-hour outage as food items may begin spoiling after the first day.

The 2012 paper by Bates White Economic Consulting found a wide range of bounds for the WTP and WTA. The survey asked 500 U.S. residents nationwide if they would be willing to undergo an outage of two days if they were paid sums ranging from $250 to $1,000 per interruption. Respondents were also asked if they were willing to pay from $10 to $40 per month to ensure that they would never experience an outage of more than four hours.

Respondents said they would pay $168 to $228 per year to avoid two to three 48-hour outages per year,[18] but would need to receive $2,325 to $2,750 to accept those outages. This ratio of WTP to WTA is relatively far from typical ratios, so the analysis halved the WTA value and converted it to 2018 dollars using the Consumer Price Index (CPI) for all urban consumers.

[18] King (2012).

As context, the average length of the PG&E power shutoffs that occurred from October 26 to 29 was about 55 hours.[19] About 941,000 unique customers lost power during the event, roughly half of the total estimated households located in Tier 2 and 3 fire zones in California. By contrast, before 2019 (when utilities began implementing PSPS events), an average of 558 households per outage in the state lost power for 34 hours.

Extra energy generated

Estimating the value of a generated kWh of electricity is complex. Wholesale electricity prices vary significantly depending on the time of day, and residential prices incorporate a variety of expenses unrelated to the cost of production, including fees for nuclear decommissioning and transmission costs. However, given that electricity prices are slated to increase in coming years, this analysis uses the current residential price of electricity, $0.23 per kilowatt-hour. This may be an overestimate today, but is likely to under-estimate electricity prices in the future due to anticipated investments in transmission and distribution line resiliency. This assumption was tested in our sensitivity analysis (see Appendix A).

The average home solar system produces 8,000 kilowatt hours to 16,000 kilowatt hours per year.[20]

Avoided costs for electrical system

This analysis estimates avoided grid costs using numbers from a report commissioned by the CPUC, prepared by the consulting group ITRON.[21] The analysis uses the study's high and low estimates of $110 and $40 per kW of rated battery capacity. This is a rough estimate given the complexity of the electrical grid and the fact that these benefits are highly variable depending on the location of the solar-paired storage.

Reduction in CO2 emissions

This analysis estimates a monetary amount for avoided CO_2 emissions by multiplying the average energy use per system with the carbon intensity of California's electrical grid and multiplying that by the Obama Administration's SCC estimate of $42 per ton of carbon at a 3% discount rate.[22]

These were estimated by assuming that every kilowatt-hour generated by solar panels saves an amount of carbon equivalent to the average marginal CO2 output per kilowatt-hour of the California electrical grid. This was estimated at .00022 tons per kWh. For CO2 savings from

---

[19] PG&E. (2019). "PG&E Public Safety Power Shutoff Report to the CPUC." https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/News_Room/NewsUpdates/2019/Nov.%2018%202019%20PGE%20ESRB-8%20Report%20for%20Oct.%2026%2029%202019.pdf

[20] Sunrun, "How much Will My Electric Bill Be With Solar Panels?", Accessed at https://bit.ly/34lx9LF on December 8, 2019.

[21] ITRON.

[22] EPA. "The Social Cost of Carbon." Accessed at https://bit.ly/2YLhzba on December 8, 2019.

batteries, we used the minimum requirement recently imposed by the California Public Utilities Commission of 5 kg saved per kilowatt of rated capacity. Therefore, each battery should save at least 37.5 kilograms of CO2 per year. This represents a lower bound of possible savings, but it is a reasonable estimate given that batteries have historically tended to *increase* CO2 emissions because consumers were not charging their batteries during off-peak times.[23]

Costs

Battery and Solar Panels

This analysis assumes a high range of 10 KW and a low range of 5 KW for solar-paired battery systems and uses an average amount of 7.5 KW assuming an equal distribution among the two system sizes.[24] The analysis assumes $3,750 per KW in total installation and purchase costs for an average sized system.[25]

Operation and Maintenance Costs

This analysis assumes annual maintenance costs of $20-30 per KW of installed capacity, which are covered by the program.[26]

Direct costs and negative externalities produced by the end of life disposal for batteries and panels

The cost of disposing a residential, solar-paired battery storage system at the end of its useful life (approximately 20 years) is estimated at 10,000 Euros or $11,120 USD based on the December 14, 2019 exchange rate.[27] In addition, the disposal process generates an estimated 12.3 tons of CO2e (carbon dioxide equivalent).[28] The current cost of a CO2e ton to the United States is estimated at $42 per ton. That means the disposal of a single solar-paired battery storage system would produce $517 in negative environmental externalities, in addition to $11,120 in direct costs (e.g. labor, dismantling, transportation, recycling, etc.).

