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An Economic Analysis of Residential Photovoltaic Systems with and without Energy Storage

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An Economic Analysis of Residential Photovoltaic Systems with and without Energy Storage

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by

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Abstract

Residential photovoltaic (PV) systems serve as a source of electricity generation that is separate from the traditional utilities. Investor investment into residential PV systems provides several financial benefits such as federal tax credit incentives for installation, net metering credit from excess generated electricity added back to the grid, and savings in price per kilowatt-hour (kWh) from the PV system generation versus the increasing conventional utility price per kWh. As much benefit as stand-alone PV systems present, the incorporation of energy storage yields even greater benefits. Energy storage (ES) is capable of storing unused PV provided energy from daytime periods of high solar supply but low consumption. This allows the investor to use the stored energy when the cost of conventional utility power is high, while also allowing for excess stored energy to be sold back to the grid. This paper aims to investigate the overall returns for investor's investing in solely PV and ES-based PV systems by using a return of investment (ROI) economic analysis. The analysis is carried out over three scenarios: (1) residence without a PV system or ES, (2) residence with just a PV system, and (3) residence with both a PV system and ES. Due to the variation in solar exposure across the regions of the United States, this paper performs an analysis for eight of the top solar market states separately, accounting for the specific solar generation capabilities of each state. A Microsoft Excel tool is provided for computation of the ROI in scenario 2 and 3. A benefit-cost ration (BCR) is used to depict the annual economic performance of the PV system (scenario 2) and PV + ES system (scenario 3). The tool allows the user to adjust the variables and parameters to satisfy the users' specific investment situation.

Acknowledgments

As cliché as the saying "It takes a village….." maybe, I truly am the poster boy for this saying. It honestly took a village for me to complete this thesis and this Master's degree. I would like to acknowledge the following people for their critical contributions towards this effort:

1. **My committee**: Dr. Pohl met with me almost every week and instead of giving me the direction I sought, he provided an environment for me to find the direction myself. His mentorship as my advisor was pivotal towards my academic success and personal growth over these past two years. Thanks to his support, and the support of Dr. Rainwater and Dr. Balda, I not only completed this thesis and Master's degree, but I am now 1000% confident in my abilities as I embark on my PhD studies this coming fall. Thank you!
2. **My friends**: My "Day 1z" – Howard, Reggie and Emeke, as well as Joe, the "Greedy Boyz" – Marcus, Prince, Ryan, Kevin, Emeka, Rob, Kobbie and Jesse, my confidant Maya, my mentee's turned friends from undergrad – Ana, Ursula, Sterling, and Danielle, my "C-Squad" here at Arkansas – Lionel, Kail, Vincent, and Alexyss. From sending me money when I was in need, to bringing me food in my office when I was up late studying, to celebrating with me every time I reached a milestone, to looking over and assisting me with my writing, to talking or hanging with me late at night when I needed company, to continually encouraging and supporting me, and the list goes on. Thank you all!
3. **Dr. Bryan Hill**: Where do I even start? This ALL started with a phone call from Dr. Hill back in April 2015. He and Dr. Pohl came together and provided me a full-funding offer, which is rare to find as a Master's student, and made graduate school possible for me. For his mentorship, the trust and responsibilities he bestowed upon me, the crucial battle he fought for me, and the access to endless coffee he gave me, I want to say thank you B!

Dedication

I dedicate this thesis to my loving family, Christopher (dad), Jessica (mom), Christa (sister), Lynette (sister), Jesse (brother) and Stacy (cousin). They have been my support system throughout these past two years of graduate school. From reading over my papers for me, listening to my rants about how challenging graduate school was, to making an honest attempt to comprehend my research whenever I talked about it with them. None of them are engineers but they saw the passion and excitement I had for my research and provided me their ears and attention when I wanted to express my research breakthroughs. My parents sacrificed so much to see me through these past two years; from driving 18 hours to help me move in back in August of 2015 when my graduate school journey began, to assisting with my finances when I was struggling, to helping me purchase a new car when my old car's engine failed so unexpectedly. My siblings and my cousin would call and provide me encouragement when I was facing challenges and constantly remind me how proud of me they were. Our siblings' groupchat, titled "My Baby Loves" by Lynette, gave me joy when I was facing tough times and kept me entertained throughout the long days of research and studying. Just reading the hilarious posts and thought-provoking discussions in the groupchat always put a smile on my face, especially during moments when I struggled to find one.

Table of Contents

I. Introduction

While we regularly propose new systems to support our society's dire need for an alternative to fossil fuel energy sources, photovoltaic (PV) energy isn't necessarily new. PV systems utilize sunlight to generate electricity through semiconductor PV cells. The particles of light (photons) strike the surface of the cells, releasing negatively charged particles (electrons) from the cells' atoms, which causes electric flow as depicted in **Figure 1**. Humans have been harnessing solar energy for centuries and advancements have been made ever since. By acknowledging PV systems' journey through history, we reveal the benefits of going solar, the various types of PV system options, and the costs associated with them. This serves to support our topic of research – how to utilize PV systems as a cost efficient and reliable energy source by augmenting energy storage (ES). The research implements a return of investment (ROI) analysis to provide economic justification for investment into residential PV and ES systems, as well as a benefit-cost ratio (BCR) to show the annual economic performance of the systems.

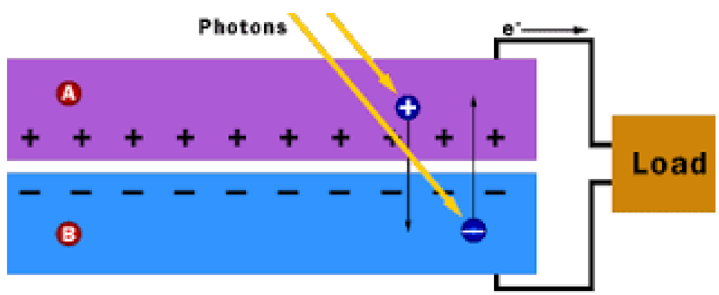

Figure 1: Photoelectric Effect. Copyright 1999 & 2005 by NJK.

A. History of Photovoltaics

It took several centuries to reach Einstein's Photoelectric Effect from using magnifying glasses and mirrors for creating fire. Technology began progressing in the late 20^{th} century once photovoltaic cells began to be manufactured [14]. In 1973, one of the first PV-powered residences was created by the University of Delaware. Their "Solar One" residence was built as a PV/Thermal hybrid, jumpstarting the production and use of photovoltaic power systems on every continent. As the NASA Lewis Research Center continued to study and use these types of systems, the US Department of energy launched the Solar Energy Research Institute (later the National Renewable Energy Laboratory (NREL) in 1977 – establishing a federal facility dedicated specifically to harnessing the sun's energy.

With this newly established federal funding, PV systems really began to take off. Shortly after the new institute was created, NASA built the first photovoltaic village system in 1978, the 3.5 kW village provided water pumping and electricity for 15 homes on the Papago Indian reservation until 1983. Throughout the 1980s, scientists continued to make PV cells thinner with higher capacity and better efficiency. In 1992, the University of South Florida developed a 15.9% efficient thin-film PV cell, breaking the 15% efficiency barrier for the first time ever in this technology's history. Soon after the efficiency increase, Pacific Gas and Electric installed the first grid-supported 500 kW PV system in Kerman, California. This installation marks the first "distributed power" effort. This is important, as present research focuses heavily on grid-supported systems.

The commercialization of PV systems continues to jump as efficiency levels increase. In 1994, NREL announced its new laboratory facility, leading to its first PV cell exceeding 30% efficiency. This pushed PV systems into the spotlight as a "clean energy" source, to be included on a variety of projects, including more residency experiments, roofing material ideas, and even aircrafts. By the year 2000, a family in Colorado installed a 12kW system in their home – the largest registered residential installation of PV technology – providing most of the electricity for the household of size eight. In 2001, Home Depot began selling PV systems in California, later spanning to 61 stores nationwide. At this stage, photovoltaic systems made a significant jump from energy research to the mainstream commercial marketplace.

Energy storage has had its own timeline of evolution. Batteries in the early 19th century began as simple set-ups with zinc and copper discs separated with cardboard including a brine solution as the electrolyte. They slowly progressed until 1949 when they reached the small dry cell design commonly known today, with an alkaline electrolyte, zinc anode, and manganese cathode. Rechargeable batteries have continued to evolve over the years based on their elemental makeup; however, Nickel-metal batteries discovered in 1899 are still used today in high power investor devices. Advances in rechargeable lithium batteries began to rapidly make progress in the 1970s. While battery lifetime and durability proved difficult and near catastrophic over 40 years due to battery fires, leaks, and insufficient storage, these energy storage units have been tailored to support larger systems such as transportation and PV grid systems.

B. Benefits, Current Options, & Costs of Photovoltaics

With the documented ongoing changes in our ecosystem and climate, as a result of energy emissions, solar energy provides some major benefits as a renewable resource [18]. A reasonable amount of sun exposure across the nation makes solar energy an attractive option in nearly every state. While many other renewable options are not yet as reliable as the sole energy provider, a standard 5kW PV system can provide up to three-quarters of an average household's energy usage [15]. This allows individuals and businesses alike to invest in solar energy to generate their own power while staying at fixed and competitive prices for the system. Added tax credit returns and dropping prices due to technological advancement make solar energy an even more attractive economic decision. Mainstream investing and innovative financing makes this resource available to investors of all socioeconomic backgrounds. With increased job opportunities in the community due to installation and maintenance (with 20- to 25-year warranties), the environmental benefits are just a bonus [18].

There are a number of options for solar/PV panels on today's market for investors to choose from. Monocrystalline Silicon Solar PV panels are the original PV technology. They are also the most efficient at 25%. However, this increased performance comes with higher cost. By using one crystal, the grid structure is produced with a uniform crystalline pattern, allowing for the highest purity and therefore advantageous efficiency levels. Polycrystalline Silicon Solar PV panels provide the best value. Their lower cost can be attributed to their manufacturing process which pours molten silicon into a cast. Although, these impurities from the process tend to cause lower efficiency levels, around 20%. The thin-film solar PV panels are a great alternative due to their physical design. While they have the smallest share of the market, they are a possible choice for projects of lesser power requirements that demand lightweight additives and portability. They have a max efficiency of 20% as well.

Energy capacity and associated costs have changed tremendously over the past decade, giving way to innovation for solar energy as an advantageous resource. The annual installed solar capacity has skyrocketed from several hundred megawatts in 2005 to seven thousand in 2015. The job opportunities in the solar energy field have doubled. These trends are accompanied by an inverse relation in PV price – whereas availability, accessibility and opportunity have increased, PV price has had a $4/watt drop over the past 7 years. **Figure 2** shows the decline in US average PV price per watt from 2009 to 2016 for residential, commercial, and utility systems. There are even more opportunities for cost decline through soft costs associated with labor, supply chain, and overhead considerations based on new emerging technologies. This competitive environment raises PV energy systems as a serious competitor when considering the added benefits of an energy storage system.

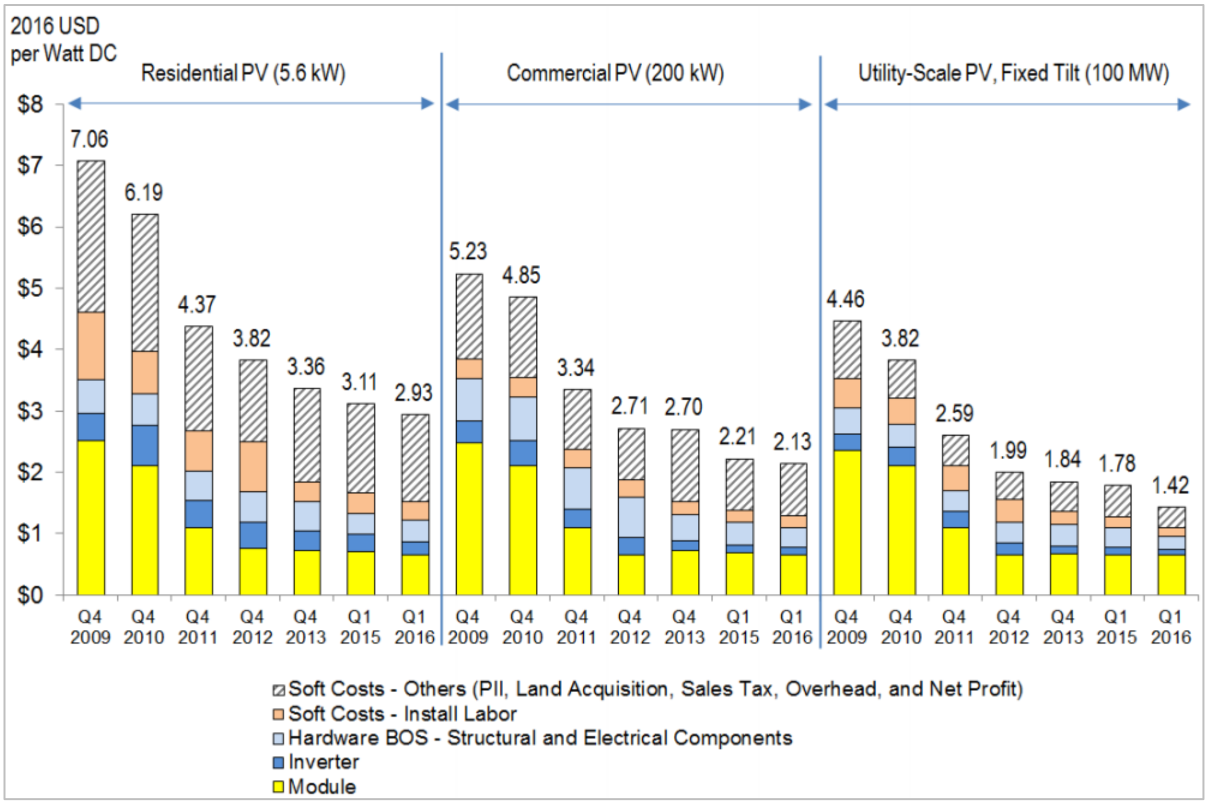

Figure 2: US average PV price decrease.
Adapted from "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016" by R. Fu et al., 2016, *NREL/TP-6A20-66532, September 2016*, p. v. Copyright 2016 by Alliance for Sustainable Energy, LLC (Alliance)

C. Energy Storage Batteries

Energy storage is becoming a prominent conversation around photovoltaic systems. With the increase in PV installations, the lower voltage grids are reaching their performance limit. Countries, such as Germany, are encouraging the use of residential systems in order to prevent the grids from reaching capacity. Energy storage systems allow for investors to harness the energy provided and use it at a later time to avoid buying electricity off the grid at a higher price [16]. Sodium-sulfur (NaS) battery systems developed in Japan has been shown to control charging or discharging based on the output of power generation [17]. This provides a closed-loop system for investors to not only save energy to avoid costs, but create a reserve for the right amount of power based on their input and output needs.

Energy systems can be identified from 5 different classifications – mechanical (pumped hydro, compressed air, and flywheel storage), electrical (double-layer capacitor and superconducting magnetic coil storage), thermal (sensible heat storage), chemical (hydrogen storage) and electrochemical (secondary batteries and flow batteries) [17]. Electrochemical storage systems are those that most often pertain to photovoltaic energy systems. Secondary batteries define the rechargeable battery systems, using Lead acid, Lithium, NaS, and Nickel-metal compounds. Flow batteries encompass the redox flow or hybrid flow in terms of the electrolysis of water and the oxidation of hydrogen – essentially the 'redox' or oxidation-reduction reaction – provides the electrochemical process.

Major role-players in the electrochemical battery market include lead acid, nickel-metal, lithium ion, and sodium sulfur batteries. Lead acid batteries are still the most widely used battery type and have been deployed since 1890. They are commonly used with emergency power systems and in stand-alone systems with photovoltaic energy. The lead acid batteries' main disadvantage is their decrease in capacity after a high power discharge [17]. Nickel metal batteries have a higher energy density, but have been proven to be only useful for stationary products due to the cadmium toxicity levels. Lithium ion batteries have become a very important and prevalent storage technology, especially for mobile applications. Despite some safety concerns, they have an extremely high efficiency and continue to be researched for further improvements. NaS batteries are very responsive, and are therefore often used in economic applications concerning controlled power and time shift inquiries. These batteries meet the requirements for grid stabilization from their response time, and could prove to be an emerging alternative in the marketplace.

D. Government Involvement

The US federal government is aware of the benefits of solar energy and, in addition to the federal solar investment tax incentives, has established initiatives such as the SunShot Initiative. The SunShot initiative is a national effort launched by the US Department of Energy in 2011 with an objective to make solar energy more attractive and affordable for all Americans. Through research and development and collaboration with private solar-based organizations, universities, and national laboratories, SunShot aims to lower the costs of solar and make the renewable energy source market-competitive. SunShot has set $0.05/kWh cost target for residential PV by the year 2030 [25]. **Figure 3** explains the three pillars of the SunShot PV subprogram.

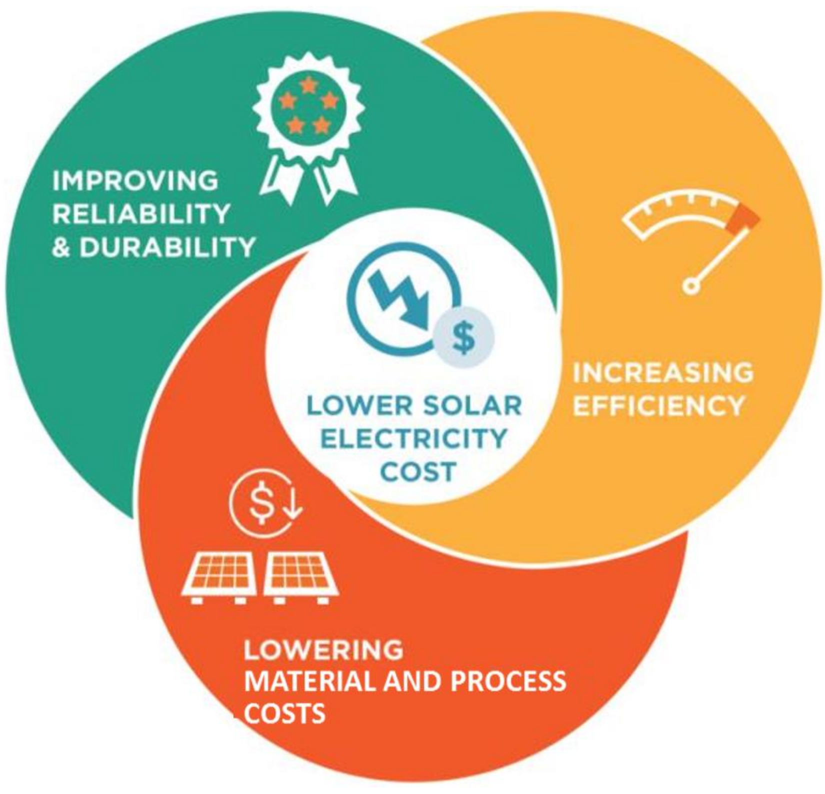

Figure 3: Three Pillars of the SunShot PV subprogram.
Adapted from “The SunShot Initiative & the U.S. Challenges and Prospects” by Dr. Drew DeJarnette, *March 2017*, p. 18. Copyright 2017 by SunShot U.S. Department of Energy

E. Research Motivation

More and more Americans, and investors across the globe, are considering the option of solar for electricity generation. With the vast number of benefits that come with the current PV and ES options and the future developments which will only improve the cost-effectiveness and quality of the PV and ES systems, economic justification will be needed to help residential investors decide whether or not to invest in solar. The return of investment (ROI) analysis performed in this research provides residential investors a clear basis and framework from which to make an appropriate economic decision. The breakdown of the analysis by eight of the top solar market states of the country further specifies the ROI to an investor based on the solar generating capabilities of the region of the country where the investor resides. The inclusion of an annual BCR provides investors an annual economic evaluation of the costs and benefits resulting from the PV and ES systems.

II. Literature Review

A literature review was performed to summarize the current research on integrated PV and battery storage systems. The literature review was used to highlight the economic objectives, constraints, and parameters used for analysis regarding the integrated systems from both a utility and investor perspective. This in turn helped with the formulation of the modeling framework used for analysis in this paper and the Microsoft Excel tool designed to assist investors with their return of investment (ROI) calculations for various scenarios.

The literature items are grouped as either published technical research papers or published research reports from energy-based government organizations and national laboratories as shown in **Table 1**. The table also depicts published technical papers by grid-area of focus, whether generation (utility) or distribution (investor), and depicts the published research reports by source, whether from NREL or other (The Frontier Group and Environment America Research and Policy Center, North Carolina Clean Energy Technology Center, or Lawrence Berkeley National Laboratory). The published research reports provide the set of necessary parameters for the various modeling frameworks used in this paper such as the capital investment cost of integrated PV and battery storage systems, the monetary value of residential generated solar, PV module degradation rates, federal and state tax incentive percentages, and home premiums for PV systems.

The published technical papers are further categorized by the economic objective used for analysis. The three analysis objectives considered are benefic/cost ratios (BCR), net present value (NPV) and return of investment (ROI). **Figure 4** displays this break down of the papers by economic analysis method, and PV system operation and maintenance costs.

Technical Paper	**Generation (Utility)**	[1] Delfanti, et al. (2015) [2] Zebarjadi, Askerzadeh (2015) [4] Rudolph, Papastergiou (2013)
	Distribution (Consumer)	[3] Cucchiella et al. (2016) [5] Hoppmann et al. (2014) [6] Rajasekaram, Costa (2015) [7] Truong et al. (2016)
Research Report	**National Renewable Energy Laboratory**	[8] Fu et al. (2016) [10] Jordan, Kurtz (2012) [13] NREL Energy Analysis (2016) [14] NREL History of Solar [20] Goodrick et al. (2012)
	Other	[9] Hallock, Sargent (2015) [11] Inskeep et al. (2015) [12] Hoen et al. (2015) [15] Feldman, et al (2014) [16] Whittingham (2012) [17] IEC Electrical Energy Storage (2011) [18] Solar City Impact Report (2015) [21] Emrath [24] Johnson and Klise (2012)

Table 1: Literature groupings by type of paper and grid-area focus.

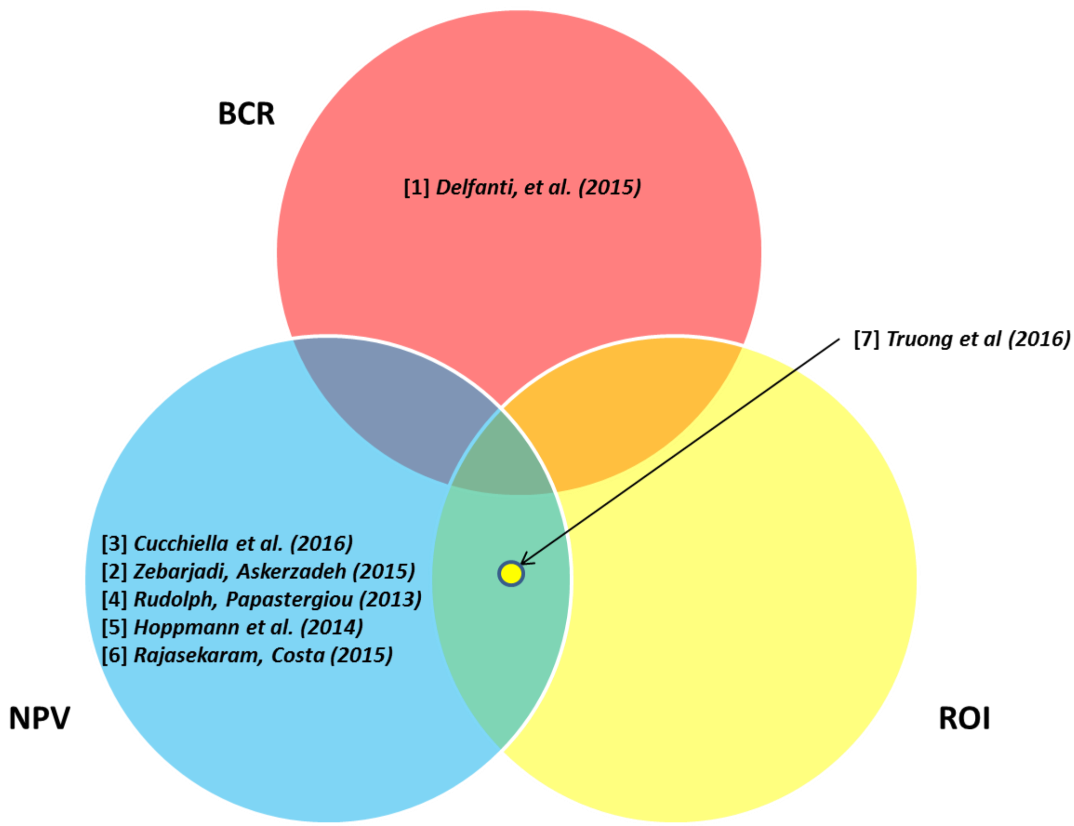

Figure 4: Literature groupings by economic objective (Technical Papers).

The Politecnico di Milano department of energy in Milan, Italy [1] explains the various characteristics of an Energy Storage System – or ESS – for a PV plant. The ultimate goal of an ESS is to minimize energy imbalances in a PV system by storing incoming energy to later dissipate at a constant rate necessary to sustain the connected community. The actual apparatus of power and capacity is designed according to performance regulations. Forecast models are applied to verify and validate weather prediction accuracy of the ESS. A benefit/cost ratio (BCR) analysis is conducted, focusing on parameters of cost, efficiency, and lifespan. Using a mathematical model depicting ESS control logic, the data shows that the ESS must be entirely operated at its full capacity to avoid added costs for the users of the system.

Due to critical accuracy and consistency of PV performance evaluations, Zebarjadi and Askerzadeh [2] used a heuristic algorithm to optimize a grid-connected PV power plant. The economic objective of this optimization model was to minimize the net present value (NPV) of the photovoltaic system overall costs, while accounting for specified levels of power supply based on the reliability of the system. The objective function calculation is composed of the initial investment and the NPVs of the operation and maintenance costs, replacement and residual value of the system components, and the income from grid exchange revenue. This economic system model is evaluated on two types of systems – one with a battery energy storage system and one without. With lower electricity costs (ψ), the two barely show any difference in NPV. The battery energy storage system becomes more beneficial to the system as the electricity cost increases as depicted in **Figure 5**.

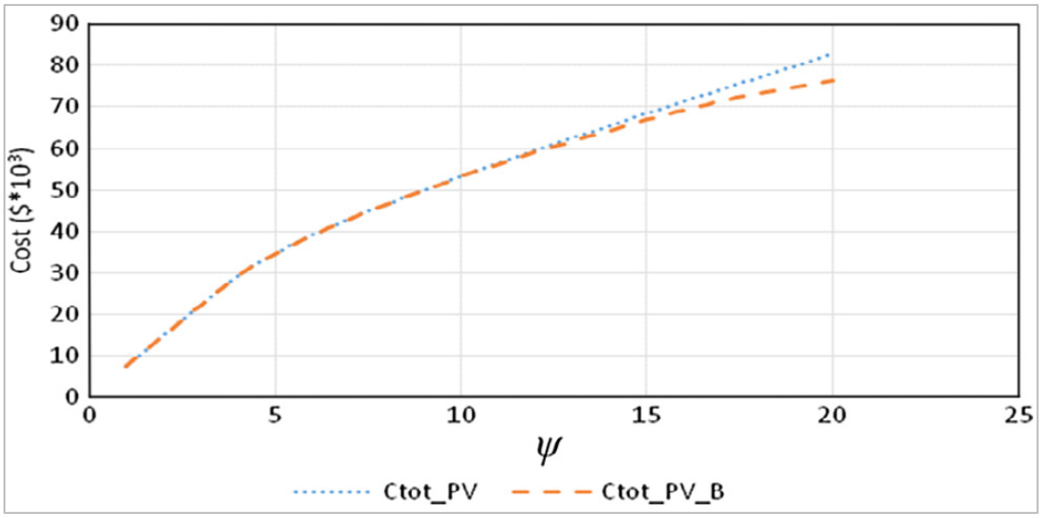

Figure 5: The effect of electricity costs on PV and PV with battery plant. Adapted from "Optimization of a reliable grid-connected PV-based power plant with/without energy storage system by a heuristic approach" by M. Zevarjadi and A. Askarzadeh, 2016, *Solar Energy, 125*, p. 20. Copyright 2015 by Elsevier Ltd.

Cucchiella et al. [3] perform an economic analysis to evaluate the potential profitability of PV systems within unsubsidized residential sectors and for energy storage systems within a mature market, which helps define the economic success criteria for an integrated PV system [3]. Using a NPV model, the profitability is first evaluated for a stand-alone PV system, then for an ESS, and then for an integrated PV and ESS system. After evaluating 528 scenarios of varying PV production, household consumption, and energy storage, the Cucchiella et al. [3] note the profitability of PV systems are strongly related to self-consumption, and the feasibility of an integrated system is dependent on the NPV of energy storage system.

A financial analysis was conducted by Rudolph and Papastergiou to determine the feasibility of using battery energy as part of a utility scale photovoltaic plant [4]. This work determined that generation shifting of batteries helps generate additional revenue for PV projects. Peak-load battery shifting is a process of delaying the effects on a power system during times of large energy loads so that the system can readily take on the additional work, minimizing the required generation capacity. Electricity market prices were revealed to be a driving force behind a project decision from a financial perspective, more relevant than battery lifetime or price. The economic viability of the project can be boosted with a battery that holds up to 50% of the daily output of photovoltaic energy. Analysis in the form of a NPV helps determine the benefit of battery energy storage as compared to original PV plant revenue. The research states that this value could increase by 65% if a 25% higher energy premium is applied [4].

Due to the lack of certainty in the economic viability of energy storage systems for residential environments, Hoppmann et al. [5] utilized a simulation model with residential PV energy in Germany to investigate the profitability of ESS. Their simulation model used eight different electricity price scenarios for 2013 to 2022 [5]. Running the model across a vast number of scenarios helped determine an economically viable configuration of PV and storage system based on the size of each system. Higher retail electricity prices and lower wholesale price/access contributed to the profitability of PV storage. The model accounted for both technological and economical barriers, revealing that most profitable PV systems are those with medium wholesale and medium retail prices. The best size begins at 4.5 kWh in 2013 and was estimated to reach 7.0 kWh in 2021. **Figure 6** displays how the electricity generation is consumed and or stored through a typical 24-hr cycle. The analysis assumes that during the peak-generation hours of the day (hours 9-17) a residence consumes its own PV generated electricity ((4) on the graph). Once a residence demand is met, the remainder of the PV generated electricity is stored in the battery ((2) on the graph). The excess electricity during this period (after residence consumption and storage) is then sold back to grid ((3) on the graph).

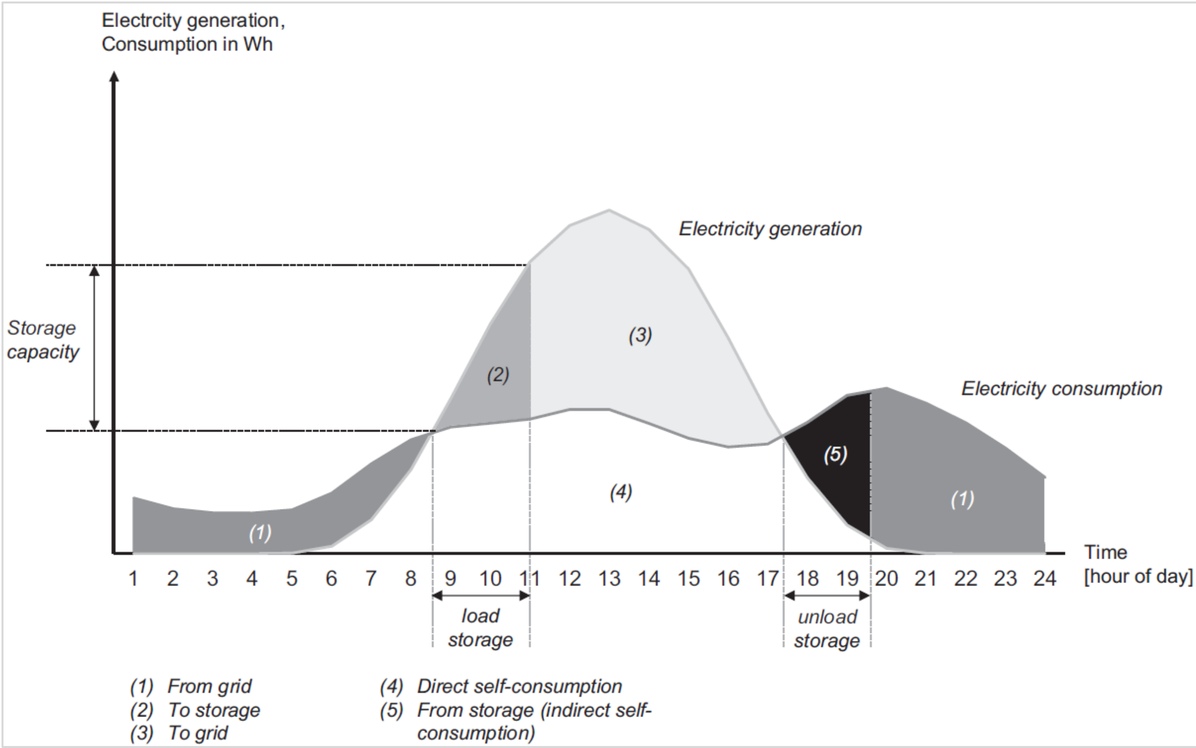

Figure 6: 24-hr energy consumption and storage.
Adapted from "The Economic Viability of Battery Storage for Residential Solar Photovoltaic Systems – A Review and a Simulation Model" by J. Hoppman et al., 2014, *Renewable and Sustainable Energy Reviews, 39,* p. 1108. Copyright 2014 by Elsevier Ltd.

Another residential analysis by Rajasekaram and Costa [6] classifies the viability of PV energy storage for multi-family homes. Economic feasibility is analyzed with an added fleet of electric cars. Scenarios with battery storage and electric cars are simulated in a System Advisor Model (SAM) while scenarios with gasoline cars are simulated in Matlab. NPV is used as an economic indicator for evaluation and proves best when a PV system with battery storage is used. However, the NPV was negative with a value of -82000 SEK, leading to the conclusion that PV battery storage is not yet economically viable for multi-family homes.

