

Come on down and play the price is right! What do you bid for keeping the lights on?

Lauren S. Robinson and Jean Shelton, Verdant Associates

ABSTRACT

California is experiencing a devastating drought, high temperatures, and dry conditions with increased winds which contribute to planned grid outages (Public Safety Power Shutoffs (PSPS)) designed to reduce the likelihood of wildfires. California's Self-Generation Incentive Program (SGIP) was created in 2001 to help improve grid reliability during the energy crisis and the program continues with its objective to improve reliability. During 2020 the SGIP provided incentives to approximately 6,500 of the over 15,000 residential battery storage systems installed in California. The desire for resilience drives battery storage installations.

This paper will present results on residential customers' willingness to pay for resilience through the lens of battery storage. The value of resilience will be assessed for SGIP customers, for battery storage customers who didn't receive an SGIP incentive, and for customers without storage. Resilience value will be characterized by important geographic and economic characteristics, including living in one of California's high fire threat districts.

The paper will compare the estimated resilience values to SGIP incentive levels, a program providing incentives to the general market and to equity customers in high fire threat regions. The results will help to illuminate where additional incentives are needed to improve resilience.

Introduction and Motivation for the Study

Over the last decade, California has experienced increased, intense, and record-breaking wildfires. These fires have resulted in a devastating loss of life and billions of dollars in property and infrastructure damage. Fires attributed to power lines account for roughly half of the most destructive fires in California history's including the 2021 Dixie Fire that burned over 950,000 acres. These fires have led to criminal charges for the utilities, substantial fines, bankruptcy, and the loss of lives. With the continuing threat of wildfire, utilities have developed fire mitigation plans that include long-term commitments to bury power lines in high fire risk areas and short-term permission to proactively cut power to electrical lines that may fail in certain weather conditions. Such power cuts reduce the risk of utility infrastructure causing, or contribute to, a wildfire. In California, these power cuts are called Public Safety Power Shutoffs (PSPS). PSPS events, however, can leave communities and essential facilities without power, which brings its own risks and hardships, particularly for vulnerable communities and individuals. From 2013 through the end of 2021 California experienced over 75,000 wildfires (averaging 8,333 per year) and 94 days of IOU PSPS de-energizations events (CPUC 2022; CAL FIRE 2020; CAL FIRE 2021). During the PSPS events of 2019, over 2.5 million people are estimated to have lost their utility provided power (Fuller 2019).

Behind the meter battery storage systems have emerged as one potential solution for customers seeking to mitigate the effects of these lengthy outages. In September of 2019 the California Public Utilities Commission (CPUC) issued Decision (D.) 19-09-027 establishing the

SGIP equity resiliency budget. To help deal with critical needs resulting from wildfire risks in the state, D. 19-09-027 establishes a new equity resiliency budget set-aside for vulnerable households located in Tier 3 and Tier 2 High Fire Threat Districts (HFTD), critical services facilities serving those districts, and customers located in those districts that participate in low-income/disadvantaged solar generation programs. By the end of 2021, the SGIP had provided incentives to roughly 27,000 advanced energy storage systems, installed across multiple customer sectors.

As customer expectations for potential electricity disruptions increase, utilities, regulators, and other market actors are increasingly seeking to understand a customer's willingness to pay for battery storage designed to backup customer loads and/or other forms of customer resilience (AER 2019; Sullivan et al. 2019; Shelton, Rufo, and Robinson 2022). The findings presented in this paper are guided by a desire to better understand the differences in characteristics and resilience concerns of residential customers who have purchased behind the meter battery storage, those that have solar but not storage, and those that do not have interconnected distributed energy resources (DER). The paper presents detailed findings on customer willingness to pay for battery storage resilience by their ownership of storage, solar, or not owning DERs, and other important domains of interest. This paper first characterizes residential battery storage within California, then describes the characteristics of customers with and without batteries and provides some information on their resilience needs. The paper concludes with a description of customers' willingness to pay for battery storage.