---

[23] "Decision approving greenhouse gas emission reduction requirements for the Self Generation Incentive Program." CPUC, August 1, 2019.
[24] Sunrun.
[25] Ibid.
[26] "Cost of Solar | Solar Panel Cost | Cost of Solar Installation." Accessed at https://bit.ly/2svO8O1 on December 8, 2019. "Average Solar Panel Maintenance Cost (with Price Factors)." Accessed at https://bit.ly/2PmxDgo on December 14, 2019.
[27] Li et.al.
[28] Ibid.

Results

The Program yields social net benefits

The first step of this benefit cost analysis is estimating the net present value (NPV) of the program comprising each of the above impacts in today's dollar value per household. NPV is estimated at the household level (since all observed benefits and costs are produced by a single solar-paired-battery storage system) using a social discount rate (SDR) of 3%.

A Monte Carlo simulation of key parameters in this study returned positive results. Assuming a 3% SDR, the simulation determined the Program would yield a mean NPV at the household level of ≈$10,800 with a 95% confidence interval of approximately -$5,000 to $27,000 per household, as shown in **Figure 1**.

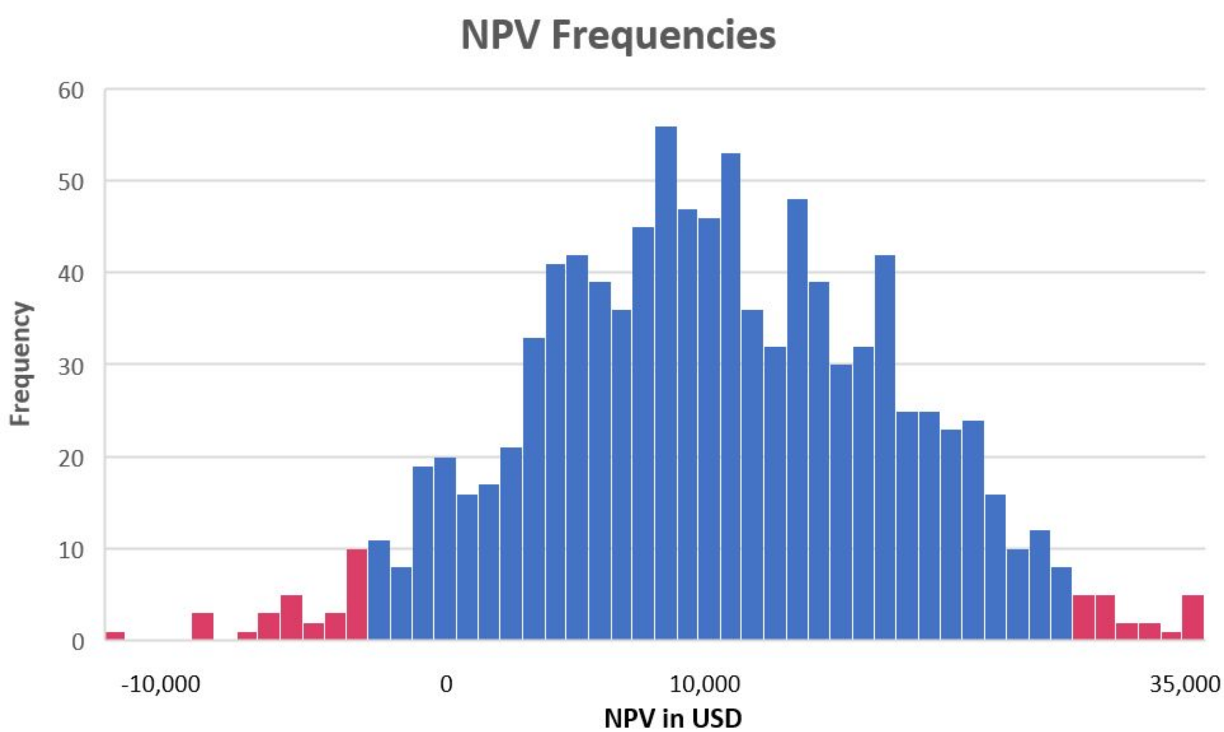

Figure 1: Results of Monte Carlo model using a 3% SDR. Blue values indicate the 95% confidence interval.