With the release of Tesla's Powerwall, the Technical University of Munich [7] investigated the economic benefit of the Powerwall with respect to Germany's average market price for electricity. Since current high investment costs deter PV systems' profitability, Tesla's product being 25% of the average price on the market may open the door to a worthwhile renewable investment. With parameters such as aging, price, retrofitting, and subsidies, scenarios are assessed through simulation models which calculate power generation, storage capacity, NPV, and ROI. With varying prices, loads, household sizes, and energy coupling, the results show it is necessary to have an accurate economic depiction of electricity prices to determine an agreeable benefit of the Powerwall. While most scenarios proved more profitable than the current market, an assumed constant electricity price did show a negative ROI for several examples, in which either the large energy throughput causes degradation and performance loss, or the households are too small to fully utilize the system.

Fu et al. from NREL provided useful information regarding US solar photovoltaic capital cost benchmarks for the first quarter of 2016, where a 5.6 kW residential PV system was the basis for analysis [8]. A national average of $2.93/W is reported weighted by 50% of installer market shares and 50% of integrator market shares from installed residential PV systems in the year 2015; the integrator business structure provides financing and monitoring on installed systems but the installer does not. The capital costs are further broken down by the top solar market states: Arizona, California, Colorado, Florida, Massachusetts, Nevada, New York, and Texas. This gives a more regional outlook on PV prices. The capital cost averages for PV used in this research are based on the NREL, a US Department of Energy funded national lab, cost model. These costs differ from fourth quarter of 2015 averages reported in the corporate filings of public solar integrators such as SolarCity ($2.71/W), Sunrun ($3.12/W), and Vivint Solar ($3.64/W) [8]. The difference is due to differing cost structures. Public sector integrators account for sold and leased PV systems, where leased system costs span the life of the lease as opposed to the period in which the system is sold; this makes it difficult to accurately determine the true costs at the time of sale. NREL and this research assume only sold systems. In addition, costs from public integrators such SolarCity include both residential and commercial PV systems, slightly skewing the reported costs. NREL and this research use exclusively residential costs.

The Frontier Group and Environment America Research and Policy Center [9] published a technical report outlining the value of solar energy from an investor and societal perspective. The report highlights certain attributes of “going solar” and how these characteristics add up to the value of solar in cents per kWh. Investor-based benefits include net energy metering, jobs, and reduced financial risk. Societal-based benefits include decreased gas emissions, lower energy costs, reduced air pollution, and increased grid resiliency. Eight out of their 11 analyses found the solar energy rate to be worth more than the average retail electricity rate in the area studied. The 11 analyses had a median of 0.1690 $/kWh as the value of rooftop solar energy.

Current average PV module lifetimes range between 20-30 years. Over the course of their lifetime modules will experience some performance degradation. For thorough economic analysis of PV system investments, degradation rates of the PV modules must be incorporated into the analysis to provide a more accurate estimation of the annual electricity generation capacities of the systems. In order to predict the lifetime of PV modules and compensate for their decreased output over time, Jordan and Kurtz of NREL [10] analyzed published degradation rates throughout the last 40 years. After an assessment of nearly 2000 reported rates, the authors assembled a report presenting a median of 0.5% degradation per year and an average of 0.8% per year as shown in **Figure 7**. 78% of all data reported a rate less than 1% per year. The red-dashed line marks the 1% threshold. Various data trends – such as lower degradation rates after the year 2000 – are very apparent through the statistical analysis provided by NREL.

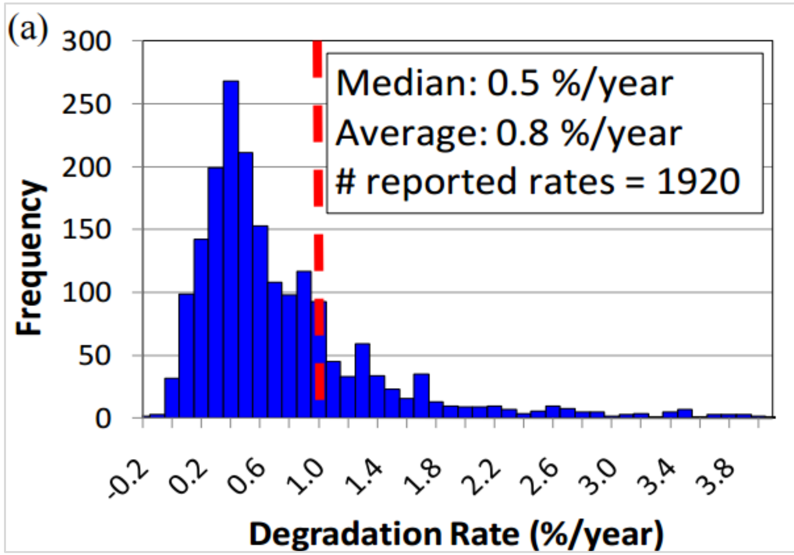

Figure 7: Average PV Module Degradation Rates.
Adapted from "Photovoltaic Degradation Rates – An Analytical Review" by D. Jordan and S. Kurtz, 2012, *NREL/JA-5200-51664*, *June 2012*, p. 6. Copyright 2012 by Alliance for Sustainable Energy, LLC (Alliance)

Answers to frequently asked questions regarding tax incentives can be found in an organized guide specifically for residential PV systems provided by the North Carolina Clean Energy Technology Center [11]. While it is not a valid substitute for professional tax advice, the guide provides the basic groundwork for tax credit, incentives, and repayment for homeowners. The report includes eligibility criteria, a variety of repayment options, and tax credit breakdowns on the state and federal level. The guide follows up with further resources for economic advice to help a homeowner make the decision of investing in a solar power system.

Home premiums for residential PV systems have a significant impact on the value and economic benefit of the system to the homeowner [12]. Through a study containing more than twenty- thousand households (18,871 without a PV system and 3,951 with a PV system), researchers from the Lawrence Berkeley National Laboratory in cooperation with the US Department of Energy SunShot initiative found that homeowners were willing to pay premiums regardless of location, market, and home type. There is a very small difference between premiums for new and existing homes and the amount customers are willing to pay depend on the system size. Both net-cost estimates and income-based estimates can be effective in predicting the market for premiums. Average premiums equate to about $4 per watt across all homes and about $3 per watt across the US excluding California. This study, published in January 2015, is based on the hedonic methodology which estimates the premiums using averages across a large sample of homes. Although researchers prefer the hedonic method, real estate appraisers and their lending clients prefer the paired sales methodology which is better suited to provide estimates for a single home versus a large sample of homes as the hedonic method does [32]. The Lawrence Berkeley National Laboratory in cooperation with the US Department of Energy SunShot initiative published the second PV home premium study using the more real estate industry accepted paired sales method in November of 2015 [32]. The paired sales method yields average premiums of $3.63 per watt across all US homes. **Figure 8** displays the PV premiums across all US homes for the paired sales and hedonic modeling approaches.

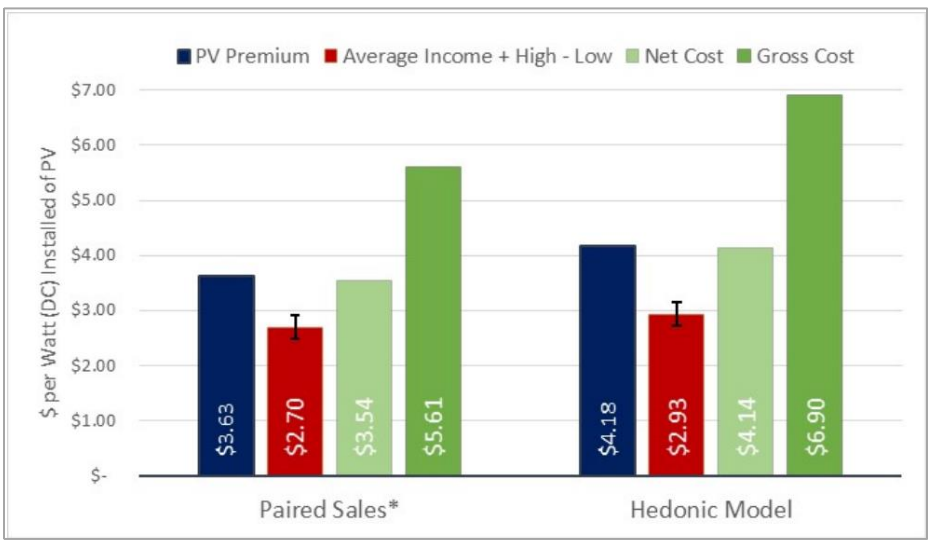

Figure 8: PV Home Premiums.
Adapted from “Appraising into the Sun: Six-State Solar Home Paired-Sales Analysis” by S. Adomatis and B. Hoen et al., 2015, p. 23. Copyright 2015 by Lawrence Berkeley National Laboratory and U.S. Department of Energy

Renewable energy cost estimates are a necessary piece of information for any economic analysis of an energy system. These costs are provided by a government-funded data acquisition for renewable energy costs by NREL [13]. While these values are not to be used to be interpreted as statistically significant they do provide a basis that can attest to economic viability. NREL provides operation and maintenance (O&M) costs for most renewable energy sources calculated from data collected since 2012. The useful life for these sources was estimated using interviews with various experts working with various energy technologies. In addition, the system sizes are also provided in order to estimate costs in dollars/kilowatt year ($/kW-yr).

Solar technology has evolved over several centuries of development. Its major milestones in history are important for understanding and analyzing current leaps in photovoltaic energy [14]. From using mirrors to light torches for religious ceremonies in 3rd Century BC to Einstein's Nobel Prize-winning photoelectric effect in 1921, we begin to see solar energy catalyze into a marketable resource. The creation of the NREL in the late 1970's led to huge increases in solar cell efficiencies by the 1990s and a decrease in the overall costs of solar energy. The implementation of residential PV is the starting point for this paper's purpose.

The US Department of Energy Sun Shot Initiative considers PV system pricing from a historical, recent and future projections perspective [15]. With the rapid market growth for photovoltaic systems pricing changes significantly over a short period of time. This stresses the need for comprehensive data on PV system pricing for future predictions. Through the compiled data it is evident that expected, reported, and modeled outcomes all show a downward trend for residential and commercial PV pricing. Since 1998, reported system prices for residential and commercial PV have fallen at an average of about 9% each year and are projected to continue decline for the foreseeable future.

Energy storage is predicted to be a key contributor to the overall growth of distributed renewable energy generation. Whittingham [16] describes the history of energy storage systems and how the technologies have advanced over time from the pumped hydro storage systems of the early 1900s to the lead-acid and lithium-ion battery systems used in the present-day. An analysis on the different storage capacities offered by the present-day battery systems is performed and a future perspective is given based on the expected growth of energy storage capabilities and the continued investment in energy storage research.

Electrical energy storage systems are discussed in a white paper published by the International Electrotechnical Commission (IEC) [17]. Various energy storage technology classifications are described along with the role and importance of energy storage for renewable energy generation. The current market for storage systems is presented and the forecasted market potential for 2030 is predicted. The paper also addresses the potential impact of growing energy trends such as smart-grid capabilities, microgrids, and electric vehicles on storage systems.

The literature discussed in this section provides a background on where PV and ES system research is in the present day. The technical papers utilized optimization through the use of NPV, BCR, and an NPV-BCR combination as economic analysis methods. The research reports provided analyses regarding the costs of solar, tax incentives for solar investment, and other parameters that relate PV and ES systems such as module degradation rates. The following section describes the formulated ROI framework that provides investors economic justification for an investment in residential solar. The ROI framework is composed of variables and parameters that reference the research and analyses presented in this literature review.

III. Scenario 2 Formulation

This research utilizes a return of investment (ROI) approach for economic analysis. The approach computes the ROI over a course of t years for scenarios 2 and 3, where scenario 2 analyzes a residence with just a PV system. An analysis tool, constructed using Microsoft Excel, is used to calculate the ROI for a proposed system. Based on the parameters of the specific PV or PV and ES system the user plans to invest in, the tool calculates the total gains, costs, and savings from the investment, as well as the ROI of the investment (expressed as a percentage). The ROI is calculated by subtracting the total costs (occur annually over the period of t years) and capital investment costs (upfront investment costs) from the total gains and energy cost savings (occur annually over the period of t years). This value is then divided by the capital investment costs. From the ROI, the user can make an economically informed decision on whether or not to proceed with the investment.

The variables used for the ROI in scenario 2 are the amount of energy provided by the PV system in year t ($\mathrm{PV_{E}}_{t}$), the amount of energy consumed from the grid by a residence in year t ($\mathrm{RSG_{E}}_{t}^{S2}$), and the amount of PV provided energy consumed by a residence in year t ($\mathrm{RSPV_{E}}_{t}^{S2}$). $\mathrm{PV_{E}}_{t}$ range is defined as

$$\mathrm{PV_{E}}_{t} \in [0\,, \mathrm{PV_{MAX}}_{t}] \quad (1)$$

where $\mathrm{PV_{MAX}}_{t}$ is the generation capacity of the PV system, in kWh, in a given year t. $\mathrm{PV_{MAX}}_{t}$ decreases over the course of n years based on the degradation rate of the PV modules. $\mathrm{RSG_{E}}_{t}^{S2}$ range is defined as

$$\mathrm{RSG_{E}}_{t}^{S2} \in [0\,, \mathrm{G_{MAX}}_{t}] \quad (2)$$

where $\mathrm{G_{MAX}}_{t}$ is the generation capacity of the grid in given year t. $\mathrm{RSPV_{E}}_{t}^{S2}$ range is defined as

$$\mathrm{RSPV_{E}}_{t}^{S2} \in [0\,, \mathrm{PV_{E}}_{t}] \quad (3)$$

because a residence can only consume up to as much as a residence's PV system generates in year t. Lastly, $\mathrm{RSPV_E}{}_t^{S2} + \mathrm{RSG_E}{}_t^{S2}$ range is defined as

$$\mathrm{RSPV_E}{}_t^{S2} + \mathrm{RSG_E}{}_t^{S2} \in [\mathrm{RSD_E}, \infty] \tag{4}$$

where $\mathrm{RSD_E}$ is the annual energy consumption of a residence. The investment gains of scenario 2 are the following: 1) the home value premium ($\mathrm{VAL_{HOME}}{}_{13}^{S2}$), added due to the inclusion of the PV system when a residence is sold in year 13 [21], defined as

$$\mathrm{VAL_{HOME}}{}_{13}^{S2} = \mathrm{PR_{HOME}}{}_{13} * \mathrm{PV_{MAX}}{}_0 \tag{5}$$

2) The federal and state tax incentives ($\mathrm{TAX_{INC}}{}_1^{S2}$) for residential renewable energy investment, which are defined as

$$\mathrm{TAX_{INC}}{}_1^{S2} = \mathrm{TPVC}_{\mathrm{CAPITAL}}^{S2} * [\mathrm{r_{FED\ TAX}}{}_1 + (1 - \mathrm{r_{INCOME\ TAX}}{}_1) * \mathrm{r_{STATE\ TAX}}{}_1] \tag{6}$$

3) The credit from net-metered energy sold/injected back into the grid from a residence, which is calculated by multiplying the amount of injected energy ($\mathrm{PV_E}{}_t - \mathrm{RSPV_E}{}_t^{S2}$) times the average energy sale price ($\mathrm{SP_E}{}_t$), is defined as

$$\sum_{t=0}^{t=13} (\mathrm{PV_E}{}_t - \mathrm{RSPV_E}{}_t^{S2}) * \mathrm{SP_E}{}_t \tag{7}$$

4) The annual energy cost savings, which are calculated by multiplying the average energy purchase price ($\mathrm{PP_E}{}_t$) by the difference between the average annual energy consumption of a residence ($\mathrm{RSD_E}$) and the energy consumed from the grid ($\mathrm{RSG_E}{}_t^{S2}$), defined as

$$\sum_{t=0}^{t=13} (\mathrm{RSD_E} - \mathrm{RSG_E}{}_t^{S2}) * \mathrm{PP_E}{}_t \tag{8}$$

The total costs of the investment are the following: 1) the costs of grid supplied energy used by a residence ($\mathrm{RSG_E}{}_t^{S2} * \mathrm{PP_E}{}_t$), which is included within the annual energy cost savings; 2) O&M costs of the PV system ($\sum_{t=0}^{t=13} \mathrm{OM_{PV}}{}_t^{S2}$); 3) the payments made on the loan used to offset the capital investment costs ($\mathrm{P_{LOAN}}{}_t^{S2}$). Loan payments are defined as

$$\sum_{t=o}^{t=13} P_{LOAN}{}_{t}^{S2} = \frac{r_{LOAN} * AMOUNT_{LOAN}^{S2}}{1-(1+r_{LOAN})^{-t_{LOAN}}} \quad (9)$$

The total capital investment costs of the PV system are the capital costs of the module costs (C_{PV}), system inverter cost (C_{INV}), labor installation cost (C_{LAB}), balance of system cost (C_{BOS}), permit, grid-interconnection, inspection cost (C_{PII}), sales tax (C_{ST}), shipping cost (C_{SHIP}) of the purchased system equipment, and the sales and marketing, overhead, and installer profit costs ($C_{SM+OV+IP}$). Total capital investment costs of the PV system are defined as

$$TPVC_{CAPITAL}^{S2} = C_{PV} + C_{LAB} + C_{INV} + C_{BOS} + C_{PII} + C_{ST} + C_{SHIP} + C_{SM+OV+IP} \quad (10)$$

Annual BCRs are used to provide the investor a year-to-year economic evaluation of the PV system. Benefits of the BCR are the credit from net-metered energy sold/injected back into the grid from a residence and the annual energy cost savings. Costs of the BCR are the annual total costs of the investment. Scenario 2 annual BCR is defined as

$$BCR_{t}^{S2} = \frac{(PV_{E_t} - RSPV_{E}{}_{t}^{S2}) * SP_{E_t} + (RSD_{E} - RSG_{E}{}_{t}^{S2}) * PP_{E_t}}{(RSG_{E}{}_{t}^{S2} * PP_{E_t}) + OM_{PV}{}_{t}^{S2} + P_{LOAN}{}_{t}^{S2}} \quad (11)$$

Scenario 1, the base scenario of a residence without a PV or ES system, does not have a computed ROI due to a lack of capital costs forcing the denominator of the equation to equal zero. Thus, scenario 1 totals are the annual energy costs for a residence ($RSD_{E} * PP_{E\,t}$).

The following is a detailed listing of the variables and parameters used in the $\mathrm{ROI}^{\mathrm{S2}}$ model:

Variables:

$\mathrm{PV_{E}}_{\,t}$ = amount of energy provided by the PV system in year (t)

$\mathrm{RSG_{E}}_{\,t}^{\,S2}$ = amount of energy consumed from grid by residence in year (t) for scenario 2

$\mathrm{RSPV_{E}}_{\,t}^{\,S2}$ = amount of PV provided energy consumed by residence in year (t) for scenario 2

Notation Parameters:

S_2 = signifies that the variable applies only to scenario 2

t = signifies the specific year; where $t = 1..n$

n = lifetime span of PV system (in t years)

Electricity Parameters:

$\mathrm{PP_{E}}_{\,t}$ = average energy purchase price in year (t); (\$/kWh)

$\mathrm{SP_{E}}_{\,t}$ = average energy sale price in year (t); (\$/kWh)

$\mathrm{PR_{HOME}}_{\,13}$ = average premium paid per residential PV capacity in year $(t = 13)$; (\$3.63/W)

$\mathrm{OM_{PV}}_{\,t}^{\,S2}$ = operation and maintenance cost of PV system in year (t); (\$/W)

$\mathrm{PV_{MAX}}_{\,0}$ = generation capacity of the PV system in purchase year $(t = 0)$; rated capacity

$\mathrm{G_{MAX}}_{\,t}$ = generation capacity of the grid in year (t); (kWh)

$\mathrm{RSD_{E}}$ = average annual energy consumption of residence

PV System Investment and Cost Parameters:

$\mathrm{C_{PV}}$ = capital cost of PV system modules (\$/W)

$\mathrm{C_{LAB}}$ = capital cost for installation labor (\$/W)

$\mathrm{C_{INV}}$ = capital cost for inverter (\$/W)

$\mathrm{C_{BOS}}$ = capital cost of balance of system equipment (wiring, mounting equipment, etc.); (\$/W)

$\mathrm{C_{PII}}$ = capital cost of permit, grid – interconnection (net metering) and inspection (\$/W)

$\mathrm{C_{ST}}$ = capital cost of sales tax on purchased system equipment (\$/W)

$\mathrm{C_{SHIP}}$ = capital cost of shipping and handling system equipment (\$/W)

$\mathrm{C_{SM+OV+IP}}$ = capital cost of sales & marketing, overhead, and installer profit (\$/W)

$\mathrm{AMOUNT_{LOAN}^{S2}}$ = amount of loan applied to capital investment costs in year 0 $(t = 0)$; (\$)

Rate-based Parameters:

$r_{FED\ TAX\ 1}$ = tax credit (30%) applied to the capital cost total of PV system in year 1 ($t = 1$)

$r_{STATE\ TAX\ 1}$ = state tax credit applied to capital cost total of PV system in year 1 ($t = 1$)

$r_{INCOME\ TAX\ 1}$ = income tax rate of PV system purchaser in year 1 ($t = 1$)

r_{LOAN} = fixed interest of loan (applied annually)

t_{LOAN} = number of years on loan payment

The following is a summary of the equations and variable limitations used in the ROI^{S2} model:

Equations:

$$ROI^{S2} = \left[\left(\frac{C_1 + C_2 - C_4 - C_5 - C_7}{C_7}\right) + \left(\frac{C_3}{C_7}\right) * \sum_{t=0}^{t=13}(RSD_E - RSG_{E\ t}^{\ S2}) + \left(\frac{C_6}{C_7}\right) * \sum_{t=0}^{t=13}(PV_{E\ t} - RSPV_{E\ t}^{\ S2})\right] * 100$$

where,

$C_1 = VAL_{HOME\ 13}^{\ S2} = PR_{HOME\ 13} * PV_{MAX_0}$

$C_2 = TAX_{INC\ 1}^{\ S2} = TC_{CAPITAL}^{S2} * [r_{FED\ TAX_1} + (1 - r_{INCOME\ TAX_1}) * r_{STATE\ TAX\ 1}]$

$C_3 = PP_{E\ t}$

$C_4 = \sum_{t=0}^{t=13} OM_{PV\ t}^{\ S2}$

$C_5 = \sum_{t=0}^{t=13} P_{LOAN\ t}^{\ S2} = \frac{r_{LOAN} * AMOUNT_{LOAN}^{S2}}{1-(1+r_{LOAN})^{-t_{LOAN}}}$

$C_6 = SP_{E\ t}$

$C_7 = TPVC_{CAPITAL}^{S2} = C_{PV} + C_{LAB} + C_{INV} + C_{BOS} + C_{PII} + C_{ST} + C_{SHIP} + C_{SM+OV+IP}$

Variable Limitations:

$PV_{E\ t} \in [0, PV_{MAX\ t}]$

$RSPV_{E\ t}^{\ S2} \in [0, PV_{E\ t}]$

$RSG_{E\ t}^{\ S2} \in [0, G_{MAX\ t}]$

$RSPV_{E\ t}^{\ S2} + RSG_{E\ t}^{\ S2} \in [RSD_E, \infty]$

A Microsoft Excel tool is provided for computation of the ROI. **Figure 9** displays the parameters and capital costs sections of the Microsoft Excel tool. The parameters in **Figure 9** are examples from a US average perspective. The tool provides each user the capability of adjusting certain parameters to meet the specific investment situation for the user. In order to perform state-specific analysis, each of the eight solar market states of the United States has its own tab in the Excel tool. The capital costs are specific to each state and are not adjustable by the user.

Congressional legislation extended the federal tax credit rate for residential PV investment to remain at 30% through the end of 2019 and can be adjusted by the tool user. The rate will fall to 26% in 2020, 22% in 2021, before dropping to 0% after 2022 [19]. Over the duration of this time period, capital costs for investing in residential PV are also expected to decrease. The NREL study by Goodrich et al. predicts a drop to $2.29/W for residential PV systems; the 2010 benchmark for residential PV system capital costs was $5.71/W [20]. Thus, the decrease in capital costs will help off-set the lost benefit of the federal tax credit rate by 2022. The state credit rate, purchaser income tax rate, fixed interest rate for the loan, loan amount (based on the percent of capital costs covered by the loan), and number of years on the loan are to be adjusted by the tool user based off his or her specific situation. The degradation rate is set at 0.5% based on the Jordan and Kurtz NREL study [10] and is not adjustable. The PV system discount rate (set at 4.6%) [29], annual US energy inflation rate (set at 3.2%) [30], annual PV system cost decrease rate (set at -9.5%) [8] and average US PV system market value % decrease after 10 years of usage (set at -32%) [29] are not adjustable by the tool-user. These non-adjustable parameters, along with the fixed discount rate for the loan [28], are key assumptions for the analysis of this research and are explained in the following assumptions section.

Average annual energy consumptions per residence and average energy purchase prices are specific to each state. **Figure 9** displays the US day-time (sunrise to sunset) and night-time averages for annual energy consumption per residence (10812 kWh total) and annual energy purchase price (0.1265 $/kWh). The tool user is able to adjust the consumption amount and energy purchase price to match his or her specific energy bill or use the state average for his or her specific state. This data was gathered from and is readily available by year on the US Energy Information Administration website [23]. An analysis by the Frontier Group and Environment America Research and Policy Center provides the median PV energy sale price of 0.1690 $/kWh [9]; this value is not adjustable by the user. Current grid-connected PV system inverters have 10 or 15 year warranties [24]. As explained by Johnson and Klise, PV system inverters have similar 10 or 15 year warranties, thus assuring an equivalent warranty period for the entire system. The average annual O&M costs for <10kW PV systems are provided through government-funded renewable energy data acquisition [13]; this value is not adjustable by the user. The Lawrence Berkeley National Laboratory study by Adomatis and Hoen provides a home premium increase of $3.63/W based off PV system capacity [32]; this value is not adjustable by the user. The generation capacity of the grid, denoted by ${G_{MAX}}_t$, is used to limit ${RSG_E}_t^{S2}$ as shown in the variable limitations above and is adjustable by the user. The home premium increase is a key assumption for the analysis of this research and is explained in the following assumptions section. The capital costs are imitated from the US solar photovoltaic capital cost benchmarks for the first quarter of 2016 [8]. The capital cost benchmark values vary and are specific for each state's Excel sheet and are expressed in 2016 dollars.

	A / B	C
1	**% Parameters (US Average Analysis)**	
2	Federal Tax Credit Rate =	30%
3	State Tax Credit Rate =	15%
4	Purchaser Income Tax Rate =	25%
5	Fixed Loan Rate =	4.2%
6	Renewable System Discount Rate =	4.6%
7	Annual US Energy Inflation Rate =	3.2%
8	Annual PV System Cost Decrease Rate =	-9.5%
9	Average US PV System Market Value % Decrease After 10 Years =	-32.0%
10	Degredation Rate per Year of PV Modules =	0.5%
11	Percent of Capital Cost Covered by Loan =	20%
12	**Electricity Totals and Cost Parameters (US Average Analysis)**	
13	Average Annual Day-time Consumption (kWh) =	6055
14	Average Annual Night-time Consumption (kWh) =	4757
15	Average Energy Purchase Price ($/kWh) =	$ 0.1265
16	Average PV Energy Sale Price ($/kWh) =	$ 0.1690
17	Potential Battery Replacement Post 10-yr Warranty ($/W) =	$ -
18	Average Annual O&M Costs for <10 kW System Modules ($/W) =	$ 0.021
19	Average Premium per Residential PV Capacity ($/W) =	$ 3.63
20	Loan Amount ($) =	$ 2,931.25
21	Number of Years on Loan Payment =	10

	E	F
1	**PV Capital Costs (US Average Analysis)**	
2	**Component**	**PV ($/W)**
3	C_PV =	$ 0.64
4	C_INV =	$ 0.21
5	S_BOS =	$ 0.12
6	E_BOS =	$ 0.25
7	C_SHIP =	$ 0.18
8	C_ST =	$ 0.08
9	C_LAB =	$ 0.31
10	C_PII =	$ 0.10
11	C_OV =	$ 0.33
12	C_SM =	$ 0.37
13	C_IP =	$ 0.35
14	**Total Cost ($/W) =**	**$ 2.93**

Figure 9: Microsoft Excel tool parameter and capital costs.

Figure 10 displays the variables, gains, investments, and costs section of the tool, broken down by the rated capacity of each PV system option (5kW, 6kW, and 7kW). Similar to the capital costs, the average annual generation for each system rated capacity is state-specific. The values in **Figure 10** are an example from the US average perspective. All values within the tables are computed based off the user-input parameters and therefore are not adjustable by the user. Appropriate formulas are included within the variable cells to account for the variable limitations.

	A / B / C	D	E	F
25	**Variables**			
26	PV System Rated Capacity (kW)	5	6	7
27	Average PV System Production (kWh/yr)	7,162	8,500	9,910
28	PV Provided Energy Sold to Grid (kWh/yr)	1,107	2,445	3,855
29	PV Provided Energy Consumed by Residence (kWh/yr)	6,055	6,055	6,055
30	Grid Energy Consumed by Residence (kWh/yr)	4,757	4,757	4,757
31	**Gains**			
32	Increase Home Premium ($)	$ 12,342	$ 14,810	$ 17,279
33	Federal & State Tax Incentive for PV System Installation ($)	$ 6,046	$ 7,255	$ 8,464
34	**Investments**			
35	Captial Cost PV System ($)	$ 14,656	$ 17,588	$ 20,519
36	**Costs**			
37	Potential Battery Replacement Post 10-yr Warranty ($/W)	$ -	$ -	$ -
38	O&M of PV System Modules ($/yr)	$ 105	$ 126	$ 147
39	Annual Loan Payment Totals ($/yr)	$ 365	$ 365	$ 365

Figure 10: Microsoft Excel tool variables, gains and costs.

IV. Scenario 2 Assumptions

A. Loan & Renewable System Discount Rate:

Energy related projected financed by the government use a different discount rate than those financed through the private sector. Khatib states a private energy sector discount rate of 4.2% for energy project investments [28]. This analysis assumes the 4.2% rate on the loan and that the loan used is from the private energy sector and not the government. The discount rate is used without the effects of inflation because PV investment loan rates are inflation-free [31]. Due to the annual totals this analysis is based off, this fixed loan discount rate is assumed to be annually compounded. The Excel tool is designed to allow the investor/tool-user the ability to change the discount rate to match whatever rate a private lender may state for the loan. The loan is assumed to be paid off in annual payments. The annual payments are calculated using the annuity payment formula, equation (9), expressed in the scenario 2 formulations.

A home solar value data analysis by EnergySage and Sandia National Laboratories (a US Department of Energy research and development lab) states a renewable system discount rate of 4.6% [29]. Truong et al. discusses the potential replacement of the storage battery post warranty [7]. Since the battery, detailed later in **Scenario 3 Assumptions**, is a component of the overall system, this analysis assumes the 4.6% discount rate for the battery replacement cost. The discount rate is applied to the multiplier for the single sum future worth replacement cost of the battery. The same discount rate of 4.6% is assumed for the PV system in year 13 when applying the increased home premium of a PV-home. This discount rate is used in the multiplier to attain the single sum future worth of the increased home premium, 3 years after the PV system market value decrease is applied, in year 13 when the home is assumed to be sold.

B. Energy Inflation Rate:

PV investment loan rates are inflation-protected (not affected by inflation), thus this research assumes no inflationary effects on the loan [31]. Although PV loans are not affected by inflation, electricity retail rates are and the effects lead to an increase in the savings experienced by the investor over time from the PV system [31]. As a result, an annual US energy inflation rate of 3.2% – the average annual US energy inflation rate from 2010-2015 [30] – is assumed and applied to all electricity retail priced based costs in this analysis. Due to a lack of data or studies concerning the inflation of PV electricity sale prices, this project assumes the average annual inflation rate of PV electricity sale prices is consistent with the annual US energy inflation rate of 3.2% used for retail prices.

C. PV System Cost & Market Value Decrease Rate:

Over the past 5 years, PV costs have experienced a decrease from $4.37/W in 2011 to $2.93/W in 2016 [8]. On average, PV costs have experienced a 9.5% annual decrease rate during this time frame. O&M annual costs are determined based on the annual generating capacity of the PV system [13] and are thus assumed to be annually adjusted at the same rate as the annual decrease rate of PV cost; the same decrease rate is assumed for the replaced battery in Scenario 3 as joint PV and ES systems become more common and more research and development is focused on reducing storage costs [34]. **Figure 11** displays a table of the PV cost decrease rate.

US Average Residential PV Cost (per Watt DC)		
Benchmark Timeframe	Residential PV Cost	% Decrease From Previous Year
2011 (Q4)	$ 4.37	-
2012 (Q4)	$ 3.82	12.6%
2013 (Q4)	$ 3.36	12.0%
2015 (Q1)	$ 3.11	7.4%
2016 (Q1)	$ 2.93	5.8%
Average US PV % Decrease =		9.5%

Figure 11: US average residential PV cost (per Watt DC).

EnergySage and Sandia National Laboratories performed an analysis on how the market value of PV systems changes over time [29]. The market value for a newly purchased PV system is compared to the market value of the PV system 5, 10, and 15 years after original purchase. Across the 15 major US cities analyzed, an average decrease in PV system market value of 32% is observed by year 10. This analysis assumes a 32% market value decrease for the average premium per residential PV capacity ($/W) applied in the year the home is assumed to be sold. **Figure 12** the table depiction of the PV system market value decrease rate.

Market Value of a Residential PV System			
US City	2015 Value of a New PV System	Value of the PV System After 10 Years	% Decrease Over 10 Years
San Francisco, CA	$ 5.46	$ 4.03	26%
Los Angeles, CA	$ 5.17	$ 3.80	26%
Las Vegas, NV	$ 4.71	$ 3.70	21%
New York, NY	$ 4.08	$ 2.93	28%
Newark, NJ	$ 3.74	$ 2.68	28%
Boston, MA	$ 3.57	$ 2.54	29%
Baltimore, MD	$ 2.96	$ 2.17	27%
Washington, D.C.	$ 2.87	$ 2.20	23%
Austin, TX	$ 2.58	$ 1.74	33%
Philadephia, PA	$ 2.80	$ 1.85	34%
Portland, OR	$ 2.23	$ 1.58	29%
St. Paul, MN	$ 2.01	$ 1.29	36%
Charlotte, NC	$ 1.62	$ 0.89	45%
New Orleans, LA	$ 1.35	$ 0.64	53%
Seattle, WA	$ 1.09	$ 0.62	43%
Average US PV System % Decrease After 10 Years =			32%

Figure 12: US Average market value of residential PV systems (per Watt DC).