Residential Battery Storage in California

Residential storage in California has shown pronounced growth since 2017 when D.16-06-055 led to the development of new budget categories within the Self Generation Incentive Program (SGIP) that provided incentives to residential customers (Small Residential Storage and Large-Scale Storage). In 2020, the SGIP also added the residential Equity Resiliency budget category that provided substantial incentives for customers living in high fire threat districts or in areas that had experienced multiple PSPS events. By the end of 2021, the SGIP had provided incentives to over 25,000 residential battery storage systems accounting for over 400 MWh of storage capacity. As residential storage within the SGIP has grown, residential storage has also grown among customers who do not receive an SGIP incentive. Figure 1 illustrates the growth in the share of residential storage adopted outside the SGIP from 2018 to 2021. In 2021, 76 percent of storage systems interconnected within the three IOU service territories were non-SGIP projects.¹

¹ The share of residential storage receiving incentives from SGIP in 2021 may increase as incentive applications move through the application process.

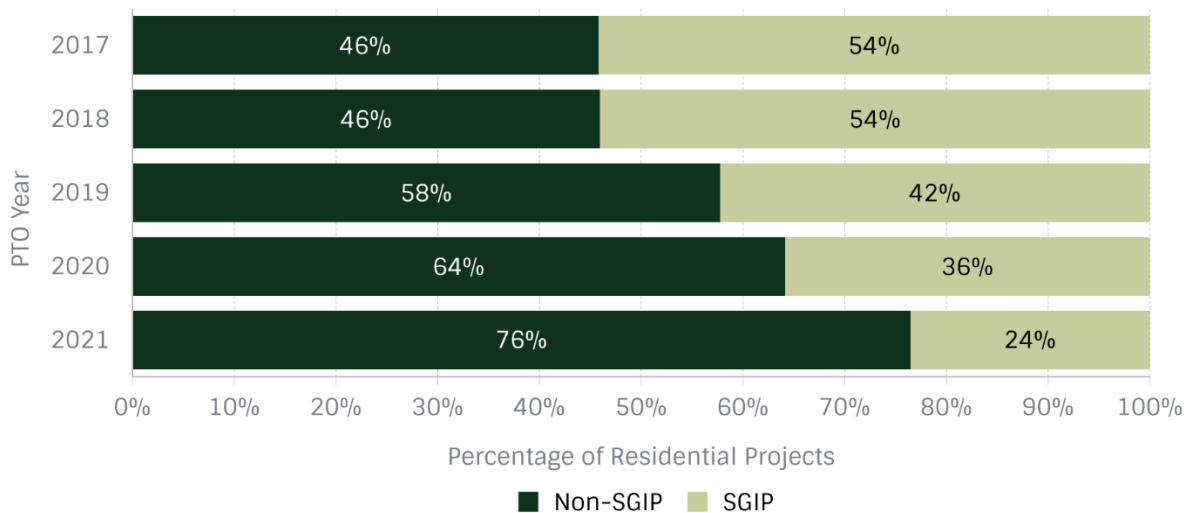


Figure 1: SGIP and Non-SGIP Projects by PTO Year

Figure 2 illustrates the average battery capacity for systems installed within and outside the SGIP. This graph shows that average system size has increased, with a substantial growth in the average system size following the significant 2019 wildfire and PSPS events.

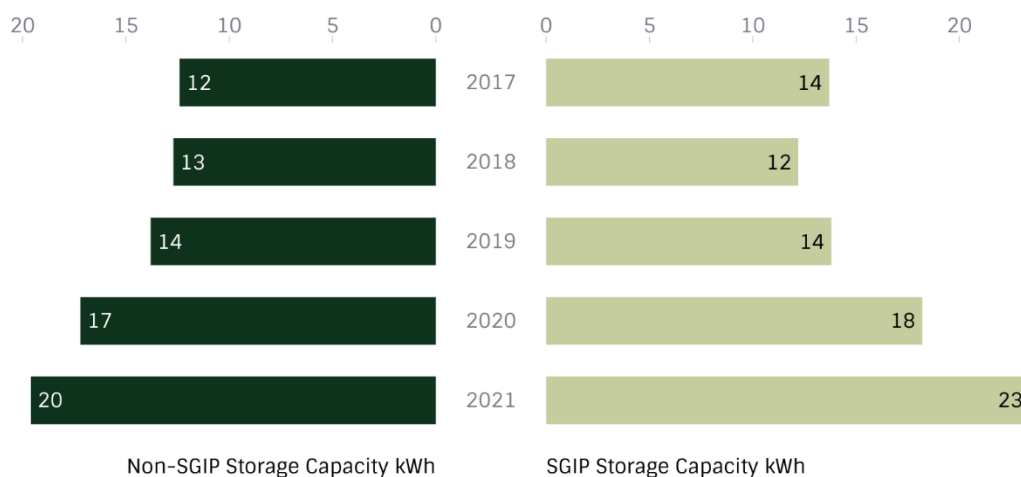


Figure 2: SGIP and Non-SGIP Average Storage Capacity kWh by Year

As non-SGIP installations increase over time, it's important to understand the cost of battery storage and customers' willingness to pay for these systems. By understanding their willingness to pay, we can better direct incentive funds to areas most in need (where outages are frequent, resilience needs are high, and ability to pay may be more limited). Within the SGIP Small Residential budget program, the average cost for a battery storage system was \$0.83/Wh in 2017