The Program's total NPV equals the per-household NPV multiplied by the ≈9,000 households covered by the subsidy.[29] Costs and benefits will be distributed across the four years of implementation, meaning subsidies will be granted in years 1 to 4 computed from its launch. Table 3 shows the net present value per year:

[29] Note that the program uptake level does not alter its per-household NPV since none of the computed impacts is a function of the number of systems installed.

Table 3. Net Present Value and Takeup

Year	Subsidized Households	Net Present Value (in millions)
0	2,300	$24.8
1	2,300	$24.1
2	2,300	$23.4
3	2,100	$20.8
Total	**9,000**	$93.1

The analysis found the implementation of the Program would yield a social net benefit of ≈$93.1 million within its budget constraints, which would cover the costs for ≈9,000 residential customers in California's HFTDs.

Break-Even Horizon

Break-even horizon analysis indicated that NPV reaches zero in year 15 on average. The 95% confidence interval ranges from 10 years, at the low end, to never. This analysis indicates that 10% of projects will not have a positive NPV under the default assumptions.

The Program yields net benefits for everyone with standing except for non-eligible Californian ratepayers

As shown in the impact table below, net social benefits are not enjoyed equally by all groups impacted by the policy. The global definition of standing employed in this analysis implies that not only subsidy recipients will benefit from the program, but the positive reduction of emissions is an impact that reaches everyone in the world, including for all California ratepayers funding the Program. In conclusion, the only group that does not benefit are non-eligible California ratepayers.

Table 4. Impact Table (USD in millions)[30]

Benefits			
	Recipient Households	**Ratepayers**	**Everyone**
Avoided Blackouts	$108.4		
Generated Electricity	$355.8		
Grid Benefits of Battery Installation		$8.5	
Avoided CO_2 Emissions			$14.5
Costs			
Battery and Solar Panels[31]		$314.3	
Operations and Maintenance Costs		$24.2	
Disposal Costs		$53.3	
CO_2 Emissions from Disposal			$2.42
Total	$464.2	($383.3)	$12.1

Limitations and Uncertainties

Additional impacts of widespread battery storage adoption may be unknown

While adoption of residential battery storage systems is on the rise, it is still relatively uncommon. There may be unknown impacts associated with large-scale uptake in the residential market for battery storage systems that are not accounted for in our model.

Commercial impacts not accounted for

Small businesses are eligible for rebates under the existing SGIP equity resiliency budget, but this analysis excludes them for several reasons:

1. The number of small businesses in Tier 2 & 3 HFID zones is unknown.
2. Commercial establishments can vary significantly in terms of size/scale and may have very different needs in terms of battery storage system capacity than residential customers. Since the size and scale of businesses in Tier 2 & 3 HFTD zones are unknown, their storage needs are also difficult to predict accurately.

[30] 3% discount rate, $42/ton social cost of carbon. Note that the resulting numbers might be slightly different for every Monte Carlo simulation that is run over the parameters. However, for the purposes of the stakeholder analysis, such randomness can be ignored.
[31] Purchase and installation costs.

3. While estimates of the financial impact of power outages on commercial establishments exist, these likely vary significantly between establishments - for example, a grocery store with large amounts of perishable food and numerous employees (who would theoretically lose wages as the result of a power outage) would be significantly more impacted by a 48-hour outage than a small retail establishment with a handful of employees.

Accounting for change in the electric grid

The mix of electrical sources on the grid is likely to change over time, so parameters set to today's values may be inaccurate in the future. In particular, the price of electricity is likely to rise over time due to transmission resiliency upgrades, while the marginal benefit of an additional renewable kilowatt will decrease. We did not analyze the effect of this reduced GHG benefit, as the carbon savings represent only 3% of the potential benefits of the program.

Acceleration of technological "learning curve"

The price of energy technology tends to follow a learning curve, where price decreases as a function of the total installed capacity. This program, though not a large proportion of the global installed capacity of energy storage systems, may increase public knowledge about such systems to the point that it stimulates demand, ultimately generating benefits beyond those quantified here.

