CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

Title 24, Part 6
Local Energy Efficiency Ordinances

PV + Battery Storage Study

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1 Introduction

The California Building Energy Efficiency Standards Title 24, Part 6 ("Title 24" or "Standards") (CEC, 2016a) is maintained and updated every three years by two state agencies, the California Energy Commission (CEC) and the Building Standards Commission (BSC). In addition to enforcing the Standards, local jurisdictions have the authority to adopt local energy efficiency ordinances, or "reach codes," that exceed the minimum standards defined by Title 24 (as established by Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards). This study evaluates the cost-effectiveness of a battery storage system when coupled with a solar photovoltaic (PV) system for electricity generation for the purposes of application in California Climate Zone 4, specifically Mountain View, CA. As an addendum to the study, Climate Zone 13 (Fresno) was also studied and is presented in Appendix B in this study. The battery is intended to be charged by the PV system during daytime hours when abundant solar energy is available, and then discharged during evening hours when electricity rates are more expensive. This study explores the economic viability of various size batteries, coupled with various sized PV systems, applied to homes which are both all electric, and mixed fuel use (gas appliances).

2 Methodology and Assumptions

2.1 Building Prototypes

The CEC defines building prototypes which it uses to evaluate the cost-effectiveness of proposed changes to Title 24 requirements. This study uses the CEC's two existing single family prototypes for the evaluation of the battery storage systems. Table 1 describes the basic characteristics of each prototype. Additional details on the prototypes can be found in the Alternative Calculation Method Approval Manual (CEC, 2016a).

Table 1: Prototype Characteristics

	Single Family One Story	Single Family Two Story
Conditioned Floor Area	2,100 ft^2	2,700 ft^2
Number of Stories	1	2
Number of Bedrooms	3	3
Window-to-Floor Area Ratio	20%	20%

2.2 Simulation Methodology

The California Building Energy Code Compliance – Residential (CBECC-Res) 2016.3.0 (1016 SP2) compliance simulation tool was used to evaluate energy impacts relative to the 2016 Title 24 Standards utilizing the 2016 time dependent valuation (TDV). For the 2019 evaluation, the CECC-Res 2019.0.9 RV (1110) tool was used (the beta release for 2019 Title 24 available at the time of the analysis) as the basis of the simulation of the prototypes, using the 2019 TDV values. TDV is the energy metric used by the CEC to evaluate compliance with the Title 24 Standards since the adoption of the 2005 Title 24 Standards. TDV values energy use differently depending on the fuel source (gas, electricity, and propane), time of day, and season. TDV was developed to reflect the "societal value or cost" of energy including long-term projected costs of energy, such as the cost of providing energy during peak periods of demand, and other societal costs, such as projected costs for carbon emissions. Electricity used (or saved) during peak periods of the summer has a much higher value than electricity used (or saved) during off-peak periods (Horii et al., 2014).

It is important to note that while the TDV methodology is used as the basis of code compliance, the study itself focuses strictly on the actual electricity consumed at the site, and the time of that consumption. While the Title 24 tools are geared towards the optimization of TDV, this study is focused on site electricity (kWh) reduction during the peak hours outlined in Section 2.6, Utility Rate Structure.

2.3 Baseline Home Development

The methodology used in the analyses for each of the prototypical building types begins with a design that precisely meets the minimum 2016 (or 2019) prescriptive requirements (0 percent compliance margin) for Climate Zone 4, as published in Table 150.1-A of the Standards. Since this study was focused on the economic viability of the battery system, the base case homes included a PV system sized as outlined in the 2019 Standards. Since the 2019 Standards will make it very difficult to comply without the use of PV, the system size dictated here was the logical starting point for the "base" home. The PV system sizes varied based upon the floor area of each prototype, with the large two story home requiring a slightly larger PV system. To accurately account for the economics, the study uses current Pacific Gas and Electric Company (PG&E) utility rates for the base case home. Two versions of each prototype were developed: one using an all-electric design and one using a mixed fuel design for a home with gas appliances:

Table 2: Baseline Home Prototypes

Home	Heating	Domestic Hot Water	Appliances	Electricity Rate	Natural Gas Rate
All Electric	Electric Heat Pump	Electric Heat Pump	Electric Range and Dryer	E-TOU, Option B	N/A
Mixed Fuel	Gas Furnace	Instantaneous Gas	Gas Range and Dryer	E-TOU, Option B	G1

2.4 Battery Options

A survey was conducted to determine the various battery offerings available in the California market. The survey involved reviewing material published by the battery manufacturer and installer websites to determine estimated costs. Table 3 summarizes product availability, including installation cost where available. In cases where the installation cost was not available, an estimate of $2,000 was used, based upon costs indicated by the other product manufacturers. In addition, based upon the product warranties offered, the study assumes that the battery life will be 10 years (yrs).

Table 3: Battery Survey

Company	Battery	Kilowatt-hours (kWh)	$/Battery	$/kWh	Warranty
Tesla	Powerwall 2	13.5	$8,600	$637	10 yrs
Sonnen	Eco	4	$11,950*	$2,987	10,000 cycles or 10 yrs
Sonnen	Eco	16	$24,800*	$1,550	10,000 cycles or 10 yrs
Enphase	AC Battery	1.2	$2,500	$2083	7,300 cycles or 10 yrs
LG/Sunrun	Brightbox	9.8	$6,000*	$612	10 yrs
Mercedes/Vivint	Energy Storage	2.5	$5,000	$2,000	10 yrs
Mercedes/Vivint	Energy Storage	20	$13,000	$650	10 yrs
Nissan	Xstorage	4.2	$4,500	$1,071	10 yrs
EletrIQ	EletrIQ	10	$16,000	$1,600	10 yrs
Samsung	ESS	4.8	Unknown	Unknown	Unknown

*installation cost not available, assumes $2,000.

The initial cost of the battery, including installation was discounted by 30 percent to account for the federal tax credit currently available for the 2016 home studied. For the 2019 home (which would be in effect in 2020) the federal tax credit was reduced to 26% to reflect the phasing out of the credit. Based on the battery warranty period, it was assumed the battery would be replaced during the 20-year study period. However, the cost of the battery was projected to drop by 30 percent in 10 years, and the installation cost reduced to $500 for the replacement battery. All replacement costs assume the federal tax credit is no longer available.

Note: The study assumes the battery will qualify for the federal tax credit, however, the federal tax code does not specifically reference storage systems. The United States Internal Revenue Service has provided “Private Letter Rulings”, most recently in 2018 (attached as Appendix A), that confirm the storage system, when paired with a PV system, is eligible (provided it meets all other requirements). It is important to note that Private Letter Rulings do not establish precedent; they only apply to the person requesting the ruling. Thus, the team recommends confirming eligibility with a tax advisor.

Three options were chosen from the products surveyed as outlined in Table 4, the smaller Sunrun product at 9.8 kWh, the medium range Tesla product at 13.5 kWh, and the largest product, the Vivint 20 kWh model.

Table 4: Battery Costs used in Study

Company	Battery	kWh/Battery	Installed Cost after Federal 30% Tax Credit	Replacement Cost
LG/Sunrun	Brightbox	9.8	$4,200	$3,300
Tesla	Powerwall 2	13.5	$6,020	$5,120
Mercedes/Vivint	Energy Storage	20	$9,100	$8,200

When modeling the batteries, the inverters required to put energy into the batteries as well as discharge the energy from the batteries for use in the home have an inherent efficiency loss. For the purposes of this study, the efficiency associated with charging the battery was modeled as 92 percent. When discharging the battery, the same efficiency was assumed. This efficiency degradation is supported by field data developed by PG&E in battery test installations. Thus, a battery such as the Vivint while requiring 20 kWh for a full charge, would only deliver 17 kWh due to the loss on the charging and discharging of the unit. This is a very important consideration in the study, since a daily cycle of the larger Vivint battery, on an annual basis, would result in over 1,000 kWh of additional electricity consumption compared to a system with no battery.