D. Loan Amount:

Capital investment costs for PV systems can be pricey. PV loans are used to help cover these initial system costs. The requested loan amount can vary between investors based on the financial situation of each separate investor and how much of the capital costs the investor can cover him or herself. With the federal and state renewable tax credit, investors are able to off-set the expensive capital costs. Although loan payments are added annual costs for the investor, a loan helps to further ease the investment and make the possibility of investing in solar more affordable for the average American. For the purposes of this analysis, the loan amount used is assumed to cover 20% of the capital investment costs. With the tax credit off-setting 30% of the capital costs and the loan covering 20% of the costs, 50% of the capital costs are accounted for, thus reducing the investor's monetary burden. The loan amount directly affects the ROI and BCRs because it reduces the total costs paid in the investment year (year 0) and dictates the annuity payments. The loan is assumed to have a 10 year payment period.

E. Analysis Horizon:

Based on a US Census Bureau analysis by Emrath, homeowners live in their homes for an average 13 years before selling the home [21]. This analysis assumes a 13 year home-stay and thus uses a 13 year horizon for the analysis. Since the PV system market value decrease rate is based off a 10 year timeframe, a multiplier is applied to provide the single sum future worth in year 13. The increase home premium is applied in year 13 when the home is sold. The 13 year horizon is applied to all the state-specific analyses. This number is not adjustable by the tool user.

V. Scenario 3 Formulation

Scenario 3 analyzes a residence with a joint PV and ES system. As with scenario 2, an analysis tool, constructed using Microsoft Excel, is used to calculate the ROI for a proposed joint PV and ES system in scenario 3. The tool uses PV system-based parameters from scenario 2 and incorporates ES system-based parameters to calculate the total gains, costs, and savings from the joint system investment, as well as calculate the ROI of the joint system investment (expressed as a percentage). Similarity to scenario 2, the ROI in scenario 3 is calculated by subtracting the joint system total costs (occur annually over the period of t years) and joint system capital investment costs (upfront investment costs) from the joint system total gains and energy cost savings (occur annually over the period of t years). This value is then divided by the joint system capital investment costs. From the ROI, the user can make an economically informed decision on whether or not to proceed with the joint system investment.

The variables used for the ROI in scenario 3 are the number of batteries required for the ES system($\mathrm{No_B}$), the amount of energy discharged from the ES system in year t ($\mathrm{ES_{E_t}}$), and the amount of energy used to charge the ES system in year t ($\mathrm{ES_{CHE_t}}$). The amount of energy discharged from the ES system in year t is equivalent to the amount ES system energy consumed by a residence in year t. $\mathrm{ES_{E_t}}$ range is defined as

$$\mathrm{ES_{E_t}} \in [0\,, \mathrm{ES_{MAX}}_{\,t}] \tag{12}$$

where $\mathrm{ES_{MAX}}_{\,t}$ is the maximum storage capacity of the ES system in a given year t. The maximum storage capacity of the ES system is based on $\mathrm{No_B}$ and $\mathrm{No_B}$ is based on the amount of ES system energy consumed by a residence in year t. $\mathrm{ES_{MAX}}_{\,t}$, $\mathrm{No_B}$, $\mathrm{ES_{CHE_t}}$, and $\mathrm{ES_{E_t}}$ are defined as

$$\mathrm{ES_{MAX}}_{\,t} = \mathrm{No_B} * \mathrm{CAP_{SOC}} \tag{13}$$

$$No_B = (RSD_{COV}) * \frac{RSD_E}{DoD * E_{ff} * CAP_{SOS} * T_{CHRG-DIS}} \tag{14}$$

$$ES_{CHE_t} = (RSD_{COV}) * \frac{RSD_E}{E_{ff}} \tag{15}$$

$$ES_{E_t} = (RSD_{COV}) * RSD_E \tag{16}$$

where CAP_{SOC} is the storage capacity of a battery when operated between the minimum and maximum state-of-charge limitations, DoD is the depth-of-discharge – how much total energy can be drawn from a battery in one complete charge/discharge cycle – of a battery, E_{ff} is the efficiency – rate of how much energy is lost or maintained during each charge/discharge cycle – of a battery, $T_{CHRG-DIS}$ is the total charge/discharge cycles in a year (one cycle per day), and RSD_{COV} is the amount (as a percent) of night-time residential consumption covered by the ES system.

The investment gains of scenario 3 are the same as those for the scenario 2, with the incorporation of the ES system. The home value premium of scenario 3 ($VAL_{HOME}{}_{13}^{S2}$) includes the added maximum capacity (ES_{MAX_t}) of the storage system divided by the 4hr discharge, converting the units from kWh to kW. The federal and state tax incentives of scenario 3 ($TAX_{INC}{}_{1}^{S3}$) include the total capital investment costs of the ES system ($TESC_{CAPITAL}$). $VAL_{HOME}{}_{13}^{S2}$, $TAX_{INC}{}_{1}^{S3}$ and $TESC_{CAPITAL}$ are defined as

$$VAL_{HOME}{}_{13}^{S3} = PR_{HOME\,13} * (PV_{MAX\,0} + \frac{No_B * CAP_{SOC}}{DISCHRG_{TIME}}) \tag{17}$$

$$TAX_{INC}{}_{1}^{S3} = (TPVC_{CAPITAL}^{S2} + TESC_{CAPITAL}) * [r_{FED\,TAX\,1} + (1 - r_{INCOME\,TAX\,1}) * r_{STATE\,TAX\,1}] \tag{18}$$

$$TESC_{CAPITAL} = ESC_{BATT} + ESC_{BOS} + ESC_{LAB} + ESC_{PII} + ESC_{ST} + ESC_{SM+OV+IP} \tag{19}$$

where $DISCHRG_{TIME}$ is the discharge time of the ES system, and the capital investment costs of the ES system are the cost per battery (ESC_{BATT}), the ES system electrical component balance of system costs (ESC_{BOS}), the added labor costs due to ES system installation (ESC_{LAB}), the added grid, permitting, and interconnection costs due to the addition of the ES system (ESC_{PII}), the sale tax of the purchased ES system equipment (ESC_{ST}), and the sales and marketing, overhead, and installer profit ($ESC_{SM+OV+IP}$). The credit from net-metered energy of scenario 3 is calculated by multiplying the average energy sale price (SP_{E_t}) times the amount of energy sold/injected back into the grid from that which is provided by the joint PV and ES system in year t ($PV_{E_t} - RSPV_{E_t}^{S3} + ES_{E_t}$). The scenario 3 net-metered energy credit is defined as

$$\sum_{t=0}^{t=13}(PV_{E_t} - RSPV_{E_t}^{S3} + ES_{E_t}) * SP_{E_t} \tag{20}$$

where $RSPV_{E_t}^{S3}$ is the amount of joint PV and ES system provided energy consumed by a residence in year t. $RSPV_{E_t}^{S3}$ combines the PV and ES energy because the energy stored and discharged from the ES system comes from the PV provided energy (PV_{E_t}). As a result, $RSPV_{E_t}^{S3}$ is greater than $RSPV_{E_t}^{S2}$. The annual energy cost savings of scenario 3 are calculated by multiplying the average energy purchase price (PP_{E_t}) by the difference between the average annual energy consumption of a residence(RSD_E) and the energy consumed from the grid ($RSG_{E_t}^{S3}$). The scenario 3 energy cost savings are defined as

$$\sum_{t=0}^{t=13}(RSD_E - RSG_{E_t}^{S3}) * PP_{E_t} \tag{21}$$

The amount energy consumed from the grid in scenario 3 ($RSG_{E_t}^{S3}$) is less than that of scenario 2 ($RSG_{E_t}^{S2}$) because of the added energy provided to the investor by the ES system in scenario 3 (ES_{E_t}).

The total costs of the investment for scenario 3 are the same as those for the scenario 2, with the incorporation of the ES system. The O&M costs for scenario 3 ($OM_{PV_t}^{S3}$) are the O&M costs for scenario 2 ($\sum_{t=0}^{t=13} OM_{PV_t}^{S2}$) plus the added O&M costs of the ES system. The ES system O&M is a percentage [35] of ES system capital investment costs ($TESC_{CAPITAL}$)

multiplied by the frequency maintenance is performed [36]. Loan payments ($P_{LOAN}{}_{t}^{S3}$) are defined similarly to equation (9) in scenario 2, with the inclusion of the ES system impacts. The total capital investment costs of the PV system ($TC_{CAPITAL}^{S3}$) incorporate the same costs as $TC_{CAPITAL}^{S2}$ with a battery-based inverter (C_{BATT_INV}) replacing the regular PV system inverter (C_{INV}) of scenario 2. A battery-based inverter is required to convert the DC (direct current) electricity from the ES system batteries into AC (alternating current) for residential consumption and injection into the grid. This C_{BATT_INV} is more costly than the C_{INV} of scenario 2, thus the increase in scenario 3 capital investment costs for the PV system ($TC_{CAPITAL}^{S3}$) when compared to those of scenario 2 ($TC_{CAPITAL}^{S2}$). The $P_{LOAN}{}_{t}^{S3}$, $TC_{CAPITAL}^{S3}$ and $OM_{PV}{}_{t}^{S3}$ are defined as

$$\sum_{t=o}^{t=13} P_{LOAN}{}_{t}^{S3} = \frac{r_{LOAN} * AMOUNT_{LOAN}^{S3}}{1-(1+r_{LOAN})^{-t_{LOAN}}} \quad (22)$$

$$TPVC_{CAPITAL}^{S3} = C_{PV} + C_{LAB} + C_{BATT\_INV} + C_{BOS} + C_{PII} + C_{ST} + C_{SHIP} + C_{SM+OV+IP} \quad (23)$$

$$\sum_{t=0}^{t=13} OM_{PV}{}_{t}^{S2} + (OM_{MULT} * TC_{CAPITAL}^{S3} * OM_{PERFORM}) \quad (24)$$

where OM_{MULT} is the muliplier applied to the capital investment costs of the ES system to attain the O&M costs and $OM_{PERFORM}$ is the frequency maintenance is performed on the ES system.

The annual BCRs of scenario 3, used to provide the investor a year-to-year economic evaluation of the PV and ES systems, are similar to those in scenario 2. Benefits of the BCR are the credit from net-metered energy sold/injected back into the grid from a residence and the annual energy cost savings, with the inclusion of the ES system impacts. Costs of the BCR are the annual total costs of the investment, with the inclusion of the ES system impacts. Scenario 3 annual BCRs are defined as

$$BCR_{t}^{S3} = \frac{(PV_{E_t} - RSPV_{E}{}_{t}^{S3} + ES_{E_t}) * SP_{E_t} + (RSD_{E} - RSG_{E}{}_{t}^{S3}) * PP_{E_t}}{(RSG_{E}{}_{t}^{S3} * PP_{E_t}) + OM_{PV}{}_{t}^{S3} + P_{LOAN}{}_{t}^{S3}} \quad (25)$$

Figure 13 (a and b) displays the US average parameters and capital costs for scenario 3 with the inclusion of the ES system parameters and capital costs. The percent-based parameters for the PV system remain as depicted in **Figure 9** and as explained in **Scenario 2 Formulation** for scenario 3. The capital costs for the PV system experience remain at $2.93/W, based off a 5.6kW PV system, and the ES system costs sum to $4.27/W and $5.93/W, based off a 3kW and 5kW ES system respectively. The ES system capacity per battery, battery efficiency, cycles until replacement, depth-of-discharge (DoD), O&M cost multiplier, and hours of discharge are imitated from Ardani et al. [34] and are not adjustable by the tool user. The ES capital costs are imitated from the installed cost benchmarks for residential PV and ES systems for the first quarter of 2016 [34] and are expressed in 2016 dollars. The capital cost benchmark values are equivalent for each state.

	A–B	C
1	**% Parameters (US Average Analysis)**	
2	Federal Tax Credit Rate =	30%
3	State Tax Credit Rate =	15%
4	Purchaser Income Tax Rate =	25%
5	Fixed Loan Rate =	4.2%
6	Renewable System Discount Rate =	4.6%
7	Annual US Energy Inflation Rate =	3.2%
8	Annual PV System Cost Decrease Rate =	-9.5%
9	Average US PV System Market Value % Decrease After 10 Years =	-32.0%
10	Degredation Rate per Year of PV Modules =	0.5%
11	Percent of Capital Cost Covered by Loan =	20%
12	**Electricity Totals and Cost Parameters (US Average Analysis)**	
13	Average Annual Day-time Consumption (kWh) =	6055
14	Average Annual Night-time Consumption (kWh) =	4757
15	Average Energy Purchase Price ($/kWh) =	$ 0.1265
16	Average PV Energy Sale Price ($/kWh) =	$ 0.1690
17	Potential Battery Replacement Post 10-yr Warranty ($/W) =	$ 1.00
18	Average Annual O&M Costs for <10 kW System Modules ($/W) =	$ 0.021
19	Average Premium per Residential PV Capacity ($/W) =	$ 3.63
20	Loan Amount ($) =	$ 5,492.85
21	Number of Years on Loan Payment =	10
22	**ES System Parameters - 3kW ES**	
23	ES System Capacity (kWh/battery) =	6
24	ES System Efficiency (per battery) =	90%
25	Cycles until Replacement (per battery) =	5475
26	Depth-of-Discharge (per battery) =	80%
27	Percent of Average Annual Consumptions covered by ES =	25.00%
28	Average Annual O&M Costs for ES System Multiplier =	0.000
29	Number of Times Maintenance is Performed per Year =	0
30	Hours of Discharge per Cycle (1 Cycle = 1 Day) =	3

PV+ES Capital Costs (US Average Analysis)		
Component	**PV ($/W)**	**ES ($/W)**
C_PV =	$ 0.64	$ -
C_BATT =	$ -	$ 1.00
C_INV =	$ 0.21	$ 0.97
S_BOS =	$ 0.12	$ -
E_BOS =	$ 0.25	$ 0.61
C_SHIP =	$ 0.18	$ -
C_ST =	$ 0.08	$ 0.17
C_LAB =	$ 0.31	$ 0.35
C_PII =	$ 0.10	$ 0.23
C_OV =	$ 0.33	$ -
C_SM =	$ 0.37	$ 0.45
C_IP =	$ 0.35	$ 0.49
Total Cost ($/W) =	**$ 2.93**	**$ 4.27**

Figure 13 (a): Microsoft Excel tool parameter and capital costs (3kW/6kWh battery).

Figure 14 (a and b) displays the variables, gains, investments, and costs section of the tool, broken down by the rated capacity of each PV system option (5kW, 6kW, and 7kW) for scenario 3 with the inclusion of the ES system values. Similar to the capital costs, the average annual generation for each system rated capacity is state-specific as in scenario 2. The values are an example from the US average perspective and are computed based off the user-input parameters and therefore are not adjustable by the user, as in scenario 2. Appropriate formulas are included within the variable cells to account for the variable limitations.

	A–C	D	E	F
32	**Variables**			
33	**PV System Rated Capacity (kW)**	**5**	**6**	**7**
34	**Average PV System Production (kWh/yr)**	7,162	8,500	9,910
35	**PV Provided Energy Sold to Grid (kWh/yr)**	0	1,123	2,533
36	**PV Provided Energy Consumed by Residence (kWh/yr)**	7,030	7,244	7,244
37	**Grid Energy Consumed by Residence (kWh/yr)**	3,782	3,568	3,568
38	**Gains**			
39	**Increase Home Premium ($)**	$ 17,279	$ 19,747	$ 22,216
40	**Federal & State Tax Incentive for PV System Installation ($)**	$ 6,046	$ 7,255	$ 8,464
41	**Investments**			
42	**Captial Cost PV System ($)**	$ 14,656	$ 17,588	$ 20,519
43	**Costs**			
44	**O&M of PV System Modules ($/yr)**	$ 105	$ 126	$ 147
45	**Annual Loan Payment Totals ($/yr)**	$ 684	$ 684	$ 684
46	**ES System Variables**			
47	**Number of Batteries in ES System**	1	1	1
48	**Annual Energy Discharged from ES (kWh/yr)**	1189	1189	1189
49	**Annual Energy to Charge ES System (kWh/yr)**	1321	1321	1321
50	**ES System Gains**			
51	**Federal & State Tax Incentive for ES System (Charged 100% by PV System) ($)**	$ 5,283	$ 5,283	$ 5,283
52	**ES System Investments & Costs**			
53	**Capital Cost ES System ($)**	$ 12,808	$ 12,808	$ 12,808
54	**O&M of ES System ($/yr)**	$ -	$ -	$ -
55	**Potential Battery Replacement Post 10-yr Warranty ($/kW)**	$ 3,000	$ 3,000	$ 3,000

Figure 14 (a): Microsoft Excel tool variables, gains and costs (3kW/6kWh battery).

	A / B	C
1	**% Parameters (US Average Analysis)**	
2	Federal Tax Credit Rate =	30%
3	State Tax Credit Rate =	15%
4	Purchaser Income Tax Rate =	25%
5	Fixed Loan Rate =	4.2%
6	Renewable System Discount Rate =	4.6%
7	Annual US Energy Inflation Rate =	3.2%
8	Annual PV System Cost Decrease Rate =	-9.5%
9	Average US PV System Market Value % Decrease After 10 Years =	-32.0%
10	Degredation Rate per Year of PV Modules =	0.5%
11	Percent of Capital Cost Covered by Loan =	20%
12	**Electricity Totals and Cost Parameters (US Average Analysis)**	
13	Average Annual Day-time Consumption (kWh) =	6055
14	Average Annual Night-time Consumption (kWh) =	4757
15	Average Energy Purchase Price ($/kWh) =	$ 0.1265
16	Average PV Energy Sale Price ($/kWh) =	$ 0.1690
17	Potential Battery Replacement Post 10-yr Warranty ($/W) =	$ 2.00
18	Average Annual O&M Costs for <10 kW System Modules ($/W) =	$ 0.021
19	Average Premium per Residential PV Capacity ($/W) =	$ 3.63
20	Loan Amount ($) =	$ 6,490.09
21	Number of Years on Loan Payment =	10
22	**ES System Parameters - 5kW ES**	
23	ES System Capacity (kWh/battery) =	20
24	ES System Efficiency (per battery) =	90%
25	Cycles until Replacement (per battery) =	5475
26	Depth-of-Discharge (per battery) =	80%
27	Percent of Average Annual Consumptions covered by ES =	50.00%
28	Average Annual O&M Costs for ES System Multiplier =	0.000
29	Number of Times Maintenance is Performed per Year =	0
30	Hours of Discharge per Cycle (1 Cycle = 1 Day) =	6

PV+ES Capital Costs (US Average Analysis)		
Component	**PV ($/W)**	**ES ($/W)**
C_PV =	$ 0.64	$ -
C_BATT =	$ -	$ 2.00
C_INV =	$ 0.21	$ 0.79
S_BOS =	$ 0.12	$ -
E_BOS =	$ 0.25	$ 0.88
C_SHIP =	$ 0.18	$ 0.05
C_ST =	$ 0.08	$ 0.25
C_LAB =	$ 0.31	$ 0.76
C_PII =	$ 0.10	$ 0.14
C_OV =	$ 0.33	$ -
C_SM =	$ 0.37	$ 0.27
C_IP =	$ 0.35	$ 0.79
Total Cost ($/W) =	**$ 2.93**	**$ 5.93**

Figure 13 (b): Microsoft Excel tool parameter and capital costs (5kW/20kWh battery).

	A–C	D	E	F
32	**Variables**			
33	PV System Rated Capacity (kW)	5	6	7
34	Average PV System Production (kWh/yr)	7,162	8,500	9,910
35	PV Provided Energy Sold to Grid (kWh/yr)	0	0	1,212
36	PV Provided Energy Consumed by Residence (kWh/yr)	6,897	8,235	8,433
37	Grid Energy Consumed by Residence (kWh/yr)	3,914	2,576	2,379
38	**Gains**			
39	Increase Home Premium ($)	$ 20,570	$ 23,038	$ 25,507
40	Federal & State Tax Incentive for PV System Installation ($)	$ 6,046	$ 7,255	$ 8,464
41	**Investments**			
42	Captial Cost PV System ($)	$ 14,656	$ 17,588	$ 20,519
43	**Costs**			
44	O&M of PV System Modules ($/yr)	$ 105	$ 126	$ 147
45	Annual Loan Payment Totals ($/yr)	$ 808	$ 808	$ 808
46	**ES System Variables**			
47	Number of Batteries in ES System	1	1	1
48	Annual Energy Discharged from ES (kWh/yr)	2379	2379	2379
49	Annual Energy to Charge ES System (kWh/yr)	2643	2643	2643
50	**ES System Gains**			
51	Federal & State Tax Incentive for ES System (Charged 100% by PV System) ($)	$ 7,340	$ 7,340	$ 7,340
52	**ES System Investments & Costs**			
53	Capital Cost ES System ($)	$ 17,794	$ 17,794	$ 17,794
54	O&M of ES System ($/yr)	$ -	$ -	$ -
55	Potential Battery Replacement Post 10-yr Warranty ($/kW)	$ 6,000	$ 6,000	$ 6,000

Figure 14 (b): Microsoft Excel tool variables, gains and costs (5kW/20kWh battery).

The following is a detailed listing of the variables and parameters used in the ROI^{S3} model:

Variables:

${PV_E}_t$ = amount of energy provided by the PV system in year (t)

${RSG_E}_t^{S3}$ = amount of energy consumed from grid by residence in year (t) for scenario 3

${RSPV_E}_t^{S3}$ = amount of PV provided energy consumed by residence in year (t) for scenario 3

${ES_E}_t$ = the amount of energy discharged from the ES system in year (t)

Notation Parameters:

S_3 = signifies that the variable applies only to scenario 3

t = signifies the specific year; where $t = 1..n$

n = lifetime span of the joint PV and ES system (in t years)

Electricity Parameters:

${PP_E}_t$ = average energy purchase price in year (t); (\$/kWh)

${SP_E}_t$ = average energy sale price in year (t); (\$/kWh)

${PR_{HOME}}_{13}$ = average premium paid per residential PV capacity in year $(t = 13)$; (\$3.63/W)

${OM_{PV}}_t^{S3}$ = operation and maintenance cost of PV system in year (t); (\$/kW)

${PV_{MAX}}_0$ = generation capacity of the PV system in purchase year $(t = 0)$; rated capacity

${G_{MAX}}_t$ = generation capacity of the grid in year (t); (kWh)

${ES_{MAX}}_t$ = maximum storage capacity of the ES system in a given year (t); (kWh)

RSD_E = average annual energy consumption of residence

PV System Investment and Cost Parameters:

C_{PV} = capital cost of PV system modules (\$/kW)

C_{LAB} = capital cost for installation labor (\$/kW)

C_{BOS} = capital cost of balance of system equipment (wiring, mounting equipment, etc.); (\$/kW)

C_{PII} = capital cost of permit, grid − interconnection (net metering) and inspection (\$/kW)

C_{ST} = capital cost of sales tax on purchased system equipment(\$/kW)

C_{SHIP} = capital cost of shipping and handling system equipment(\$/kW)

$C_{SM+OV+IP}$ = capital cost of sales & marketing, overhead, and installer profit (\$/kW)

PV and ES System Investment and Cost Parameters:

$\mathrm{ESC_{BATT}}$ = capital cost for each battery($/W)

$\mathrm{ESC_{BOS}}$ = capital cost of ES balance of system equipment (conductors, combiners, etc.); ($/W)

$\mathrm{ESC_{LAB}}$ = capital cost of ES electrical balance of system equipment (charge controler, etc.); ($/W)

$\mathrm{ESC_{PII}}$ = capital cost of ES permit, grid − interconnection (net metering) and inspection ($/W)

$\mathrm{ESC_{ST}}$ = capital cost of sales tax on purchased ES system equipment ($/W)

$\mathrm{ESC_{SM+OV+IP}}$ = capital cost of sales & marketing, overhead, and installer profit ($/W)

$\mathrm{C_{BATT\_INV}}$ = capital cost for battery − based inverter ($/W)

$\mathrm{AMOUNT_{LOAN}^{S3}}$ = amount of loan applied to capital investment costs in year 0 ($t = 0$); ($)

Rate-based Parameters:

$\mathrm{r_{FED\ TAX\ 1}}$ = tax credit (30%) applied to the capital cost total of PV system in year 1 ($t = 1$)

$\mathrm{r_{STATE\ TAX\ 1}}$ = state tax credit applied to capital cost total of PV system in year 1 ($t = 1$)

$\mathrm{r_{INCOME\ TAX\ 1}}$ = income tax rate of PV system purchaser in year 1 ($t = 1$)

$\mathrm{r_{LOAN}}$ = fixed interest of loan (applied annually)

$\mathrm{t_{LOAN}}$ = number of years on loan payment

$\mathrm{CAP_{SOC}}$ = battery storage capacity when operated between the min and max state of charge limits

DoD = how much total energy can be drawn from a battery in one complete charge/discharge cycle

$\mathrm{E_{ff}}$ = rate of how much energy is lost or maintained during each charge/discharge cycle

$\mathrm{RSD_{COV}}$ = percent of average night − time consumption covered by the ES system

$\mathrm{OM_{MULT}}$ = multiplier applied to capital investment cost of ES system; (0.5%)

$\mathrm{OM_{PERFOM}}$ = multiplier applied to capital investment cost of ES system; (quarterly − 4)

$\mathrm{DISCHRG_{TIME}}$ = hours of discharge of the ES system per charge/discharge cycle ; (4 hours)

$\mathrm{T_{CHRG-DIS}}$ = total number of charge/discharge cycles in a year (one/day − 365 total)

The following is a summary of the equations and variable limitations used in the ROI^{S3} model:

Equations:

$$ROI^{S3} = \left[\left(\frac{C_1 + C_2 - C_4 - C_5 - C_7}{C_7}\right) + \left(\frac{C_3}{C_7}\right) * \sum_{t=0}^{t=13} (RSD_E - RSG_{E\ t}^{\ S3}) + \left(\frac{C_6}{C_7}\right) * \sum_{t=0}^{t=13} (PV_{E\ t} - RSPV_{E\ t}^{\ S2} + ES_{E_t})\right] * 100$$

where,

$$C_1 = VAL_{HOME\ 13}^{\ S3} = PR_{HOME\ 13} * (PV_{MAX\ 0} + \frac{No_B * CAP_{SOC}}{DISCHRG_{TIME}})$$

$$C_2 = TAX_{INC\ 1}^{\ S3} = (TPVC_{CAPITAL}^{S2} + TESC_{CAPITAL}) * [r_{FED\ TAX\ 1} + (1 - r_{INCOME\ TAX\ 1}) * r_{STATE\ TAX\ 1}]$$

$$C_3 = PP_{E\ t}$$

$$C_4 = \sum_{t=0}^{t=13} OM_{PV\ t}^{\ S2} + (OM_{MULT} * TC_{CAPITAL}^{S3} * OM_{PERFORM})$$

$$C_5 = \sum_{t=o}^{t=13} P_{LOAN\ t}^{\ S3} = \frac{r_{LOAN} * AMOUNT_{LOAN}^{S3}}{1-(1+r_{LOAN})^{-t_{LOAN}}}$$

$$C_6 = SP_{E\ t}$$

$$C_7 = TPVC_{CAPITAL}^{S3} + TESC_{CAPITAL}$$

where,

$$TPVC_{CAPITAL}^{S3} = C_{PV} + C_{LAB} + C_{BATT\_INV} + C_{BOS} + C_{PII} + C_{ST} + C_{SHIP} + C_{SM+OV-IP}$$

$$TESC_{CAPITAL} = ESC_{BATT} + ESC_{BOS} + ESC_{LAB} + ESC_{PII} + ESC_{ST} + ESC_{SM+OV+IP}$$

Variable Limitations:

$$PV_{E\ t} \in [0, PV_{MAX\ t}]$$

$$RSPV_{E\ t}^{\ S2} \in [0, PV_{E\ t}]$$

$$RSG_{E\ t}^{\ S2} \in [0, G_{MAX\ t}]$$

$$RSPV_{E\ t}^{\ S2} + RSG_{E\ t}^{\ S2} \in [RSD_E, \infty]$$

$$ES_{E_t} \in [0, ES_{MAX\ t}]$$

VI. Scenario 3 Assumptions

This analysis is based on two Tesla Powerwall batteries with capacities of 3kW and 5kW.

A. Lifetime Cycles – SoC – Replacement After Warranty:

The storage batteries used in this analysis are Tesla Powerwalls. DiOrio et al. state that Tesla Powerwall batteries have a 10 year warranty and an expected lifetime, when operating within assumed 30% (minimum) and 100% (maximum) state-of-charge (SoC) limitations, of 5475 charge/discharge cycles before degrading to 70% of their rated maximum capacity; at which point the batteries must be replaced [26]. 5475 cycles, with 1 full cycle occurring each day, equates to 15 years before the batteries must be replaced. However, this analysis assumes a potential battery replacement prior to the 15 year time frame and after the 10 year warranty period. As stated previously, Truong et al. references but does not consider battery replacement after the warranty period to avoid complexity in the results [7]. This analysis assumes the potential necessity for a battery replacement after the 10 year warranty and considers this replacement cost in year 11 of the analysis.

B. Charging/Discharging – Night-Time Consumption:

Elgqvist et al. state that battery storage system capital investment costs are also impacted by the renewable energy investment tax credit (ITC) [33]. The impact level is based on what percentage of the ES system is charged by the joint PV system. In order to claim the full 30% tax credit, the ES system must be 100% charged by the provided PV energy [33]. This analysis assumes the ES system is charged during the day-time-generating hours of the PV system, using the excess PV provided energy that a residence doesn't consume. The ES system then discharges during the night-time-non-generating hours of the PV system. Thus, the analysis assumes the full 30% tax credit is claimed on the ES system capital investment costs.

In situations where the excess PV provided energy that a residence doesn't consume is not sufficient to fully charge the ES system, grid provided energy is used to charge the remaining portions of the ES system. This grid provided energy is factored into the total costs of grid consumed energy by a residence. According to Elgqvist et al. the tax credit percentage applied to the ES system capital investment costs for an ES system that is only partially charged by the PV system, is equal to the federal tax credit multiplied by the percentage the ES system is charged by the PV system [33]. For example, an ES system charged by PV provided energy 70% of the time is eligible for the 30% federal tax credit multiplied by 70%, which equals a 21% federal tax credit instead of 30%. For such situations within the analysis, it is assumed that the percentage of PV provided energy used for ES system charging is equal to the ES system charged by PV provided energy percentages for each year averaged over the 13 year horizon. There is no PV energy sold/injected into the grid in such situations and as a result, there is no credit gained from net-metered energy sold/injected back into the grid from a residence.

Since the discharged ES system energy originates from the provided PV energy, the discharged ES system energy is assumed to also be PV energy and is added to the total PV energy consumed by a residence in this analysis. Due to the inclusion of battery replacement prior to battery degradation to 70% of the rated battery capacity, the annual energy used to charge the ES system and the annual discharged energy from the system is assumed to be constant each year of the 13 year analysis horizon.

The Office of Energy Efficiency & Renewable Energy (EERE) provides data-sets of the hourly residential load profiles in all listed states of this analysis [39]. These data-sets were used to calculate the assumed average annual day-time and night-time energy consumption levels for all listed states of this analysis.

C. Capacity – DoD – Efficiency –Discharge Time:

The Tesla Powerwall batteries used in this analysis have capacities of 3kW/6kWh and 5kW/20kWh. The 3kW/6kWh battery has a 2 hour on-peak and 4 hour off-peak discharge time. The 5kW/20kWh battery has a 4 hour on-peak and 8 hour off-peak discharge time [34]. An efficiency of 90% and a depth-of-discharge of 80% are assumed for the batteries to meet the stated discharge times [34]. Pacific Power, an electric company, states annual average on-peak consumption hours of 4pm – 8pm [36]. The United States Naval Observatory (USNO) provides the average annual sun rise and sun set time (6pm – 7pm) for all listed states in this analysis [37]. Sunset is assumed to be the end of the PV generation hours. Since the sun set average covers half of the on-peak consumption hours, this analysis assumes the batteries' total discharge time is the average of the on-peak and off-peak consumption discharge times. Thus, the 3kW/6kWh and 5kW/20kWh batteries are assumed to discharge for 3 and 6 hours, respectively, in each daily charge/discharge cycle. This discharged energy is applied towards the average annual night-time consumption (RSD_{COV}), thus reducing the amount of grid consumed energy at night. The sun rise and sun set times provided by USNO provide an annual average of 12 night-time hours. Using the assumed discharge times for the batteries RSD_{COV} is 25% (3 hours discharge/12 hours of night-time consumption) and 50% (6 hours discharge/12 hours of night-time consumption) for the 3kW/6kWh and 5kW/20kWh batteries respectively. The battery capacity, DoD, efficiency and discharge time are not adjustable by the tool user.

D. O&M Costs:

Kaldellis and Zafirakis state that the O&M costs of storage systems are a percentage of the system's capital investment costs [35]. Tesla Powerwall batteries do not require labor-based maintenance thus O&M costs are assumed negligible.

VII. Analysis

The analysis for scenario 1 does not require an energy consumption breakdown. Scenario 1 is analyzed by multiplying the average annual energy purchase price by the average annual consumption totals of a residence within each analyzed state and the US average. This product gives the energy costs of a residence without a PV or PV + ES system. The analysis for scenario 2 and scenario 3 do require an energy consumption breakdown and are detailed below. The results are divided and described as follows:

A. Scenario 2 – Residence with just a PV system

B. Scenario 3 – Residence with a PV + ES system

The average annual PV system production outputs (kWh) used in the analysis are provided by EnergySage for each system size and for each state. EnergySage utilized PV Watts, a tool developed by NREL, to calculate the outputs [38]. The averages of the state outputs are used as the US output. All monetary amounts are in 2016 United States dollars. Visuals of the Microsoft Excel tool calculations sheets of the US are provided for each scenario. State calculation sheets use the same template as the US, with each state's respective energy and monetary amounts.

A. Scenario 2 – Residence with just a PV System:

Figures 15, 16 and **17** display the Microsoft Excel tool calculated values, specific to the US average, for a 5kW, 6kW and 7kW PV system respectively. Column J states the year of analysis. Columns K, L, M, and N calculate the amounts of PV production, PV provided energy sold/injected into the grid, PV provided energy consumed by a residence, and grid provided energy consumed by a residence in kWh respectively. The PV production in Column K is annually degraded by the PV module degradation rate [10].

