ENERGY STORAGE MARKETS: 2019

An Update for Southern California Edison

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EXECUTIVE SUMMARY

Product Title: ENERGY STORAGE MARKETS: 2019: An Update for Southern California Edison

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PRIMARY AUDIENCE: Emerging technology teams, grid operation and planning teams, Demand Response teams, Energy procurement teams, customer programs within Utilities

SECONDARY AUDIENCE: Transmission and distribution planning teams, Information Technology teams within utility, research institutes, residential customers, regulators and government agencies.

KEY RESEARCH QUESTION

The objective of this project is to help characterize California's residential energy storage markets, with implications for the potential residential energy storage must play in grid operations.

RESEARCH OVERVIEW

Boice Dunham Group (BDG) undertook this work under contract with EPRI. In this report, BDG describes and summarizes how the residential energy storage market in Southern California is transiting from a fringe market on the edge of the industry to a young, growing market serving early adopters.

BDG bases the report on interviews with industry suppliers, installers, regulators, consultants, utilities, and financiers, as well as public reports, articles, and product materials. BDG has combined and extended the concepts of many other researchers, employing an analytic framework developed over the years. The framework is based on the traditions of market analysis, market transformation, and early market development. The statistics, estimates, and market perspectives were gathered in late 2019: market conditions have changed in some respects since then.

The review of the market has been focused on residential energy storage within the SCE service territory. The report does not consider utility-scale or commercial, industrial, and institutional (CII) energy storage. The work does not analyze the closely related solar energy and electric vehicle markets. BDG has not conducted its own customer surveys to verify the size and dynamics of the overall California residential energy storage market, and while the company has reviewed the estimates of others (e.g., GTM, Navigant, the California Self Generation Incentive Program), the research has not found a sound market benchmark in those sources. But the report has assembled important narratives and market perspectives that reveal market drivers and has identified critical themes and developments that are essential for SCE to consider.

KEY FINDINGS

Situational Analysis – Markets

The market for residential energy storage has emerged across the last decade as lithium batteries have improved, solar energy installations have grown, and environmental concerns have become prominent in California legislation and energy policy. There are now at least 10,000 grid-connected residential energy storage systems installed in California[1], with at least 3,700 more being installed annually. At a general average cost of $17,000 per system, the California market for residential energy storage systems now exceeds $55 MM annually.

While less than 1% of SCE's customers use energy storage, SCE spokesperson Julia Roether told Utility Dive that SCE saw "a 197% increase in 2017 and a 341% increase in 2018" in energy storage deployment.[2] In SCE's franchise territory, more than 3,000 residential energy storage systems now connected to the grid and at least 1,100 systems are being added annually. Market forces could easily lead these numbers to triple in the next few years, with growth continuing to accelerate after that. There is also a case to be made for the market stalling out until major advances occur in battery chemistry.

For branded products and custom systems, the key components are batteries, inverters, and control systems. Systems differ in design across these components, in price, and in performance. The economic value propositions of established systems are still marginal, despite state SGIP rebates and federal tax credits, so the market is still open to new solutions based on better ideas. SCE and regulators have tried to provide a safe and equitable path for the residential market to follow, but the pace of change remains challenging. New SCE strategies and new SCE rates are combining with statewide Building Code changes to create a new phase of market development.

Today, the leading suppliers of grid-connected residential energy storage systems in SCE's franchise territory are Tesla, LG Chem, Sunrun, Pika (Generac), Sonnen (Shell), and SimpliPhi. Although the market as yet has no established standards or terms of competition, Tesla leads the market through its brand presence and numerous installations, with LG Chem just behind. Beyond the major offerings, the market also includes many grid-connected systems developers, installers, and electricians assemble on a custom basis. There is a complex ecosystem of technologies, from hardware suppliers, software APIs, integrators, and advanced management systems that actually make up the energy storage systems that customers ultimately install in their homes.

Situational Analysis – Pathways

The suppliers of residential energy storage systems work through different installers, who play strong roles in system marketing, selection, cost, and customer education. Almost all of these installers are based primarily in the solar industry. Some suppliers offer in-house installation services, and some work with multiple third-party installers. Regulators, builders, and utilities also impact the market, often engaging with residential energy storage systems as an adjunct to other strategies in large-scale storage, solar energy, electric transportation, energy efficiency and demand response.

Customers usually encounter residential energy storage systems in the process of considering solar energy for an existing or new home. The first customers for residential energy storage systems have been fringe innovators who wanted energy storage for its own sake and could afford it even if the economics were speculative. Spurred by Building Code changes, rate changes, and environmental concerns, the market is now making a transition to early adopters, who will require more of an economic rationale to buy into residential energy storage systems.