2.5 Battery Control Options

Controlling the battery, specifically when it charges and when it discharges, is an important part of the overall economics of the system. The study runs for the 2016 analysis used the CBECC-Res battery control strategy labeled as “Advanced”. While a simpler option is available in the software, labeled as “Basic”, this control strategy simply seeks to charge the battery from the PV system when excess solar energy is available, and then once the home needs additional power in the evening, to discharge the entire battery into the night. The more advanced strategy seeks to optimize charging and discharging around the TDV (see Section 2.2) energy peaks that are anticipated in advance for the particular day, thus reducing grid demand.

The 2019 CBECC-Res simulation software includes a more advanced control option, labeled as “Advanced TOU” (TOU is time-of-use). This strategy allows the user to specify the time to begin discharging, which was set to 4pm consistent with the peak TOU periods. Thus, we are able to direct the system to charge the battery fully, in anticipation of the peak period outlined in the rate structure in Section 2.6. However, it must be pointed out that the control strategy does not allow us to control the hour when the discharge cycle ends. Ideally, a battery control strategy would be to discharge at 4pm and stop the discharge at 12 am, reserving some capacity for reliability protection. The control strategies are fixed in the CBECC-Res software, and in general these strategies are geared more towards optimization for the grid demand than for the consumer costs.

2.6 Utility Rate Structure for the Home with Batteries

The California Public Utilities Commission (CPUC) is currently considering new rate structures proposed by PG&E and other utilities designed to update the peak and off-peak hours to reflect current electricity grid conditions. The proposed EV-A rate (Residential Electric Vehicle rate) structure shown below was used for the home equipped with the battery. As of the published date of this report, this is not a current rate structure, however, PG&E has proposed this as their replacement EV-A rate. This proposed rate structure offers considerably lower rates during off peak hours, but imposes much higher rates during the peak period of 4 pm until 9 pm. This rate offers an advantage to the home with the battery, given the ability to avoid the peak rates that occur between 4 pm and 9 pm, as well as the part-peak rates from 9 pm until 12 am.

PG&E anticipates that this rate will be open to a limited number of customers, and it is designed for customers who own an electric vehicle. Given the limited availability, the conventional E6- B rate (Residential Time of Use rate) was also considered, and the economics for the battery are considerably worse in that case. This emphasizes the importance of a rate structure that favors the off-peak cost of electricity to the success of a battery system. The proposed EV-A rate used in the study is summarized as follows:

Pacific Gas and Electric Company
2017 General Rate Case – Phase II
Residential Rate Design Settlement Agreement Appendix C
Present and Illustrative Proposed Rates

EVA (Electric Vehicles)

		Distr	Gen	PPP	Other	Total
ENERGY CHARGE (/kWh)						
Summer						
	Peak	.20693	.16652	.01495	.03915	.42755
	Part-Peak	.14114	.12181	.01495	.03915	.31706
	Off-Peak	.01522	.08067	.01495	.03915	.14999
Winter						
	Peak	.13669	.10965	.01495	.03915	.30044
	Part-Peak	.13248	.09716	.01495	.03915	.28374
	Off-Peak	.02221	.07368	.01495	.03915	.14999

Seasons:

Summer: June – September
Winter: October – May

TOU Periods:

Peak: 4PM – 9PM, All Days
Part-Peak: 3PM – 4PM & 9PM – 12AM, All Days
Off-Peak: 12AM – 3PM, All Days

2.7 Photovoltaics

Since this study was geared towards exploring the cost-effectiveness of adding a battery system to a home that utilizes a PV system for electricity generation, the base prototypes in this study included a PV system. The sizing of the PV system was calculated using the Energy Design Rating (EDR) as would be required for compliance with the recently adopted 2019 Title 24 Standards. The 2019 Standards utilize the EDR score as an overall determination of building energy efficiency, and the 2016 home PV system was sized to give an equivalent EDR score to the 2019 home. In the case of the 1 story home, the system was sized at a 2.1 kilowatt direct current (kW DC) rating, and was increased to a 2.5 kW DC in the two story home. Just as different sized batteries were considered, different sized PV systems were also included in the analysis. To study this impact, the PV system size was increased in increments of 0.25 kW, however once the electricity production of the PV system exceeded the requirements of the home, no additional size increases were considered. Over-production of the PV system is in violation of the Net Energy Metering rules adopted by the CPUC unless the home has electrical vehicle charging stations.

Also, in the case of over-production the buy-back rate of approximately 3 cents/kWh makes this an economically unviable consideration.

This study chose to include a moderately sized PV system in all the baseline homes so that the study could focus on the economic benefit of the batteries. As such, the study includes no incremental cost for that initial PV system. However, in the case of the battery options which have increased PV system sizes, an incremental cost for the PV system of $3/watt was assumed, minus the federal tax credit.

3 Results

Cost-effectiveness analysis including evaluating three battery options paired with numerous PV system sizes was completed for Climate Zone 4. Evaluations looked to identify cost-effective combinations of batteries and PV systems for both one story and two story single family prototypes that were configured with either all electric appliances or a combination of electric and gas appliances. The study was completed under both the 2016 analysis tools, using the 2016 prototype homes, as well as the upcoming 2019 analysis tools, using the more efficient 2019 prototype homes.

The following definitions apply to the results presented in Tables 5 to 12.

Photovoltaic kW – The direct current rating in kilowatts of the solar PV system in the study.

Photovoltaic Incremental Cost – The added cost of the solar PV system over the baseline home design, calculated at $3/watt, less the 30 percent federal tax credit.

Battery Cost – The total cost of the battery system, including inverters and installation cost, less the federal tax credit.

Battery Replacement – The total original cost of the battery, reduced by 30 percent to account for price reductions, plus a replacement labor cost of $500. Note no federal tax credit is assumed for the replacement given the assumption this will not be in place in 10 years.

Annual Consumption kWh – The calculated net annual electricity consumption of the home in kilowatt- hours, after factoring in the production from the PV system. When a battery system is present, the data also includes the additional electricity use resulting from losses with charging and discharging the battery (overall 15 percent loss). Note in no case in this study was it assumed the battery would be charged directly from the grid, all charging occurs from the PV system.

Annual Consumption Therms – The calculated annual natural gas usage in therms for the furnace, water heater, stove, and dryer for the home. This is not applicable to the all-electric home.

Annual Energy Cost – Based upon the rate structures outlined in Sections 2.3 and 2.5, the annual net cost of the home electricity and natural gas.

Total 20 Year Cost – The total cost including the PV Incremental cost, initial Battery Cost, Battery Replacement Cost as well as the Annual Energy Cost. Energy costs do not include any escalation and are assumed to remain constant for 20 years.

3.1 2016 Prototype Results

3.1.1 Gas Appliance Home

Tables 5 and 6 present the results of the 1 story and 2 story home prototypes utilizing gas appliances (furnace, instantaneous water heater, range, and dryer. This home configuration was shown to be the least economic viability for the application of the battery system. The option with the lowest 20 year cost was the smaller battery in both cases, combined with a PV system that offsets virtually all of the estimated electricity use (2.6 kW on the 1 story home, and 3 kW on the 2 story home; both in yellow highlight). In both cases, adding a battery increases the total operating costs over the 20-year study period.