The provided PV energy (Column K) is used to supply the average day-time consumption of a residence. Once this consumption is met, the remaining amount is sold/injected into the grid. Thus the calculation for PV energy sold/injected into the grid is the difference between the provided PV amount and the average day-time consumption of a residence; the PV provided energy consumed by a residence is then equal to the average day-time consumption of the residence, and the grid provided energy consumed by the residence is equal to the average night-time consumption of a residence. If the provided PV energy is insufficient to meet the average daily consumption levels of a residence, then grid provided energy is used to meet the remaining amount of average day-time consumption and to meet the average night-time consumption of a residence; there is no PV provided energy sold/injected into the grid in such a situation.

Column O calculates the energy costs of a residence without a PV or ES system (scenario 1); the assumed annual US energy inflation rate is applied to these costs. Column P calculates the capital invested amount, minus the loan amount used to off-set the capital costs, in year 0 when the system is purchased. Column Q calculates the O&M costs of the PV system; the assumed annual PV system cost decrease is applied to these costs. Column R calculates the battery replacement costs post warranty and is blank because scenario 2 does not incorporate an ES system. Column S calculates the cost of grid provided energy consumed by a residence; the assumed annual US energy inflation rate is applied to these costs. Column T calculates the loan payments based of the fixed loan rate. Column U calculates the added home premium. The PV system market value decrease after 10 years is applied and this value is then discounted to year 13. Column V calculates the federal and state tax incentive credits claimed by an investor in the year (year 1) following the purchase of the PV system. Column W calculates the energy costs of a residence with just a PV system. Column X calculates the net-metered credits earned by a residence from the energy amounts sold/injected into the grid from Column L; the assumed annual US energy inflation rate is applied to these costs. Column Y calculates the energy cost savings by taking the difference between the energy costs of a residence without a PV or PV + ES system (Column O) and the energy of a residence when just a PV system is added (Column W). Column Z calculates the annual BCR of the PV system by dividing the annual benefits experienced as a result of the system (Column X and Column Y) by the annual costs experienced as a result of the system (Column W and Column T).

The ROI, analyzed for the 13 year horizon, is calculated by taking the difference between the investment gains (Columns U, V, X, and Y) and the investment costs (Column P and Column T). This value is then divided by the capital costs of the system. An ROI is presented with and without the added home premium (Column U) included.

J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	10,812	$ 1,367.68	$11,725.00	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
1	7,162	1107	6,055	4,757	$ 1,411.45	$ -	$ 95.06	$ -	$ 621.02	$ 365.00	$ -	$ 6,045.70	$ 716.08	$ 193.07	$ 695.37	0.82
2	7,090	1036	6,055	4,757	$ 1,456.61	$ -	$ 86.06	$ -	$ 640.89	$ 365.00	$ -	$ -	$ 726.95	$ 186.40	$ 729.66	0.84
3	7,055	1000	6,055	4,757	$ 1,503.23	$ -	$ 77.92	$ -	$ 661.40	$ 365.00	$ -	$ -	$ 739.32	$ 185.77	$ 763.91	0.86
4	7,020	965	6,055	4,757	$ 1,551.33	$ -	$ 70.54	$ -	$ 682.56	$ 365.00	$ -	$ -	$ 753.11	$ 184.96	$ 798.22	0.88
5	6,984	930	6,055	4,757	$ 1,600.97	$ -	$ 63.87	$ -	$ 704.40	$ 365.00	$ -	$ -	$ 768.27	$ 183.93	$ 832.70	0.90
6	6,950	895	6,055	4,757	$ 1,652.20	$ -	$ 57.82	$ -	$ 726.95	$ 365.00	$ -	$ -	$ 784.77	$ 182.69	$ 867.44	0.91
7	6,915	860	6,055	4,757	$ 1,705.07	$ -	$ 52.35	$ -	$ 750.21	$ 365.00	$ -	$ -	$ 802.56	$ 181.21	$ 902.52	0.93
8	6,880	826	6,055	4,757	$ 1,759.64	$ -	$ 47.39	$ -	$ 774.21	$ 365.00	$ -	$ -	$ 821.61	$ 179.50	$ 938.03	0.94
9	6,846	791	6,055	4,757	$ 1,815.94	$ -	$ 42.91	$ -	$ 798.99	$ 365.00	$ -	$ -	$ 841.90	$ 177.52	$ 974.05	0.95
10	6,812	757	6,055	4,757	$ 1,874.05	$ -	$ 38.85	$ -	$ 824.56	$ 365.00	$ -	$ -	$ 863.40	$ 175.27	$ 1,010.65	0.97
11	6,778	723	6,055	4,757	$ 1,934.02	$ -	$ 35.17	$ -	$ 850.94	$ -	$ -	$ -	$ 886.11	$ 172.74	$ 1,047.91	1.38
12	6,744	689	6,055	4,757	$ 1,995.91	$ -	$ 31.84	$ -	$ 878.17	$ -	$ -	$ -	$ 910.01	$ 169.91	$ 1,085.90	1.38
13	6,710	655	6,055	4,757	$ 2,059.78	$ -	$ 28.83	$ -	$ 906.27	$ -	$ 14,136.90	$ -	$ 935.10	$ 166.77	$ 1,124.68	1.38
					$ 23,687.91	$11,725.00	$ 728.61		$ 11,188.26	$ 3,650.04	$ 14,136.90	$ 6,045.70	$ 11,916.87	$ 2,339.76	$ 11,771.04	
													ROI w/ Premium =		129.08%	
													ROI w/o Premium =		32.62%	

Figure 15: Microsoft Excel tool calculations for the US – 5kW PV (Scenario 1 and 2).

J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	10,812	$ 1,367.68	$14,070.00	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
1	8,500	2445	6,055	4,757	$ 1,411.45	$ -	$ 114.07	$ -	$ 621.02	$ 438.00	$ -	$ 7,254.84	$ 735.09	$ 426.39	$ 676.36	0.94
2	8,415	2360	6,055	4,757	$ 1,456.61	$ -	$ 103.28	$ -	$ 640.89	$ 438.00	$ -	$ -	$ 744.17	$ 424.77	$ 712.45	0.96
3	8,373	2318	6,055	4,757	$ 1,503.23	$ -	$ 93.50	$ -	$ 661.40	$ 438.00	$ -	$ -	$ 754.90	$ 430.55	$ 748.33	0.99
4	8,331	2276	6,055	4,757	$ 1,551.33	$ -	$ 84.65	$ -	$ 682.56	$ 438.00	$ -	$ -	$ 767.21	$ 436.30	$ 784.12	1.01
5	8,289	2234	6,055	4,757	$ 1,600.97	$ -	$ 76.64	$ -	$ 704.40	$ 438.00	$ -	$ -	$ 781.04	$ 442.03	$ 819.93	1.04
6	8,248	2193	6,055	4,757	$ 1,652.20	$ -	$ 69.39	$ -	$ 726.95	$ 438.00	$ -	$ -	$ 796.33	$ 447.71	$ 855.87	1.06
7	8,206	2152	6,055	4,757	$ 1,705.07	$ -	$ 62.82	$ -	$ 750.21	$ 438.00	$ -	$ -	$ 813.03	$ 453.35	$ 892.05	1.08
8	8,165	2111	6,055	4,757	$ 1,759.64	$ -	$ 56.87	$ -	$ 774.21	$ 438.00	$ -	$ -	$ 831.09	$ 458.93	$ 928.55	1.09
9	8,125	2070	6,055	4,757	$ 1,815.94	$ -	$ 51.49	$ -	$ 798.99	$ 438.00	$ -	$ -	$ 850.48	$ 464.46	$ 965.47	1.11
10	8,084	2029	6,055	4,757	$ 1,874.05	$ -	$ 46.62	$ -	$ 824.56	$ 438.00	$ -	$ -	$ 871.17	$ 469.91	$ 1,002.88	1.12
11	8,044	1989	6,055	4,757	$ 1,934.02	$ -	$ 42.20	$ -	$ 850.94	$ -	$ -	$ -	$ 893.15	$ 475.29	$ 1,040.88	1.70
12	8,003	1949	6,055	4,757	$ 1,995.91	$ -	$ 38.21	$ -	$ 878.17	$ -	$ -	$ -	$ 916.38	$ 480.58	$ 1,079.53	1.70
13	7,963	1909	6,055	4,757	$ 2,059.78	$ -	$ 34.59	$ -	$ 906.27	$ -	$ 16,964.28	$ -	$ 940.87	$ 485.77	$ 1,118.92	1.71
					$ 23,687.91	$14,070.00				$ 4,380.04	$ 16,964.28	$ 7,254.84	$12,062.59	$ 5,896.05	$ 11,625.32	
													ROI w/ Premium =		158.91%	
													ROI w/o Premium =		43.16%	

Figure 16: Microsoft Excel tool calculations for the US – 6kW PV (Scenario 1 and 2).

	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1–3	EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
4	0	0	0	0	10,812	$ 1,367.68	$16,415.00	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
5	1	9,910	3855	6,055	4,757	$ 1,411.45	$ -	$ 133.09	$ -	$ 621.02	$ 511.01	$ -	$ 8,463.98	$ 754.10	$ 672.30	$ 657.35	1.05
6	2	9,811	3756	6,055	4,757	$ 1,456.61	$ -	$ 120.49	$ -	$ 640.89	$ 511.01	$ -	$ -	$ 761.38	$ 676.03	$ 695.24	1.08
7	3	9,762	3707	6,055	4,757	$ 1,503.23	$ -	$ 109.09	$ -	$ 661.40	$ 511.01	$ -	$ -	$ 770.48	$ 688.55	$ 732.74	1.11
8	4	9,713	3658	6,055	4,757	$ 1,551.33	$ -	$ 98.76	$ -	$ 682.56	$ 511.01	$ -	$ -	$ 781.32	$ 701.23	$ 770.01	1.14
9	5	9,664	3610	6,055	4,757	$ 1,600.97	$ -	$ 89.41	$ -	$ 704.40	$ 511.01	$ -	$ -	$ 793.82	$ 714.06	$ 807.15	1.17
10	6	9,616	3561	6,055	4,757	$ 1,652.20	$ -	$ 80.95	$ -	$ 726.95	$ 511.01	$ -	$ -	$ 807.90	$ 727.04	$ 844.31	1.19
11	7	9,568	3513	6,055	4,757	$ 1,705.07	$ -	$ 73.29	$ -	$ 750.21	$ 511.01	$ -	$ -	$ 823.50	$ 740.18	$ 881.58	1.22
12	8	9,520	3465	6,055	4,757	$ 1,759.64	$ -	$ 66.35	$ -	$ 774.21	$ 511.01	$ -	$ -	$ 840.57	$ 753.46	$ 919.07	1.24
13	9	9,472	3418	6,055	4,757	$ 1,815.94	$ -	$ 60.07	$ -	$ 798.99	$ 511.01	$ -	$ -	$ 859.06	$ 766.89	$ 956.88	1.26
14	10	9,425	3370	6,055	4,757	$ 1,874.05	$ -	$ 54.39	$ -	$ 824.56	$ 511.01	$ -	$ -	$ 878.94	$ 780.46	$ 995.11	1.28
15	11	9,378	3323	6,055	4,757	$ 1,934.02	$ -	$ 49.24	$ -	$ 850.94	$ -	$ -	$ -	$ 900.18	$ 794.18	$ 1,033.84	2.03
16	12	9,331	3276	6,055	4,757	$ 1,995.91	$ -	$ 44.58	$ -	$ 878.17	$ -	$ -	$ -	$ 922.75	$ 808.03	$ 1,073.16	2.04
17	13	9,284	3230	6,055	4,757	$ 2,059.78	$ -	$ 40.36	$ -	$ 906.27	$ -	$ 19,791.66	$ -	$ 946.63	$ 822.01	$ 1,113.15	2.04
18						$ 23,687.91	$16,415.00				$ 5,110.05	$ 19,791.66	$ 8,463.98	$ 12,208.31	$ 9,644.41	$11,479.60	
19																	
20															ROI w/ Premium =	190.05%	
21																	
22															ROI w/o Premium =	55.01%	

Figure 17: Microsoft Excel tool calculations for the US – 7kW PV (Scenario 1 and 2).

B. Scenario 3 – Residence with a PV + ES system:

Figures 18, 19, 20, 21, 22 and **23** display the Microsoft Excel tool calculated values, specific to the US average, for a 5kW PV + 3kW ES, 6kW PV + 3kW ES, 7kW PV + 3kW ES, 5kW PV + 5kW ES, 6kW PV + 5kW ES, and 7kW PV + 5kW ES joint system respectively. The calculations for Columns J, K, M, O, P, Q, R, S, T, U, V, W, X, Y, Z, AA, and AB are as described by Column J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y and Z respectively in scenario 2. Columns R, W, and X (the loan amount, home premium, tax incentives) include the capital costs of the ES system in the cost calculations, and thus have larger amounts than their scenario 2 equivalents – Columns P, U, and V respectively – where the amounts were based only on the cost of the PV system. Column T accounts for the battery replacement cost in year 11 and is no longer blank as it was in its scenario 2 equivalent, Column R, where no ES system was considered; the assumed annual PV system cost decrease and the renewable system discount rate are applied to this cost.

The new scenario 3 specific columns, Column L and Column N, calculate the annual energy used to charge the ES system and the annual energy discharged from the ES system respectively; both values are assumed constant throughout the 13 year horizon.

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	10,812	$ 1,367.68	$21,971.40	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
1	7,162	1,321	0	1189	7,030	3,782	$ 1,411.45	$ -	$ 95.06	$ -	$ 493.75	$ 683.98	$ -	$ 11,329.00	$ 588.81	$ -	$ 822.64	0.65
2	7,090	1,321	0	1189	6,958	3,854	$ 1,456.61	$ -	$ 86.06	$ -	$ 519.17	$ 683.98	$ -	$ -	$ 605.24	$ -	$ 851.38	0.66
3	7,055	1,321	0	1189	6,923	3,889	$ 1,503.23	$ -	$ 77.92	$ -	$ 540.71	$ 683.98	$ -	$ -	$ 618.63	$ -	$ 884.59	0.68
4	7,020	1,321	0	1189	6,887	3,924	$ 1,551.33	$ -	$ 70.54	$ -	$ 563.08	$ 683.98	$ -	$ -	$ 633.62	$ -	$ 917.71	0.70
5	6,984	1,321	0	1189	6,852	3,959	$ 1,600.97	$ -	$ 63.87	$ -	$ 586.29	$ 683.98	$ -	$ -	$ 650.16	$ -	$ 950.81	0.71
6	6,950	1,321	0	1189	6,817	3,994	$ 1,652.20	$ -	$ 57.82	$ -	$ 610.39	$ 683.98	$ -	$ -	$ 668.21	$ -	$ 983.99	0.73
7	6,915	1,321	0	1189	6,783	4,029	$ 1,705.07	$ -	$ 52.35	$ -	$ 635.40	$ 683.98	$ -	$ -	$ 687.75	$ -	$ 1,017.32	0.74
8	6,880	1,321	0	1189	6,748	4,064	$ 1,759.64	$ -	$ 47.39	$ -	$ 661.36	$ 683.98	$ -	$ -	$ 708.76	$ -	$ 1,050.88	0.75
9	6,846	1,321	0	1189	6,714	4,098	$ 1,815.94	$ -	$ 42.91	$ -	$ 688.31	$ 683.98	$ -	$ -	$ 731.21	$ -	$ 1,084.73	0.77
10	6,812	1,321	0	1189	6,679	4,132	$ 1,874.05	$ -	$ 38.85	$ -	$ 716.26	$ 683.98	$ -	$ -	$ 755.11	$ -	$ 1,118.94	0.78
11	6,778	1,321	0	1189	6,645	4,166	$ 1,934.02	$ -	$ 35.17	$ 1,653.18	$ 745.28	$ -	$ -	$ -	$ 2,433.63	$ -	$ (499.61)	-0.21
12	6,744	1,321	0	1189	6,612	4,200	$ 1,995.91	$ -	$ 31.84	$ -	$ 775.38	$ -	$ -	$ -	$ 807.22	$ -	$ 1,188.69	1.47
13	6,710	1,321	0	1189	6,578	4,234	$ 2,059.78	$ -	$ 28.83	$ -	$ 806.62	$ -	$ 19,791.66	$ -	$ 835.45	$ -	$ 1,224.34	1.47
							$ 23,687.91	$21,971.40	$ 728.61		$ 9,709.70	$ 6,839.78	$ 19,791.66	$ 11,329.00	$ 12,091.49	$ -	$ 11,596.42	
															ROI w/ Premium =		50.63%	
															ROI w/o Premium =		-21.43%	

Figure 18: Microsoft Excel tool calculations for the US – 5kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	10,812	$ 1,367.68	$24,316.40	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
1	8,500	1,321	1123	1189	7,244	3,568	$ 1,411.45	$ -	$ 114.07	$ -	$ 465.76	$ 756.98	$ -	$ 12,538.14	$ 579.84	$ 195.93	$ 831.61	0.77
2	8,415	1,321	1039	1189	7,244	3,568	$ 1,456.61	$ -	$ 103.28	$ -	$ 480.67	$ 756.98	$ -	$ -	$ 583.94	$ 186.94	$ 872.67	0.79
3	8,373	1,321	997	1189	7,244	3,568	$ 1,503.23	$ -	$ 93.50	$ -	$ 496.05	$ 756.98	$ -	$ -	$ 589.55	$ 185.11	$ 913.68	0.82
4	8,331	1,321	955	1189	7,244	3,568	$ 1,551.33	$ -	$ 84.65	$ -	$ 511.92	$ 756.98	$ -	$ -	$ 596.57	$ 183.00	$ 954.76	0.84
5	8,289	1,321	913	1189	7,244	3,568	$ 1,600.97	$ -	$ 76.64	$ -	$ 528.30	$ 756.98	$ -	$ -	$ 604.94	$ 180.62	$ 996.03	0.86
6	8,248	1,321	872	1189	7,244	3,568	$ 1,652.20	$ -	$ 69.39	$ -	$ 545.21	$ 756.98	$ -	$ -	$ 614.59	$ 177.94	$ 1,037.61	0.89
7	8,206	1,321	830	1189	7,244	3,568	$ 1,705.07	$ -	$ 62.82	$ -	$ 562.66	$ 756.98	$ -	$ -	$ 625.47	$ 174.94	$ 1,079.60	0.91
8	8,165	1,321	789	1189	7,244	3,568	$ 1,759.64	$ -	$ 56.87	$ -	$ 580.66	$ 756.98	$ -	$ -	$ 637.53	$ 171.62	$ 1,122.10	0.93
9	8,125	1,321	748	1189	7,244	3,568	$ 1,815.94	$ -	$ 51.49	$ -	$ 599.24	$ 756.98	$ -	$ -	$ 650.73	$ 167.95	$ 1,165.21	0.95
10	8,084	1,321	708	1189	7,244	3,568	$ 1,874.05	$ -	$ 46.62	$ -	$ 618.42	$ 756.98	$ -	$ -	$ 665.03	$ 163.92	$ 1,209.02	0.97
11	8,044	1,321	667	1189	7,244	3,568	$ 1,934.02	$ -	$ 42.20	$ 1,653.18	$ 638.21	$ -	$ -	$ -	$ 2,333.60	$ 159.50	$ (399.57)	-0.10
12	8,003	1,321	627	1189	7,244	3,568	$ 1,995.91	$ -	$ 38.21	$ -	$ 658.63	$ -	$ -	$ -	$ 696.84	$ 154.69	$ 1,299.07	2.09
13	7,963	1,321	587	1189	7,244	3,568	$ 2,059.78	$ -	$ 34.59	$ -	$ 679.71	$ -	$ 22,619.04	$ -	$ 714.30	$ 149.45	$ 1,345.48	2.09
							$ 23,687.91	$24,316.40				$ 7,569.79	$ 22,619.04	$ 12,538.14	$ 11,260.63	$ 2,251.61	$ 12,427.28	
															ROI w/ Premium =		65.36%	
															ROI w/o Premium =		-17.00%	

Figure 19: Microsoft Excel tool calculations for the US – 6kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	10,812	$ 1,367.68	$26,661.40	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
1	9,910	1,321	2533	1189	7,244	3,568	$ 1,411.45	$ -	$ 133.09	$ -	$ 465.76	$ 829.98	$ -	$ 13,747.28	$ 598.85	$ 441.84	$ 812.60	0.88
2	9,811	1,321	2435	1189	7,244	3,568	$ 1,456.61	$ -	$ 120.49	$ -	$ 480.67	$ 829.98	$ -	$ -	$ 601.16	$ 438.19	$ 855.46	0.90
3	9,762	1,321	2385	1189	7,244	3,568	$ 1,503.23	$ -	$ 109.09	$ -	$ 496.05	$ 829.98	$ -	$ -	$ 605.13	$ 443.10	$ 898.09	0.93
4	9,713	1,321	2337	1189	7,244	3,568	$ 1,551.33	$ -	$ 98.76	$ -	$ 511.92	$ 829.98	$ -	$ -	$ 610.68	$ 447.92	$ 940.65	0.96
5	9,664	1,321	2288	1189	7,244	3,568	$ 1,600.97	$ -	$ 89.41	$ -	$ 528.30	$ 829.98	$ -	$ -	$ 617.72	$ 452.65	$ 983.26	0.99
6	9,616	1,321	2240	1189	7,244	3,568	$ 1,652.20	$ -	$ 80.95	$ -	$ 545.21	$ 829.98	$ -	$ -	$ 626.16	$ 457.27	$ 1,026.04	1.02
7	9,568	1,321	2192	1189	7,244	3,568	$ 1,705.07	$ -	$ 73.29	$ -	$ 562.66	$ 829.98	$ -	$ -	$ 635.94	$ 461.77	$ 1,069.13	1.04
8	9,520	1,321	2144	1189	7,244	3,568	$ 1,759.64	$ -	$ 66.35	$ -	$ 580.66	$ 829.98	$ -	$ -	$ 647.01	$ 466.15	$ 1,112.62	1.07
9	9,472	1,321	2096	1189	7,244	3,568	$ 1,815.94	$ -	$ 60.07	$ -	$ 599.24	$ 829.98	$ -	$ -	$ 659.31	$ 470.38	$ 1,156.63	1.09
10	9,425	1,321	2049	1189	7,244	3,568	$ 1,874.05	$ -	$ 54.39	$ -	$ 618.42	$ 829.98	$ -	$ -	$ 672.80	$ 474.47	$ 1,201.25	1.12
11	9,378	1,321	2002	1189	7,244	3,568	$ 1,934.02	$ -	$ 49.24	$ 1,653.18	$ 638.21	$ -	$ -	$ -	$ 2,340.63	$ 478.39	$ (406.60)	0.03
12	9,331	1,321	1955	1189	7,244	3,568	$ 1,995.91	$ -	$ 44.58	$ -	$ 658.63	$ -	$ -	$ -	$ 703.21	$ 482.13	$ 1,292.71	2.52
13	9,284	1,321	1908	1189	7,244	3,568	$ 2,059.78	$ -	$ 40.36	$ -	$ 679.71	$ -	$ 25,446.42	$ -	$ 720.06	$ 485.69	$ 1,339.72	2.54
							$ 23,687.91	$26,661.40				$ 8,299.80	$ 25,446.42	$ 13,747.28	$ 11,406.35	$ 5,999.97	$ 12,281.55	
															ROI w/ Premium =		81.98%	
															ROI w/o Premium =		-10.68%	

Figure 20: Microsoft Excel tool calculations for the US – 7kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	10,812	$ 1,367.68	$25,960.36	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
1	7,162	2,643	0	2379	6,897	3,914	$ 1,411.45	$ -	$ 95.06	$ -	$ 511.00	$ 808.16	$ -	$13,385.81	$ 606.06	$ -	$ 805.39	0.57
2	7,090	2,643	0	2379	6,826	3,986	$ 1,456.61	$ -	$ 86.06	$ -	$ 536.97	$ 808.16	$ -	$ -	$ 623.04	$ -	$ 833.58	0.58
3	7,055	2,643	0	2379	6,791	4,021	$ 1,503.23	$ -	$ 77.92	$ -	$ 559.09	$ 808.16	$ -	$ -	$ 637.00	$ -	$ 866.22	0.60
4	7,020	2,643	0	2379	6,755	4,056	$ 1,551.33	$ -	$ 70.54	$ -	$ 582.04	$ 808.16	$ -	$ -	$ 652.58	$ -	$ 898.75	0.62
5	6,984	2,643	0	2379	6,720	4,092	$ 1,600.97	$ -	$ 63.87	$ -	$ 605.86	$ 808.16	$ -	$ -	$ 669.73	$ -	$ 931.25	0.63
6	6,950	2,643	0	2379	6,685	4,126	$ 1,652.20	$ -	$ 57.82	$ -	$ 630.58	$ 808.16	$ -	$ -	$ 688.41	$ -	$ 963.80	0.64
7	6,915	2,643	0	2379	6,651	4,161	$ 1,705.07	$ -	$ 52.35	$ -	$ 656.24	$ 808.16	$ -	$ -	$ 708.59	$ -	$ 996.48	0.66
8	6,880	2,643	0	2379	6,616	4,196	$ 1,759.64	$ -	$ 47.39	$ -	$ 682.87	$ 808.16	$ -	$ -	$ 730.26	$ -	$ 1,029.37	0.67
9	6,846	2,643	0	2379	6,582	4,230	$ 1,815.94	$ -	$ 42.91	$ -	$ 710.50	$ 808.16	$ -	$ -	$ 753.41	$ -	$ 1,062.54	0.68
10	6,812	2,643	0	2379	6,547	4,264	$ 1,874.05	$ -	$ 38.85	$ -	$ 739.17	$ 808.16	$ -	$ -	$ 778.02	$ -	$ 1,096.04	0.69
11	6,778	2,643	0	2379	6,513	4,298	$ 1,934.02	$ -	$ 35.17	$ 3,306.37	$ 768.92	$ -	$ -	$ -	$ 4,110.45	$ -	$ (2,176.43)	-0.53
12	6,744	2,643	0	2379	6,479	4,332	$ 1,995.91	$ -	$ 31.84	$ -	$ 799.78	$ -	$ -	$ -	$ 831.62	$ -	$ 1,164.30	1.40
13	6,710	2,643	0	2379	6,446	4,366	$ 2,059.78	$ -	$ 28.83	$ -	$ 831.79	$ -	$ 23,561.50	$ -	$ 860.62	$ -	$ 1,199.16	1.39
							$ 23,687.91	$25,960.36			$ 9,982.49	$ 8,081.56	$ 23,561.50	$13,385.81	$ 14,017.47	$ -	$ 9,670.44	
															ROI w/ Premium =		38.75%	
															ROI w/o Premium =		-33.85%	

Figure 21: Microsoft Excel tool calculations for the US – 5kW PV + 5kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	10,812	$ 1,367.68	$28,305.36	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
1	8,500	2,643	0	2379	8,235	2,576	$ 1,411.45	$ -	$ 114.07	$ -	$ 336.36	$ 881.16	$ -	$ 14,594.95	$ 450.43	$ -	$ 961.02	0.72
2	8,415	2,643	0	2379	8,150	2,661	$ 1,456.61	$ -	$ 103.28	$ -	$ 358.54	$ 881.16	$ -	$ -	$ 461.82	$ -	$ 994.80	0.74
3	8,373	2,643	0	2379	8,108	2,703	$ 1,503.23	$ -	$ 93.50	$ -	$ 375.87	$ 881.16	$ -	$ -	$ 469.37	$ -	$ 1,033.86	0.77
4	8,331	2,643	0	2379	8,067	2,745	$ 1,551.33	$ -	$ 84.65	$ -	$ 393.90	$ 881.16	$ -	$ -	$ 478.55	$ -	$ 1,072.78	0.79
5	8,289	2,643	0	2379	8,025	2,787	$ 1,600.97	$ -	$ 76.64	$ -	$ 412.67	$ 881.16	$ -	$ -	$ 489.31	$ -	$ 1,111.66	0.81
6	8,248	2,643	0	2379	7,983	2,828	$ 1,652.20	$ -	$ 69.39	$ -	$ 432.21	$ 881.16	$ -	$ -	$ 501.60	$ -	$ 1,150.61	0.83
7	8,206	2,643	0	2379	7,942	2,870	$ 1,705.07	$ -	$ 62.82	$ -	$ 452.55	$ 881.16	$ -	$ -	$ 515.36	$ -	$ 1,189.71	0.85
8	8,165	2,643	0	2379	7,901	2,911	$ 1,759.64	$ -	$ 56.87	$ -	$ 473.71	$ 881.16	$ -	$ -	$ 530.58	$ -	$ 1,229.06	0.87
9	8,125	2,643	0	2379	7,860	2,951	$ 1,815.94	$ -	$ 51.49	$ -	$ 495.72	$ 881.16	$ -	$ -	$ 547.21	$ -	$ 1,268.73	0.89
10	8,084	2,643	0	2379	7,820	2,992	$ 1,874.05	$ -	$ 46.62	$ -	$ 518.63	$ 881.16	$ -	$ -	$ 565.24	$ -	$ 1,308.81	0.90
11	8,044	2,643	0	2379	7,779	3,032	$ 1,934.02	$ -	$ 42.20	$ 3,306.37	$ 542.45	$ -	$ -	$ -	$ 3,891.03	$ -	$ (1,957.00)	-0.50
12	8,003	2,643	0	2379	7,739	3,073	$ 1,995.91	$ -	$ 38.21	$ -	$ 567.24	$ -	$ -	$ -	$ 605.44	$ -	$ 1,390.47	2.30
13	7,963	2,643	0	2379	7,699	3,113	$ 2,059.78	$ -	$ 34.59	$ -	$ 593.01	$ -	$ 26,388.88	$ -	$ 627.60	$ -	$ 1,432.18	2.28
							$ 23,687.91	$28,305.36			$ 7,320.53	$ 8,811.57	$ 26,388.88	$ 14,594.95	$ 11,501.23	$ -	$ 12,186.68	
																ROI w/ Premium =	49.47%	
																ROI w/o Premium =	-31.85%	

Figure 22: Microsoft Excel tool calculations for the US – 6kW PV + 5kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	10,812	$ 1,367.68	$30,650.36	$ -	$ -	$ 1,367.68	$ -	$ -	$ -	$ 1,367.68	$ -	$ -	0.00
1	9,910	2,643	1212	2379	8,433	2,379	$ 1,411.45	$ -	$ 133.09	$ -	$ 310.51	$ 954.16	$ -	$ 15,804.09	$ 443.59	$ 211.38	$ 967.85	0.84
2	9,811	2,643	1113	2379	8,433	2,379	$ 1,456.61	$ -	$ 120.49	$ -	$ 320.44	$ 954.16	$ -	$ -	$ 440.93	$ 200.36	$ 1,015.68	0.87
3	9,762	2,643	1064	2379	8,433	2,379	$ 1,503.23	$ -	$ 109.09	$ -	$ 330.70	$ 954.16	$ -	$ -	$ 439.78	$ 197.66	$ 1,063.44	0.90
4	9,713	2,643	1015	2379	8,433	2,379	$ 1,551.33	$ -	$ 98.76	$ -	$ 341.28	$ 954.16	$ -	$ -	$ 440.04	$ 194.62	$ 1,111.29	0.94
5	9,664	2,643	967	2379	8,433	2,379	$ 1,600.97	$ -	$ 89.41	$ -	$ 352.20	$ 954.16	$ -	$ -	$ 441.62	$ 191.25	$ 1,159.36	0.97
6	9,616	2,643	918	2379	8,433	2,379	$ 1,652.20	$ -	$ 80.95	$ -	$ 363.47	$ 954.16	$ -	$ -	$ 444.42	$ 187.50	$ 1,207.78	1.00
7	9,568	2,643	870	2379	8,433	2,379	$ 1,705.07	$ -	$ 73.29	$ -	$ 375.10	$ 954.16	$ -	$ -	$ 448.39	$ 183.37	$ 1,256.68	1.03
8	9,520	2,643	822	2379	8,433	2,379	$ 1,759.64	$ -	$ 66.35	$ -	$ 387.11	$ 954.16	$ -	$ -	$ 453.46	$ 178.84	$ 1,306.18	1.05
9	9,472	2,643	775	2379	8,433	2,379	$ 1,815.94	$ -	$ 60.07	$ -	$ 399.49	$ 954.16	$ -	$ -	$ 459.57	$ 173.88	$ 1,356.38	1.08
10	9,425	2,643	728	2379	8,433	2,379	$ 1,874.05	$ -	$ 54.39	$ -	$ 412.28	$ 954.16	$ -	$ -	$ 466.66	$ 168.47	$ 1,407.39	1.11
11	9,378	2,643	680	2379	8,433	2,379	$ 1,934.02	$ -	$ 49.24	$ 3,306.37	$ 425.47	$ -	$ -	$ -	$ 3,781.08	$ 162.60	$ (1,847.05)	-0.45
12	9,331	2,643	634	2379	8,433	2,379	$ 1,995.91	$ -	$ 44.58	$ -	$ 439.09	$ -	$ -	$ -	$ 483.66	$ 156.24	$ 1,512.25	3.45
13	9,284	2,643	587	2379	8,433	2,379	$ 2,059.78	$ -	$ 40.36	$ -	$ 453.14	$ -	$ 29,216.26	$ -	$ 493.50	$ 149.37	$ 1,566.29	3.48
							$ 23,687.91	$30,650.36				$ 9,541.57	$ 29,216.26	$ 15,804.09	$ 10,604.39	$ 2,355.53	$ 13,083.51	
																ROI w/ Premium =	62.46%	
																ROI w/o Premium =	-27.58%	

Figure 23: Microsoft Excel tool calculations for the US – 7kW PV + 5kW ES (Scenario 3).

Once ES is added, the calculations for grid provided energy consumed by a residence and the total costs of this energy change from those of scenario 2 where ES was not included. This is because the ES system is 100% charged by the PV provided energy (see **Scenario 3 Assumptions, B**) and the amount of energy required to charge the ES system (ES_{CHE_t}) and the amount of energy discharged from the ES system to supply the average night-time consumption of a residence (ES_{E_t}), increase as the size of the ES system increases; the 5kW ES system has a larger ES_{CHE_t} and ES_{E_t} than the 3kW ES system. **Table 2** summarizes what is evaluated in each scenario. Metric

Scenario 1	Grid-provided energy consumption Grid-provided energy costs
Scenario 2	PV-provided energy consumption PV-provided energy costs PV-provided energy injected into grid Grid-provided energy consumption Grid-provided energy costs
Scenario 3	PV + ES-provided energy consumption PV + ES-provided energy costs PV + ES-provided energy injtected into grid Grid-provided energy consumption Grid-provided energy costs

Table 2: Scenario evaluation breakdown.