Conclusion

Fully subsidizing solar-paired storage systems for people living in fire zones is likely to pass benefit-cost analysis, although it is highly dependent on certain parameters. Under default assumptions, our analyses found that this program would have a negative NPV only 10% of the time. Sensitivity analysis revealed that these results are highly dependent on the discount rate (Figure 2) and the value of generated electricity (Figure 5). California's "net metering" law credits residential solar owners at retail rates for the electricity they generate, but this may not reflect the true value of the electricity. Any value lower than $0.27 per kilowatt-hour has a greater than 5% chance of a negative NPV. SCC does not have a significant influence on our results (Figure 3).

Given that fluctuation in these values could result in a zero or negative NPV, policymakers should carefully consider other options for addressing PSPS events before committing to a policy of full subsidization of solar-paired energy storage systems.

Appendix A - Sensitivity Analysis

Even though the program yields net benefits within a 95% confidence interval, we conducted a partial sensitivity analysis on the following parameters as they have the largest impact on the program's net benefits or are the most likely to vary.

Social Discounting Rate

For most of our analysis, we used a SDR of 3%, in line with the OMB and recommended in Boardman. Here, we varied the discount rate from 2.5% to 7% and found that the mean NPV remained positive for all values of discount rate, although lower bounds of values' 95% confidence intervals were uniformly negative (Figure 2).

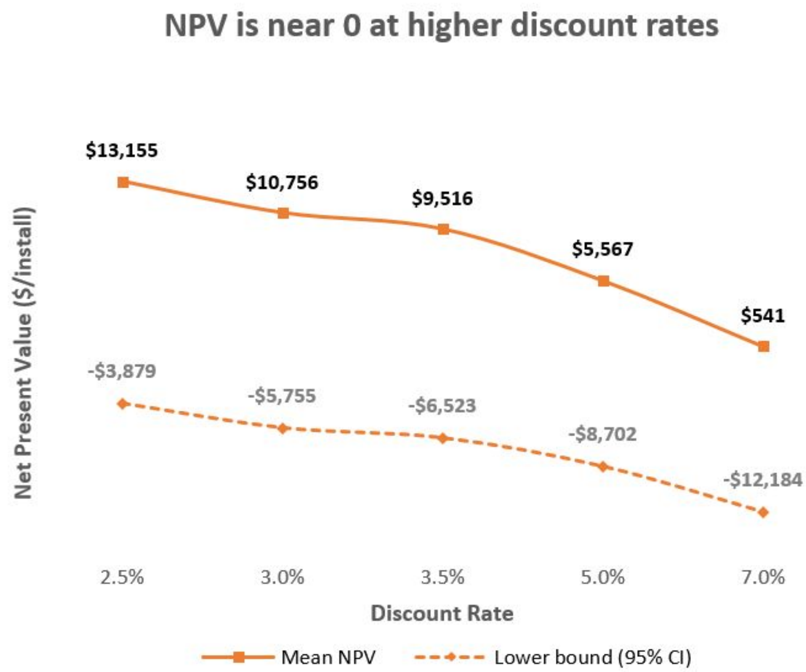

Figure 2: Estimated mean and lower-bound NPV by discount rate.

Social Cost of Carbon

Estimates of the social cost of carbon (SCC) vary significantly. We use an estimated cost of $42/ton of CO2 in our analysis, which was the standard defined by the Obama Administration's Environmental Protection Agency (EPA). The Trump Administration has proposed lowering this value to $1-$7/ton, while recent research suggests the true social cost of carbon may exceed $200/ton.[32] Figure 3 shows how different SCC estimates impact the projected NPV of our

---

[32] Moore, F., Diaz, D. Temperature impacts on economic growth warrant stringent mitigation policy. Nature Clim Change 5, 127–131 (2015). Accessed at https://doi.org/10.1038/nclimate2481 on December 14, 2019.

program. To ensure that 95% of trials return a positive NPV, the social cost of carbon must be at least $134.