Table 5: 2016 1 Story Gas Prototype

2016 1 Story Prototype Gas Appliances	Photovoltaic		Battery Cost		Annual Consumption		Annual Energy Cost	Total 20 Year Cost	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Therms				
No Battery	2.1	$ -	$ -	$ -	495	325	$ 551	$ 11,016		
Sunrun Battery 9.8 kWh	2.1	$ -	$ 4,200	$ 3,300	778	325	$ 509	$ 17,683	0.11	>100
	2.35	$ 525	$ 4,200	$ 3,300	398	325	$ 470	$ 17,425	0.20	99
	2.6	$ 1,050	$ 4,200	$ 3,300	12	325	$ 440	$ 17,350	0.26	77
	2.85	$ 1,575	$ 4,200	$ 3,300	-376	325	$ 423	$ 17,535	0.28	71
Tesla Battery 13.5 kWh	2.1	$ -	$ 6,020	$ 5,120	780	325	$ 510	$ 21,340	0.07	>100
	2.35	$ 525	$ 6,020	$ 5,120	402	325	$ 471	$ 21,085	0.14	>100
	2.6	$ 1,050	$ 6,020	$ 5,120	16	325	$ 441	$ 21,010	0.18	>100
	2.85	$ 1,575	$ 6,020	$ 5,120	-372	325	$ 423	$ 21,175	0.20	99
Vivint Battery 20 kWh	2.1	$ -	$ 9,100	$ 8,200	782	325	$ 511	$ 27,520	0.05	>100
	2.35	$ 525	$ 9,100	$ 8,200	406	325	$ 473	$ 27,285	0.09	>100
	2.6	$ 1,050	$ 9,100	$ 8,200	20	325	$ 444	$ 27,230	0.12	>100
	2.85	$ 1,575	$ 9,100	$ 8,200	-370	325	$ 423	$ 27,335	0.14	>100

Table 6: 2016 2 Story Gas Prototype

2016 2 Story Prototype Gas Appliances	Photovoltaic		Battery Cost		Annual Consumption		Annual	Total		Simple
	kW	Incremental Cost	Initial	Replacement	kWh	Therms	Energy Cost	20 Year Cost	Lifecycle B/C Ratio	Payback (yrs)
No Battery	2.5	$ -	$ -	$ -	526	362	$ 613	$ 12,254		
Sunrun Battery 9.8 kWh	2.5	$ -	$ 4,200	$ 3,300	862	362	$ 574	$ 18,981	0.10	>100
	2.75	$ 525	$ 4,200	$ 3,300	481	362	$ 534	$ 18,705	0.20	>100
	3	$ 1,050	$ 4,200	$ 3,300	95	362	$ 497	$ 18,490	0.27	74
	3.25	$ 1,575	$ 4,200	$ 3,300	-294	362	$ 479	$ 18,655	0.30	68
Tesla Battery 13.5 kWh	2.5	$ -	$ 6,020	$ 5,120	866	362	$ 574	$ 22,620	0.07	>100
	2.75	$ 525	$ 6,020	$ 5,120	486	362	$ 536	$ 22,385	0.13	>100
	3	$ 1,050	$ 6,020	$ 5,120	101	362	$ 498	$ 22,150	0.19	>100
	3.25	$ 1,575	$ 6,020	$ 5,120	-287	362	$ 480	$ 22,315	0.21	96
Vivint Battery 20 kWh	2.5	$ -	$ 9,100	$ 8,200	868	362	$ 575	$ 28,800	0.04	>100
	2.75	$ 525	$ 9,100	$ 8,200	492	362	$ 537	$ 28,565	0.09	>100
	3	$ 1,050	$ 9,100	$ 8,200	107	362	$ 501	$ 28,370	0.12	>100
	3.25	$ 1,575	$ 9,100	$ 8,200	-281	362	$ 480	$ 28,475	0.14	>100

3.1.2 All Electric Home

Tables 7 and 8 present the results of the 1 story and 2 story all electric home prototypes using heat pumps for heating and domestic hot water, an electric range and an electric dryer. The all electric homes were shown to be the most likely viability for the battery application. For comparison purposes, this table includes the option of not installing any PV at all, which is indicated to have the highest 20 year cost. Note the study showed the option with the lowest 20 year cost to be the smaller battery once again paired with a 4.1 kW PV system for the one story home, and a 4.5 kW system in the two story home (both in yellow highlight). In addition, in the case of the one story home, the study considers the impact of not using the more advantageous EV-A rate, but instead the same rate as used in the baseline home, E6-B. Clearly, without the EV-A rate, the annual utility costs increase significantly. As a final option, the result highlighted in orange considers the use of no battery, but instead investing in a larger PV system that offsets most of the annual electricity use for the home. This option produces the most favorable economic results in the study.

Table 7: 2016 1 Story Electric Prototype

2016 1 Story Prototype All Electric	Photovoltaic		Battery Cost		Annual	Annual Cost		Total 20 Year Cost		Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	TOU-B	EV-A	TOU-B	EV-A		
No Solar	0	$ (5,880)			7605	$ 1,777		$ 29,660			
No Battery	2.1	$ -			4222	$ 943		$ 18,855			
	3.85	$ 3,675			1404	$ 585		$ 15,375		2.06	10.3
Sunrun Battery 9.8 kWh	2.1	$ -	$ 4,200	$ 3,300	4458		$ 883		$ 25,160	0.16	>100
	2.6	$ 1,050	$ 4,200	$ 3,300	3739		$ 719		$ 22,930	0.52	38
	3.1	$ 2,100	$ 4,200	$ 3,300	2988		$ 606		$ 21,720	0.70	28
	3.6	$ 3,150	$ 4,200	$ 3,300	2215		$ 522		$ 21,090	0.79	25
	4.1	$ 4,200	$ 4,200	$ 3,300	1431	$ 586	$ 446	$ 23,420	$ 20,620	0.85	24
Tesla Battery 13.5 kWh	2.1	$ -	$ 6,020	$ 5,120	4458		$ 883		$ 28,800	0.11	>100
	2.6	$ 1,050	$ 6,020	$ 5,120	3747		$ 724		$ 26,670	0.36	56
	3.1	$ 2,100	$ 6,020	$ 5,120	3005		$ 613		$ 25,500	0.50	40
	3.6	$ 3,150	$ 6,020	$ 5,120	2242		$ 532		$ 24,930	0.58	35
	4.1	$ 4,200	$ 6,020	$ 5,120	1465		$ 455		$ 24,440	0.64	31
Vivint Battery 20 kWh	2.1	$ -	$ 9,100	$ 8,200	4458		$ 883		$ 34,960	0.07	>100
	2.6	$ 1,050	$ 9,100	$ 8,200	3750		$ 727		$ 32,890	0.24	85
	3.1	$ 2,100	$ 9,100	$ 8,200	3011		$ 615		$ 31,700	0.34	59
	3.6	$ 3,150	$ 9,100	$ 8,200	2250		$ 537		$ 31,190	0.40	50
	4.1	$ 4,200	$ 9,100	$ 8,200	1480		$ 465		$ 30,800	0.44	45