The provided PV energy is first used to fully charges the ES system based on the amount of energy required to charge the ES system (ES_{CHE_t}). The remaining PV provided energy is then used as supply towards the average day-time consumption of a residence. After the average day-time consumption of a residence is met, any remaining amount of the PV provided energy is sold/injected into the grid. Two situations can occur in scenario 3 and are described as follows:

Situation 1:

If after fully charging the ES system the provided PV energy is not enough to supply the full amount of average day-time consumption of a residence, then the overall amount of PV provided energy consumed by a residence is equal to the amount of provided PV minus the amount used to fully charge the ES system, plus the stored amount discharged later as supply towards the average night-time consumption of a residence. In this situation, grid provided energy is used to supply the remaining average day-time consumption that the PV provided energy supply was not able to meet; there is no PV provided energy sold/injected into the grid in this situation due to a lack of supply.

Situation 2:

If after fully charging the ES system the provided PV energy is enough to supply the full amount of average day-time consumption of a residence, the overall amount of PV provided energy consumed by a residence is equal to the average day-time consumption of a residence plus the stored amount discharged later as supply towards the average night-time consumption of a residence. In this situation, grid provided energy is only used to supply the amount of average night-time consumption that is not met by the discharged ES system energy. During the day-time, the remaining PV provided energy (after the ES system is fully charged and the average day-time consumption of a residence is met) is sold/injected into the grid.

In this analysis, the states that undergo situation 1 experience a decrease in grid provided energy consumed by a residence as the PV system size increases (with the ES system size remaining constant). This is attributed to the increase in PV provided energy that comes with a larger PV system. Once the PV system is large enough to provide for the full charging of the ES system and the full average day-time consumption of a residence, the amount of grid provided energy consumed by a residence decreases because none is needed as supply towards the average day-time consumption of a residence. The states that undergo situation 2 experience a constant amount of grid provided energy consumed by a residence (the amount used as supply towards average night-time consumption that is not met by the discharged ES system energy) as the PV system size increases and the ES system size remains constant.

VIII. Results

A Microsoft Excel tool is used to compute the economic evaluation of the various alternatives. The tool calculates an ROI over the 13 year horizon and a BCR for each year of the 13 year horizon. Economic evaluation is performed for the US average, and for the states of Arizona (AZ), California (CA), Colorado (CO), Florida (FL), Massachusetts (MA), Nevada (NV), New York (NY) and Texas (TX), to provide a more regional outlook. The evaluation investigates the ROI and BCR of a 5kW, 6kW, and 7kW PV system with and without a coupled energy storage system. The results are divided and described as follows:

C. Scenario 1 – Residence without a PV or ES system

D. Scenario 2 – Residence with just a PV system

E. Scenario 3 – Residence with a PV + ES system

Graphs depicting the total energy costs with and without a PV or PV + ES system, the net-metered credits resulting from selling/injected into the grid, and total energy costs savings experienced are provided. Tables depicting the annual BCR and BCR average for the 13 year horizon, as well as the ROI values are also provided. All monetary amounts are in 2016 United States dollars.

A. Scenario 1:

Figure 24 displays the energy costs of a residence without a PV or a PV + ES system. The costs are the summed total of the 13 year horizon, including the year in which the PV or PV + ES system would be installed (year 0), for the US and for each of the listed states. Each annual cost is calculated using the average energy purchase price ($/kWh) and average annual consumption (kWh/yr) for the US and for each listed state [23]. Annual US energy price inflation is applied to purchase prices [30].

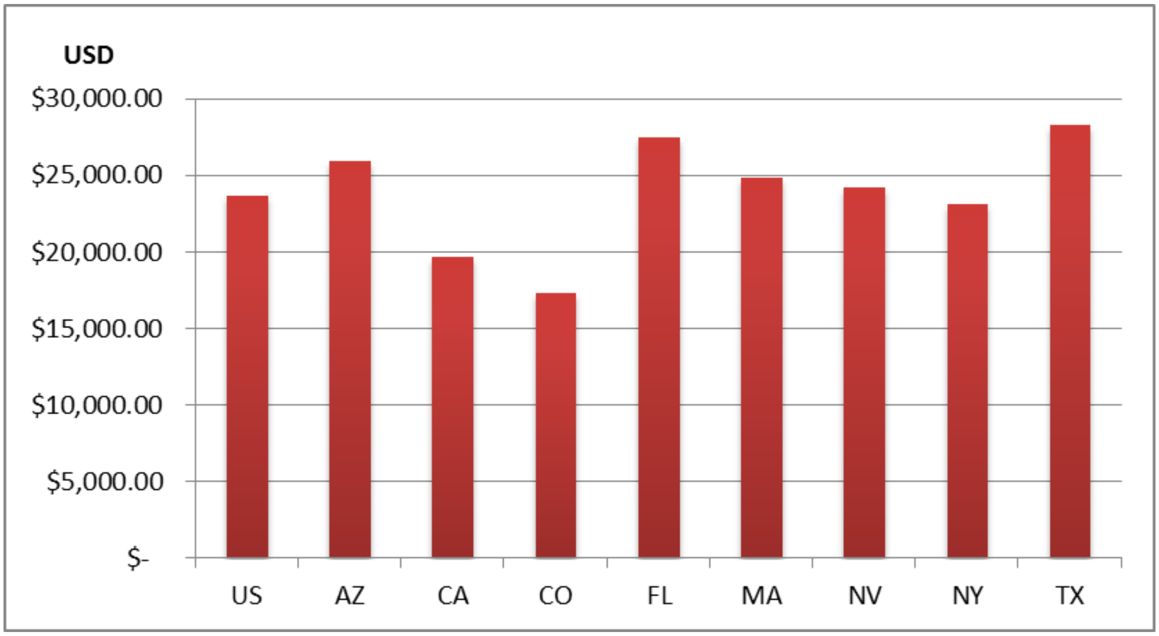

Figure 24: 13 year energy cost totals of a residence without a PV or PV + ES system.

Over the 13 year analysis horizon, the results show Texas ($28,254.51) and Florida ($27,461.03) as the most expensive states in terms of energy costs for a residence without a PV or a PV + ES system; both states are above the US average ($23,687.91). Colorado's average annual energy price (0.1212 $/kWh) and average annual consumption (8,256kWh) are both less than the US averages (0.1265 $/kWh and 10,812 kWh). Although California's average annual energy price is greater than the US average (0.1699 $/kWh), the average annual consumption (6,684kWh) is significantly less than the US average. Thus, Colorado ($17,330.60) and California ($19,668.50) are the least expensive states in scenario 1 and are both below the US average ($23,687.91).

B. Scenario 2:

Figure 25 displays the energy costs of a residence with just a PV system, totaled over the 13 year horizon. The costs are provided for a residence with a 5kW, 6kW and 7kW PV system. Energy costs with just a PV system are calculated by adding the annual PV module O&M costs and the annual costs of grid provided energy consumed by a residence.

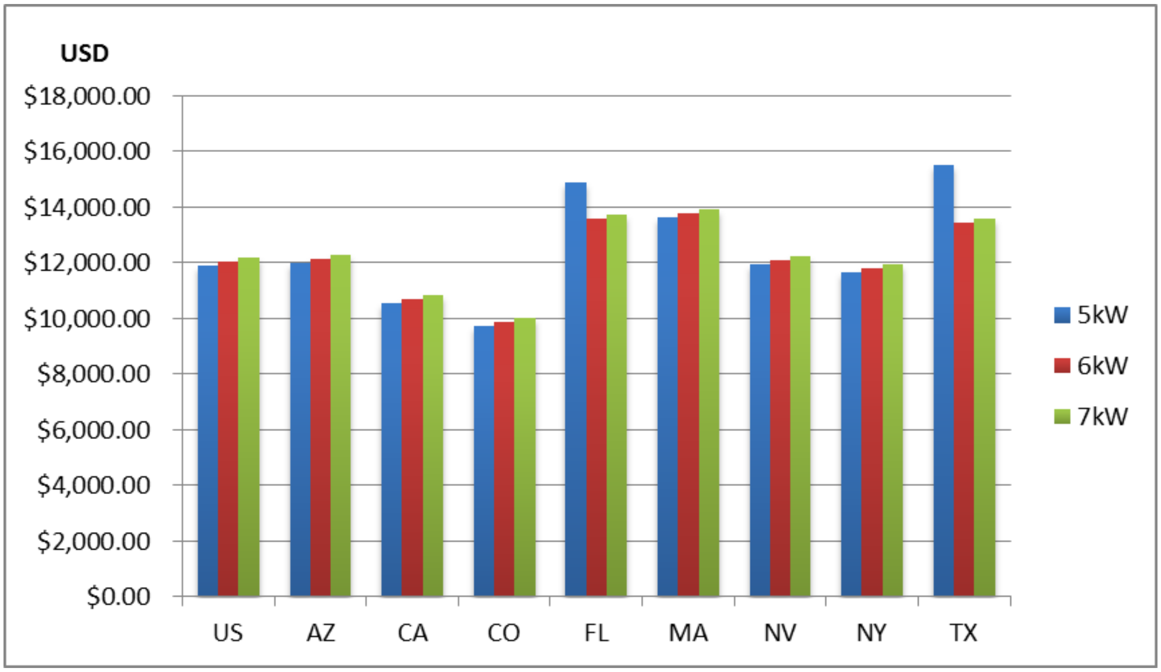

Figure 25: 13 year energy cost totals of a residence with just a PV system.

The results show a decrease in total energy cost over the 13 year horizon for the US and each of all the listed states, when a PV system is added to a residence, versus the total energy costs without a PV or PV + ES system on a residence, as depicted in **Figure 24**. The results also show a minor increasing trend in total energy costs as the PV system sizes increase, for the US and each listed state. The increase in energy costs of a residence with just a PV system is attributed to an increase in PV module O&M costs. PV module O&M costs are dependent on the size/generation capacity of the PV system (kW), thus an increase in PV system size causes an increase in the module O&M costs.

Figure 26 displays the percentage change in the total energy costs from **Figure 25**, for a residence with a 5kW to one with a 6kW PV system, a 6kW to 7kW PV system, and 5kW to 7kW PV system; the percentages are displayed for the US and each of the listed states. For the states of Florida (FL) and Texas (TX), the change from a 5kW to 6kW and 5kW to 7kW experiences a decrease in total energy cost. This is because a 5kW PV system generates less energy than a residence in Florida and Texas consume on average during the day-time. As a result, a residence must consume grid provided energy to satisfy the full amount of average day-time consumption. This grid provided energy consumed during the day-time is added to the grid energy a residence consumes during the night-time hours, resulting in an increase in total energy cost of a residence with just a PV system. A 6kW and 7kW PV system generate a sufficient enough amount of energy to satisfy the day-time energy consumption of residence in Florida and Texas, resulting in lower total energy costs for a residence with just a PV system. For all the other listed states, and the US average, the larger PV system has the higher total energy cost.

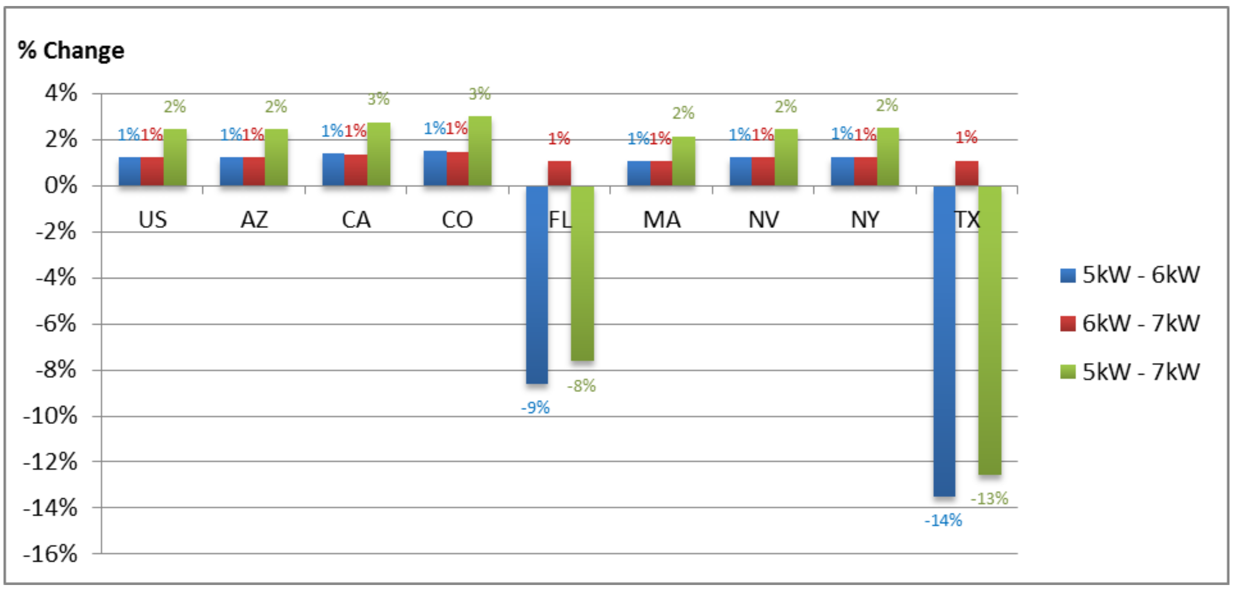

Figure 26: Percentage change in energy cost totals of a residence with just a PV system.

Figure 27 displays the credit from net-metered energy sold/injected back into the grid from a residence; the credit amounts are summed over the 13 year horizon. The credits are provided for a residence with a 5kW, 6kW and 7kW PV system. To calculate the credit from net-metering the annual amounts of PV provided energy sold/injected in the grid (kWh) are multiplied by the average energy sale price ($/kWh) [9], with the annual average US energy inflation rate applied.

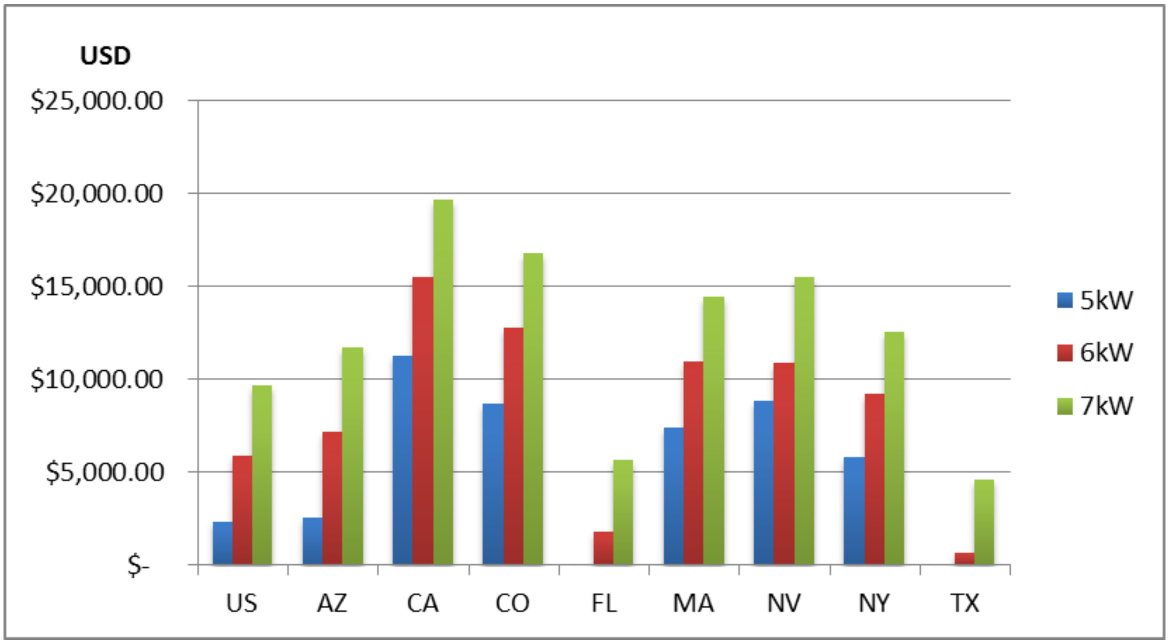

Figure 27: 13 year net-metered energy credit totals of a residence with just a PV system.

The results show an increasing trend in earned credit as the PV system size increases. This is due to the increased generating capacities of larger PV systems. With a residence's energy consumption averages remaining relatively constant, an increase in the amount of net-metered credit earned is expected as the PV system sizes increases. If a PV system fails to produce this surplus of energy, such as is the case for a 5kW PV system in Florida and Texas, there is no energy sold/injected into the grid and thus no net-metered credit earned. The states of California and Colorado have the largest net-metered credit amounts because they experience the largest difference in PV generation and day-time residential energy consumptions amounts.

Figure 28 displays the energy cost savings, summed over the 13 year horizon, experienced for a residence with just a PV system. The cost savings are provided for a residence with a 5kW, 6kW and 7kW PV system. The cost savings are calculated by subtracting the energy costs for a residence with just a PV system from the energy costs for a residence without a PV or PV + ES system.

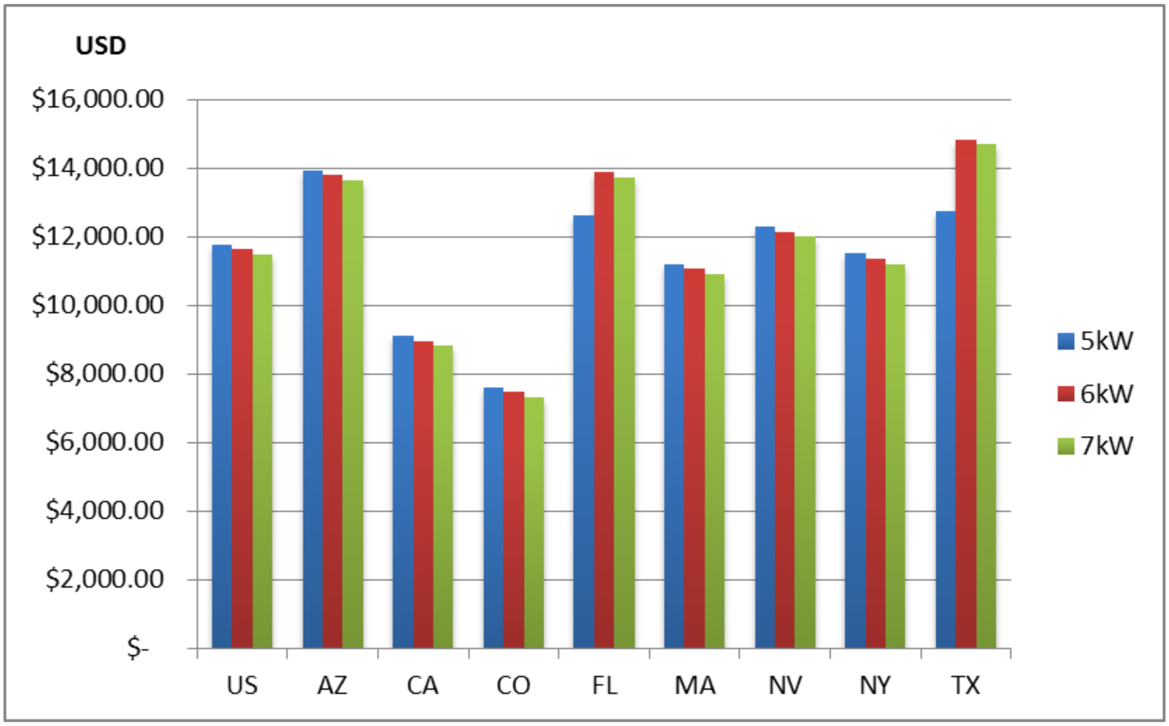

Figure 28: 13 year energy cost savings totals of a residence with just a PV system.

The results show a minor decreasing trend in energy cost savings as the PV system size increases. The decrease is attributed to the increase experienced in energy costs as PV system sizes increase as depicted in **Figure 25**. Florida and Texas experience an anomaly, consistent with **Figure 26**, as the trend of the two states is unlike that of the other states and US average. As previously stated, this anomaly is due to a 5kW PV system's inability to generate enough PV to account for the day-time average consumptions of a residence in Florida and Texas.

Annual BCRs are used to provide a year-to-year economic evaluation of the PV system. The BCRs are calculated by dividing the PV system annual benefits (net-metered credit earned and energy cost savings) by the PV system annual costs (energy costs for a residence with just a PV system and loan payments). A BCR value of 1 indicates that the annual benefits of the PV system equal the annual costs. A BCR value less than 1 indicates that the annual costs of the PV system outweigh the annual benefits, signifying a poor annual economic evaluation for the system in the specific year. A BCR value greater than 1 indicates that the annual benefits of the

PV system outweigh the annual costs, signifying a desirable annual economic evaluation for the system in the specific year. The BCRs for a 5kW, 6kW, and 7kW PV system, across the US and the listed states, are displayed in **Figure 29, Figure 30,** and **Figure 31.**

Annual Benefit-Cost Ratios (BCR) - 5kW PV System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	0.82	0.98	1.26	1.08	0.64	0.96	1.26	1.01	0.63
2	0.84	1.00	1.29	1.11	0.65	0.98	1.28	1.03	0.64
3	0.86	1.02	1.32	1.14	0.67	1.00	1.31	1.05	0.66
4	0.88	1.04	1.35	1.16	0.68	1.02	1.34	1.08	0.67
5	0.90	1.06	1.38	1.19	0.69	1.04	1.36	1.10	0.68
6	0.91	1.08	1.40	1.21	0.70	1.06	1.38	1.12	0.69
7	0.93	1.10	1.43	1.23	0.71	1.08	1.40	1.14	0.70
8	0.94	1.11	1.45	1.25	0.72	1.09	1.42	1.16	0.70
9	0.95	1.13	1.47	1.27	0.72	1.11	1.44	1.18	0.71
10	0.97	1.14	1.49	1.29	0.73	1.12	1.45	1.19	0.71
11	1.38	1.61	2.23	1.93	0.96	1.57	2.05	1.73	0.93
12	1.38	1.61	2.23	1.94	0.96	1.57	2.05	1.73	0.93
13	1.38	1.61	2.24	1.94	0.95	1.57	2.05	1.74	0.92
Avgerage =	1.01	1.19	1.58	1.36	0.75	1.17	1.52	1.25	0.74

Figure 29: Annual BCR values for a 5kW PV system.

Annual Benefit-Cost Ratios (BCR) - 6kW PV System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	0.94	1.15	1.38	1.23	0.80	1.05	1.26	1.10	0.80
2	0.96	1.17	1.42	1.26	0.81	1.07	1.29	1.13	0.82
3	0.99	1.20	1.45	1.30	0.83	1.10	1.32	1.16	0.84
4	1.01	1.23	1.49	1.33	0.85	1.13	1.35	1.19	0.86
5	1.04	1.26	1.52	1.36	0.87	1.15	1.38	1.21	0.88
6	1.06	1.28	1.56	1.39	0.89	1.17	1.41	1.24	0.89
7	1.08	1.30	1.59	1.42	0.90	1.19	1.43	1.26	0.91
8	1.09	1.32	1.61	1.44	0.91	1.21	1.45	1.28	0.92
9	1.11	1.34	1.64	1.47	0.93	1.23	1.47	1.31	0.93
10	1.12	1.36	1.66	1.49	0.94	1.25	1.49	1.33	0.94
11	1.70	2.03	2.65	2.38	1.35	1.84	2.22	2.04	1.36
12	1.70	2.04	2.66	2.39	1.35	1.85	2.23	2.05	1.36
13	1.71	2.04	2.67	2.39	1.35	1.85	2.23	2.05	1.36
Avgerage =	1.19	1.44	1.79	1.60	0.98	1.31	1.58	1.41	0.99

Figure 30: Annual BCR values for a 6kW PV system.

Annual Benefit-Cost Ratios (BCR) - 7kW PV System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	1.05	1.29	1.49	1.35	0.92	1.13	1.40	1.18	0.93
2	1.08	1.32	1.52	1.39	0.94	1.15	1.44	1.21	0.95
3	1.11	1.36	1.57	1.43	0.97	1.19	1.47	1.24	0.98
4	1.14	1.39	1.61	1.47	0.99	1.21	1.51	1.28	1.00
5	1.17	1.42	1.65	1.51	1.01	1.24	1.54	1.31	1.02
6	1.19	1.45	1.69	1.54	1.03	1.27	1.57	1.34	1.04
7	1.22	1.48	1.72	1.58	1.05	1.29	1.60	1.37	1.06
8	1.24	1.51	1.76	1.61	1.07	1.31	1.63	1.39	1.08
9	1.26	1.53	1.79	1.64	1.08	1.34	1.66	1.42	1.10
10	1.28	1.55	1.82	1.66	1.10	1.36	1.68	1.44	1.11
11	2.03	2.44	3.06	2.81	1.66	2.11	2.64	2.34	1.68
12	2.04	2.45	3.08	2.82	1.66	2.11	2.64	2.35	1.68
13	2.04	2.46	3.09	2.83	1.66	2.12	2.65	2.36	1.68
Avgerage =	1.37	1.67	1.99	1.82	1.16	1.45	1.80	1.56	1.18

Figure 31: Annual BCR values for a 7kW PV system.

The results show an improvement in BCR with each consecutive year for all PV system sizes. This is attributed to the increases observed in annual energy cost savings and net-metered credits, with each consecutive year, while the energy costs totals only slightly increase. Each location improves in BCR as the PV system size increases implying that the increase in the PV system benefits outweighs the increase is PV system costs as PV system sizes increase. Year 0 has a 0.00 BCR for the US and all states and system sizes because Year 0 is the year the PV system is installed. Evaluation of the PV system's performance begins the year after the system is installed (Year 1). California, Colorado and Nevada are the states where residences experience the most benefit from PV systems; all three states show BCRs greater than the US average. For a 5kW PV system, Florida and Texas are the only locations where the average 13 year BCR is less than 1, signifying a poor annual economic evaluation of the PV system. For a 6kW PV system, Florida and Texas see an increase but still remain under 1 for their BCR values. For a 7kW PV system, the US average and all listed states show a BCR value of 1 or greater thus signifying a desirable annual economic evaluation.

Figure 32 and **Figure 33** display the 13 year horizon ROIs for a residence with just a PV system, with the home premium included and without the premium. The results are shown for all system sizes across the US and all listed states. ROI is calculated by subtracting the capital investments from year 0, the total loan payments, and the total energy costs over the 13 year horizon, from the sum of the added home premium in year 13, tax credit incentive from year 1, total net-metered credits over the 13 year horizon, and the total energy cost savings over the 13 year horizon. This value is then divided by the capital investments and expressed as a percentage. Due to the significant increase the home premium adds to the ROI, **Figure 33** is provided to display the ROI values without the inclusion of the added home premium.

Return of Investment (ROI) - Scenario 2 with Home Premium									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
5kW	129%	151%	164%	153%	124%	142%	186%	144%	128%
6kW	159%	190%	196%	188%	153%	168%	207%	172%	155%
7kW	190%	228%	229%	223%	187%	194%	246%	199%	190%

Figure 32: 13 year horizon ROI calculations with added home premium (Scenario 2).

Return of Investment (ROI) - Scenario 2 without Home Premium									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
5kW	33%	52%	70%	52%	25%	53%	86%	51%	27%
6kW	43%	71%	85%	67%	34%	62%	86%	59%	34%
7kW	55%	89%	99%	82%	47%	70%	106%	68%	48%

Figure 33: 13 year horizon ROI calculations without added home premium (Scenario 2).

The results show an increasing trend in ROI as the PV system size increases. This increasing trend is expected because the tax credit incentives, net-metered credit totals and home premium amounts all increase, while the energy costs decreases as the PV system size increases. Arizona, California, Colorado, and Nevada have the highest ROIs primarily due to two main factors: (1) a large difference between the annual PV system production output levels (kWh) [38] and the average annual day-time energy consumption levels for a residence in the state (California and Colorado); (2) high annual PV system production output levels for systems within the state [38], which leads to relatively greater gains from net-metered credit (Arizona and Nevada). For example the US annual PV production output for the 7kW system is 9,910kWh, whereas the annual production outputs for the 7kW system in Arizona and Nevada are 12,099 and 12,313 respectively.

Florida and Texas resulted in the lowest ROIs and are the only states with ROIs less than the US average, which shows consistency with the low BCR results for the two states. The low ROIs are a result of the high average day-time consumption levels, high total energy costs and low net-metered credit totals for the two states; Florida and Texas have the two highest day-time consumption levels and energy cost totals, as well as the two lowest net-metered credit totals of all the listed locations. Nevada's ROIs for a 5kW and 6kW are identical, which is contrary to the other listed states and the US average, due to a very small increase in the average annual PV production output for a 6kW system in Nevada from that of a 5kW system.

The added home premiums are calculated by multiplying average premium home buyers are willing to pay per PV system capacity ($/W) times the PV system rated capacity [12]. After applying the PV system market value decrease and discounting the values to year 13 when the home is assumed to be sold, the added home premiums equate to $14,137 (5kW), $16,964 (6kW), and $19,792 (7kW) for each system in scenario 2. These premiums serve as a gain that is greater than even the capital investments costs in year 0 (once the loan is applied), which leads to the significant increase in ROI value when the home premiums are included.

C. Scenario 3:

Figure 34 and **Figure 35** display the energy costs of a residence with a PV + ES system and the percentage change in total energy costs, totaled over the 13 year horizon. The energy costs and percent changes are provided for a residence with a joint PV + ES system (5kW + 3kW, 6kW + 3kW, 7kW + 3kW, 5kW + 5kW, 6kW + 5kW, and 7kW + 5kW). Energy costs of a residence with a joint PV + ES are calculated by adding the annual PV module and ES battery O&M costs, the annual costs of grid provided energy consumed by a residence, and the battery replacement costs in year 11.

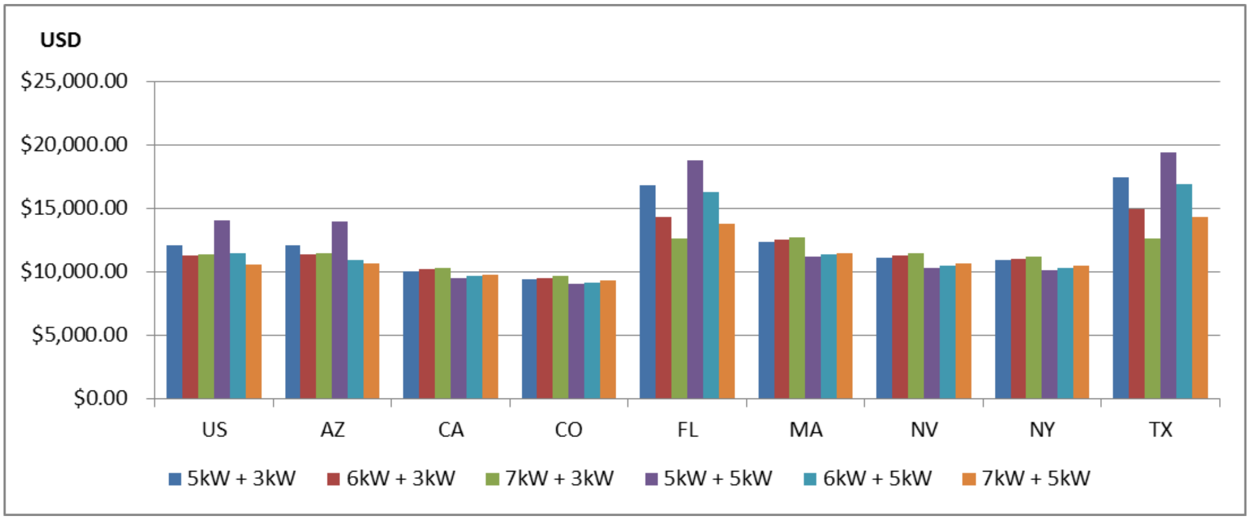

Figure 34: 13 year energy cost totals of a residence with a PV + ES system.

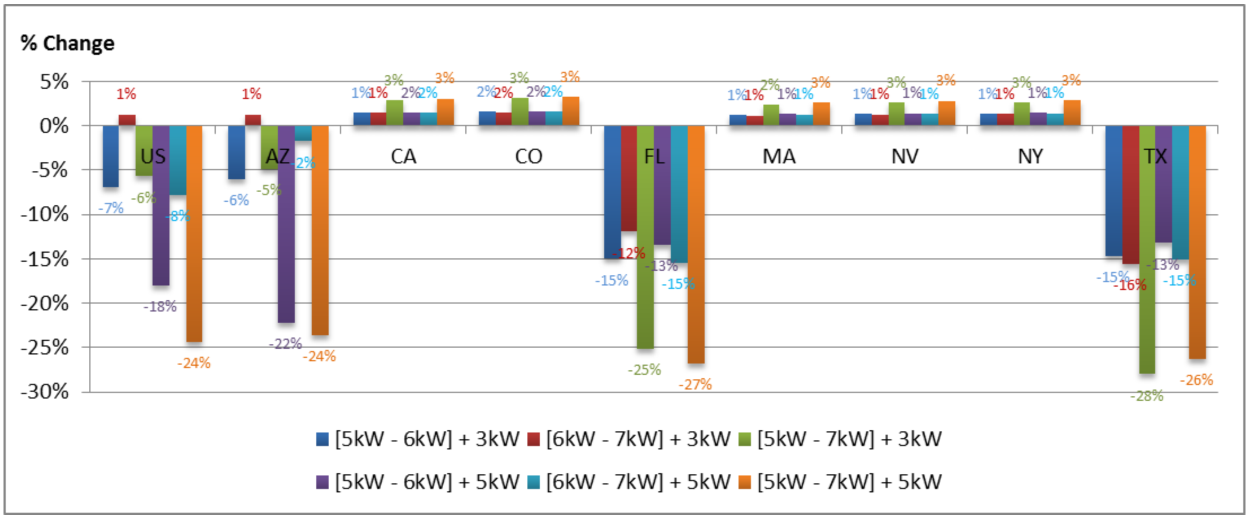

Figure 35: Percentage change in energy cost totals of a residence with PV + ES system.