and climbed to \$1.18/Wh in 2021. Increased costs are a result of a myriad of factors including the emergence of new products and new developers at higher price points and increased labor costs.

The average SGIP incentive payment ranges from a few thousand dollars to \$25,000 depending on budget category. As shown in Figure 3 below, the SGIP incentive covered a small portion of the total system cost in the small residential storage and residential large-scale storage budget categories, and nearly the entire cost in the equity resiliency category.²

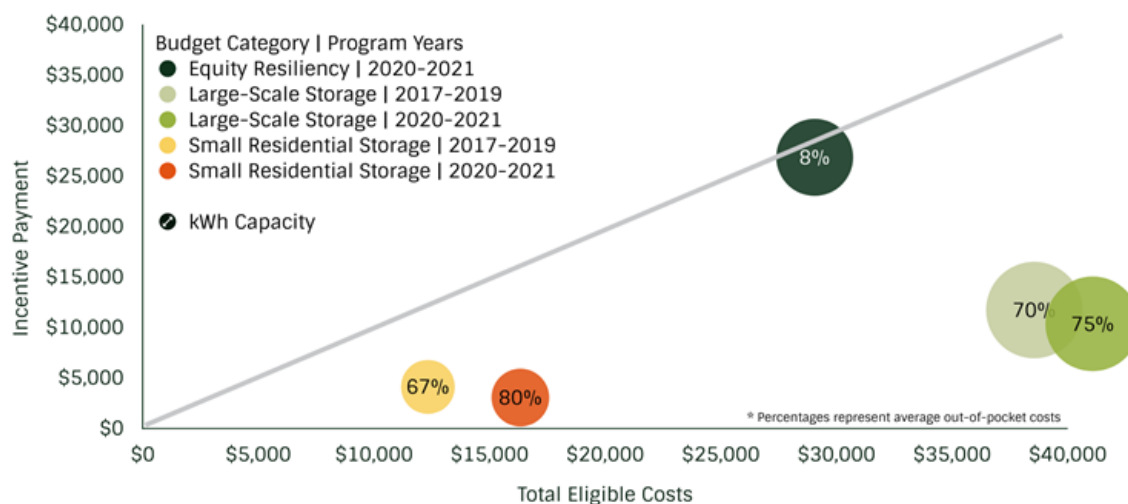


Figure 3: Average SGIP Residential Incentive and Costs by Budget Category and Year Groupings

Method/Survey/Demographics

To better understand residential customers' willingness to pay for battery storage, and the value of resilience provided by battery storage systems, Verdant conducted surveys with four cohorts of California customers: (1) SGIP storage participants (SGIP cohort), (2) customers who have installed storage that had not received an incentive from the SGIP (Storage Non-SGIP cohort), (3) solar non-storage participants (Solar Non-SGIP cohort), and (4) customers without DERs (Non-DER cohort). Information was collected on customer demographics, customer outage experience and their need for resilience, their satisfaction with their battery systems for customers with storage (SGIP and Storage Non-SGIP cohorts) and their knowledge and likelihood of future purchase for customers without storage (Solar Non-SGIP and Non-DER cohort). All customers were also asked about their willingness to pay for battery storage.

The survey responses for the residential SGIP cohorts are analyzed by budget category: Small Residential, Large-Scale Storage, and Equity Resiliency. The Equity Resiliency budget category provides higher incentives for customers who meet eligibility criteria that include living in a high fire threat district or a location that has experienced multiple PSPS events.

Figure 4 presents the household income distribution for customers with storage, those with solar, and those without DERs. Households with battery storage systems have higher incomes than households without battery storage systems. These data also show that households

² The share of system cost listed as out-of-pocket costs does not consider the receipt of a federal investment tax credit. For the years included in the figure, the FITC was 26% to 30%. The FITC would future reduce the out-of-pocket costs for eligible households.

adopting storage outside the SGIP have household incomes very similar to SGIP customers. Equity Resiliency customers have a smaller share of households with incomes over \$200,000 and have an income distribution similar to solar households. Understanding the income distribution of households with and without battery storage provides information on the economic status of current adopters of storage and may help to explain the willingness to pay for storage.