Table 8: 2016 2 Story Electric Prototype

2016 2 Story Prototype All Electric	Photovoltaic kW	Photovoltaic Incremental Cost	Battery Cost Initial	Battery Cost Replacement	Annual kWh	Annual Energy Cost	Total 20 Year Cost	Lifecycle B/C Ratio	Simple Payback (yrs)
No Battery	2.5	$ -	$ -	$ -	4653	$ 1,037	$ 20,748		
Sunrun Battery 9.8 kWh	2.5	$ -	$ 4,200	$ 3,300	4939	$ 970	$ 26,900	0.18	>100
	3	$ 1,050	$ 4,200	$ 3,300	4215	$ 802	$ 24,590	0.55	36
	3.5	$ 2,100	$ 4,200	$ 3,300	3457	$ 677	$ 23,140	0.75	27
	4	$ 3,150	$ 4,200	$ 3,300	2681	$ 575	$ 22,150	0.87	23
	4.5	$ 4,200	$ 4,200	$ 3,300	1897	$ 500	$ 21,700	0.92	22
Tesla Battery 13.5 kWh	2.5	$ -	$ 6,020	$ 5,120	4939	$ 970	$ 30,540	0.12	>100
	3	$ 1,050	$ 6,020	$ 5,120	4228	$ 811	$ 28,410	0.37	54
	3.5	$ 2,100	$ 6,020	$ 5,120	3489	$ 693	$ 27,100	0.52	38
	4	$ 3,150	$ 6,020	$ 5,120	2725	$ 591	$ 26,110	0.62	32
	4.5	$ 4,200	$ 6,020	$ 5,120	1951	$ 511	$ 25,560	0.69	29
Vivint Battery 20 kWh	2.5	$ -	$ 9,100	$ 8,200	4939	$ 970	$ 36,700	0.08	>100
	3	$ 1,050	$ 9,100	$ 8,200	4233	$ 814	$ 34,630	0.24	82
	3.5	$ 2,100	$ 9,100	$ 8,200	3500	$ 695	$ 33,300	0.35	57
	4	$ 3,150	$ 9,100	$ 8,200	2741	$ 597	$ 32,390	0.43	46
	4.5	$ 4,200	$ 9,100	$ 8,200	1974	$ 522	$ 31,940	0.48	42

3.2 2019 Prototype Results

3.2.1 Gas Appliance Home

Tables 9 and 10 present the results of the 1 story and 2 story home prototypes utilizing gas appliances (furnace, instantaneous water heater, range and dryer). This home configuration was shown to be the least economic viability for the application of the battery system. The option with the lowest 20 year cost was the smaller battery in both cases, combined with a PV system that offsets virtually all of the estimated electricity use (2.6 kW on the 1 story home, and 3 kW on the 2 story home; both in yellow highlight). In both cases, adding a battery increases the total operating costs over the 20-year study period.

Table 9: 2019 1 Story Gas Prototype

2019 1 Story Prototype Gas Appliances	Photovoltaic		Battery Cost		Annual Consumption		Annual	Total		Simple
	kW	Incremental Cost	Initial	Replacement	kWh	Therms	Energy Cost	20 Year Cost	Lifecycle B/C Ratio	Payback (yrs)
No Battery	2.1	$ -	$ -	$ -	565	307	$ 538	$ 10,762		
Sunrun Battery 9.8 kWh	2.1	$ -	$ 4,440	$ 3,300	849	307	$ 492	$ 17,580	0.12	>100
	2.35	$ 555	$ 4,440	$ 3,300	482	307	$ 458	$ 17,455	0.19	>100
	2.6	$ 1,110	$ 4,440	$ 3,300	107	307	$ 428	$ 17,410	0.25	80
	2.85	$ 1,665	$ 4,440	$ 3,300	-278	307	$ 408	$ 17,565	0.28	72
Tesla Battery 13.5 kWh	2.1	$ -	$ 6,364	$ 5,120	850	307	$ 493	$ 21,344	0.08	>100
	2.35	$ 555	$ 6,364	$ 5,120	485	307	$ 459	$ 21,219	0.13	>100
	2.6	$ 1,110	$ 6,364	$ 5,120	115	307	$ 430	$ 21,194	0.17	>100
	2.85	$ 1,665	$ 6,364	$ 5,120	-257	307	$ 408	$ 21,309	0.20	>100
Vivint Battery 20 kWh	2.1	$ -	$ 9,620	$ 8,200	852	307	$ 494	$ 27,700	0.05	>100
	2.35	$ 555	$ 9,620	$ 8,200	489	307	$ 461	$ 27,595	0.08	>100
	2.6	$ 1,110	$ 9,620	$ 8,200	120	307	$ 433	$ 27,590	0.11	>100
	2.85	$ 1,665	$ 9,620	$ 8,200	-252	307	$ 408	$ 27,645	0.13	>100

Table 10: 2019 2 Story Gas Prototype

2019 2 Story Prototype Gas Appliances	Photovoltaic		Battery Cost		Annual Consumption		Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Therms	Energy Cost	20 Year Cost		
No Battery	2.5	$ -	$ -	$ -	575	332	$ 582	$ 11,631		
Sunrun Battery 9.8 kWh	2.5	$ -	$ 4,440	$ 3,300	913	332	$ 531	$ 18,360	0.13	>100
	2.75	$ 555	$ 4,440	$ 3,300	539	332	$ 500	$ 18,295	0.20	>100
	3	$ 1,110	$ 4,440	$ 3,300	154	332	$ 470	$ 18,250	0.25	79
	3.25	$ 1,665	$ 4,440	$ 3,300	-236	332	$ 449	$ 18,385	0.28	71
Tesla Battery 13.5 kWh	2.5	$ -	$ 6,364	$ 5,120	917	332	$ 534	$ 22,164	0.08	>100
	2.75	$ 555	$ 6,364	$ 5,120	549	332	$ 503	$ 22,099	0.13	>100
	3	$ 1,110	$ 6,364	$ 5,120	180	332	$ 473	$ 22,054	0.17	>100
	3.25	$ 1,665	$ 6,364	$ 5,120	-193	332	$ 451	$ 22,169	0.20	100
Vivint Battery 20 kWh	2.5	$ -	$ 9,620	$ 8,200	919	332	$ 536	$ 28,540	0.05	>100
	2.75	$ 555	$ 9,620	$ 8,200	554	332	$ 504	$ 28,455	0.08	>100
	3	$ 1,110	$ 9,620	$ 8,200	185	332	$ 476	$ 28,450	0.11	>100
	3.25	$ 1,665	$ 9,620	$ 8,200	-187	332	$ 452	$ 28,525	0.13	>100

3.2.2 All Electric Home

Tables 11 and 12 present the results of the 1 story and 2 story all electric home prototypes using heat pumps for heating and domestic hot water, an electric range and an electric dryer. The all electric homes were shown to be the most viable for the battery application. Note the study showed the option with the lowest 20 year cost to be the smaller battery, once again paired with a 4.1 kW PV system for the one story home, and a 4.5 kW system in the two story home (both in yellow highlight).

Table 11: 2019 1 Story Electric Prototype

2019 1 Story Prototype All Electric	Photovoltaic		Battery Cost		Annual Consumption	Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Energy Cost	20 Year Cost		
No Battery	2.1	$ -	$ -	$ -	4057	$ 906	$ 18,121		
Sunrun Battery 9.8 kWh	2.1	$ -	$ 4,440	$ 3,300	4285	$ 813	$ 24,000	0.24	83
	2.6	$ 1,110	$ 4,440	$ 3,300	3562	$ 659	$ 22,030	0.56	36
	3.1	$ 2,220	$ 4,440	$ 3,300	2808	$ 570	$ 21,360	0.67	30
	3.6	$ 3,330	$ 4,440	$ 3,300	2035	$ 490	$ 20,870	0.75	27
	4.1	$ 4,440	$ 4,440	$ 3,300	1248	$ 414	$ 20,460	0.81	25
Tesla Battery 13.5 kWh	2.1	$ -	$ 6,364	$ 5,120	4285	$ 813	$ 27,744	0.16	>100
	2.6	$ 1,110	$ 6,364	$ 5,120	3569	$ 664	$ 25,874	0.38	52
	3.1	$ 2,220	$ 6,364	$ 5,120	2841	$ 580	$ 25,304	0.48	42
	3.6	$ 3,330	$ 6,364	$ 5,120	2097	$ 500	$ 24,814	0.55	36
	4.1	$ 4,440	$ 6,364	$ 5,120	1329	$ 423	$ 24,384	0.61	33
Vivint Battery 20 kWh	2.1	$ -	$ 9,620	$ 8,200	4285	$ 813	$ 34,080	0.10	>100
	2.6	$ 1,110	$ 9,620	$ 8,200	3573	$ 668	$ 32,290	0.25	80
	3.1	$ 2,220	$ 9,620	$ 8,200	2846	$ 582	$ 31,680	0.32	62
	3.6	$ 3,330	$ 9,620	$ 8,200	2115	$ 509	$ 31,330	0.38	53
	4.1	$ 4,440	$ 9,620	$ 8,200	1377	$ 436	$ 30,980	0.42	47