The results consistently show total energy costs for joint system residences with a 3kW ES system are more expensive than those with a 5kW ES system for California, Colorado, Massachusetts, Nevada, and New York. These states undergo situation 2, and as a result, energy cost totals increase as the PV system size increases and ES system size stays constant. This minor increase in energy costs for situation 2 joint systems is because as the PV system size increases the O&M costs increase significantly. Recall that O&M costs, which are based on the capacity of the PV system, increase as the size of the PV system increases. Undergoing situation 2 also means that a residence in these states consumes less grid provided energy with 5kW ES system than a 3kW because of the increased average annual night-time consumption (RSD_{COV}) a 5kW ES system provides. For the US average, Arizona, Florida, and Texas, energy costs for joint systems with a 5kW ES system experience a decreasing trend in **Figure 34** as the PV system size increases because these locations undergo situation 1; these same locations experience negative percent changes in **Figure 35** as the residential PV system sizes change from 5kW to one with a 6kW PV system, a 6kW to 7kW PV system, and 5kW to 7kW PV system. The change from a 6kW + 3kW to a 7kW + 3kW joint system for the US and Arizona shows a positive percent change. This signifies an increase in energy cost totals from 6kW + 3kW to a 7kW + 3kW joint system and is because the 6kW and 7kW PV systems undergo situation 2 in these two states.

Figure 36 displays the credit from net-metered energy sold/injected back into the grid from a residence, summed over the 13 year horizon. The credits are provided for a residence with a joint PV + ES system (5kW + 3kW, 6kW + 3kW, 7kW + 3kW, 5kW + 5kW, 6kW + 5kW, and 7kW + 5kW). To calculate the credit from net-metering the annual amounts of PV provided energy sold/injected back into the grid (kWh) are multiplied by the average energy sale price ($/kWh) [9], with the annual average US energy inflation rate applied.

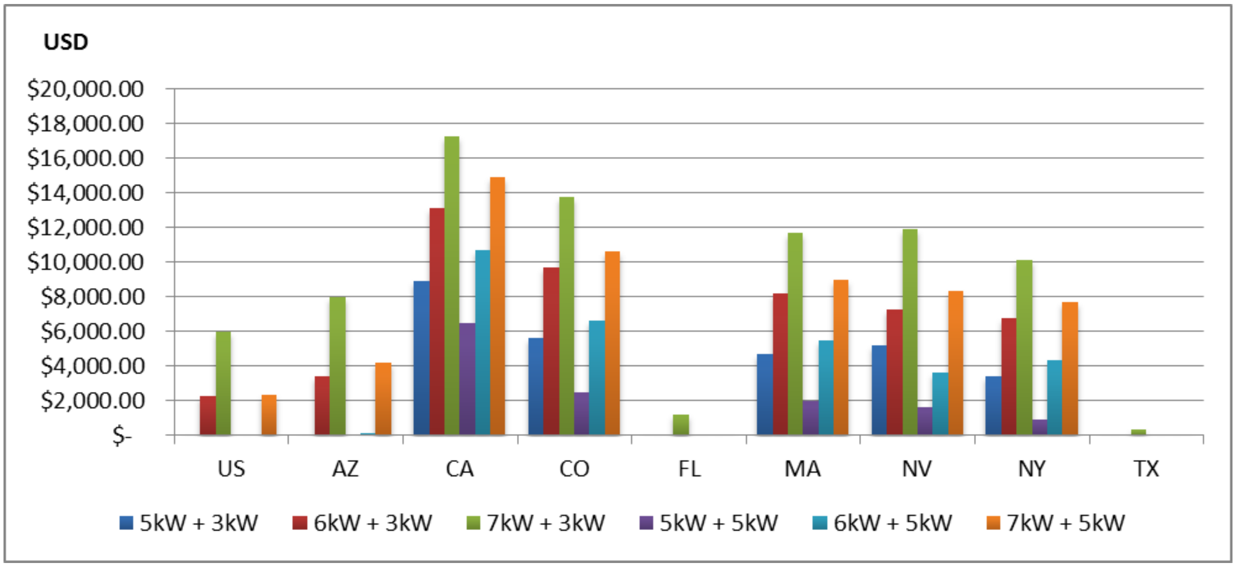

Figure 36: 13 year net-metered energy credit totals of a residence with PV + ES system.

The results show an increasing trend in earned credit as the PV system size increases for the states of California, Colorado, Massachusetts, Nevada and New York. This is due to the increased generating capacities of larger PV systems. These states undergo situation 2 and thus this increasing trend in the results of net-metered credit totals are consistent with the increasing trend observed in the results displayed in **Figure 34** and **Figure 35**. Situation 1 joint system combinations, such as a 5kW + 3kW for the US, Arizona, Florida, and Texas, do not experience excess PV provided energy sold/injected into the grid. As a result, these joint system combinations have zero net-metered credit as depicted in **Figure 36**. For the states of Florida and Texas, the only system combination to undergo situation 2 is a 7kW + 3kW system. Thus, this is the only system combination to produce net-metered credit. **Figure 37** displays the energy cost savings, summed over the 13 year horizon, for a residence with a joint PV + ES system. The cost savings are provided for a residence with a 5kW + 3kW, 6kW + 3kW, 7kW + 3kW, 5kW + 5kW, 6kW + 5kW, and 7kW + 5kW system combination. The cost savings are calculated by subtracting the energy costs for a residence with a joint PV + ES system from the energy costs for the residence without a PV or PV + ES system.

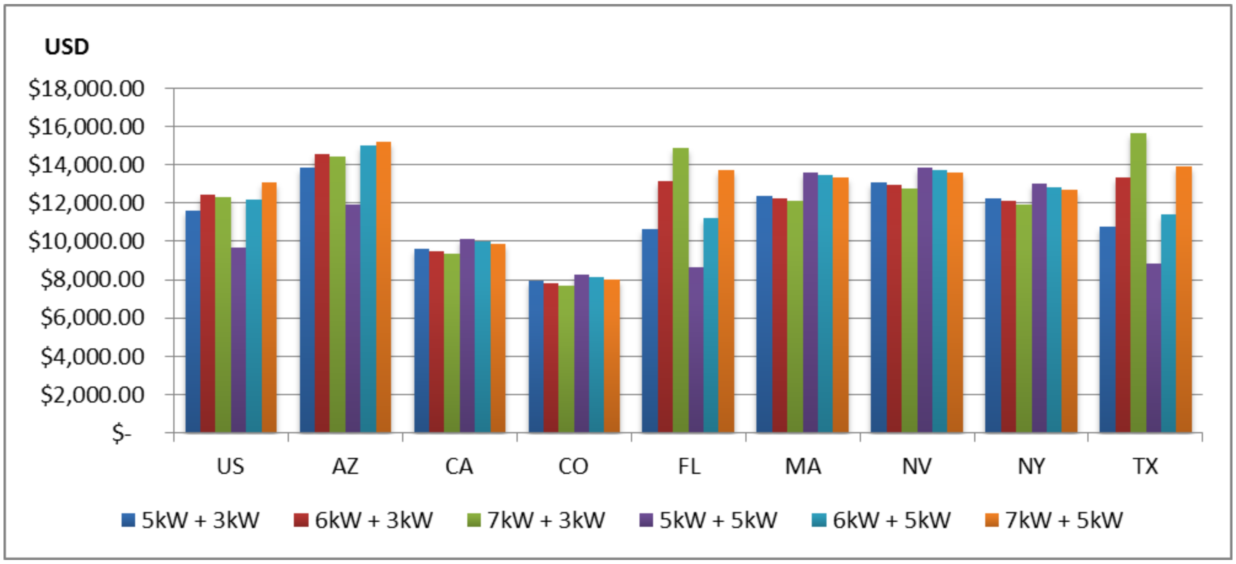

Figure 37: 13 year energy cost savings totals of a residence with a joint PV + ES system.

The results show a minor decrease in energy cost savings totals for a residence with a joint PV + ES system for all system combinations in the states of California, Colorado, Massachusetts, Nevada, and New York. This decrease in energy cost savings occurs because the energy costs totals of a residence with a joint PV + ES system slightly increases, due to the increase in O&M costs as explained in the **Figure 34** results, but the energy costs for the residence without a PV or PV + ES system remain constant; recall that the cost savings are calculated by subtracting the energy costs for a residence with a joint PV + ES system from the energy costs for the residence without a PV or PV + ES system. The situation 1 states – the US, Arizona, Florida and Texas – generally see increases in the energy cost savings totals as the PV sizes increase and ES sizes remain constant. This is caused by the decrease in grid energy consumed by a residence in situation 1 as the PV size and PV provided energy amounts increase. The decrease in grid energy consumed by a residence leads to a decrease in grid energy costs. This in-turn lead to a decrease in total energy costs of the residence with a joint PV + ES system and an eventual increase in energy cost savings totals because the energy costs without a PV or PV + ES system remain constant.

When comparing ES systems paired with the same PV system size, the 5kW ES system provides larger energy costs savings than the 3kW for situation 2 in California, Colorado, Massachusetts, Nevada, and New York, due to the 3kW ES system causing larger energy cost totals as explained in the **Figure 34** results. The reverse is witnessed for the situation 1 locations – US average, Arizona, Florida, and Texas – as the 3kW ES system provides larger energy costs savings than the 5kW. The US average and Florida when looking at the 7kW PV system size combinations because a 7kW PV system undergoes situation 2 in these two states.

Annual BCRs are used to provide a year-to-year economic evaluation of the joint system. The BCRs are calculated by dividing the PV+ ES system annual benefits (net-metered credit earned and energy cost savings) by the PV + ES system annual costs (energy costs for a residence with a joint system and loan payments). The BCRs for a residence with joint system combination, for the US, and the listed states are displayed in **Figure 38, 39, 40, 41, 42** and **43.**

Annual Benefit-Cost Ratios (BCR) - 5kW PV + 3kW ES System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	0.65	0.78	1.06	0.84	0.49	0.87	1.03	0.87	0.49
2	0.66	0.79	1.09	0.86	0.50	0.89	1.06	0.89	0.50
3	0.68	0.81	1.12	0.89	0.51	0.92	1.09	0.92	0.51
4	0.70	0.83	1.15	0.92	0.52	0.94	1.11	0.95	0.52
5	0.71	0.85	1.18	0.94	0.53	0.97	1.14	0.97	0.53
6	0.73	0.87	1.21	0.97	0.54	0.99	1.17	1.00	0.54
7	0.74	0.88	1.24	0.99	0.55	1.01	1.19	1.02	0.55
8	0.75	0.89	1.26	1.01	0.56	1.03	1.21	1.04	0.55
9	0.77	0.91	1.29	1.03	0.57	1.05	1.24	1.06	0.56
10	0.78	0.92	1.32	1.05	0.57	1.07	1.26	1.08	0.57
11	-0.21	-0.13	0.04	-0.15	-0.21	-0.01	0.03	-0.07	-0.20
12	1.47	1.73	2.91	2.38	0.91	2.09	2.55	2.28	0.88
13	1.47	1.72	2.92	2.38	0.91	2.10	2.56	2.29	0.88
Avgerage =	0.76	0.91	1.37	1.08	0.54	1.07	1.28	1.10	0.53

Figure 38: Annual BCR values for a joint 5kW + 3kW system.

Annual Benefit-Cost Ratios (BCR) -6kW PV + 3kW ES System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	0.77	0.94	1.18	0.98	0.62	0.96	1.05	0.96	0.62
2	0.79	0.97	1.21	1.01	0.64	0.98	1.08	0.99	0.63
3	0.82	1.00	1.25	1.04	0.66	1.01	1.11	1.02	0.65
4	0.84	1.02	1.29	1.08	0.67	1.04	1.14	1.05	0.67
5	0.86	1.05	1.32	1.11	0.69	1.07	1.17	1.08	0.68
6	0.89	1.08	1.36	1.14	0.70	1.10	1.20	1.11	0.70
7	0.91	1.10	1.39	1.17	0.72	1.12	1.23	1.14	0.71
8	0.93	1.12	1.42	1.19	0.73	1.14	1.25	1.16	0.72
9	0.95	1.15	1.45	1.22	0.74	1.17	1.28	1.19	0.73
10	0.97	1.17	1.49	1.25	0.75	1.19	1.30	1.21	0.74
11	-0.10	0.02	0.19	0.00	-0.14	0.11	0.10	0.05	-0.13
12	2.09	2.51	3.46	2.96	1.35	2.45	2.78	2.69	1.30
13	2.09	2.51	3.47	2.97	1.35	2.46	2.79	2.70	1.30
Avgerage =	0.98	1.20	1.58	1.32	0.73	1.22	1.34	1.26	0.72

Figure 39: Annual BCR values for a joint 6kW + 3kW system.

Annual Benefit-Cost Ratios (BCR) - 7kW PV + 3kW ES System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	0.88	1.08	1.28	1.10	0.76	1.03	1.19	1.04	0.76
2	0.90	1.11	1.32	1.13	0.78	1.06	1.22	1.07	0.78
3	0.93	1.15	1.36	1.17	0.80	1.10	1.26	1.11	0.81
4	0.96	1.18	1.41	1.21	0.83	1.13	1.30	1.14	0.83
5	0.99	1.21	1.45	1.25	0.85	1.16	1.33	1.18	0.85
6	1.02	1.24	1.49	1.28	0.87	1.19	1.36	1.21	0.88
7	1.04	1.27	1.53	1.32	0.89	1.22	1.40	1.24	0.90
8	1.07	1.30	1.56	1.35	0.91	1.25	1.43	1.27	0.92
9	1.09	1.33	1.60	1.38	0.93	1.27	1.46	1.30	0.93
10	1.12	1.36	1.63	1.41	0.95	1.30	1.49	1.33	0.95
11	0.03	0.18	0.35	0.15	-0.05	0.23	0.26	0.17	-0.05
12	2.52	3.04	4.00	3.52	1.99	2.80	3.32	3.08	1.96
13	2.54	3.06	4.02	3.54	1.99	2.81	3.34	3.10	1.95
Avgerage =	1.16	1.42	1.77	1.53	0.96	1.35	1.57	1.40	0.96

Figure 40: Annual BCR values for a joint 7kW + 3kW system.

Annual Benefit-Cost Ratios (BCR) - 5kW PV + 5kW ES System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	0.57	0.69	1.06	0.78	0.44	0.92	1.00	0.89	0.43
2	0.58	0.70	1.09	0.80	0.45	0.94	1.03	0.92	0.44
3	0.60	0.72	1.13	0.83	0.46	0.97	1.06	0.95	0.45
4	0.62	0.74	1.16	0.86	0.47	1.00	1.09	0.98	0.47
5	0.63	0.75	1.20	0.89	0.48	1.03	1.12	1.01	0.47
6	0.64	0.77	1.23	0.91	0.49	1.06	1.15	1.04	0.48
7	0.66	0.78	1.27	0.94	0.50	1.09	1.18	1.07	0.49
8	0.67	0.79	1.30	0.97	0.50	1.12	1.21	1.10	0.50
9	0.68	0.81	1.33	0.99	0.51	1.14	1.23	1.12	0.51
10	0.69	0.82	1.36	1.01	0.52	1.17	1.26	1.15	0.51
11	-0.53	-0.48	-0.43	-0.57	-0.50	-0.43	-0.45	-0.48	-0.49
12	1.40	1.65	4.20	3.21	0.87	3.10	3.53	3.34	0.84
13	1.39	1.64	4.23	3.23	0.87	3.12	3.54	3.36	0.84
Avgerage =	0.66	0.80	1.55	1.14	0.47	1.25	1.38	1.27	0.46

Figure 41: Annual BCR values for a joint 5kW + 5kW system.

Annual Benefit-Cost Ratios (BCR) -6kW PV + 5kW ES System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	0.72	0.90	1.18	0.93	0.56	1.00	1.02	0.98	0.56
2	0.74	0.93	1.22	0.96	0.57	1.03	1.05	1.01	0.57
3	0.77	0.96	1.26	0.99	0.59	1.07	1.09	1.05	0.58
4	0.79	0.99	1.30	1.03	0.60	1.11	1.12	1.08	0.60
5	0.81	1.02	1.34	1.06	0.62	1.14	1.15	1.12	0.61
6	0.83	1.04	1.38	1.09	0.63	1.17	1.19	1.15	0.63
7	0.85	1.07	1.42	1.12	0.64	1.20	1.22	1.19	0.64
8	0.87	1.09	1.46	1.15	0.65	1.23	1.25	1.22	0.65
9	0.89	1.11	1.50	1.19	0.67	1.27	1.28	1.25	0.66
10	0.90	1.13	1.54	1.21	0.68	1.30	1.31	1.28	0.67
11	-0.50	-0.45	-0.33	-0.47	-0.48	-0.36	-0.40	-0.41	-0.47
12	2.30	3.04	4.99	4.05	1.29	3.61	3.84	3.91	1.25
13	2.28	3.01	5.03	4.08	1.28	3.64	3.86	3.94	1.24
Avgerage =	0.94	1.22	1.79	1.41	0.64	1.42	1.46	1.44	0.63

Figure 42: Annual BCR values for a joint 6kW + 5kW system.

Annual Benefit-Cost Ratios (BCR) - 7kW PV + 5kW ES System									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
1	0.84	1.04	1.28	1.05	0.69	1.08	1.16	1.06	0.69
2	0.87	1.08	1.33	1.09	0.71	1.11	1.20	1.09	0.71
3	0.90	1.11	1.38	1.13	0.73	1.15	1.24	1.13	0.73
4	0.94	1.15	1.42	1.17	0.75	1.19	1.28	1.17	0.75
5	0.97	1.19	1.47	1.21	0.77	1.23	1.32	1.21	0.77
6	1.00	1.22	1.51	1.25	0.79	1.27	1.36	1.25	0.79
7	1.03	1.26	1.56	1.28	0.81	1.30	1.40	1.29	0.81
8	1.05	1.29	1.60	1.32	0.83	1.34	1.43	1.33	0.82
9	1.08	1.32	1.65	1.36	0.84	1.37	1.47	1.36	0.84
10	1.11	1.35	1.69	1.39	0.86	1.41	1.50	1.40	0.85
11	-0.45	-0.36	-0.24	-0.38	-0.45	-0.28	-0.30	-0.33	-0.44
12	3.45	4.18	5.74	4.84	1.95	4.11	4.62	4.47	1.86
13	3.48	4.21	5.80	4.89	1.94	4.14	4.65	4.51	1.85
Avgerage =	1.25	1.54	2.01	1.66	0.86	1.57	1.72	1.61	0.85

Figure 43: Annual BCR values for a joint 7kW + 5kW system.

For each joint system combination, the results show an improvement in BCR with each consecutive year, with the exception in year 11 where a decrease in BCR is observed due to the battery replacement cost. Year 0 has a 0.00 BCR for the US and across all listed states and system sizes because Year 0 is the year the PV + ES system is installed. Evaluation of the PV + ES joint system's performance begins the year after the joint system is installed (Year 1). As in scenario 2, the increase in BCR for each consecutive year is primarily attributed to the increases observed in annual energy cost savings and net-metered credits, with each consecutive year, while the energy costs totals only slightly increase The battery replacement cost is large enough ($3,306.37) to produce a negative BCR for all three 5kW ES coupled systems. A 7kW + 5kW joint system produces the highest BCR values for all locations except for Florida and Texas. This is because the 7kW + 5kW combination gives a residence the highest PV production capabilities (7kW PV system) coupled with the highest ES system coverage (5kW ES system). In the case of Florida and Texas, recall that the only system combination to produce net-metered credit is a

7kW + 3kW joint system and thus produces the highest 13 year BCR average for the two states. The net-metered credit produced for this joint system is less than $2,000 for both Florida and Texas. By adding a 5kW ES system, the battery replacement cost of $3,306.37 is now added to the Florida and Texas energy cost totals, nullifying the less than $2,000 net-metered credit that a 7kW + 3kW ES system was contributing to the 13 year BCR average of the two states; hence why a 7kW + 5kW joint system does not produce the highest BCR for these two states as it does the other locations.

The results for Texas and Florida are consistent with scenario 2 as these two states produce the lowest BCR values across all listed locations. California and Nevada produce the highest BCR values across all listed locations. Colorado, which produced amongst the top three highest BCR value in scenario 2, falls below or equal to New York and Massachusetts when comparing joint 5kW + 5kW and 6kW + 5kW systems. Adding a 5kW ES system increases Colorado's energy savings cost totals by a lesser amount than the increase experienced for New York and Massachusetts, as depicted by the difference between the 3kW ES system energy costs savings totals and the 5kW energy cost savings totals of the three states in **Figure 37**. It's not until the 7kW + 5kW joint system combination that Colorado produces a higher BCR value than New York and Massachusetts again. This is attributed to the larger increase in net-metered credit totals experienced by Colorado over those experienced by New York and Massachusetts, as depicted by the orange bars in **Figure 36**.

Figure 44 and **Figure 45** display the 13 year horizon ROIs for a residence with a joint PV + ES system. As in scenario 2, the ROI's are presented with the added home premium included and without the premium and are shown for all joint system combinations across the US and the listed states. ROI is calculated by subtracting the capital investments from year 0, the total loan payments, and the total energy costs over the 13 year horizon, from the sum of the added home premium in year 13, tax credit incentive from year 1, total net-metered credits over the 13 year horizon, and the total energy cost savings over the 13 year horizon. This value is then divided by the capital investments and expressed as a percentage.

The scenario 3 ROI calculations of this analysis differ from those of Truong et al. [7], which also reports ROI for a residence with a joint PV + ES system, due to following factors: (1) the inclusion of the added home premium when the PV residence is assumed to be sold in year 13; (2) the consideration of the ES battery replacement after the 10-year warranty (see **Scenario 3 Assumptions**), a limitation in the Truong et al. study; (3) the consideration of PV system's decrease in market value over the 13 years; (4) the inflation impacts applied to the PV provided energy sale price; (5) the usage of a 13 year horizon, equivalent to the average number of years US homeowners stay in a home [21]. The added home premium is the main contributor to the larger than previously reported, by Truong et al., ROI values. In addition, Truong et al. uses a 20 year fixed PV provided energy sale price due to Germany's renewable energy regulations, whereas this analysis applies the US energy inflation rate to the PV provided energy sale price (see **Scenario 2 Assumptions**).

Return of Investment (ROI) - Scenario 3 with Home Premium									
Year	**US**	**AZ**	**CA**	**CO**	**FL**	**MA**	**NV**	**NY**	**TX**
5kW PV + 3kW ES	51%	61%	73%	60%	49%	65%	78%	63%	50%
6kW PV + 3kW ES	65%	80%	91%	79%	62%	79%	89%	78%	64%
7kW PV + 3kW ES	82%	100%	108%	97%	76%	94%	109%	93%	77%
5kW PV + 5kW ES	39%	47%	58%	44%	37%	52%	59%	50%	38%
6kW PV + 5kW ES	49%	60%	73%	60%	48%	65%	68%	63%	49%
7kW PV + 5kW ES	62%	77%	88%	75%	59%	77%	85%	75%	61%

Figure 44: 13 year horizon ROI calculations with added home premium (Scenario 3).

Return of Investment (ROI) - Scenario 3 without Home Premium									
Year	US	AZ	CA	CO	FL	MA	NV	NY	TX
5kW PV + 3kW ES	-21%	-13%	2%	-13%	-24%	-4%	4%	-8%	-23%
6kW PV + 3kW ES	-17%	-4%	10%	-5%	-22%	1%	5%	-3%	-21%
7kW PV + 3kW ES	-11%	6%	18%	3%	-18%	5%	15%	2%	-17%
5kW PV + 5kW ES	-34%	-26%	-13%	-30%	-37%	-17%	-15%	-21%	-36%
6kW PV + 5kW ES	-32%	-22%	-7%	-23%	-34%	-13%	-15%	-17%	-33%
7kW PV + 5kW ES	-28%	-14%	0%	-16%	-32%	-9%	-6%	-13%	-31%

Figure 45: 13 year horizon ROI calculations without added home premium (Scenario 3).

As with scenario 2, the results show an increasing trend in ROI as the PV system size increases for each ES system combination. California and Nevada display the highest ROI with and without the added home premium, and are the only states to produce a positive ROI for all three combinations of 3kW ES system when the home premium is not included. As in scenario 2, this because of: (1) a large difference between the annual PV system production output levels (kWh) [38] and the average annual day-time energy consumption levels for a residence in the state (California); (2) high annual PV system production output levels for systems within the state [38], which leads to greater gains from net-metered credit (Nevada). Colorado no longer consistently bests Massachusetts and New York in ROI as it was in scenario 2 due to the lesser increase in energy cost savings totals when a 5kW ES system is added, as described above in the scenario 3 BCR results. Arizona is also no longer a consistently leading state in terms of ROI as it was in scenario 2 due to undergoing situation 1. Florida and Texas display the lowest ROI totals, with and without the added home premium, as they did in scenario 2.

Consistent with the scenario 2, the ROI results show how significantly impactful the added home premium is to the results. All ROI values are positive when the added home premium is included (**Figure 44**) and the majority of ROIs are negative, including the all 5kW ES system combinations, when the home premium is not included (**Figure 45**). The 7kW + 5kW joint system combination is -0.42% but appears as 0% due to rounding.

Sensitivity Analysis:

A sensitivity analysis is performed to evaluate the effects the federal ITC's upcoming changes, as well as the likely technological advancements of ES batteries, have on the ROI. Under current federal regulation, the ITC is expected to remain at 30% until 2019, and then drop to 26% in 2020, 22% in 2021, and eventually 0% in 2022 for residential investors. For the ES batteries, this sensitivity analysis assumes technological advancements will decrease the considered battery replacement cost in year 11. The analysis assumes a battery replacement cost decrease of 25% and 50% of the current year 11 cost. The US average 5kW PV, 5kW + 3kW and 5kW + 5kW system options are used in the analysis.

Figure 46 and **Figure 47** display the ITC sensitivity analysis with and without the added home premium included in the ROI. The results show an equal drop in ROI for all three system options. The ITC only affects the capital investment costs in year 0, thus the effect of the ITC drop will be consistent across all system options' ROIs unless the capital costs were to increase/decrease at different rates for the system options. By 2022, when the ITC is at 0% for residential investors, the ROI witnesses the steepest drop as expected.

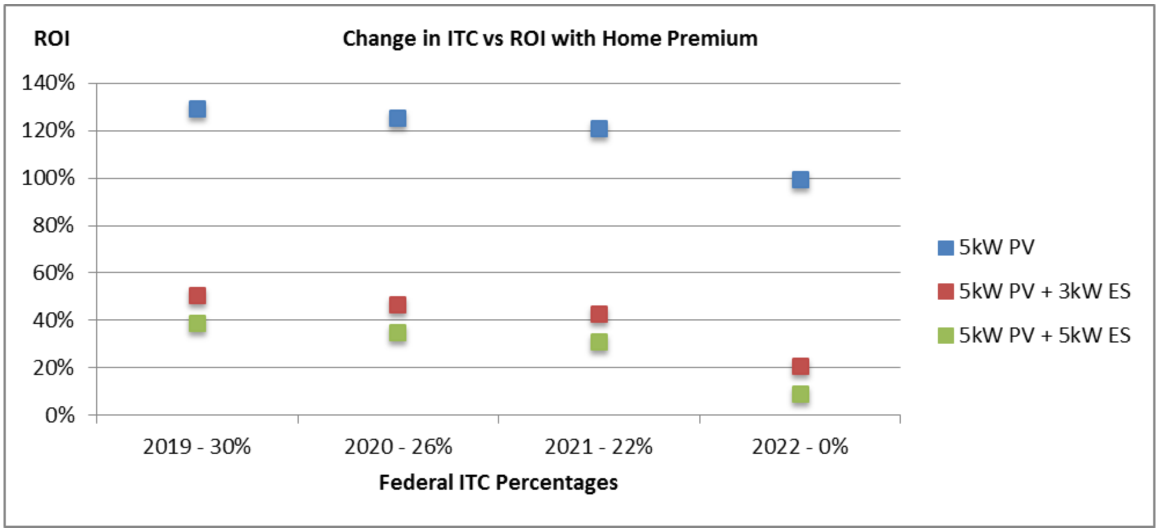

Figure 46: ITC sensitivity analysis with the added home premium included.

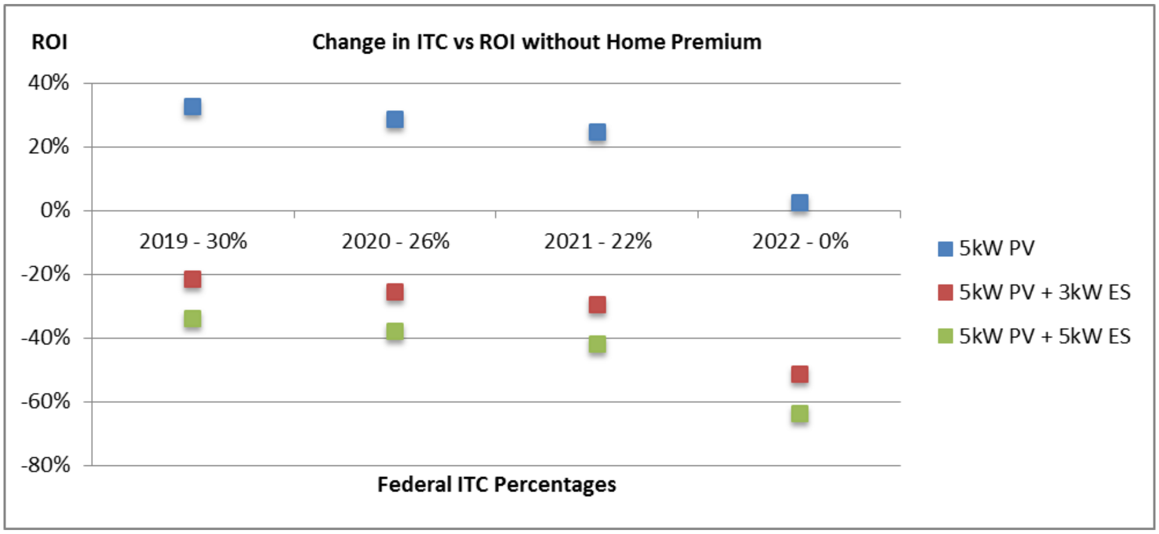

Figure 47: ITC sensitivity analysis without the added home premium.

Figure 48 and **Figure 49** display the battery replacement cost sensitivity analysis with and without the added home premium included in the ROI. The results show that the 5kW PV system's ROI remains constant because it has no ES system and is thus not affected by drops in the battery cost. The 5kW + 3kW and 5kW + 5kW joint systems witness minor improvement in ROI, but enough to make them more viable options than the 5kW PV system. This is because a reduction in battery costs alone is not enough to account for the large capital costs the ES systems (as a whole) currently come with. The battery costs account for 23% ($1.00/W of $4.27/W total) and 34% ($2.00/W of $5.93/W total) of the total ES system costs for the 3kW and 5kW ES system respectively. Only the battery is replaced in year 11; the other components of the overall ES system are not. As a result, the improvement on the overall ROI is minimal.

The most likely route for the joint system to become economically favored over the sole PV system is for the ES system (as a whole) capital costs to experience the same drastic decrease over the next 5-10 years that the PV system capital costs experienced over the past decade. As the interest in ES systems continues to grow, so will the research and development dedicated to the systems. This will lead to eventual decreases in overall ES system costs.

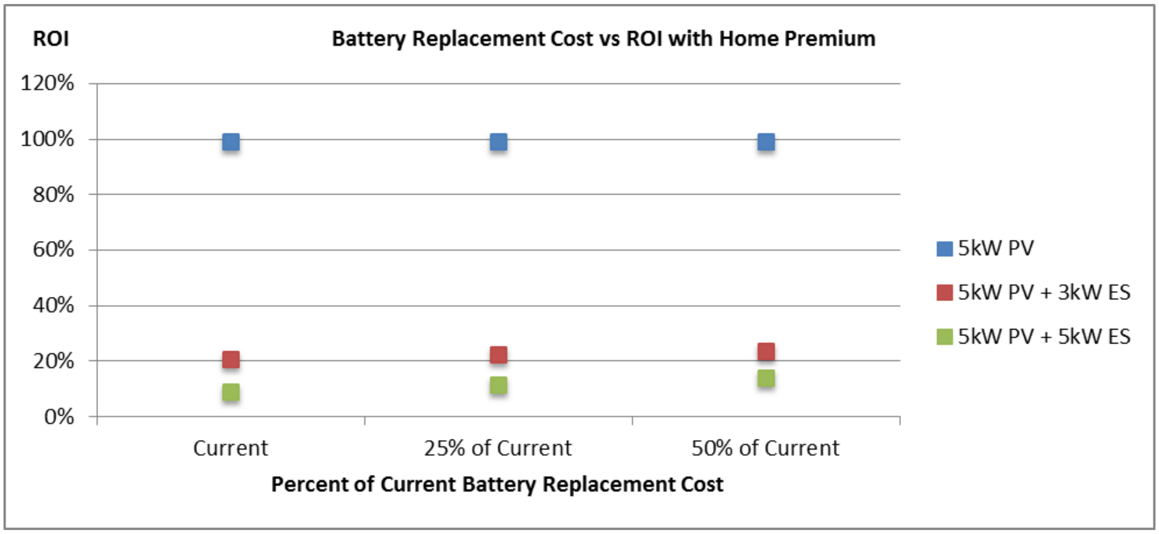

Figure 48: Battery replacement cost sensitivity analysis with the added home premium included.

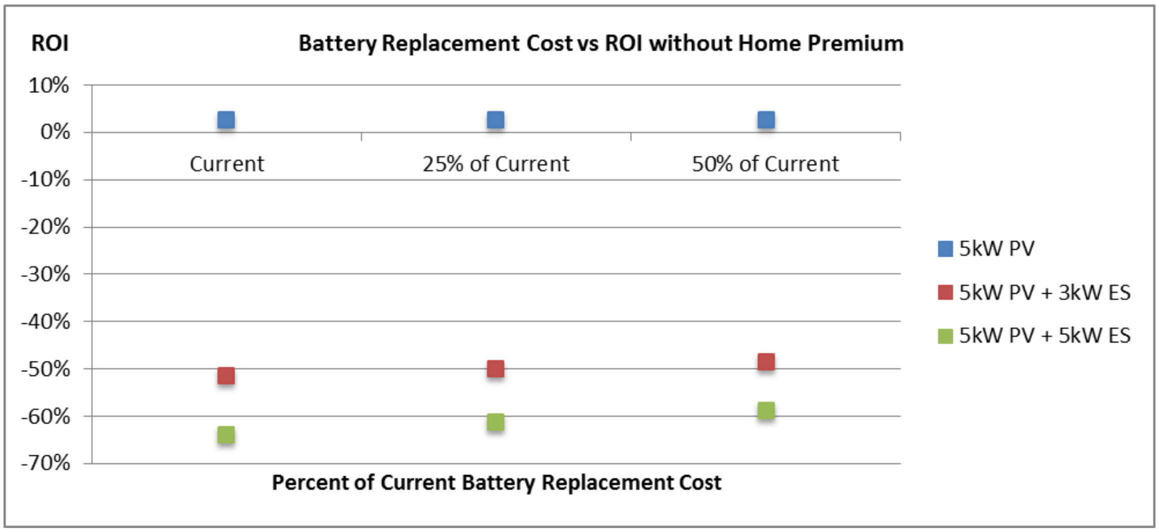

Figure 49: Battery replacement cost sensitivity analysis without the added home premium.