The leading use cases for residential energy storage systems are backup power, self-supply, energy cost management, and grid services. These use cases are untested at scale. Although anecdotal experience and research results suggest that the use cases will prove valuable in California, confidence is limited. Backup

[1] In this report, the residential energy storage systems discussed are grid-connected, rather than off-grid systems. Off-grid systems are primarily lead-acid installations in remote areas. Off-grid systems do not share the value propositions and broad appeal of on-grid connected systems.

[2] "As solar-plus-storage surges can smart devices help overcome deployment barriers?" by Herman Trabish, Utility Dive, January 29, 2019.

power provides insurance value in the event of grid disruptions. Self-supply provides investment returns by enabling local energy production and use. Energy cost management provides savings through time-of-day rate arbitrage. Grid services manage local stresses on the grid. The values of all of these use cases are contingent on events, rates, and customer behavior.

Residential energy storage suppliers will continue to compete based on improving system performance against these use cases, but suppliers may come to recognize that their category is driven by outside forces, i.e., solar adoption, utility rates, the utility's need for grid services, customer behavior, and the incidence of outages. Well-positioned suppliers in these adjacent categories will be advantaged. Suppliers will also be advantaged who realize that the perceived insurance value of residential energy storage in emergencies can be targeted and influenced as it has been in other categories. Good stories will reassure prospective customers and foster the growth of residential energy storage.

Strategic Opportunities for SCE

To best foster the market for residential energy storage systems, SCE will need a set of initiatives, including active community outreach, online information and analytics, strategic intent, SGIP improvements, and installer support. Without SCE's help, the market could stall as new residential construction bypasses residential energy storage in favor of supporting larger solar arrays. The imminent changes to the California Energy Code to include solar in new construction places SCE at a crossroads. On the one hand, an active strategy requires investment, management, and engagement with customers. On the other hand, a passive, hands-off strategy will distance SCE's distribution planners from the storage industry and may reduce SCE's options for grid operations.

With SCE's help, the residential energy storage market could grow rapidly, as product design and performance improve, costs fall, and customer use cases prove valuable. Market growth could improve grid reliability, when aligned with future distribution needs. SCE's plans and strategies for encouraging and engaging residential energy storage will be influenced by these imminent market changes. BDG notes that SCE is in control of few of these changes.

However, SCE could influence the market for residential energy storage, by taking steps in five areas: active community outreach, online information and analytics, strategic intent, SGIP improvements, and installer support. SCE is active in some of these areas already; discussing these current activities is beyond the scope of this report. These steps are within SCE's control. They require few additional resources. They require streamlined work processes and a willingness to support innovative customers.

For example, as a research project, SCE could assess and map its residential energy storage interconnection processes, identify potential improvements in dialogue with installers, and then test these potential improvements in practice. The adoption rate could rise through installer support, as bidding would be based on better information, and the SGIP, interconnection, and local approval would all be easier -- making for more profitable projects, and more support for optimal residential energy storage placement.

WHY THIS MATTERS

This research ""Residential Energy Storage Integration Opportunities", ultimately, helps customers achieve their goals for installing residential energy storage and helps SCE achieve its vision of a safe, reliable, and decarbonized grid of the future. As SCE stated it is 2018 Sustainability Report[3]:

"Energy storage is essential to meeting climate change goals. SCE is committed to leading the industry and accelerating the adoption of energy storage, both as a utility-scale resource and by our customers."

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[3] https://www.edison.com/content/dam/eix/documents/sustainability/eix-2018-sustainability-report.pdf

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RESIDENTIAL STORAGE - BACKGROUND

1.1 The Rise of Solar, and the Rise of Energy Storage

Long the province of small, portable gas-powered generators, the market for residential backup electric power in California also began to include a small number of off-grid-connected lead-acid battery-powered installations as early as 2003[4]. As solar energy[5] began to scale in California, residential storage markets followed.

In 2006, recognizing that manufacturing improvements were making solar energy more and more affordable, Governor Arnold Schwarzenegger launched the California Solar Initiative (CSI), aiming for 1 million solar roofs. Shortly thereafter, in 2009 Sunverge was founded to capitalize on similar progress in lithium-ion rechargeable battery chemistry. Sunverge had 38 Li-ion systems online by 2012, and as trials expanded in 2013 and 2014, it installed hundreds more. Across the same period, beginning with a 2010 California Public Utilities Commission (CPUC) grant, SolarCity linked solar power to Tesla lithium-ion batteries at a dozen sites. By 2015, SolarCity had installed more than 300 wall-mounted residential energy storage systems in California households.