Table 12: 2019 2 Story Electric Prototype

2019 2 Story Prototype All Electric	Photovoltaic		Battery Cost		Annual Consumption	Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Energy Cost	20 Year Cost		
No Battery	2.5	$ -	$ -	$ -	4374	$ 975	$ 19,509		
Sunrun Battery 9.8 kWh	2.5	$ -	$ 4,440	$ 3,300	4649	$ 868	$ 25,100	0.28	72
	3	$ 1,110	$ 4,440	$ 3,300	3912	$ 724	$ 23,330	0.57	35
	3.5	$ 2,220	$ 4,440	$ 3,300	3147	$ 609	$ 22,140	0.73	27
	4	$ 3,330	$ 4,440	$ 3,300	2368	$ 526	$ 21,590	0.81	25
	4.5	$ 4,440	$ 4,440	$ 3,300	1579	$ 454	$ 21,260	0.86	23
Tesla Battery 13.5 kWh	2.5	$ -	$ 6,364	$ 5,120	4651	$ 869	$ 28,864	0.18	>100
	3	$ 1,110	$ 6,364	$ 5,120	3936	$ 733	$ 27,254	0.38	52
	3.5	$ 2,220	$ 6,364	$ 5,120	3206	$ 623	$ 26,164	0.51	39
	4	$ 3,330	$ 6,364	$ 5,120	2449	$ 536	$ 25,534	0.59	34
	4.5	$ 4,440	$ 6,364	$ 5,120	1676	$ 462	$ 25,164	0.64	31
Vivint Battery 20 kWh	2.5	$ -	$ 9,620	$ 8,200	4651	$ 869	$ 35,200	0.12	>100
	3	$ 1,110	$ 9,620	$ 8,200	3940	$ 734	$ 33,610	0.25	79
	3.5	$ 2,220	$ 9,620	$ 8,200	3219	$ 630	$ 32,640	0.34	58
	4	$ 3,330	$ 9,620	$ 8,200	2487	$ 549	$ 32,130	0.40	50
	4.5	$ 4,440	$ 9,620	$ 8,200	1748	$ 474	$ 31,740	0.45	44

4 Conclusions & Summary

This report evaluated the feasibility and cost-effectiveness of battery storage systems combined with PV electricity generation for new single family homes in Climate Zone 4. In addition, Climate Zone 13 (Fresno) results are presented in Appendix B to illustrate the impact in a warm central valley climate. In both climates, the viability of the battery storage system is highly dependent upon the initial cost of the battery system, the installation cost, as well as the life of the system. In addition, the application of the battery to an all-electric home versus a home with gas appliances shows different economic outcomes, and finally the utility rate structure makes a sizable difference in the economics for both climates.

Based upon the results shown, the following conclusions can be reached:

- The battery storage system is not cost-effective. It is less costly on an all-electric home than one that has gas appliances given the larger electric load expected during the peak periods. All electric homes without batteries will see higher energy costs due to the operation of the electrical equipment during the peak time, while the homes with gas have less electric equipment operating. As a result, the use of the batteries to avoid those peak charges provides a higher benefit to the all-electric home.
- The larger battery storage systems have a higher initial cost, and are less cost-effective than the smaller battery systems. This conclusion would obviously vary based upon the size of the home, but the 2,100 sqft and 2,700 sqft homes used in this study have enough capacity from the battery for the 4 pm – 12 am period.
- Battery losses based upon daily charge/discharge cycles contribute to higher electricity consumption than a home without a battery, but with proper controls, results in lower energy bills.
- The utility rate structure impacts the economics of the battery system. The EV-A rate structure significantly favors off-peak usage, with the difference equal to $0.15 to 0.27/kWh versus $0.12/kWh difference on the E6-B rate. Without the benefit of a rate structure to favor off peak usage, the battery operational costs are higher.
- Battery costs, installation costs, and replacement costs drive the economics of the product. Looking at a battery system in which the cost was 50 percent of what is shown in this study resulted in a favorable outcome. Also, were the battery to have a life span of 20 years, instead of the 10 years used in the study, the outcome would be more favorable.
- Given the current economics, an investment in a larger PV system than required by the Standards (assuming the home has the roof space) shows a more favorable outcome than the battery investment.

The results demonstrate that the investment in a battery is not cost effective, while a smaller economic investment in a PV system size increase is cost effective. However, the results show that an all-electric solar PV home with a battery added is within $1,800 of showing an economic payback over the PV only system. No doubt, the battery products will evolve and become more robust, possibly with better cost reductions than assumed here. In addition, as utility rate structures evolve to higher rates during the peak periods and less credit for grid exports via NEM, it is expected that battery systems will show more attractive economics in the future.

5 References

CEC. 2016a. 2016 Alternative Calculation Method Approval Manual. CEC-400-2015-039-CMF. June 2015. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-039/CEC-400-2015-039-CMF.pdf

US Internal Revenue Service: https://www.irs.gov/pub/irs-wd/201809003.pdf

Appendix A – IRS Letter

Internal Revenue Service

Number: **201809003**
Release Date: 3/2/2018

Index Number: 25D.00-00

In Re: Request for rulings under IRC § 25D

Department of the Treasury
Washington, DC 20224

Third Party Communication: None
Date of Communication: Not Applicable

Person To Contact:
, ID No.

Telephone Number:

Refer Reply To:
CC:PSI:B06
PLR-118431-17

Date:
November 27, 2017

Legend:
State =
Year 1 =
Year 2 =
Date 1 =
Director =

Dear :

This letter is in response to your letter dated June 9, 2017, and subsequent correspondence dated September 21, 2017, submitted by your authorized representatives, requesting rulings under § 25D of the Internal Revenue Code (Code). Specifically, you request a letter ruling that the cost of installing certain energy storage property to be integrated into other residential solar photovoltaic system property will qualify as a "qualified solar electric property expenditure" eligible for the tax credit under § 25D.

The facts and representations submitted are as follows:

You are married individuals who reside in State and file joint federal income tax returns. You use the cash method of accounting and are a calendar year taxpayer.

In Year 1, you purchased from an installer a system of components which you collectively refer to as a Solar Energy System and each component of which you refer to as a Solar Energy System Component. You acquired the Solar Energy System to use solar energy to generate electricity for use in your dwelling unit which you use as a residence. The Solar Energy System was interconnected into the electrical grid of the local utility and installation was considered to be complete for purposes of § 25D(e)(8)(A) of the Code on Date 1. The associated costs of the Solar Energy System met the requirements for "qualified solar electric property expenditures" under § 25D(d)(2). Accordingly, you claimed a tax credit under § 25D equal to 30 percent of

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the costs of the Solar Energy System property in Year 1, the year in which the installation of the property was completed.