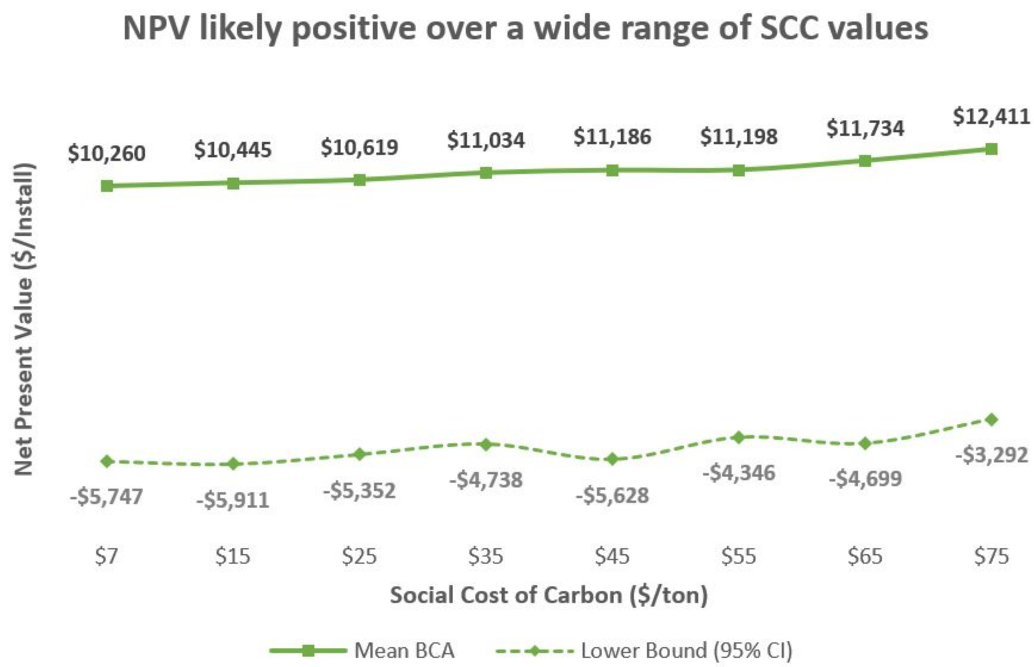

Figure 3: NPV by SCC estimate.

Battery Disposal Costs

The cost of disposing a residential battery storage system is currently valued at around $11,120. However, methods for more efficiently disposing of lithium ion batteries continue to advance and costs may decrease over time. Figure 4 shows the estimated NPV of the program across a range of battery disposal costs.

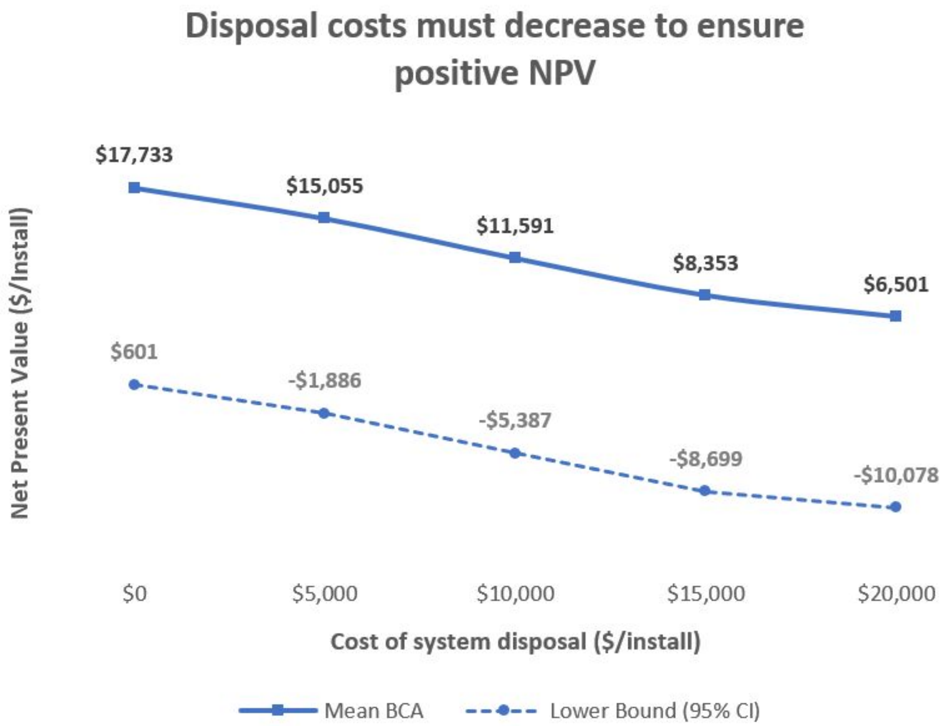

Figure 4: Program NPV by battery disposal cost

Value of Generated Electricity

The NPV of this program is highly dependent on the value of the electricity generated by solar panels (see Figure 5). A break-even analysis found that electricity must have a value of at least $0.27 per kWh for the 95% confidence interval to be above zero.