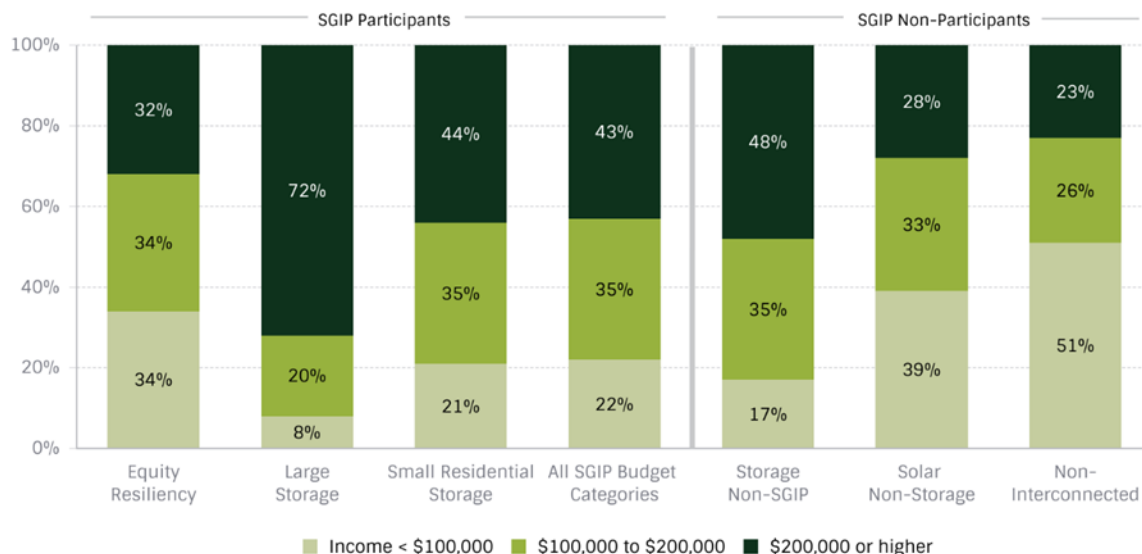


Figure 4: Household Income Distribution

To better understand customers' resilience needs, the survey asked customers to self-report their wildfire risk. As shown in Figure 5 below, the results show that 64% of the SGIP storage cohort and 68% of the storage non-SGIP cohort report living in a high or mid wildfire risk area while 99% of the customers in the equity resiliency budget category report living in a high or mid wildfire risk area. Customers without storage systems tend to live in areas with notably lower perceived wildfire risk. Understanding customers' perception of their wildfire risk may help to explain their willingness to pay for battery storage.