You are purchasing an energy storage product from an installer that can be integrated into existing Solar Energy Systems as an additional Solar Energy System Component. The product is comprised of 1) an AC battery; 2) an inverter that will convert solar electricity between AC and DC so the battery can charge and discharge the solar electricity; 3) required wiring to interconnect the product into your current Solar Energy System Components and your dwelling unit; and 4) a software management tool that will monitor and control the charging and discharging of energy (collectively, the "Battery"). You represent that the Battery is AC coupled to any new or existing Solar Energy System. The Battery contains a meter with current transformers that monitor the solar production and grid import as well as internal meters within the Battery that monitor charge and discharge power. When the Battery is constrained to charge only from solar, the software monitors these signals (every 0.1 seconds) and controls the Battery such that charging only occurs when the Solar Energy System is producing energy and only up to the instantaneous solar power. Thus all energy that is used to charge the Battery can be effectively assured to come from the Solar Energy System. Your purchase price for the Battery will include the labor costs allocable to onsite preparation, assembly, and original installation of the Battery. You intend for the original installation of the Battery to be completed in Year 2. The Battery is expected to have a storage capacity of 13.5 kilowatt hours ("kWh") and a power rating of 5 kilowatts ("kW").

Software controls will ensure your Battery will store solar electricity generated by the PV Panel and use it a later point in time – either later in the day or at night. In addition, integrating the Battery into the other Solar Energy System Components will enable you to disconnect from the grid in the event of a grid outage and continue using solar electricity in compliance with electrical codes when other Solar Energy Systems without a Battery will be forced to cease operating. The remaining useful life of your Solar Energy System is expected to exceed the useful life of the Battery and, much like a typical inverter, the Battery will likely need to be replaced at some point during the remaining useful life of the Solar Energy System.

For the reasons set forth in this letter ruling request, you request that the Internal Revenue Service rule on the following issues:

1) Whether the Battery will be considered a "qualified solar electric property expenditure" within the meaning of § 25D(d)(2) of the Code when installed as a component part of a Solar Energy System to solely function as an energy storage device and use solar energy, and, therefore, a tax credit under § 25D may be claimed on its full cost.

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2) Whether the Battery cost remains a "qualified solar electric property expenditure" when installed in a taxable year after the taxable year in which the installation of your other Solar Energy System Components are completed.

Law and Analysis

Section 25D(a)(1) of the Code allows an individual a credit against the income tax imposed for the taxable year in an amount equal to the applicable percentage of the qualified solar electric property expenditures made by the taxpayer during such year.

Section 25D(a)(2) of the Code allows an individual a credit against the income tax imposed for the taxable year in an amount equal to the applicable percentage of the qualified solar water heating property expenditures made by the taxpayer during such year.

Section 25D(d)(1) of the Code defines the term "qualified solar water heating property expenditure" as an expenditure for property to heat water for use in a dwelling unit located in the United States and used as a residence by the taxpayer if at least half of the energy used by such property for such purpose is derived from the sun.

Section 25D(d)(2) of the Code defines the term "qualified solar electric property expenditure" as an expenditure for property which uses solar energy to generate electricity for use in a dwelling unit located in the United States and used as a residence by the taxpayer.

Section 25D(e)(1) of the Code allows the expenditures for labor costs properly allocable to the onsite preparation, assembly, or original installation of the qualified solar electric property and for piping or wiring to interconnect such property to the dwelling unit to be taken into account for purposes of section 25D.

Section 25D(e)(3) of the Code provides that expenditures which are properly allocable to a swimming pool, hot tub, or any other energy storage medium which has a function other than the function of such storage shall not be taken into account for purposes of this section.

Under § 25D(e)(8)(A) of the Code, generally, for purposes of determining the tax year when the credit is allowed, an expenditure with respect to an item shall be treated as made when the original installation of the item is completed. Under § 25D(e)(8)(B), in the case of an expenditure in connection with the construction or reconstruction of a structure, such expenditure shall be treated as made when the original use of the constructed or reconstructed structure by the taxpayer begins.

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Section 25D(g) of the Code provides that for § 25D(a)(1) and (2), the applicable percentage shall be 30 percent in the case of property placed in service after December 31, 2016, and before January 1, 2020.

We conclude that this Battery meets the definition of a "qualified solar electric property expenditure" under § 25D(d)(2) of the Code, and therefore, you may claim a tax credit on this Battery. The Battery is considered to be property which uses solar energy to generate electricity for use in your dwelling unit located in the United States and used as a residence by you. The software management tool portion is only considered part of the qualified solar electric property so long as it is required in monitoring the charging and discharging of solar energy. Additionally, as provided by § 25D(e)(1), labor costs that are properly allocable to the onsite preparation, assembly, or original installation of the Battery and for piping or wiring to interconnect the Battery to your home are eligible for the credit. Because under the statute, expenditures that are treated as made in Year 2 provide for a 30 percent tax credit, the applicable percentage in the case of your request is 30 percent.

Your representation that all energy that is used to charge the Battery can be effectively assured to come from the Solar Energy System is essential for this ruling. Section 25D(d)(1) of the Code includes as a requirement in its definition of "qualified solar water heating property expenditure" that at least half of the energy used by such property for such purpose is derived from the sun. The definition of "qualified solar electric property expenditure" under § 25D(d)(2) omits this language. Thus, the Congress purposefully chose to include a 50 percent usage requirement in the definition of "qualified solar water heating property", but the Congress did not include such language in the definition of "qualified solar electric property." This demonstrates that the Congress expects the energy used by a "qualified solar electric property expenditure" to be derived solely from the sun. Accordingly, 100 percent of the energy used by the Battery must be derived from the sun. If this is not the case, the Battery does not meet the definition of "qualified solar electric property" in the Code.

Lastly, in regard to your second request, we conclude that the Battery cost is a "qualified solar electric property expenditure" when installed in a taxable year after the taxable year in which the installation of your other Solar Energy System Components are completed. If the Battery qualifies as a "qualified solar electric property expenditure," you can follow the rules in § 25D(e)(8) of the Code about when the expenditure is treated as being made for purposes of claiming the credit. Earlier installations of qualifying property do not affect the availability of the credit for qualifying property in later years.

Accordingly, based solely upon the facts submitted and representations made, we conclude that your expenditure for the Battery constitutes a "qualified solar electric property expenditure" under § 25D(d)(2) of the Code and this expenditure as well as the

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installation services that are in accord with § 25D(e)(1) are eligible for the 30 percent tax credit in Year 2.

We based the rulings contained in this letter upon information and representations submitted by your representatives and accompanied by penalties of perjury statements executed by you. While this office has not verified any of the material submitted in support of the request for rulings, it is subject to verification on examination.

Except as specifically set forth above, we express or imply no opinion regarding the tax consequences of any aspect of any transaction or item discussed or referenced in this letter.

This ruling is directed only to the taxpayer who requested it. Section 6110(k)(3) of the Code provides it may not be used or cited as precedent. In accordance with the power of attorney on file with this office, a copy of this letter is being sent to your authorized representative. We are also sending a copy of this letter ruling to the Director.