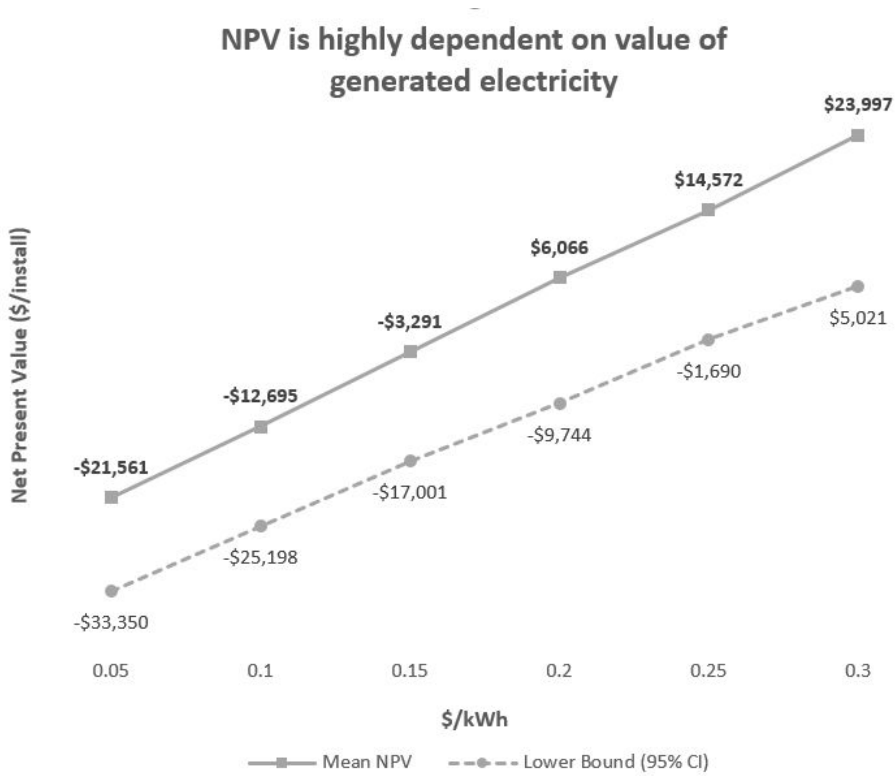

Figure 5. Net present value depends strongly on the value of electricity generated by the solar panels.

Works Cited

1. California Public Utilities Commission, “De-Energization (PSPS)”
2. California Public Utilities Commission. (2017). “Decision Adopting Regulations to Enhance Fire Safety in the High Fire-Threat District.” Decision 17-12-024 December 14, 2017.
3. California Public Utilities Commission. (2019). “Decision Establishing a Self-Generation Incentive Program Equity Resiliency Budget, Modifying Existing Equity Budget Incentives, Approving Carry-Over of Accumulated Unspent Funds, and Approving $10 Million to Support the San Joaquin Valley Disadvantaged Community Pilot Programs.”
4. ITRON, “2017 Advanced Energy Storage Impact Evaluation,” Figure 1-17.
5. King, Kathleen. (2012). “Willingness to Pay to Avoid Outages: Reliability Demand Survey.” Bates White Economic Consulting.
6. Li, X., Chalvatzis, K., Stephanides, Ph., “*Innovative Energy Islands: Life-Cycle Cost-Benefit Analysis for Battery Energy Storage*” in Sustainability 2018, 10, 3371.
7. Moore, F., Diaz, D. Temperature impacts on economic growth warrant stringent mitigation policy. Nature Clim Change 5, 127–131 (2015).
8. PG&E. (2019). “PG&E Public Safety Power Shutoff Report to the CPUC.”

9. Sunrun. (2019). “How Much Will My Electric Bill Be With Solar Panels?”
10. Sylvia, T. (2019). “Power shutoffs cause a battery boom in California.” *PV Magazine*.
11. United States Environmental Protection Agency. (2017). “Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis.”
12. United States Environmental Protection Agency. “The Social Cost of Carbon.”w
13. Wolfram, C. (2019). “Measuring the Economic Costs of the PG&E Outages.” Energy Institute Blog.