IX. Conclusions & Outlook

This research performs an economic analysis of residential PV systems with and without ES. An ROI is used to determine the economic evaluation of the systems over a 13 year analysis horizon. BCR is used to determine the annual economic evaluations of the system. Several factors are assumed, such as energy price inflation rates, ES system operation levels, PV system discount rates, and cost decrease rates, to help calculate the ROI and BCR results of the analysis. 2016 NREL PV installation benchmark costs are used and analyzed across eight of the top solar market states and the US average. The analysis is performed for a 5kW, 6kW, and 7kW PV system in scenario 2. These same PV system sizes are coupled with Tesla Powerwall 3kW and 5kW ES systems and analyzed in scenario 3. The main conclusions drawn from this research are as follows:

1. The most economically valuable option is a 7kW PV system without ES.

A residence with just a 7kW PV system is the most economically viable option at this time. The results for such a residence produced the highest ROIs with and without the added home premium across all listed locations. Such a residence also produced the highest annual BCR values and 13 year BCR averages, also across all listed locations. The 7kW residence is the only option to produce BCR values above 1, signifying a desirable economic evaluation, for all listed states and the US average.

2. A 3kW ES system is a more economically valuable option than a 5kW ES system.

The ROIs for the 3kW ES coupled joint system are greater than those of the 5kW ES coupled joint system; this stands across all states and the US average. The increase in average night-time demand covered that the 5kW system provides over the 3kW is not enough to overcome the increase in total ES system capital cost and battery replacement costs in year 11.

3. Coupling a PV system with an ES system is not economically beneficial at this time.

Across all listed locations, the incorporation of an ES system significantly reduces the ROI with and without the added home premium showing that even with the added PV provided energy supply towards the average night-time consumption, the current ES system costs are too high to provide economic benefit over just utilizing a PV system.

4. California and Nevada experience the most economic value for all scenario options.

California and Nevada produces the highest ROI and BCR values for all combinations in scenario 2 and scenario 3, and they are the least expensive states in scenario 1. When a 3kW ES system is added any PV system size, California and Nevada are the states to produce a positive ROI for all the joint PV + ES combinations.

5. Florida and Texas experience the least economic value for all scenario options.

Florida and Texas produce the lowest ROI and BCR values for all combinations in scenario 2 and scenario 3, and they are the most expensive states in scenario 1. Florida and Texas are the only states to not produce a 13 year BCR average above 1 for any of the PV + ES joint system combinations. In addition, Florida and Texas are the only states to produce negative ROIs for all PV + ES joint system combinations.

Over the past two decades, a substantial amount research and development has been performed on PV systems. As a result, the cost of PV systems has decreased drastically. Currently, the cost of joint PV + ES systems is almost double the cost of just PV systems [34]. As ES and joint PV + ES system interest continues to increase, so will the research and development into ES system. This will lead to decreases in the cost of ES system and potentially make the added energy supply ES system provide a more economically valuable option that just utilizing PV system alone.

Appendix A.

Table 3 displays the average annual PV production outputs (kWh) for each listed location across the three analyzed PV system sizes. The production amounts are provided by EnergySage. EnergySage calculates the production amount using PV Watts, a tool developed by NREL [38].

Average Annual PV Production (kWh)			
	5kW	6kW	7kW
US	7,162	8,500	9,910
AZ	8,643	10,379	12,099
CA	7,915	9,501	11,078
CO	7,639	9,175	10,695
FL	7,313	8,778	10,237
MA	6,606	7,931	9,247
NY	6,372	7,649	8,920
NV	9,794	10,565	12,313
TX	7,405	8,894	10,371

Table 3: Average annual PV production for each listed location.

Table 4 displays the assumed average annual day-time and night-time consumption (kWh) for a residence in the listed locations. The consumption averages are provided by the Office of Energy Efficiency & Renewable Energy (EERE). EERE publishes data-sets of the hourly residential load profiles in all listed states of this analysis [39]. These hourly loads are summed for the day-time hours and night-time hours to produce the average consumptions.

Average Annual Consumption for a Residence (kWh)			
	Day-Time	Night-Time	Total
US	6,055	4,757	10,812
AZ	7,402	4,934	12,336
CA	3,543	3,141	6,684
CO	4,211	4,045	8,256
FL	7,804	5,888	13,692
MA	3,684	3,540	7,224
NY	4,039	3,173	7,212
NV	6,245	4,711	10,956
TX	8,326	5,786	14,112

Table 4: Average annual consumption for a residence for each listed location.

Table 5 displays the capital costs for PV in each of the listed states ($/W). The costs provided are based off the US 2016 solar cost benchmarks, published by the National Renewable Energy Laboratory (NREL) in the first quarter of 2016 [8].

Captial PV Costs ($/W)		
US	$	2.93
AZ	$	2.85
CA	$	3.04
CO	$	2.81
FL	$	2.84
MA	$	3.18
NY	$	3.02
NV	$	2.82
TX	$	2.80

Table 5: Capital costs of PV for each listed location.

Table 6 displays the average annual energy purchase price ($/kWh) for each of the listed locations. The energy prices are provided by the US Energy Information Administration (EIA). The prices are based off 2015.

Average Annual Energy Purchase Price ($/kWh)		
US	$	0.1265
AZ	$	0.1213
CA	$	0.1699
CO	$	0.1212
FL	$	0.1158
MA	$	0.1983
NY	$	0.1854
NV	$	0.1276
TX	$	0.1156

Table 6: Average annual energy purchase price for each listed location

Appendix B and **Appendix C** contain the Microsoft Excel tool calculations for California (CA) – one of top two viable states, and Texas (TX) – one of the two least viable states, respectively; all system options are displayed for both states. The Microsoft Excel tool calculations for the US average are displayed in the **Analysis** chapter of this paper and the calculations for the remaining states are available in the Excel tool.

Appendix B.

Figures 50, 51 and **52** display the Microsoft Excel tool calculated values, specific to the state of California (CA), for a 5kW, 6kW and 7kW PV system respectively.

EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	6,684	$ 1,135.61	$ 12,145	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	7,915	4372	3,543	3,141	$ 1,171.95	$ -	$ 95.06	$ -	$ 550.73	$ 378.08	$ -	$ 6,262.27	$ 645.79	$ 762.51	$ 526.16	1.26
2	7,836	4293	3,543	3,141	$ 1,209.45	$ -	$ 86.06	$ -	$ 568.36	$ 378.08	$ -	$ -	$ 654.42	$ 772.70	$ 555.03	1.29
3	7,797	4254	3,543	3,141	$ 1,248.16	$ -	$ 77.92	$ -	$ 586.54	$ 378.08	$ -	$ -	$ 664.46	$ 790.15	$ 583.69	1.32
4	7,758	4215	3,543	3,141	$ 1,288.10	$ -	$ 70.54	$ -	$ 605.31	$ 378.08	$ -	$ -	$ 675.86	$ 807.96	$ 612.24	1.35
5	7,719	4176	3,543	3,141	$ 1,329.32	$ -	$ 63.87	$ -	$ 624.68	$ 378.08	$ -	$ -	$ 688.55	$ 826.14	$ 640.77	1.38
6	7,680	4137	3,543	3,141	$ 1,371.85	$ -	$ 57.82	$ -	$ 644.67	$ 378.08	$ -	$ -	$ 702.49	$ 844.70	$ 669.36	1.40
7	7,642	4099	3,543	3,141	$ 1,415.75	$ -	$ 52.35	$ -	$ 665.30	$ 378.08	$ -	$ -	$ 717.65	$ 863.64	$ 698.10	1.43
8	7,604	4061	3,543	3,141	$ 1,461.06	$ -	$ 47.39	$ -	$ 686.59	$ 378.08	$ -	$ -	$ 733.99	$ 882.97	$ 727.07	1.45
9	7,566	4023	3,543	3,141	$ 1,507.81	$ -	$ 42.91	$ -	$ 708.56	$ 378.08	$ -	$ -	$ 751.47	$ 902.69	$ 756.34	1.47
10	7,528	3985	3,543	3,141	$ 1,556.06	$ -	$ 38.85	$ -	$ 731.24	$ 378.08	$ -	$ -	$ 770.08	$ 922.82	$ 785.98	1.49
11	7,490	3947	3,543	3,141	$ 1,605.86	$ -	$ 35.17	$ -	$ 754.64	$ -	$ -	$ -	$ 789.81	$ 943.35	$ 816.05	2.23
12	7,453	3910	3,543	3,141	$ 1,657.24	$ -	$ 31.84	$ -	$ 778.79	$ -	$ -	$ -	$ 810.63	$ 964.30	$ 846.62	2.23
13	7,416	3873	3,543	3,141	$ 1,710.27	$ -	$ 28.83	$ -	$ 803.71	$ -	$ 14,136.90	$ -	$ 832.53	$ 985.68	$ 877.74	2.24
					$ 19,668.50	$ 12,145				$ 3,780.78	$ 14,136.90	$ 6,262.27	$ 10,573.35	$11,269.62	$ 9,095.15	
													ROI w/ Premium =		163.61%	
													ROI w/o Premium =		70.49%	

Figure 50: Microsoft Excel tool calculations for the CA – 5kW PV (Scenario 1 and 2).

EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	6,684	$ 1,135.61	$ 14,574	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	9,501	5958	3,543	3,141	$ 1,171.95	$ -	$ 114.07	$ -	$ 550.73	$ 453.69	$ -	$ 7,514.72	$ 664.81	$ 1,039.12	$ 507.14	1.38
2	9,406	5863	3,543	3,141	$ 1,209.45	$ -	$ 103.28	$ -	$ 568.36	$ 453.69	$ -	$ -	$ 671.63	$ 1,055.32	$ 537.82	1.42
3	9,359	5816	3,543	3,141	$ 1,248.16	$ -	$ 93.50	$ -	$ 586.54	$ 453.69	$ -	$ -	$ 680.05	$ 1,080.35	$ 568.11	1.45
4	9,312	5769	3,543	3,141	$ 1,288.10	$ -	$ 84.65	$ -	$ 605.31	$ 453.69	$ -	$ -	$ 689.97	$ 1,105.95	$ 598.13	1.49
5	9,266	5723	3,543	3,141	$ 1,329.32	$ -	$ 76.64	$ -	$ 624.68	$ 453.69	$ -	$ -	$ 701.32	$ 1,132.13	$ 627.99	1.52
6	9,220	5677	3,543	3,141	$ 1,371.85	$ -	$ 69.39	$ -	$ 644.67	$ 453.69	$ -	$ -	$ 714.06	$ 1,158.90	$ 657.80	1.56
7	9,173	5630	3,543	3,141	$ 1,415.75	$ -	$ 62.82	$ -	$ 665.30	$ 453.69	$ -	$ -	$ 728.12	$ 1,186.27	$ 687.63	1.59
8	9,128	5585	3,543	3,141	$ 1,461.06	$ -	$ 56.87	$ -	$ 686.59	$ 453.69	$ -	$ -	$ 743.46	$ 1,214.26	$ 717.59	1.61
9	9,082	5539	3,543	3,141	$ 1,507.81	$ -	$ 51.49	$ -	$ 708.56	$ 453.69	$ -	$ -	$ 760.05	$ 1,242.88	$ 747.76	1.64
10	9,036	5493	3,543	3,141	$ 1,556.06	$ -	$ 46.62	$ -	$ 731.24	$ 453.69	$ -	$ -	$ 777.85	$ 1,272.13	$ 778.21	1.66
11	8,991	5448	3,543	3,141	$ 1,605.86	$ -	$ 42.20	$ -	$ 754.64	$ -	$ -	$ -	$ 796.84	$ 1,302.04	$ 809.01	2.65
12	8,946	5403	3,543	3,141	$ 1,657.24	$ -	$ 38.21	$ -	$ 778.79	$ -	$ -	$ -	$ 816.99	$ 1,332.62	$ 840.25	2.66
13	8,902	5359	3,543	3,141	$ 1,710.27	$ -	$ 34.59	$ -	$ 803.71	$ -	$ 16,964.28	$ -	$ 838.30	$ 1,363.88	$ 871.98	2.67
					$ 19,668.50	$ 14,574				$ 4,536.94	$ 16,964.28	$ 7,514.72	$ 10,719.07	$ 15,485.86	$ 8,949.43	
													ROI w/ Premium =		196.32%	
													ROI w/o Premium =		84.57%	

Figure 51: Microsoft Excel tool calculations for the CA – 6kW PV (Scenario 1 and 2).

EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	6,684	$ 1,135.61	$ 17,003	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	11,078	7535	3,543	3,141	$ 1,171.95	$ -	$ 133.09	$ -	$ 550.73	$ 529.31	$ -	$ 8,767.17	$ 683.82	$ 1,314.16	$ 488.13	1.49
2	10,967	7424	3,543	3,141	$ 1,209.45	$ -	$ 120.49	$ -	$ 568.36	$ 529.31	$ -	$ -	$ 688.85	$ 1,336.33	$ 520.61	1.52
3	10,913	7370	3,543	3,141	$ 1,248.16	$ -	$ 109.09	$ -	$ 586.54	$ 529.31	$ -	$ -	$ 695.63	$ 1,368.90	$ 552.53	1.57
4	10,858	7315	3,543	3,141	$ 1,288.10	$ -	$ 98.76	$ -	$ 605.31	$ 529.31	$ -	$ -	$ 704.07	$ 1,402.25	$ 584.02	1.61
5	10,804	7261	3,543	3,141	$ 1,329.32	$ -	$ 89.41	$ -	$ 624.68	$ 529.31	$ -	$ -	$ 714.10	$ 1,436.38	$ 615.22	1.65
6	10,750	7207	3,543	3,141	$ 1,371.85	$ -	$ 80.95	$ -	$ 644.67	$ 529.31	$ -	$ -	$ 725.62	$ 1,471.32	$ 646.23	1.69
7	10,696	7153	3,543	3,141	$ 1,415.75	$ -	$ 73.29	$ -	$ 665.30	$ 529.31	$ -	$ -	$ 738.59	$ 1,507.08	$ 677.16	1.72
8	10,643	7100	3,543	3,141	$ 1,461.06	$ -	$ 66.35	$ -	$ 686.59	$ 529.31	$ -	$ -	$ 752.94	$ 1,543.67	$ 708.11	1.76
9	10,589	7046	3,543	3,141	$ 1,507.81	$ -	$ 60.07	$ -	$ 708.56	$ 529.31	$ -	$ -	$ 768.63	$ 1,581.13	$ 739.18	1.79
10	10,536	6993	3,543	3,141	$ 1,556.06	$ -	$ 54.39	$ -	$ 731.24	$ 529.31	$ -	$ -	$ 785.62	$ 1,619.47	$ 770.44	1.82
11	10,484	6941	3,543	3,141	$ 1,605.86	$ -	$ 49.24	$ -	$ 754.64	$ -	$ -	$ -	$ 803.87	$ 1,658.70	$ 801.98	3.06
12	10,431	6888	3,543	3,141	$ 1,657.24	$ -	$ 44.58	$ -	$ 778.79	$ -	$ -	$ -	$ 823.36	$ 1,698.85	$ 833.88	3.08
13	10,379	6836	3,543	3,141	$ 1,710.27	$ -	$ 40.36	$ -	$ 803.71	$ -	$ 19,791.66	$ -	$ 844.06	$ 1,739.94	$ 866.21	3.09
					$ 19,668.50	$ 17,003				$ 5,293.10	$ 19,791.66	$ 8,767.17	$ 10,864.79	$19,678.18	$ 8,803.71	
													ROI w/ Premium =		228.87%	
													ROI w/o Premium =		98.50%	

Figure 52: Microsoft Excel tool calculations for the CA – 7kW PV (Scenario 1 and 2).

Figures 53, 54, 55, 56, 57 and **58** display the Microsoft Excel tool calculated values, specific to the state of California (CA), for a 5kW PV + 3kW ES, 6kW PV + 3kW ES, 7kW PV + 3kW ES, 5kW PV + 5kW ES, 6kW PV + 5kW ES, and 7kW PV + 5kW ES joint system respectively.

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	6,684	$ 1,135.61	$ 22,391	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	7,915	873	3500	785	4,328	2,356	$ 1,171.95	$ -	$ 95.06	$ -	$ 413.05	$ 697.05	$ -	$11,545.57	$ 508.11	$ 610.34	$ 663.84	1.06
2	7,836	873	3421	785	4,328	2,356	$ 1,209.45	$ -	$ 86.06	$ -	$ 426.27	$ 697.05	$ -	$ -	$ 512.33	$ 615.66	$ 697.12	1.09
3	7,797	873	3381	785	4,328	2,356	$ 1,248.16	$ -	$ 77.92	$ -	$ 439.91	$ 697.05	$ -	$ -	$ 517.83	$ 628.08	$ 730.33	1.12
4	7,758	873	3342	785	4,328	2,356	$ 1,288.10	$ -	$ 70.54	$ -	$ 453.98	$ 697.05	$ -	$ -	$ 524.53	$ 640.71	$ 763.57	1.15
5	7,719	873	3304	785	4,328	2,356	$ 1,329.32	$ -	$ 63.87	$ -	$ 468.51	$ 697.05	$ -	$ -	$ 532.38	$ 653.54	$ 796.94	1.18
6	7,680	873	3265	785	4,328	2,356	$ 1,371.85	$ -	$ 57.82	$ -	$ 483.50	$ 697.05	$ -	$ -	$ 541.33	$ 666.57	$ 830.53	1.21
7	7,642	873	3227	785	4,328	2,356	$ 1,415.75	$ -	$ 52.35	$ -	$ 498.98	$ 697.05	$ -	$ -	$ 551.33	$ 679.81	$ 864.43	1.24
8	7,604	873	3188	785	4,328	2,356	$ 1,461.06	$ -	$ 47.39	$ -	$ 514.94	$ 697.05	$ -	$ -	$ 562.34	$ 693.26	$ 898.72	1.26
9	7,566	873	3150	785	4,328	2,356	$ 1,507.81	$ -	$ 42.91	$ -	$ 531.42	$ 697.05	$ -	$ -	$ 574.33	$ 706.91	$ 933.48	1.29
10	7,528	873	3113	785	4,328	2,356	$ 1,556.06	$ -	$ 38.85	$ -	$ 548.43	$ 697.05	$ -	$ -	$ 587.27	$ 720.77	$ 968.79	1.32
11	7,490	873	3075	785	4,328	2,356	$ 1,605.86	$ -	$ 35.17	$ 1,653.18	$ 565.98	$ -	$ -	$ -	$ 2,254.33	$ 734.84	$ (648.48)	0.04
12	7,453	873	3037	785	4,328	2,356	$ 1,657.24	$ -	$ 31.84	$ -	$ 584.09	$ -	$ -	$ -	$ 615.93	$ 749.12	$ 1,041.31	2.91
13	7,416	873	3000	785	4,328	2,356	$ 1,710.27	$ -	$ 28.83	$ -	$ 602.78	$ -	$ 19,791.66	$ -	$ 631.61	$ 763.61	$ 1,078.67	2.92
							$ 19,668.50	$ 22,391				$ 6,970.53	$ 19,791.66	$11,545.57	$ 10,049.25	$ 8,863.23	$ 9,619.25	
																ROI w/ Premium =	73.09%	
																ROI w/o Premium =	2.38%	

Figure 53: Microsoft Excel tool calculations for the CA – 5kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	6,684	$ 1,135.61	$ 24,820	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	9,501	873	5086	785	4,328	2,356	$ 1,171.95	$ -	$ 114.07	$ -	$ 413.05	$ 772.67	$ -	$ 12,798.02	$ 527.12	$ 886.95	$ 644.83	1.18
2	9,406	873	4991	785	4,328	2,356	$ 1,209.45	$ -	$ 103.28	$ -	$ 426.27	$ 772.67	$ -	$ -	$ 529.54	$ 898.28	$ 679.91	1.21
3	9,359	873	4944	785	4,328	2,356	$ 1,248.16	$ -	$ 93.50	$ -	$ 439.91	$ 772.67	$ -	$ -	$ 533.41	$ 918.29	$ 714.75	1.25
4	9,312	873	4897	785	4,328	2,356	$ 1,288.10	$ -	$ 84.65	$ -	$ 453.98	$ 772.67	$ -	$ -	$ 538.64	$ 938.70	$ 749.46	1.29
5	9,266	873	4850	785	4,328	2,356	$ 1,329.32	$ -	$ 76.64	$ -	$ 468.51	$ 772.67	$ -	$ -	$ 545.15	$ 959.53	$ 784.16	1.32
6	9,220	873	4804	785	4,328	2,356	$ 1,371.85	$ -	$ 69.39	$ -	$ 483.50	$ 772.67	$ -	$ -	$ 552.89	$ 980.77	$ 818.96	1.36
7	9,173	873	4758	785	4,328	2,356	$ 1,415.75	$ -	$ 62.82	$ -	$ 498.98	$ 772.67	$ -	$ -	$ 561.80	$ 1,002.45	$ 853.96	1.39
8	9,128	873	4712	785	4,328	2,356	$ 1,461.06	$ -	$ 56.87	$ -	$ 514.94	$ 772.67	$ -	$ -	$ 571.82	$ 1,024.55	$ 889.24	1.42
9	9,082	873	4666	785	4,328	2,356	$ 1,507.81	$ -	$ 51.49	$ -	$ 531.42	$ 772.67	$ -	$ -	$ 582.91	$ 1,047.10	$ 924.90	1.45
10	9,036	873	4621	785	4,328	2,356	$ 1,556.06	$ -	$ 46.62	$ -	$ 548.43	$ 772.67	$ -	$ -	$ 595.04	$ 1,070.09	$ 961.02	1.49
11	8,991	873	4576	785	4,328	2,356	$ 1,605.86	$ -	$ 42.20	$ 1,653.18	$ 565.98	$ -	$ -	$ -	$ 2,261.37	$ 1,093.53	$ (655.51)	0.19
12	8,946	873	4531	785	4,328	2,356	$ 1,657.24	$ -	$ 38.21	$ -	$ 584.09	$ -	$ -	$ -	$ 622.30	$ 1,117.44	$ 1,034.94	3.46
13	8,902	873	4486	785	4,328	2,356	$ 1,710.27	$ -	$ 34.59	$ -	$ 602.78	$ -	$ 22,619.04	$ -	$ 637.37	$ 1,141.81	$ 1,072.90	3.47
							$ 19,668.50	$ 24,820				$ 7,726.69	$ 22,619.04	$ 12,798.02	$ 10,194.97	$13,079.48	$ 9,473.53	
																ROI w/ Premium =	90.83%	
																ROI w/o Premium =	10.02%	

Figure 54: Microsoft Excel tool calculations for the CA – 6kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	6,684	$ 1,135.61	$ 27,249	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	11,078	873	6663	785	4,328	2,356	$ 1,171.95	$ -	$ 133.09	$ -	$ 413.05	$ 848.28	$ -	$ 14,050.47	$ 546.14	$ 1,161.99	$ 625.82	1.28
2	10,967	873	6552	785	4,328	2,356	$ 1,209.45	$ -	$ 120.49	$ -	$ 426.27	$ 848.28	$ -	$ -	$ 546.76	$ 1,179.29	$ 662.70	1.32
3	10,913	873	6497	785	4,328	2,356	$ 1,248.16	$ -	$ 109.09	$ -	$ 439.91	$ 848.28	$ -	$ -	$ 548.99	$ 1,206.84	$ 699.16	1.36
4	10,858	873	6443	785	4,328	2,356	$ 1,288.10	$ -	$ 98.76	$ -	$ 453.98	$ 848.28	$ -	$ -	$ 552.75	$ 1,235.00	$ 735.35	1.41
5	10,804	873	6388	785	4,328	2,356	$ 1,329.32	$ -	$ 89.41	$ -	$ 468.51	$ 848.28	$ -	$ -	$ 557.93	$ 1,263.78	$ 771.39	1.45
6	10,750	873	6334	785	4,328	2,356	$ 1,371.85	$ -	$ 80.95	$ -	$ 483.50	$ 848.28	$ -	$ -	$ 564.45	$ 1,293.19	$ 807.40	1.49
7	10,696	873	6281	785	4,328	2,356	$ 1,415.75	$ -	$ 73.29	$ -	$ 498.98	$ 848.28	$ -	$ -	$ 572.26	$ 1,323.25	$ 843.49	1.53
8	10,643	873	6227	785	4,328	2,356	$ 1,461.06	$ -	$ 66.35	$ -	$ 514.94	$ 848.28	$ -	$ -	$ 581.30	$ 1,353.96	$ 879.76	1.56
9	10,589	873	6174	785	4,328	2,356	$ 1,507.81	$ -	$ 60.07	$ -	$ 531.42	$ 848.28	$ -	$ -	$ 591.49	$ 1,385.35	$ 916.32	1.60
10	10,536	873	6121	785	4,328	2,356	$ 1,556.06	$ -	$ 54.39	$ -	$ 548.43	$ 848.28	$ -	$ -	$ 602.81	$ 1,417.42	$ 953.25	1.63
11	10,484	873	6068	785	4,328	2,356	$ 1,605.86	$ -	$ 49.24	$ 1,653.18	$ 565.98	$ -	$ -	$ -	$ 2,268.40	$ 1,450.19	$ (662.54)	0.35
12	10,431	873	6016	785	4,328	2,356	$ 1,657.24	$ -	$ 44.58	$ -	$ 584.09	$ -	$ -	$ -	$ 628.67	$ 1,483.67	$ 1,028.58	4.00
13	10,379	873	5964	785	4,328	2,356	$ 1,710.27	$ -	$ 40.36	$ -	$ 602.78	$ -	$ 25,446.42	$ -	$ 643.14	$ 1,517.87	$ 1,067.14	4.02
							$ 19,668.50	$ 27,249				$ 8,482.84	$ 25,446.42	$ 14,050.47	$ 10,340.69	$17,271.80	$ 9,327.80	
																ROI w/ Premium =	108.49%	
																ROI w/o Premium =	17.57%	

Figure 55: Microsoft Excel tool calculations for the CA – 7kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	6,684	$ 1,135.61	$ 26,380	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	7,915	1,745	2627	1571	5,114	1,571	$ 1,171.95	$ -	$ 95.06	$ -	$ 275.37	$ 821.23	$ -	$13,602.37	$ 370.43	$ 458.17	$ 801.52	1.06
2	7,836	1,745	2548	1571	5,114	1,571	$ 1,209.45	$ -	$ 86.06	$ -	$ 284.18	$ 821.23	$ -	$ -	$ 370.24	$ 458.62	$ 839.21	1.09
3	7,797	1,745	2509	1571	5,114	1,571	$ 1,248.16	$ -	$ 77.92	$ -	$ 293.27	$ 821.23	$ -	$ -	$ 371.19	$ 466.02	$ 876.97	1.13
4	7,758	1,745	2470	1571	5,114	1,571	$ 1,288.10	$ -	$ 70.54	$ -	$ 302.66	$ 821.23	$ -	$ -	$ 373.20	$ 473.46	$ 914.90	1.16
5	7,719	1,745	2431	1571	5,114	1,571	$ 1,329.32	$ -	$ 63.87	$ -	$ 312.34	$ 821.23	$ -	$ -	$ 376.21	$ 480.94	$ 953.11	1.20
6	7,680	1,745	2392	1571	5,114	1,571	$ 1,371.85	$ -	$ 57.82	$ -	$ 322.34	$ 821.23	$ -	$ -	$ 380.16	$ 488.45	$ 991.70	1.23
7	7,642	1,745	2354	1571	5,114	1,571	$ 1,415.75	$ -	$ 52.35	$ -	$ 332.65	$ 821.23	$ -	$ -	$ 385.00	$ 495.99	$ 1,030.75	1.27
8	7,604	1,745	2316	1571	5,114	1,571	$ 1,461.06	$ -	$ 47.39	$ -	$ 343.30	$ 821.23	$ -	$ -	$ 390.69	$ 503.55	$ 1,070.37	1.30
9	7,566	1,745	2278	1571	5,114	1,571	$ 1,507.81	$ -	$ 42.91	$ -	$ 354.28	$ 821.23	$ -	$ -	$ 397.19	$ 511.13	$ 1,110.62	1.33
10	7,528	1,745	2240	1571	5,114	1,571	$ 1,556.06	$ -	$ 38.85	$ -	$ 365.62	$ 821.23	$ -	$ -	$ 404.47	$ 518.73	$ 1,151.60	1.36
11	7,490	1,745	2202	1571	5,114	1,571	$ 1,605.86	$ -	$ 35.17	$ 3,306.37	$ 377.32	$ -	$ -	$ -	$ 3,718.86	$ 526.33	$ (2,113.00)	-0.43
12	7,453	1,745	2165	1571	5,114	1,571	$ 1,657.24	$ -	$ 31.84	$ -	$ 389.39	$ -	$ -	$ -	$ 421.23	$ 533.94	$ 1,236.01	4.20
13	7,416	1,745	2128	1571	5,114	1,571	$ 1,710.27	$ -	$ 28.83	$ -	$ 401.85	$ -	$ 23,561.50	$ -	$ 430.68	$ 541.54	$ 1,279.59	4.23
							$ 19,668.50	$ 26,380				$ 8,212.31	$ 23,561.50	$13,602.37	$ 9,525.15	$ 6,456.85	$ 10,143.34	
															ROI w/ Premium =		58.14%	
															ROI w/o Premium =		-13.31%	

Figure 56: Microsoft Excel tool calculations for the CA – 5kW PV + 5kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	6,684	$ 1,135.61	$ 28,809	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	9,501	1,745	4213	1571	5,114	1,571	$ 1,171.95	$ -	$ 114.07	$ -	$ 275.37	$ 896.85	$ -	$ 14,854.83	$ 389.44	$ 734.78	$ 782.51	1.18
2	9,406	1,745	4118	1571	5,114	1,571	$ 1,209.45	$ -	$ 103.28	$ -	$ 284.18	$ 896.85	$ -	$ -	$ 387.46	$ 741.24	$ 822.00	1.22
3	9,359	1,745	4071	1571	5,114	1,571	$ 1,248.16	$ -	$ 93.50	$ -	$ 293.27	$ 896.85	$ -	$ -	$ 386.77	$ 756.22	$ 861.38	1.26
4	9,312	1,745	4024	1571	5,114	1,571	$ 1,288.10	$ -	$ 84.65	$ -	$ 302.66	$ 896.85	$ -	$ -	$ 387.31	$ 771.45	$ 900.79	1.30
5	9,266	1,745	3978	1571	5,114	1,571	$ 1,329.32	$ -	$ 76.64	$ -	$ 312.34	$ 896.85	$ -	$ -	$ 388.98	$ 786.92	$ 940.34	1.34
6	9,220	1,745	3932	1571	5,114	1,571	$ 1,371.85	$ -	$ 69.39	$ -	$ 322.34	$ 896.85	$ -	$ -	$ 391.72	$ 802.65	$ 980.13	1.38
7	9,173	1,745	3885	1571	5,114	1,571	$ 1,415.75	$ -	$ 62.82	$ -	$ 332.65	$ 896.85	$ -	$ -	$ 395.47	$ 818.62	$ 1,020.28	1.42
8	9,128	1,745	3840	1571	5,114	1,571	$ 1,461.06	$ -	$ 56.87	$ -	$ 343.30	$ 896.85	$ -	$ -	$ 400.17	$ 834.84	$ 1,060.89	1.46
9	9,082	1,745	3794	1571	5,114	1,571	$ 1,507.81	$ -	$ 51.49	$ -	$ 354.28	$ 896.85	$ -	$ -	$ 405.77	$ 851.32	$ 1,102.04	1.50
10	9,036	1,745	3748	1571	5,114	1,571	$ 1,556.06	$ -	$ 46.62	$ -	$ 365.62	$ 896.85	$ -	$ -	$ 412.23	$ 868.04	$ 1,143.83	1.54
11	8,991	1,745	3703	1571	5,114	1,571	$ 1,605.86	$ -	$ 42.20	$ 3,306.37	$ 377.32	$ -	$ -	$ -	$ 3,725.89	$ 885.02	$ (2,120.04)	-0.33
12	8,946	1,745	3658	1571	5,114	1,571	$ 1,657.24	$ -	$ 38.21	$ -	$ 389.39	$ -	$ -	$ -	$ 427.60	$ 902.26	$ 1,229.64	4.99
13	8,902	1,745	3614	1571	5,114	1,571	$ 1,710.27	$ -	$ 34.59	$ -	$ 401.85	$ -	$ 26,388.88	$ -	$ 436.45	$ 919.74	$ 1,273.83	5.03
							$ 19,668.50	$ 28,809				$ 8,968.46	$ 26,388.88	$ 14,854.83	$ 9,670.88	$ 10,673.09	$ 9,997.62	
															ROI w/ Premium =		73.20%	
															ROI w/o Premium =		-6.83%	

Figure 57: Microsoft Excel tool calculations for the CA – 6kW PV + 6kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	6,684	$ 1,135.61	$ 31,238	$ -	$ -	$ 1,135.61	$ -	$ -	$ -	$ 1,135.61	$ -	$ -	0.00
1	11,078	1,745	5790	1571	5,114	1,571	$ 1,171.95	$ -	$ 133.09	$ -	$ 275.37	$ 972.46	$ -	$ 16,107.28	$ 408.45	$ 1,009.82	$ 763.50	1.28
2	10,967	1,745	5679	1571	5,114	1,571	$ 1,209.45	$ -	$ 120.49	$ -	$ 284.18	$ 972.46	$ -	$ -	$ 404.67	$ 1,022.25	$ 804.79	1.33
3	10,913	1,745	5625	1571	5,114	1,571	$ 1,248.16	$ -	$ 109.09	$ -	$ 293.27	$ 972.46	$ -	$ -	$ 402.36	$ 1,044.77	$ 845.80	1.38
4	10,858	1,745	5570	1571	5,114	1,571	$ 1,288.10	$ -	$ 98.76	$ -	$ 302.66	$ 972.46	$ -	$ -	$ 401.42	$ 1,067.75	$ 886.68	1.42
5	10,804	1,745	5516	1571	5,114	1,571	$ 1,329.32	$ -	$ 89.41	$ -	$ 312.34	$ 972.46	$ -	$ -	$ 401.75	$ 1,091.17	$ 927.56	1.47
6	10,750	1,745	5462	1571	5,114	1,571	$ 1,371.85	$ -	$ 80.95	$ -	$ 322.34	$ 972.46	$ -	$ -	$ 403.29	$ 1,115.06	$ 968.57	1.51
7	10,696	1,745	5408	1571	5,114	1,571	$ 1,415.75	$ -	$ 73.29	$ -	$ 332.65	$ 972.46	$ -	$ -	$ 405.94	$ 1,139.42	$ 1,009.81	1.56
8	10,643	1,745	5355	1571	5,114	1,571	$ 1,461.06	$ -	$ 66.35	$ -	$ 343.30	$ 972.46	$ -	$ -	$ 409.65	$ 1,164.25	$ 1,051.41	1.60
9	10,589	1,745	5301	1571	5,114	1,571	$ 1,507.81	$ -	$ 60.07	$ -	$ 354.28	$ 972.46	$ -	$ -	$ 414.35	$ 1,189.57	$ 1,093.46	1.65
10	10,536	1,745	5248	1571	5,114	1,571	$ 1,556.06	$ -	$ 54.39	$ -	$ 365.62	$ 972.46	$ -	$ -	$ 420.00	$ 1,215.38	$ 1,136.06	1.69
11	10,484	1,745	5196	1571	5,114	1,571	$ 1,605.86	$ -	$ 49.24	$ 3,306.37	$ 377.32	$ -	$ -	$ -	$ 3,732.93	$ 1,241.68	$ (2,127.07)	-0.24
12	10,431	1,745	5143	1571	5,114	1,571	$ 1,657.24	$ -	$ 44.58	$ -	$ 389.39	$ -	$ -	$ -	$ 433.97	$ 1,268.48	$ 1,223.27	5.74
13	10,379	1,745	5091	1571	5,114	1,571	$ 1,710.27	$ -	$ 40.36	$ -	$ 401.85	$ -	$ 29,216.26	$ -	$ 442.21	$ 1,295.80	$ 1,268.06	5.80
							$ 19,668.50	$ 31,238				$ 9,724.62	$ 29,216.26	$ 16,107.28	$ 9,816.60	$ 14,865.41	$ 9,851.90	
															ROI w/ Premium =		88.18%	
															ROI w/o Premium =		-0.42%	

Figure 58: Microsoft Excel tool calculations for the CA – 7kW PV + 5kW ES (Scenario 3).