Sincerely,

Peter C. Friedman
Senior Technician Reviewer, Branch 6
Office of Associate Chief Counsel
(Passthroughs & Special Industries)

cc:

Appendix B – Climate Zone 13 Results

Table 13: CZ 13 2016 1 Story Gas Prototype

2016 1 Story Prototype Gas Appliances	Photovoltaic		Battery Cost		Annual Consumption		Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Therms	Energy Cost	20 Year Cost		
No Battery	3.4	$ -	$ -	$ -	141	322	$ 660	$ 13,198		
Sunrun Battery 9.8 kWh	3.4	$ -	$ 4,200	$ 3,300	552	322	$ 619	$ 19,880	0.11	>100
	3.65	$ 525	$ 4,200	$ 3,300	173	322	$ 580	$ 19,625	0.20	100
	3.9	$ 1,050	$ 4,200	$ 3,300	-209	322	$ 545	$ 19,450	0.27	74
Tesla Battery 13.5 kWh	3.4	$ -	$ 6,020	$ 5,120	580	322	$ 617	$ 23,480	0.08	>100
	3.65	$ 525	$ 6,020	$ 5,120	216	322	$ 567	$ 23,005	0.16	>100
	3.9	$ 1,050	$ 6,020	$ 5,120	-154	322	$ 521	$ 22,610	0.23	88
Vivint Battery 20 kWh	3.4	$ -	$ 9,100	$ 8,200	588	322	$ 618	$ 29,660	0.05	>100
	3.65	$ 525	$ 9,100	$ 8,200	226	322	$ 570	$ 29,225	0.10	>100
	3.9	$ 1,050	$ 9,100	$ 8,200	-140	322	$ 525	$ 28,850	0.15	>100

Table 14: CZ 13 2016 2 Story Gas Prototype

2016 2 Story Prototype Gas Appliances	Photovoltaic		Battery Cost		Annual Consumption		Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Therms	Energy Cost	20 Year Cost		
No Battery	4.1	$ -	$ -	$ -	232	379	$ 794	$ 15,886		
Sunrun Battery 9.8 kWh	4.1	$ -	$ 4,200	$ 3,300	682	379	$ 795	$ 23,400	0.00	>100
	4.35	$ 525	$ 4,200	$ 3,300	300	379	$ 754	$ 23,105	0.10	>100
	4.6	$ 1,050	$ 4,200	$ 3,300	-82	379	$ 721	$ 22,970	0.17	>100
Tesla Battery 13.5 kWh	4.1	$ -	$ 6,020	$ 5,120	749	379	$ 755	$ 26,240	0.07	>100
	4.35	$ 525	$ 6,020	$ 5,120	376	379	$ 704	$ 25,745	0.15	>100
	4.6	$ 1,050	$ 6,020	$ 5,120	-3	379	$ 665	$ 25,490	0.21	94
Vivint Battery 20 kWh	4.1	$ -	$ 9,100	$ 8,200	768	379	$ 758	$ 32,460	0.04	>100
	4.35	$ 525	$ 9,100	$ 8,200	405	379	$ 709	$ 32,005	0.10	>100
	4.6	$ 1,050	$ 9,100	$ 8,200	39	379	$ 663	$ 31,610	0.14	>100

Table 15: CZ 13 2016 1 Story Electric Prototype

2016 1 Story Prototype All Electric	Photovoltaic		Battery Cost		Annual Consumption	Annual Cost		Total 20 Year Cost		Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	TOU-B	EV-A	TOU-B	EV-A		
No Battery	3.4	$ -			3846	$ 975		$ 19,500			
	5.4	$ 4,200			754	$ 573		$ 15,660		1.91	10
Sunrun Battery 9.8 kWh	3.4	$ -	$ 4,200	$ 3,300	4242		$ 948		$ 26,460	0.07	>100
	3.65	$ 525	$ 4,200	$ 3,300	3874		$ 866		$ 25,345	0.27	74
	3.9	$ 1,050	$ 4,200	$ 3,300	3502		$ 794		$ 24,430	0.42	47
	4.15	$ 1,575	$ 4,200	$ 3,300	3127		$ 743		$ 23,935	0.51	39
	4.4	$ 2,100	$ 4,200	$ 3,300	2749		$ 693		$ 23,460	0.59	34
	4.65	$ 2,625	$ 4,200	$ 3,300	2369		$ 646		$ 23,045	0.65	31
	4.9	$ 3,150	$ 4,200	$ 3,300	1989		$ 605		$ 22,750	0.69	29
	5.15	$ 3,675	$ 4,200	$ 3,300	1607		$ 566		$ 22,495	0.73	27
	5.4	$ 4,200	$ 4,200	$ 3,300	1225		$ 528		$ 22,260	0.76	26
	5.65	$ 4,725	$ 4,200	$ 3,300	842	$ 564	$ 490	$ 23,505	$ 22,025	0.79	25
Tesla Battery 13.5 kWh	3.4	$ -	$ 6,020	$ 5,120	4268		$ 956		$ 30,260	0.03	>100
	3.65	$ 525	$ 6,020	$ 5,120	3914		$ 868		$ 29,025	0.18	>100
	3.9	$ 1,050	$ 6,020	$ 5,120	3557		$ 786		$ 27,910	0.31	64
	4.15	$ 1,575	$ 6,020	$ 5,120	3194		$ 724		$ 27,195	0.39	51
	4.4	$ 2,100	$ 6,020	$ 5,120	2824		$ 665		$ 26,540	0.47	43
Vivint Battery 20 kWh	3.4	$ -	$ 9,100	$ 8,200	4277		$ 961		$ 36,520	0.02	>100
	3.65	$ 525	$ 9,100	$ 8,200	3927		$ 876		$ 35,345	0.11	>100
	3.9	$ 1,050	$ 9,100	$ 8,200	3572		$ 790		$ 34,150	0.20	99
	4.15	$ 1,575	$ 9,100	$ 8,200	3213		$ 730		$ 33,475	0.26	77
	4.4	$ 2,100	$ 9,100	$ 8,200	2852		$ 674		$ 32,880	0.31	64

Table 16: CZ 13 2016 2 Story Electric Prototype

2016 2 Story Prototype All Electric	Photovoltaic		Battery Cost		Annual Consumption	Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Energy Cost	20 Year Cost		
No Battery	4.1	$ -	$ -	$ -	4488	$ 1,141	$ 22,811		
Sunrun Battery 9.8 kWh	4.1	$ -	$ 4,200	$ 3,300	4925	$ 1,120	$ 29,900	0.06	>100
	4.35	$ 525	$ 4,200	$ 3,300	4551	$ 1,047	$ 28,965	0.23	85
	4.6	$ 1,050	$ 4,200	$ 3,300	4174	$ 989	$ 28,330	0.36	56
	4.85	$ 1,575	$ 4,200	$ 3,300	3796	$ 932	$ 27,715	0.46	43
	5.1	$ 2,100	$ 4,200	$ 3,300	3417	$ 876	$ 27,120	0.55	36
	5.35	$ 2,625	$ 4,200	$ 3,300	3036	$ 835	$ 26,825	0.60	33
	5.6	$ 3,150	$ 4,200	$ 3,300	2654	$ 796	$ 26,570	0.65	31
	5.85	$ 3,675	$ 4,200	$ 3,300	2271	$ 757	$ 26,315	0.69	29
	6.1	$ 4,200	$ 4,200	$ 3,300	1889	$ 718	$ 26,060	0.72	28
	6.35	$ 4,725	$ 4,200	$ 3,300	1505	$ 680	$ 25,825	0.75	27
Tesla Battery 13.5 kWh	4.1	$ -	$ 6,020	$ 5,120	4992	$ 1,106	$ 33,260	0.06	>100
	4.35	$ 525	$ 6,020	$ 5,120	4630	$ 1,014	$ 31,945	0.22	92
	4.6	$ 1,050	$ 6,020	$ 5,120	4263	$ 942	$ 31,030	0.33	61
	4.85	$ 1,575	$ 6,020	$ 5,120	3891	$ 878	$ 30,275	0.41	48
	5.1	$ 2,100	$ 6,020	$ 5,120	3517	$ 826	$ 29,760	0.48	42
Vivint Battery 20 kWh	4.1	$ -	$ 9,100	$ 8,200	5013	$ 1,118	$ 39,660	0.03	>100
	4.35	$ 525	$ 9,100	$ 8,200	4660	$ 1,027	$ 38,365	0.13	>100
	4.6	$ 1,050	$ 9,100	$ 8,200	4304	$ 949	$ 37,330	0.21	96
	4.85	$ 1,575	$ 9,100	$ 8,200	3944	$ 879	$ 36,455	0.28	72
	5.1	$ 2,100	$ 9,100	$ 8,200	3583	$ 820	$ 35,800	0.33	60