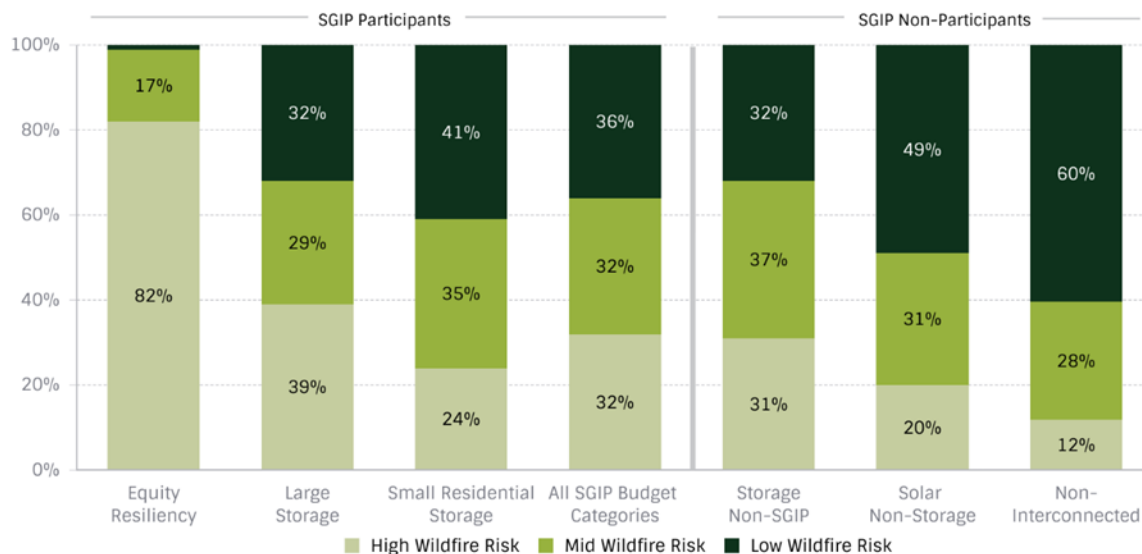


Figure 5: Self-Reported Wildfire Risk

All survey cohorts were asked to describe the longest outage they experienced in the previous two years. Figure 6 shows that a higher share of storage owners have experienced outages lasting longer than a day than customers without storage, supporting their higher need for backup resilience.

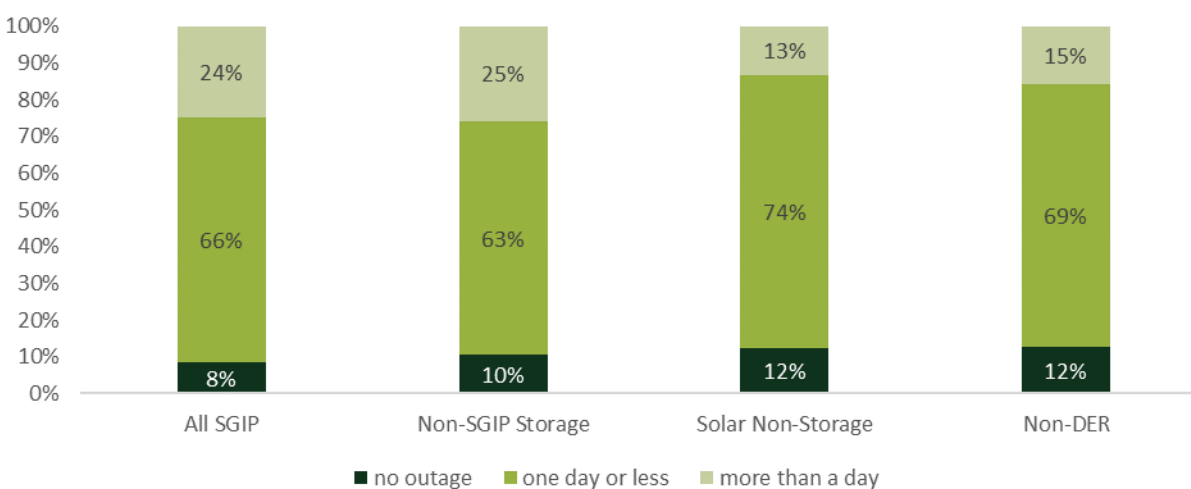


Figure 6: Length of Longest Outage within the last Two Years

The surveys asked customers to report the primary, secondary, and tertiary reason for installing battery storage. As shown in Figure 7 below, energy backup or resilience was chosen by nearly 100% of storage customers as one of their top three reasons for storage adoption.