The residential energy storage market reached a new stage in 2015, when Tesla launched its Powerwall product. The CSI had closed out after substantial success, and California had a sizable set of residential solar customers who could consider energy storage for their homes. Expensive, branded, and stylish, the Powerwall announced that residential energy storage had arrived.

In the beginning days of the California residential solar markets, the solar value proposition for customers was still poor. Incentives were important. Customers with solar energy earned some money exporting energy to the grid at fixed tiered rates, when solar energy was abundant (e.g., summer midday), but these early solar systems still required decades to pay for themselves. However, the perception of climate change, California's incentives, the rise of system financing, the fall in solar panel prices, and the extension of federal tax credits all combined to power the California residential solar market through the Great Recession of 2008 and on to substantial growth. Residential energy storage would follow a similar path.

As the solar market boomed and the residential storage market was born, California's regulators and utilities moved fast to set priorities, and keep pace. Regulators refocused the Self-Generation Incentive Program (SGIP) in 2011 towards greenhouse gas reduction, and away from its initial role fostering renewable energy[6]. California's 2013.

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[4] Paul Dailey (Director of Product & Market Strategy, OutBack Power) estimates that today, California hosts about as many off-grid residential energy storage systems (10-15,000) as on-grid interconnected systems.

[5] The first residential photovoltaic (PV) system was installed on the Solar One Building at the University of Delaware in 1973.

[6] The SGIP continues to be bedeviled to this day by GHG reduction requirements left within what has become a storage incentive program. Recent analyses revealed that SGIP-funded residential storage systems might increase GHG production

Net Energy Metering (NEM) Rules, Renewable Portfolio Standard (RPS) and energy storage mandate all pointed at large markets to come for both renewable energy and energy storage, but roles and responsibilities weren't clear.

The industries were running ahead of the policies to manage them. In 2013, the regulatory tariff intended for solar generation required SCE to certify that any self-generated power receiving compensation from the utility was either solar power or was qualified under a multi-tariff application. But in order to make such a certification, SCE would have to know whether the owners of solar arrays had charged their batteries with solar power, or ordinary non-renewable grid power. Identifying the source of power used to charge batteries required prohibitively expensive separate metering. With no clear path forward, SCE suggested that all customers with batteries should be excluded from the NEM program, whether there was any evidence of non-renewable power use.

Some solar and storage advocates objected to regulators that SCE was opposing innovation and trying to prevent customers from earning export revenues. In fact, a few households started to cancel planned storage installations, sending a disturbing signal to the industry. Eventually, the CPUC set aside SCE's concerns, approved new NEM rules, and instructed California utilities to expand their support of energy storage. SCE went on to conduct highly publicized tests of residential storage in Fontana and Irvine to better understand the grid impacts of solar and storage installations. But the solar and storage communities did not forget SCE's earlier hesitations about supporting residential battery use.[7]

Across the last decade, the solar and energy storage industries have boomed in California. As innovative suppliers continued to reduce costs, and regulations changed repeatedly, distributed energy resources were installed in utilities, commercial and industrial sites, and residential households. SCE reported 63,216 solar households at the close of 2013. Today, SCE has over 300,000 solar households, and the number of SCE households hosting solar and storage systems will continue to rise in coming years, due to the impact of the new California 2020 Building Code provisions. These new provisions require solar energy on all new single-family residential construction in California.

The energy storage industry has also grown, even in its fledgling residential segment. After the launch of Tesla's *Powerwall* and Sunverge's field trial with SMUD, in 2016 the statewide SGIP established a list of tested systems eligible for incentives, and thousands of California households now host residential energy storage systems. As was true for solar energy in its early days, the early residential energy storage systems haven't been particularly good financial investments. They have required customers who wanted them for their own sakes. But grid-connected residential energy storage systems have provided environmental, technology, and "cool-brand" credentials to these customers, and there have been enough initial customers to place a couple of the leading offerings on backorder as manufacturers worked to meet demand.

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slightly, by occasionally recharging from typical grid power rather than renewable energy. CPUC staff made recommendations that the SGIP-aided systems should only charge from the cleanest power, and discharge to replace the dirtiest power. These proposed limitations on use were judged too onerous by interveners and the Commission, but it isn't clear that the "GHG Signal" approach being pursued as an alternative is less burdensome.

[7] See AMECO Solar (amecosolar.com), and "Fight Over Battery-Backed Solar in Southern California," by Jeff St. John, GTM News, September 23, 2013, interviewing Phil Undercuffler of Outback Power.