Table 17: CZ 13 2019 1 Story Gas Prototype

2019 1 Story Prototype Gas Appliances	Photovoltaic		Battery Cost		Annual Consumption		Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Therms	Energy Cost	20 Year Cost		
No Battery	3.4	$ -	$ -	$ -	-19	304	$ 587	$ 11,738		
Sunrun Battery 9.8 kWh	3.4	$ -	$ 4,440	$ 3,300	354	302	$ 538	$ 18,500	0.13	>100
	3.65	$ 525	$ 4,440	$ 3,300	-27	302	$ 499	$ 18,245	0.21	94
Tesla Battery 13.5 kWh	3.4	$ -	$ 6,364	$ 5,120	407	302	$ 501	$ 21,504	0.15	>100
	3.65	$ 525	$ 6,364	$ 5,120	35	302	$ 449	$ 20,989	0.23	87
Vivint Battery 20 kWh	3.4	$ -	$ 9,620	$ 8,200	416	302	$ 500	$ 27,820	0.10	>100
	3.65	$ 525	$ 9,620	$ 8,200	54	302	$ 445	$ 27,245	0.15	>100

Table 18: CZ 13 2019 2 Story Gas Prototype

2019 2 Story Prototype Gas Appliances	Photovoltaic		Battery Cost		Annual Consumption		Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Therms	Energy Cost	20 Year Cost		
No Battery	4.1	$ -	$ -	$ -	-8	349	$ 690	$ 13,799		
Sunrun Battery 9.8 kWh	4.1	$ -	$ 4,440	$ 3,300	394	347	$ 679	$ 21,320	0.03	>100
	4.35	$ 525	$ 4,440	$ 3,300	11	347	$ 641	$ 21,085	0.12	>100
	4.6	$ 1,050	$ 4,440	$ 3,300	-372	347	$ 607	$ 20,930	0.19	>100
Tesla Battery 13.5 kWh	4.1	$ -	$ 6,364	$ 5,120	473	347	$ 619	$ 23,864	0.12	>100
	4.35	$ 525	$ 6,364	$ 5,120	93	347	$ 580	$ 23,609	0.18	>100
	4.6	$ 1,050	$ 6,364	$ 5,120	-289	347	$ 545	$ 23,434	0.23	86
Vivint Battery 20 kWh	4.1	$ -	$ 9,620	$ 8,200	518	347	$ 599	$ 29,800	0.10	>100
	4.35	$ 525	$ 9,620	$ 8,200	156	347	$ 542	$ 29,185	0.16	>100
	4.6	$ 1,050	$ 9,620	$ 8,200	-208	347	$ 499	$ 28,850	0.20	99

Table 19: CZ 13 2019 1 Story Electric Prototype

2019 1 Story Prototype All Electric	Photovoltaic		Battery Cost		Annual Consumption	Annual	Total	Lifecycle	Simple Payback
	kW	Incremental Cost	Initial	Replacement	kWh	Energy Cost	20 Year Cost	B/C Ratio	(yrs)
No Battery	3.4	$ -	$ -	$ -	1814	$ 705	$ 14,104		
Sunrun Battery 9.8 kWh	3.4	$ -	$ 4,440	$ 3,300	2190	$ 695	$ 21,640	0.03	>100
	3.65	$ 525	$ 4,440	$ 3,300	1817	$ 628	$ 20,825	0.19	>100
	3.9	$ 1,050	$ 4,440	$ 3,300	1440	$ 578	$ 20,350	0.29	69
	4.15	$ 1,575	$ 4,440	$ 3,300	1060	$ 537	$ 20,055	0.36	55
	4.4	$ 2,100	$ 4,440	$ 3,300	680	$ 496	$ 19,760	0.42	47
	4.65	$ 2,625	$ 4,440	$ 3,300	298	$ 457	$ 19,505	0.48	42
	4.9	$ 3,150	$ 4,440	$ 3,300	-84	$ 417	$ 19,230	0.53	38
Tesla Battery 13.5 kWh	3.4	$ -	$ 6,364	$ 5,120	2240	$ 680	$ 25,084	0.04	>100
	3.65	$ 525	$ 6,364	$ 5,120	1881	$ 601	$ 24,029	0.17	>100
	3.9	$ 1,050	$ 6,364	$ 5,120	1515	$ 535	$ 23,234	0.27	74
Vivint Battery 20 kWh	3.4	$ -	$ 9,620	$ 8,200	2250	$ 685	$ 31,520	0.02	>100
	3.65	$ 525	$ 9,620	$ 8,200	1899	$ 604	$ 30,425	0.11	>100
	3.9	$ 1,050	$ 9,620	$ 8,200	1543	$ 531	$ 29,490	0.18	>100

Table 20: CZ 13 2019 2 Story Electric Prototype

2019 2 Story Prototype All Electric	Photovoltaic		Battery Cost		Annual Consumption	Annual	Total	Lifecycle B/C Ratio	Simple Payback (yrs)
	kW	Incremental Cost	Initial	Replacement	kWh	Energy Cost	20 Year Cost		
No Battery	4.1	$ -	$ -	$ -	3869	$ 982	$ 19,641		
Sunrun Battery 9.8 kWh	4.1	$ -	$ 4,440	$ 3,300	4261	$ 959	$ 26,920	0.06	>100
	4.35	$ 525	$ 4,440	$ 3,300	3883	$ 896	$ 26,185	0.21	96
	4.6	$ 1,050	$ 4,440	$ 3,300	3504	$ 839	$ 25,570	0.33	61
	4.85	$ 1,575	$ 4,440	$ 3,300	3123	$ 788	$ 25,075	0.42	48
	5.1	$ 2,100	$ 4,440	$ 3,300	2742	$ 744	$ 24,720	0.48	41
	5.35	$ 2,625	$ 4,440	$ 3,300	2360	$ 705	$ 24,465	0.53	37
	5.6	$ 3,150	$ 4,440	$ 3,300	1977	$ 666	$ 24,210	0.58	34
	5.85	$ 3,675	$ 4,440	$ 3,300	1593	$ 628	$ 23,975	0.62	32
	6.1	$ 4,200	$ 4,440	$ 3,300	1210	$ 590	$ 23,740	0.66	30
	6.35	$ 4,725	$ 4,440	$ 3,300	825	$ 552	$ 23,505	0.69	29
Tesla Battery 13.5 kWh	4.1	$ -	$ 6,364	$ 5,120	4348	$ 913	$ 29,744	0.12	>100
	4.35	$ 525	$ 6,364	$ 5,120	3978	$ 836	$ 28,729	0.24	82
	4.6	$ 1,050	$ 6,364	$ 5,120	3604	$ 778	$ 28,094	0.33	61
	4.85	$ 1,575	$ 6,364	$ 5,120	3228	$ 728	$ 27,619	0.39	51
	5.1	$ 2,100	$ 6,364	$ 5,120	2851	$ 681	$ 27,204	0.44	45
Vivint Battery 20 kWh	4.1	$ -	$ 9,620	$ 8,200	4389	$ 916	$ 36,140	0.07	>100
	4.35	$ 525	$ 9,620	$ 8,200	4036	$ 826	$ 34,865	0.17	>100
	4.6	$ 1,050	$ 9,620	$ 8,200	3680	$ 749	$ 33,850	0.25	81
	4.85	$ 1,575	$ 9,620	$ 8,200	3321	$ 683	$ 33,055	0.31	65
	5.1	$ 2,100	$ 9,620	$ 8,200	2957	$ 618	$ 32,280	0.37	55