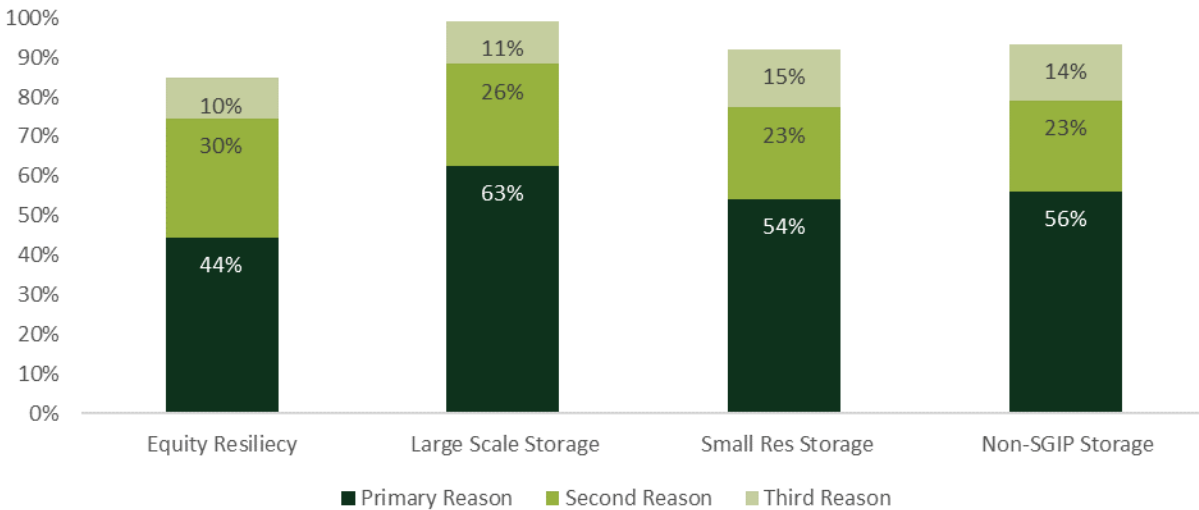


Figure 7: Share of Residential storage owners whose primary, secondary, or tertiary reason for installing storage is resilience

The survey findings support the conclusion that the installation of residential battery storage in California has increased as the incidence of wildfires and PSPS events have grown. Over 50% of storage customers report that their primary reason for battery storage installation is backup and almost all battery storage customers report backup as one of the top three reasons why they installed battery storage. Storage customers are also more likely to live in areas with high wildfire risks, to have experienced longer outages, and have higher household incomes than customers without battery storage. All of these attributes likely contribute to customer willingness to pay for storage.

Willingness to Pay for Battery Storage Methods

Residential customer willingness to pay was estimated through discrete choice modeling (Train 2009). Residential respondents in the SGIP Participant, Storage Non-SGIP, Solar Non-Storage, and Non-DER surveys were presented with a series of questions to investigate their willingness to pay for battery storage. Prior to the willingness to pay questions, the customers were provided the following paragraphs about battery storage and resilience:

Utility power outages can be very short, lasting only a couple of minutes. On the other hand, outages that are implemented to reduce the risk of fires during dry, high-wind conditions can range from a couple of hours to over a week. Solar panels must be paired with battery storage to maintain power during an outage. The solar plus battery system can be sized to provide electricity to the whole house or only to critical loads such as a refrigerator, essential medical equipment, or lighting. Systems designed to back up the whole house are larger and more expensive than those designed to provide backup for critical loads.

We understand that your home [has/does not have] a [solar/storage/storage and solar] system. The following questions are investigating your willingness to pay for battery storage systems. Your responses will help improve California's storage programs and support California's clean energy goals.

Please respond to the questions below as if your home has solar but does not have a battery storage system."

The series of scenarios associated with purchasing a battery storage system were presented to respondents, who were asked to choose between different battery purchase options. The following three options were generally described:

- Option 1) purchase a battery storage system that would provide electricity for their whole house
- Option 2) purchase a battery storage system that would provide electricity for 30 percent of their electrical needs (their most critical needs)
- Option 3) do not purchase a battery storage system

Option 1 (whole house system) and option 2 (partial house system) were presented to a single customer multiple times with a series of different price points. If the customer chose option 3 to the first question (to not purchase a battery storage system), they were presented with a scenario where an incentive was available to lower the price for both the whole and partial house battery systems, to determine if they would change their purchase decision.

The price presented to customers for a whole house system varied from a high of \$20,000 to a low of \$7,000. The partial house price options ranged from a high of \$7,000 to a low of \$1,000. Each respondent received three or four sets of scenario options depending on their response to questions. There were eight different sets of scenario prices that respondents were randomly assigned to receive.

We used these data in a mixed multinomial logit model to estimate the willingness to pay for the whole and partial house batteries. The model estimates the probability of a respondent choosing a whole house, partial house, or no battery storage system as a function of price and battery size. The model estimates parameters that are assumed to vary from one individual to another. The whole and partial battery size parameters are modeled as random variables with a normal distribution, where the random variables are allowed to be correlated. The model takes advantage of the multiple question responses provided by a given respondent to estimate the impact of price on the respondent's choice to purchase a whole house battery, a partial house battery, or not to purchase a battery.

To calculate the willingness to pay for whole house batteries relative to not purchasing a battery, the model's estimated coefficient on whole house is divided by the price coefficient. The willingness to pay for the partial house battery is developed using a similar approach. The mixed logit willingness to pay model was analyzed across many different domains of interest to better understand how different factors influence the results.