Appendix C.

Figures 59, 60 and **61** display the Microsoft Excel tool calculated values, specific to the state of Florida (FL), for a 5kW, 6kW and 7kW PV system respectively.

	J	K	L	M	N	O	P	Q
1–3	EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs
4	0	0	0	0	14,112	$ 1,631.35	$ 11,217	$ -
5	1	7,405	0	7,405	6,707	$ 1,683.55	$ -	$ 95.06
6	2	7,331	0	7,331	6,781	$ 1,737.42	$ -	$ 86.06
7	3	7,294	0	7,294	6,818	$ 1,793.02	$ -	$ 77.92
8	4	7,258	0	7,258	6,854	$ 1,850.40	$ -	$ 70.54
9	5	7,222	0	7,222	6,890	$ 1,909.61	$ -	$ 63.87
10	6	7,186	0	7,186	6,926	$ 1,970.72	$ -	$ 57.82
11	7	7,150	0	7,150	6,962	$ 2,033.78	$ -	$ 52.35
12	8	7,114	0	7,114	6,998	$ 2,098.86	$ -	$ 47.39
13	9	7,078	0	7,078	7,034	$ 2,166.03	$ -	$ 42.91
14	10	7,043	0	7,043	7,069	$ 2,235.34	$ -	$ 38.85
15	11	7,008	0	7,008	7,104	$ 2,306.87	$ -	$ 35.17
16	12	6,973	0	6,973	7,139	$ 2,380.69	$ -	$ 31.84
17	13	6,938	0	6,938	7,174	$ 2,456.87	$ -	$ 28.83
18						$ 28,254.51	$ 11,217	
19–22								

	R	S	T	U	V	W	X	Y	Z
1–3	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
4	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
5	$ -	$ 800.14	$ 349.19	$ -	$ 5,783.84	$ 895.20	$ -	$ 788.35	0.63
6	$ -	$ 834.84	$ 349.19	$ -	$ -	$ 920.90	$ -	$ 816.52	0.64
7	$ -	$ 866.21	$ 349.19	$ -	$ -	$ 944.13	$ -	$ 848.89	0.66
8	$ -	$ 898.71	$ 349.19	$ -	$ -	$ 969.25	$ -	$ 881.14	0.67
9	$ -	$ 932.38	$ 349.19	$ -	$ -	$ 996.25	$ -	$ 913.36	0.68
10	$ -	$ 967.26	$ 349.19	$ -	$ -	$ 1,025.08	$ -	$ 945.64	0.69
11	$ -	$ 1,003.39	$ 349.19	$ -	$ -	$ 1,055.74	$ -	$ 978.04	0.70
12	$ -	$ 1,040.82	$ 349.19	$ -	$ -	$ 1,088.21	$ -	$ 1,010.65	0.70
13	$ -	$ 1,079.58	$ 349.19	$ -	$ -	$ 1,122.49	$ -	$ 1,043.54	0.71
14	$ -	$ 1,119.73	$ 349.19	$ -	$ -	$ 1,158.58	$ -	$ 1,076.76	0.71
15	$ -	$ 1,161.32	$ -	$ -	$ -	$ 1,196.49	$ -	$ 1,110.38	0.93
16	$ -	$ 1,204.39	$ -	$ -	$ -	$ 1,236.24	$ -	$ 1,144.45	0.93
17	$ -	$ 1,249.00	$ -	$ 14,136.90	$ -	$ 1,277.83	$ -	$ 1,179.04	0.92
18			$ 3,491.94	$ 14,136.90	$ 5,783.84	$ 15,517.74	$ -	$ 12,736.77	
19–20						ROI w/ Premium =		128.01%	
21–22						ROI w/o Premium =		27.18%	

Figure 59: Microsoft Excel tool calculations for the TX – 5kW PV (Scenario 1 and 2).

	J	K	L	M	N	O	P	Q
1–3	EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs
4	0	0	0	0	14,112	$ 1,631.35	$ 13,461	$ -
5	1	8,894	568	8,326	5,786	$ 1,683.55	$ -	$ 114.07
6	2	8,805	479	8,326	5,786	$ 1,737.42	$ -	$ 103.28
7	3	8,761	435	8,326	5,786	$ 1,793.02	$ -	$ 93.50
8	4	8,717	391	8,326	5,786	$ 1,850.40	$ -	$ 84.65
9	5	8,674	348	8,326	5,786	$ 1,909.61	$ -	$ 76.64
10	6	8,630	304	8,326	5,786	$ 1,970.72	$ -	$ 69.39
11	7	8,587	261	8,326	5,786	$ 2,033.78	$ -	$ 62.82
12	8	8,544	218	8,326	5,786	$ 2,098.86	$ -	$ 56.87
13	9	8,502	176	8,326	5,786	$ 2,166.03	$ -	$ 51.49
14	10	8,459	133	8,326	5,786	$ 2,235.34	$ -	$ 46.62
15	11	8,417	91	8,326	5,786	$ 2,306.87	$ -	$ 42.20
16	12	8,375	49	8,326	5,786	$ 2,380.69	$ -	$ 38.21
17	13	8,333	7	8,326	5,786	$ 2,456.87	$ -	$ 34.59
18						$ 28,254.51	$ 13,461	
19–22								

	R	S	T	U	V	W	X	Y	Z
1–3	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
4	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
5	$ -	$ 690.27	$ 419.03	$ -	$ 6,940.61	$ 804.34	$ 99.06	$ 879.21	0.80
6	$ -	$ 712.35	$ 419.03	$ -	$ -	$ 815.63	$ 86.27	$ 921.79	0.82
7	$ -	$ 735.15	$ 419.03	$ -	$ -	$ 828.65	$ 80.85	$ 964.37	0.84
8	$ -	$ 758.67	$ 419.03	$ -	$ -	$ 843.33	$ 75.04	$ 1,007.07	0.86
9	$ -	$ 782.95	$ 419.03	$ -	$ -	$ 859.59	$ 68.82	$ 1,050.02	0.88
10	$ -	$ 808.01	$ 419.03	$ -	$ -	$ 877.39	$ 62.16	$ 1,093.33	0.89
11	$ -	$ 833.86	$ 419.03	$ -	$ -	$ 896.68	$ 55.06	$ 1,137.10	0.91
12	$ -	$ 860.55	$ 419.03	$ -	$ -	$ 917.42	$ 47.49	$ 1,181.44	0.92
13	$ -	$ 888.08	$ 419.03	$ -	$ -	$ 939.57	$ 39.42	$ 1,226.45	0.93
14	$ -	$ 916.50	$ 419.03	$ -	$ -	$ 963.12	$ 30.84	$ 1,272.22	0.94
15	$ -	$ 945.83	$ -	$ -	$ -	$ 988.03	$ 21.72	$ 1,318.84	1.36
16	$ -	$ 976.10	$ -	$ -	$ -	$ 1,014.31	$ 12.03	$ 1,366.38	1.36
17	$ -	$ 1,007.33	$ -	$ 16,964.28	$ -	$ 1,041.92	$ 1.76	$ 1,414.95	1.36
18			$ 4,190.33	$ 16,964.28	$ 6,940.61	$ 13,421.33	$ 680.52	$ 14,833.18	
19–20						ROI w/ Premium =		155.25%	
21–22						ROI w/o Premium =		34.26%	

Figure 60: Microsoft Excel tool calculations for the TX – 6kW PV (Scenario 1 and 2).

	J	K	L	M	N	O	P	Q
1–3	EOY	PV Production (kWh)	PV Sold to Grid (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs
4	0	0	0	0	14,112	$ 1,631.35	$ 15,704	$ -
5	1	10,371	2045	8,326	5,786	$ 1,683.55	$ -	$ 133.09
6	2	10,268	1942	8,326	5,786	$ 1,737.42	$ -	$ 120.49
7	3	10,216	1890	8,326	5,786	$ 1,793.02	$ -	$ 109.09
8	4	10,165	1839	8,326	5,786	$ 1,850.40	$ -	$ 98.76
9	5	10,114	1788	8,326	5,786	$ 1,909.61	$ -	$ 89.41
10	6	10,064	1738	8,326	5,786	$ 1,970.72	$ -	$ 80.95
11	7	10,013	1687	8,326	5,786	$ 2,033.78	$ -	$ 73.29
12	8	9,963	1637	8,326	5,786	$ 2,098.86	$ -	$ 66.35
13	9	9,914	1588	8,326	5,786	$ 2,166.03	$ -	$ 60.07
14	10	9,864	1538	8,326	5,786	$ 2,235.34	$ -	$ 54.39
15	11	9,815	1489	8,326	5,786	$ 2,306.87	$ -	$ 49.24
16	12	9,766	1440	8,326	5,786	$ 2,380.69	$ -	$ 44.58
17	13	9,717	1391	8,326	5,786	$ 2,456.87	$ -	$ 40.36
18						$ 28,254.51	$ 15,704	
19–22								

	R	S	T	U	V	W	X	Y	Z
1–3	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payment	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
4	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
5	$ -	$ 690.27	$ 488.87	$ -	$ 8,097.38	$ 823.35	$ 356.66	$ 860.20	0.93
6	$ -	$ 712.35	$ 488.87	$ -	$ -	$ 832.84	$ 349.46	$ 904.58	0.95
7	$ -	$ 735.15	$ 488.87	$ -	$ -	$ 844.23	$ 351.10	$ 948.79	0.98
8	$ -	$ 758.67	$ 488.87	$ -	$ -	$ 857.43	$ 352.55	$ 992.96	1.00
9	$ -	$ 782.95	$ 488.87	$ -	$ -	$ 872.36	$ 353.77	$ 1,037.25	1.02
10	$ -	$ 808.01	$ 488.87	$ -	$ -	$ 888.96	$ 354.77	$ 1,081.76	1.04
11	$ -	$ 833.86	$ 488.87	$ -	$ -	$ 907.15	$ 355.52	$ 1,126.63	1.06
12	$ -	$ 860.55	$ 488.87	$ -	$ -	$ 926.90	$ 356.01	$ 1,171.97	1.08
13	$ -	$ 888.08	$ 488.87	$ -	$ -	$ 948.15	$ 356.23	$ 1,217.87	1.10
14	$ -	$ 916.50	$ 488.87	$ -	$ -	$ 970.89	$ 356.15	$ 1,264.45	1.11
15	$ -	$ 945.83	$ -	$ -	$ -	$ 995.07	$ 355.76	$ 1,311.80	1.68
16	$ -	$ 976.10	$ -	$ -	$ -	$ 1,020.67	$ 355.04	$ 1,360.02	1.68
17	$ -	$ 1,007.33	$ -	$ 19,791.66	$ -	$ 1,047.69	$ 353.97	$ 1,409.18	1.68
18			$ 4,888.71	$ 19,791.66	$ 8,097.38	$ 13,567.05	$ 4,607.00	$ 14,687.46	
19–20						ROI w/ Premium =		189.64%	
21–22						ROI w/o Premium =		48.49%	

Figure 61: Microsoft Excel tool calculations for the TX – 7kW PV (Scenario 1 and 2).

Figures 62, 63, 64, 65, 66 and **67** display the Microsoft Excel tool calculated values, specific to the state of Florida (FL), for a 5kW PV + 3kW ES, 6kW PV + 3kW ES, 7kW PV + 3kW ES, 5kW PV + 5kW ES, 6kW PV + 5kW ES, and 7kW PV + 5kW ES joint system respectively.

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	14,112	$ 1,631.35	$ 21,464	$ -	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
1	7,405	1,607	0	1447	7,244	6,868	$ 1,683.55	$ -	$ 95.06	$ -	$ 819.31	$ 668.17	$ -	$ 11,067.14	$ 914.38	$ -	$ 769.17	0.49
2	7,331	1,607	0	1447	7,170	6,942	$ 1,737.42	$ -	$ 86.06	$ -	$ 854.63	$ 668.17	$ -	$ -	$ 940.69	$ -	$ 796.73	0.50
3	7,294	1,607	0	1447	7,134	6,978	$ 1,793.02	$ -	$ 77.92	$ -	$ 886.63	$ 668.17	$ -	$ -	$ 964.55	$ -	$ 828.47	0.51
4	7,258	1,607	0	1447	7,097	7,015	$ 1,850.40	$ -	$ 70.54	$ -	$ 919.79	$ 668.17	$ -	$ -	$ 990.33	$ -	$ 860.07	0.52
5	7,222	1,607	0	1447	7,061	7,051	$ 1,909.61	$ -	$ 63.87	$ -	$ 954.13	$ 668.17	$ -	$ -	$ 1,018.00	$ -	$ 891.62	0.53
6	7,186	1,607	0	1447	7,025	7,087	$ 1,970.72	$ -	$ 57.82	$ -	$ 989.70	$ 668.17	$ -	$ -	$ 1,047.53	$ -	$ 923.19	0.54
7	7,150	1,607	0	1447	6,989	7,123	$ 2,033.78	$ -	$ 52.35	$ -	$ 1,026.55	$ 668.17	$ -	$ -	$ 1,078.90	$ -	$ 954.88	0.55
8	7,114	1,607	0	1447	6,953	7,159	$ 2,098.86	$ -	$ 47.39	$ -	$ 1,064.72	$ 668.17	$ -	$ -	$ 1,112.11	$ -	$ 986.75	0.55
9	7,078	1,607	0	1447	6,918	7,194	$ 2,166.03	$ -	$ 42.91	$ -	$ 1,104.25	$ 668.17	$ -	$ -	$ 1,147.16	$ -	$ 1,018.87	0.56
10	7,043	1,607	0	1447	6,882	7,230	$ 2,235.34	$ -	$ 38.85	$ -	$ 1,145.19	$ 668.17	$ -	$ -	$ 1,184.04	$ -	$ 1,051.30	0.57
11	7,008	1,607	0	1447	6,847	7,265	$ 2,306.87	$ -	$ 35.17	$ 1,653.18	$ 1,187.59	$ -	$ -	$ -	$ 2,875.95	$ -	$ (569.08)	-0.20
12	6,973	1,607	0	1447	6,812	7,300	$ 2,380.69	$ -	$ 31.84	$ -	$ 1,231.51	$ -	$ -	$ -	$ 1,263.35	$ -	$ 1,117.34	0.88
13	6,938	1,607	0	1447	6,777	7,335	$ 2,456.87	$ -	$ 28.83	$ -	$ 1,276.99	$ -	$ 19,791.66	$ -	$ 1,305.81	$ -	$ 1,151.06	0.88
							$ 28,254.51	$ 21,464				$ 6,681.68	$ 19,791.66	$ 11,067.14	$ 17,474.13	$ -	$ 10,780.38	
															ROI w/ Premium =		50.30%	
															ROI w/o Premium =		-23.47%	

Figure 62: Microsoft Excel tool calculations for the TX – 5kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	14,112	$ 1,631.35	$ 23,707	$ -	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
1	8,894	1,607	0	1447	8,733	5,379	$ 1,683.55	$ -	$ 114.07	$ -	$ 641.68	$ 738.01	$ -	$ 12,223.91	$ 755.75	$ -	$ 927.80	0.62
2	8,805	1,607	0	1447	8,645	5,467	$ 1,737.42	$ -	$ 103.28	$ -	$ 673.13	$ 738.01	$ -	$ -	$ 776.41	$ -	$ 961.01	0.63
3	8,761	1,607	0	1447	8,601	5,511	$ 1,793.02	$ -	$ 93.50	$ -	$ 700.27	$ 738.01	$ -	$ -	$ 793.77	$ -	$ 999.25	0.65
4	8,717	1,607	0	1447	8,557	5,555	$ 1,850.40	$ -	$ 84.65	$ -	$ 728.42	$ 738.01	$ -	$ -	$ 813.07	$ -	$ 1,037.33	0.67
5	8,674	1,607	0	1447	8,513	5,599	$ 1,909.61	$ -	$ 76.64	$ -	$ 757.63	$ 738.01	$ -	$ -	$ 834.27	$ -	$ 1,075.34	0.68
6	8,630	1,607	0	1447	8,470	5,642	$ 1,970.72	$ -	$ 69.39	$ -	$ 787.93	$ 738.01	$ -	$ -	$ 857.31	$ -	$ 1,113.40	0.70
7	8,587	1,607	0	1447	8,427	5,685	$ 2,033.78	$ -	$ 62.82	$ -	$ 819.36	$ 738.01	$ -	$ -	$ 882.18	$ -	$ 1,151.60	0.71
8	8,544	1,607	0	1447	8,384	5,728	$ 2,098.86	$ -	$ 56.87	$ -	$ 851.97	$ 738.01	$ -	$ -	$ 908.84	$ -	$ 1,190.02	0.72
9	8,502	1,607	0	1447	8,341	5,771	$ 2,166.03	$ -	$ 51.49	$ -	$ 885.79	$ 738.01	$ -	$ -	$ 937.28	$ -	$ 1,228.75	0.73
10	8,459	1,607	0	1447	8,298	5,814	$ 2,235.34	$ -	$ 46.62	$ -	$ 920.87	$ 738.01	$ -	$ -	$ 967.48	$ -	$ 1,267.86	0.74
11	8,417	1,607	0	1447	8,256	5,856	$ 2,306.87	$ -	$ 42.20	$ 1,653.18	$ 957.25	$ -	$ -	$ -	$ 2,652.64	$ -	$ (345.77)	-0.13
12	8,375	1,607	0	1447	8,214	5,898	$ 2,380.69	$ -	$ 38.21	$ -	$ 994.98	$ -	$ -	$ -	$ 1,033.19	$ -	$ 1,347.50	1.30
13	8,333	1,607	0	1447	8,172	5,940	$ 2,456.87	$ -	$ 34.59	$ -	$ 1,034.11	$ -	$ 22,619.04	$ -	$ 1,068.70	$ -	$ 1,388.17	1.30
							$ 28,254.51	$ 23,707				$ 7,380.07	$ 22,619.04	$ 12,223.91	$ 14,912.23	$ -	$ 13,342.28	
															ROI w/ Premium =		63.73%	
															ROI w/o Premium =		-20.58%	

Figure 63: Microsoft Excel tool calculations for the TX – 6kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	14,112	$ 1,631.35	$ 25,950	$ -	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
1	10,371	1,607	438	1447	9,773	4,340	$ 1,683.55	$ -	$ 133.09	$ -	$ 517.70	$ 807.85	$ -	$ 13,380.68	$ 650.79	$ 76.35	$ 1,032.76	0.76
2	10,268	1,607	334	1447	9,773	4,340	$ 1,737.42	$ -	$ 120.49	$ -	$ 534.27	$ 807.85	$ -	$ -	$ 654.76	$ 60.18	$ 1,082.67	0.78
3	10,216	1,607	283	1447	9,773	4,340	$ 1,793.02	$ -	$ 109.09	$ -	$ 551.36	$ 807.85	$ -	$ -	$ 660.45	$ 52.56	$ 1,132.57	0.81
4	10,165	1,607	232	1447	9,773	4,340	$ 1,850.40	$ -	$ 98.76	$ -	$ 569.01	$ 807.85	$ -	$ -	$ 667.77	$ 44.46	$ 1,182.63	0.83
5	10,114	1,607	181	1447	9,773	4,340	$ 1,909.61	$ -	$ 89.41	$ -	$ 587.21	$ 807.85	$ -	$ -	$ 676.63	$ 35.82	$ 1,232.98	0.85
6	10,064	1,607	131	1447	9,773	4,340	$ 1,970.72	$ -	$ 80.95	$ -	$ 606.00	$ 807.85	$ -	$ -	$ 686.95	$ 26.64	$ 1,283.76	0.88
7	10,013	1,607	80	1447	9,773	4,340	$ 2,033.78	$ -	$ 73.29	$ -	$ 625.40	$ 807.85	$ -	$ -	$ 698.68	$ 16.90	$ 1,335.10	0.90
8	9,963	1,607	30	1447	9,773	4,340	$ 2,098.86	$ -	$ 66.35	$ -	$ 645.41	$ 807.85	$ -	$ -	$ 711.76	$ 6.55	$ 1,387.10	0.92
9	9,914	1,607	0	1447	9,753	4,359	$ 2,166.03	$ -	$ 60.07	$ -	$ 669.08	$ 807.85	$ -	$ -	$ 729.16	$ -	$ 1,436.87	0.93
10	9,864	1,607	0	1447	9,703	4,409	$ 2,235.34	$ -	$ 54.39	$ -	$ 698.35	$ 807.85	$ -	$ -	$ 752.73	$ -	$ 1,482.61	0.95
11	9,815	1,607	0	1447	9,654	4,458	$ 2,306.87	$ -	$ 49.24	$ 1,653.18	$ 728.76	$ -	$ -	$ -	$ 2,431.18	$ -	$ (124.31)	-0.05
12	9,766	1,607	0	1447	9,605	4,507	$ 2,380.69	$ -	$ 44.58	$ -	$ 760.36	$ -	$ -	$ -	$ 804.93	$ -	$ 1,575.76	1.96
13	9,717	1,607	0	1447	9,556	4,556	$ 2,456.87	$ -	$ 40.36	$ -	$ 793.19	$ -	$ 25,446.42	$ -	$ 833.55	$ -	$ 1,623.33	1.95
							$ 28,254.51	$ 25,950				$ 8,078.46	$ 25,446.42	$ 13,380.68	$ 12,590.67	$ 319.46	$ 15,663.84	
															ROI w/ Premium =		77.46%	
															ROI w/o Premium =		-17.39%	

Figure 64: Microsoft Excel tool calculations for the TX – 7kW PV + 3kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	14,112	$ 1,631.35	$ 25,453	$ -	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
1	7,405	3,214	0	2893	7,084	7,028	$ 1,683.55	$ -	$ 95.06	$ -	$ 838.49	$ 792.35	$ -	$13,123.95	$ 933.55	$ -	$ 750.00	0.43
2	7,331	3,214	0	2893	7,010	7,102	$ 1,737.42	$ -	$ 86.06	$ -	$ 874.41	$ 792.35	$ -	$ -	$ 960.48	$ -	$ 776.95	0.44
3	7,294	3,214	0	2893	6,973	7,139	$ 1,793.02	$ -	$ 77.92	$ -	$ 907.05	$ 792.35	$ -	$ -	$ 984.97	$ -	$ 808.05	0.45
4	7,258	3,214	0	2893	6,937	7,175	$ 1,850.40	$ -	$ 70.54	$ -	$ 940.86	$ 792.35	$ -	$ -	$ 1,011.40	$ -	$ 838.99	0.47
5	7,222	3,214	0	2893	6,900	7,212	$ 1,909.61	$ -	$ 63.87	$ -	$ 975.88	$ 792.35	$ -	$ -	$ 1,039.74	$ -	$ 869.87	0.47
6	7,186	3,214	0	2893	6,864	7,248	$ 1,970.72	$ -	$ 57.82	$ -	$ 1,012.15	$ 792.35	$ -	$ -	$ 1,069.97	$ -	$ 900.75	0.48
7	7,150	3,214	0	2893	6,828	7,284	$ 2,033.78	$ -	$ 52.35	$ -	$ 1,049.72	$ 792.35	$ -	$ -	$ 1,102.06	$ -	$ 931.72	0.49
8	7,114	3,214	0	2893	6,792	7,320	$ 2,098.86	$ -	$ 47.39	$ -	$ 1,088.62	$ 792.35	$ -	$ -	$ 1,136.02	$ -	$ 962.85	0.50
9	7,078	3,214	0	2893	6,757	7,355	$ 2,166.03	$ -	$ 42.91	$ -	$ 1,128.92	$ 792.35	$ -	$ -	$ 1,171.83	$ -	$ 994.20	0.51
10	7,043	3,214	0	2893	6,722	7,390	$ 2,235.34	$ -	$ 38.85	$ -	$ 1,170.65	$ 792.35	$ -	$ -	$ 1,209.50	$ -	$ 1,025.84	0.51
11	7,008	3,214	0	2893	6,686	7,426	$ 2,306.87	$ -	$ 35.17	$ 3,306.37	$ 1,213.87	$ -	$ -	$ -	$ 4,555.41	$ -	$ (2,248.54)	-0.49
12	6,973	3,214	0	2893	6,651	7,461	$ 2,380.69	$ -	$ 31.84	$ -	$ 1,258.62	$ -	$ -	$ -	$ 1,290.46	$ -	$ 1,090.23	0.84
13	6,938	3,214	0	2893	6,616	7,496	$ 2,456.87	$ -	$ 28.83	$ -	$ 1,304.97	$ -	$ 23,561.50	$ -	$ 1,333.80	$ -	$ 1,123.08	0.84
							$ 28,254.51	$ 25,453				$ 7,923.46	$ 23,561.50	$13,123.95	$ 19,430.53	$ -	$ 8,823.98	
															ROI w/ Premium =		38.14%	
															ROI w/o Premium =		-35.92%	

Figure 65: Microsoft Excel tool calculations for the TX – 5kW PV + 5kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	14,112	$ 1,631.35	$ 27,696	$ -	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
1	8,894	3,214	0	2893	8,573	5,539	$ 1,683.55	$ -	$ 114.07	$ -	$ 660.85	$ 862.18	$ -	$ 14,280.71	$ 774.93	$ -	$ 908.62	0.56
2	8,805	3,214	0	2893	8,484	5,628	$ 1,737.42	$ -	$ 103.28	$ -	$ 692.92	$ 862.18	$ -	$ -	$ 796.20	$ -	$ 941.23	0.57
3	8,761	3,214	0	2893	8,440	5,672	$ 1,793.02	$ -	$ 93.50	$ -	$ 720.69	$ 862.18	$ -	$ -	$ 814.19	$ -	$ 978.83	0.58
4	8,717	3,214	0	2893	8,396	5,716	$ 1,850.40	$ -	$ 84.65	$ -	$ 749.49	$ 862.18	$ -	$ -	$ 834.15	$ -	$ 1,016.25	0.60
5	8,674	3,214	0	2893	8,352	5,760	$ 1,909.61	$ -	$ 76.64	$ -	$ 779.38	$ 862.18	$ -	$ -	$ 856.02	$ -	$ 1,053.59	0.61
6	8,630	3,214	0	2893	8,309	5,803	$ 1,970.72	$ -	$ 69.39	$ -	$ 810.37	$ 862.18	$ -	$ -	$ 879.76	$ -	$ 1,090.96	0.63
7	8,587	3,214	0	2893	8,266	5,846	$ 2,033.78	$ -	$ 62.82	$ -	$ 842.52	$ 862.18	$ -	$ -	$ 905.34	$ -	$ 1,128.44	0.64
8	8,544	3,214	0	2893	8,223	5,889	$ 2,098.86	$ -	$ 56.87	$ -	$ 875.87	$ 862.18	$ -	$ -	$ 932.74	$ -	$ 1,166.12	0.65
9	8,502	3,214	0	2893	8,180	5,932	$ 2,166.03	$ -	$ 51.49	$ -	$ 910.46	$ 862.18	$ -	$ -	$ 961.95	$ -	$ 1,204.08	0.66
10	8,459	3,214	0	2893	8,138	5,974	$ 2,235.34	$ -	$ 46.62	$ -	$ 946.32	$ 862.18	$ -	$ -	$ 992.94	$ -	$ 1,242.40	0.67
11	8,417	3,214	0	2893	8,095	6,017	$ 2,306.87	$ -	$ 42.20	$ 3,306.37	$ 983.52	$ -	$ -	$ -	$ 4,332.09	$ -	$ (2,025.22)	-0.47
12	8,375	3,214	0	2893	8,053	6,059	$ 2,380.69	$ -	$ 38.21	$ -	$ 1,022.09	$ -	$ -	$ -	$ 1,060.30	$ -	$ 1,320.39	1.25
13	8,333	3,214	0	2893	8,011	6,101	$ 2,456.87	$ -	$ 34.59	$ -	$ 1,062.09	$ -	$ 26,388.88	$ -	$ 1,096.68	$ -	$ 1,360.19	1.24
							$ 28,254.51	$ 27,696				$ 8,621.85	$ 26,388.88	$ 14,280.71	$ 16,868.63	$ -	$ 11,385.88	
															ROI w/ Premium =		49.47%	
															ROI w/o Premium =		-33.48%	

Figure 66: Microsoft Excel tool calculations for the TX – 6kW PV + 5kW ES (Scenario 3).

EOY	PV Production (kWh)	Energy to Charge ES System (kWh)	PV Sold to Grid (kWh)	ES Energy Discharged (kWh)	PV Consumed by Residence (kWh)	Grid Energy Consumed by Residence (kWh)	Energy Costs w/o PV System	Capital Costs - Loan	PV Modules O&M Costs	Battery Replacement Post Warranty	Costs of Grid Energy Used	Loan Payments	Increase Home Premium	Fed. & State Tax Incentive	Energy Costs w/ PV System	Net-metered Credits	Energy Cost Savings	BCR
0	0	0	0	0	0	14,112	$ 1,631.35	$ 29,939	$ -	$ -	$ 1,631.35	$ -	$ -	$ -	$ 1,631.35	$ -	$ -	0.00
1	10,371	3,214	0	2893	10,050	4,062	$ 1,683.55	$ -	$ 133.09	$ -	$ 484.65	$ 932.02	$ -	$15,437.48	$ 617.73	$ -	$ 1,065.82	0.69
2	10,268	3,214	0	2893	9,946	4,166	$ 1,737.42	$ -	$ 120.49	$ -	$ 512.89	$ 932.02	$ -	$ -	$ 633.38	$ -	$ 1,104.04	0.71
3	10,216	3,214	0	2893	9,895	4,217	$ 1,793.02	$ -	$ 109.09	$ -	$ 535.83	$ 932.02	$ -	$ -	$ 644.91	$ -	$ 1,148.11	0.73
4	10,165	3,214	0	2893	9,844	4,268	$ 1,850.40	$ -	$ 98.76	$ -	$ 559.67	$ 932.02	$ -	$ -	$ 658.43	$ -	$ 1,191.97	0.75
5	10,114	3,214	0	2893	9,793	4,319	$ 1,909.61	$ -	$ 89.41	$ -	$ 584.46	$ 932.02	$ -	$ -	$ 673.87	$ -	$ 1,235.74	0.77
6	10,064	3,214	0	2893	9,742	4,370	$ 1,970.72	$ -	$ 80.95	$ -	$ 610.22	$ 932.02	$ -	$ -	$ 691.17	$ -	$ 1,279.55	0.79
7	10,013	3,214	0	2893	9,692	4,420	$ 2,033.78	$ -	$ 73.29	$ -	$ 637.00	$ 932.02	$ -	$ -	$ 710.29	$ -	$ 1,323.49	0.81
8	9,963	3,214	0	2893	9,642	4,470	$ 2,098.86	$ -	$ 66.35	$ -	$ 664.83	$ 932.02	$ -	$ -	$ 731.18	$ -	$ 1,367.68	0.82
9	9,914	3,214	0	2893	9,592	4,520	$ 2,166.03	$ -	$ 60.07	$ -	$ 693.75	$ 932.02	$ -	$ -	$ 753.82	$ -	$ 1,412.20	0.84
10	9,864	3,214	0	2893	9,543	4,569	$ 2,235.34	$ -	$ 54.39	$ -	$ 723.81	$ 932.02	$ -	$ -	$ 778.19	$ -	$ 1,457.15	0.85
11	9,815	3,214	0	2893	9,493	4,619	$ 2,306.87	$ -	$ 49.24	$ 3,306.37	$ 755.03	$ -	$ -	$ -	$ 4,110.64	$ -	$ (1,803.77)	-0.44
12	9,766	3,214	0	2893	9,444	4,668	$ 2,380.69	$ -	$ 44.58	$ -	$ 787.47	$ -	$ -	$ -	$ 832.05	$ -	$ 1,548.64	1.86
13	9,717	3,214	0	2893	9,395	4,717	$ 2,456.87	$ -	$ 40.36	$ -	$ 821.17	$ -	$ 29,216.26	$ -	$ 861.53	$ -	$ 1,595.34	1.85
							$ 28,254.51	$ 29,939				$ 9,320.24	$ 29,216.26	$15,437.48	$ 14,328.55	$ -	$ 13,925.96	
															ROI w/ Premium =		60.73%	
															ROI w/o Premium =		-31.10%	

Figure 67: Microsoft Excel tool calculations for the TX – 7kW PV + 5kW ES (Scenario 3).

X. References

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