1.2 The Future of Residential Storage for SCE

Energy storage has become a vital strategy for SCE, featured in both the Distribution Resources Plan (DRP) and the Integrated Distributed Energy Resources (IDER) proceedings. SCE's energy storage acquisition has been headlined by large-scale procurements replacing natural gas-based resources. As renewable resource prices have fallen, and the perceived risk of natural gas resources has increased (e.g., after the Aliso Canyon disaster), SCE has moved to away from fossil fuels to an electrification strategy. Energy storage procurement has ramped up from adding 260 MW in 2014 for Los Angeles basin reliability needs, to an initial 67 MW for Aliso Canyon disaster recovery, to a second 181 MW Aliso Canyon Energy Storage 2 request.

Residential storage has been in the background for SCE, growing more slowly than the larger sectors, although still active. SCE received 888 applications for SGIP rebates in 2017 and 1,876 in 2018[8]. In 2018 SCE recorded 963 completed SGIP residential storage projects[9]. As of May,2019 another 273 applications have been logged. Even accounting for processing delays between application and project completion, there have only been a few thousand residential energy storage installations interconnected to SCE's grid. Applications for SGIP rebates take time to process, and as outlined below, are bypassed by some customers. Most market sources believe SGIP projects represent 75-90% of total residential energy storage projects. Based on these estimates, SCE will interconnect several thousand residential energy storage systems each year, in the years to come.

The 75 MW Orange County Preferred Resources Pilot (PRP)1 had included a variety of storage systems alongside other resources, and SCE tested residential energy storage in Irvine and Fontana. SCE's PRP 2 project includes 3,000 residential energy storage installations (5 MW) from Swell Energy. The Swell Energy project is one of five PRP so-called "Demo C" test projects aggregating DERs to reduce peak loads, balance energy flows, and manage the grid. Recently, SCE's primary participation in the residential energy storage market has been through the SGIP, taking advantage of another program repositioning in 2016 toward energy storage, which includes rebates for residential storage customers[10].

Even though SCE has not become a direct provider of residential storage systems like Arizona Public Service or redesigned its distribution planning around residential solar and storage like the Hawaiian Electric Company, residential energy storage is of interest to SCE for several reasons.

First, new California Building Code standards coming into effect in 2020 require all new single-family residential construction (and all very small multifamily projects) to include solar and consider energy storage as an option. In justifying those requirements, an optimistic analysis

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[8] SCE SGIP staff cited these numbers, but they were not from standardized reports. More accurate numbers would be available from utility interconnection records, but these were not available to us.

[9] Self-Generation Incentive Program, http://energycenter.org/sgip/statistics

[10] The California Energy Storage Alliance reports that 98-99% of small residential SGIP-funded energy storage systems are paired with renewable energy. "COMMENTS OF THE CALIFORNIA ENERGY STORAGE ALLIANCE TO THE ASSIGNED COMMISSIONER'S RULING SEEKING COMMENT ON IMPLEMENTATION OF SENATE BILL 700 AND OTHER PROGRAM MODIFICATIONS," Rulemaking 12-11-005, California Public Utilities Commission, May 30, 2019.

sponsored by the California Energy Commission (CEC) has indicated that the required solar investment should pay for itself twice over during the life of a typical 30-year mortgage.[11] Many builders who are unfamiliar with residential energy storage are about to be advising many customers who would not have considered energy storage for their new homes if absent in the new code provisions. SCE will see an uptick in information requests and interconnections.

Second, in both new and renovated homes, electrification as a household strategy creates household peak loads and peak charges during the day that residential storage can help manage. As a strategy, electrification also includes de-electrification, in the form of Public Safety Power Shutoffs (PSPS), the practice of de-energizing lines through in emergencies. SCE has supported recent statewide efforts to add a resiliency focus to the SGIP, including providing additional incentives for households in high-risk Fire Zones installing residential energy storage systems. PSPS outages are already occurring as preventative measures; they each may last for 48 hours or more. Paired with solar, 2-3 batteries targeted to critical household loads through a residential energy storage system could last that long or longer.

Third, programs that include energy storage such as SGIP, the PRP, and other experiments (e.g., Fontana, Irvine, and Mosaic Gardens) have the potential to directly impact the design of SCE's residential customer experiences. From new construction to emergency service to day-to-day living, residential energy storage could impact customer satisfaction with SCE. The customer experiences of major SCE initiatives such as electric transportation can be enhanced by residential energy storage. SCE is in the process of defining the journeys for its residential customers through evaluating, acquiring, installing, operating, and maintaining residential storage.