Willingness to Pay for Battery Storage Results

Customers with battery storage have a relatively high willingness to pay for a whole house battery storage system and a low valuation for a partial house system relative to customers who do not currently own battery storage systems. Table 1 presents the statewide willingness to pay for battery storage results for the four survey cohorts. These results show that customers who own battery storage systems are willing to pay substantially more for a battery system that provides backup for their whole house than one that only provides backup for 30 percent of their electrical needs (approximately \$19,500 to \$20,000 versus \$2,500 to \$2,700). The willingness to pay findings support the conclusion that the average SGIP residential battery storage customer is very similar to the average battery storage customer that did not receive an SGIP incentive.

Table 1: Statewide Willingness to Pay for Battery Storage by Survey Population

WTP for Storage	SGIP Residential Storage Customer	Storage, Non-SGIP	Solar Non-Storage	Non-DER
Whole House	\$19,928	\$19,443	\$11,157	\$6,520
Partial House (30% of electrical needs)	\$2,432	\$2,714	\$5,072	\$4,741

The results presented in Table 1 above show that solar and non-DER customers are willing to pay substantially less for whole house battery storage than customers who currently own storage, but these customers are estimated to have a higher willingness to pay for a partial house storage system than customers who currently own storage. The lower willingness to pay for whole house storage may be attributed to their lower average household income levels, their perception that they live in an area with lower wildfire risk, their lower likelihood of experiencing an outage and the shorter average length of reported outages. Customers who do not currently own a battery, however, are willing to pay more for a partial house battery (described to provide backup for 30 percent of their home's electrical needs) than customers who own a battery. The higher relative willingness to pay for a partial home battery, by customers who do not currently own a battery, may reflect their assumption that these batteries may provide them with the resilience they desire (e.g., provide backup for their refrigerator) without the larger expenditure necessary for a whole house battery system. Survey results from current owners of battery storage, however, indicate that customers with smaller sized batteries are less satisfied relative to customers with larger sized battery storage systems.

Willingness to Pay compared with SGIP incentives

Table 2 shows the average incentive provided to residential customers in the SGIP during program years 2020 and 2021 was approximately \$10,900. Assuming the customer expects to receive a 26 percent Federal Investment Tax Credit (ITC), the average out-of-pocket cost for SGIP residential participants was around \$7,900. Per Table 1 above, the willingness to pay for a whole system for each DER cohort is above the SGIP average out-of-pocket after ITC of \$7,860. Whereas the non-DER average willingness to pay is around \$1,300 below the average estimated out-of-pocket cost after the ITC. It is possible that the DER customers are more familiar with the

availability of the ITC and therefore resulted in higher willingness to pay amounts because they assumed they would receive back a portion of their initial out-of-pocket cost through the tax credit. The average willingness to pay for each DER cohort is also above the average SGIP out-of-pocket cost before ITC of \$10,621. Note that customers are only eligible to claim the Federal ITC if the system is paired with solar PV and it charges from on-site solar.

Table 2: 2020-2021 Residential SGIP Average Incentive, Eligible System Cost, and System Capacity by Budget Category

2020-2021 Average	Equity Resiliency	Small Residential Storage	Large Scale Storage	All SGIP Residential
System Capacity	27.3 kWh	15.4 kWh	41.2 kWh	20.4 kWh
Eligible System Cost	\$29,060	\$16,333	\$41,080	\$21,535
Incentive Amount	\$26,855	\$3,064	\$10,364	\$10,914
Out of Pocket Cost	\$2,205	\$13,269	\$30,716	\$10,621
Estimated Out-Of-Pocket Cost After ITC	\$1,632	\$9,819	\$22,730	\$7,860

While the size of battery needed to provide whole house backup will vary with the customer's load, for an example, let's assume a whole house system would need a capacity close to 27.3kWh (with a cost of \$29,060). If customers received an incentive at the small residential storage rate, the average incentive received on a 27.3kWh system would be \$5,432. The customer would have \$23,628 in out-of-pocket costs or \$17,385 after ITC. This cost is less than the amount the average storage customer is willing to pay but higher than what solar or non-DER customers are willing to pay on average. A higher, but very targeted, incentive may be necessary to achieve continued adoption of storage outside the early adoption customers given the lower willingness to pay values for the solar and non-DER customers.

Willingness to Pay by Customer Characteristics

The willingness to pay for a battery storage system was also calculated for sub-groups of customers based on various characteristics. Table 3 shows the average willingness to pay for a whole house system by customers' geographic location in an urban, suburban, or rural area, whether they are in a HFTD Tier 2 or Tier 3 area, household income, whether they experienced an outage longer than six hours, and whether they stated their household has a health-related need that requires electricity to power medical equipment.

Table 3: Willingness to Pay for Whole House Battery Storage System by Customer Characteristics

Group		SGIP Residential Storage Customer	Storage, Non-SGIP	Solar Non-Storage	Non-DER
Geographic	Urban	\$17,331	\$18,476	--	--
	Suburban	\$16,402	\$18,813	\$11,009	\$7,156
	Rural	\$18,615	\$24,509	--	\$14,036

Group		SGIP Residential Storage Customer	Storage, Non-SGIP	Solar Non-Storage	Non-DER
HFTD	Yes	\$17,389	\$19,194	\$11,211	\$8,667
	No	\$16,555	\$19,376	\$11,031	\$5,904
Income	>\$200k	\$18,550	\$20,799	\$9,300	\$12,359
	<\$200k	\$15,734	\$18,037	\$11,037	\$5,583
Long Outage	Yes	\$17,348	\$21,031	\$12,573	\$9,814
	No	\$16,280	\$17,995	--	\$3,380
Medical Need	Yes	\$16,204	\$20,135	\$14,818	\$8,766
	No	\$16,876	\$19,176	\$10,080	\$5,478

The starkest contrast in willingness to pay throughout different customer segmentations is seen within the non-DER cohort. These customers are willing to pay nearly three times more for a whole house system if they had experienced a long outage. The non-DER cohort is also willing to pay over twice as much for a system if their household income is above \$200,000 or if they are in a rural area (as opposed to urban). Finally, they are willing to pay around 50 percent more if they have a medical need or are in a HFTD.

Conclusion

The survey findings support the conclusion that the installation of residential battery storage in California has increased as the incidence of wildfires and PSPS events have grown. Over 50% of storage customers report that their primary reason for battery storage installation is backup and almost all battery storage customers report backup as one of the top three reasons why they installed battery storage. Storage customers are also more likely to live in areas with high wildfire risks, to have experienced longer outages, and have higher household incomes than customers without battery storage.

The willingness to pay results show that customers who already have battery storage whether with or without SGIP have similar levels of willingness to pay for whole and partial systems. Customers without battery storage have lower levels of willingness to pay overall, though there is significant upward variation in the non-DER cohort for customers that experienced a long outage, live in rural areas, or have household incomes greater than \$200,000. While non-DER customers are willing to pay almost three times more for a whole house system if they had experienced a long outage, there is still a significant gap between their level of willingness to pay (\$9,800) and the estimated cost of a whole house system after the SGIP and ITC incentives (\$17,400). When comparing willingness to pay to the current SGIP incentive, the findings show that current incentive levels may be adequate for early adopters (customers that currently have battery storage), but they may need to be substantially higher to reach other types of customers.

References

Australian Energy Regulator (AER). 2019. Values of Customer Reliability: Final report on VCR values. Melbourne: AER. www.aer.gov.au/system/files/AER%20-

[%20Values%20of%20Customer%20Reliability%20Review%20-%20Final%20Report%20-%20December%202019.pdf](#)

California Department of Forestry and Fire Protection (CAL FIRE). 2020. 2020 Incident Archive. Accessed 2022. www.fire.ca.gov/incidents/2020/

CAL FIRE. 2021. 2021 Incident Archive. Accessed 2022. www.fire.ca.gov/incidents/2021/

California Public Utilities Commission (CPUC). Utility Public Safety Power Shutoff Plans (De-Energization) website. Accessed 2022. www.cpuc.ca.gov/psps

Fuller, T. 2019. *500,000 in California Are Without Electricity in Planned Shutdown: Pacific Gas & Electric is cutting electricity as a precaution against sparking wildfires in high-wind conditions*. New York: The New York Times. www.nytimes.com/2019/10/09/us/pge-shut-off-power-outage.html

Shelton, J., W. Marin, M. Rufo, L. Robinson. 2022. *What is the Residential Value of Resiliency? The Answer May Lie in the Shadows*. To be published: San Diego: 2022 International Energy Program Evaluation Conference.

Sullivan, M., M. Collins, J. Schellenberg, and P. Larsen. 2018. Estimating Power System Interruption Costs: A Guidebook for Electric Utilities. Berkeley: Lawrence Berkeley National Laboratory. eta-publications.lbl.gov/sites/default/files/interruption_cost_estimate_guidebook_final2_9july2018.pdf

Train, K. 2009. Discrete Choice Methods with Simulation. New York: Cambridge University Press. eml.berkeley.edu/books/choice2.html