Fourth, and perhaps most important for many customers, residential energy storage can be a defining factor in how well households do when they convert from older SCE rates to the new SCE TOU rates. SCE rates influence the residential energy storage value proposition for customers, and vice versa. Right now, the impacts are mixed. Below, we discuss the transition to these new rates in some detail.

1.3 Changing Solar and Storage Economics

In this section, it is explained how the residential energy storage market is growing beyond its initial fringe customers to a much larger set of early adopters. Though the initial fringe customers buy what they want, the early adopters usually require some sort of value proposition. To understand the value of storage and its economics, it is important to understand solar.

Utility customers have long been wary of being served by monopolies, and with some skepticism, these utility customers have relied on regulators to establish utilities' terms of service, including rates. Customers believe they should pay fair, cost-based rates for the services they receive, even if the services they receive are unusual, and not required for every customer.

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[11] However, the median residence for Los Angeles homeowners is 14.4 years, and residential energy storage systems are only warrantied for 10-15 years. Achieving positive investment returns for the first owner of a new home may occur in many cases, but not by any means in all of them. ValuePenguin, June 2018, "How Long do Homeowners Stay In Their Homes?", https://www.valuepenguin.com/how-long-homeowners-stay-in-their-homes#nogo

Occasionally, utilities also seek services from their customers, such as demand response load reduction, and renewable energy provision under net energy metering (NEM). In these instances, customers believe they should receive fair, market-based prices for the services they provide, even if the services they provide are unusual, and not provided by every customer. Challenges arise when technologies and markets change e.g., when solar energy arises.

The adopters of residential solar systems generally assume they can get paid an equitable price for generating more energy than they use. The NEM tariffs were created to benefit both the customer and the serving utility. So, the revenues from exporting power to the grid were very important to both customers and SCE.

But a combination of air conditioning use and changes in SCE's resource mix has been shifting SCE's cost of service from summer weekday peaks into the late afternoon and early evening, when gas power plants ramp up as solar is less available[12]. Like other utilities, SCE now finds itself with increasing quantities of mistimed energy. Solar energy isn't dispatchable and grid balancing isn't simple, so some utilities have excess energy available early on some afternoons, and they must pay others to take it. California has experienced negative wholesale energy prices and renewables curtailment. Afternoon solar energy that replaced dispatchable gas generation has proven to be a mixed blessing for utilities.

Furthermore, as cheaper and cheaper renewable resources were bid into SCE contracts, prices fell, and midday supply from residential solar arrays became less valuable. Because of this, SCE's solar customers weren't helping to supply energy when it was needed. Clearly, SCE needed to revise residential rates and NEM rules to reflect how solar innovation had changed its energy markets.

Today, SCE's new residential time-of-use (TOU) rates better reflect the utility's time-based value of electricity, as they continue to incent load shift away from peaks. The new TOU rates have prices differing on weekdays and weekends; summer and winter; and across the day, evening and night. SCE now has two basic residential TOU rates, one based on a 4-9 PM evening peak, and another based on a 5-8 PM evening peak. These new residential TOU rates may reflect SCE's current circumstances and priorities, but in doing so, they have impacted the residential solar value proposition.

Simply put, exporting midday is worth much less than it once was. It's harder to help pay for a solar system by serving the electric load of other households.[13] Furthermore, solar customers

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[12] Under commercial real-time pricing (RTP) rates, designed to signal market prices, energy storage can save many commercial customers thousands of dollars per month. SCE's new commercial RTP tariff posted March 1 shows its largest peaks in extremely hot summer weekday prices (hourly Utility-Retained Generation rate, $/kWh):

- 9 AM: 0.06
- Noon: 0.55
- 5 PM: 3.17
- 9 PM: 1.15
- Midnight: 0.06

See GS-2-RTP (real time pricing) for customers using <= 200 kW: **https://www1.sce.com/NR/sc3/tm2/pdf/CE331.pdf**

[13] The new rates also complicate the business propositions for firms that own residential PV systems, and the households that lease the systems from them.

(like all residential customers) now pay more for electricity during the early evening peaks, when solar systems do not fully support household loads. Even though NEM 2.0 and SCE's TOU rates still credit energy export at a retail rate, a solar system doesn't pay as much of the household electric bill as it used to. Of course, for those households who value energy efficiency, conservation, and greenhouse gas reduction, solar is still valuable for its own sake, and as a lifestyle choice, even though electric bills have gone up.

What's a customer to do? For a few farsighted customers with older solar systems (installed under NEM 1.0 before July 1, 2017) NEM provisions are grandfathered. These systems benefit from remaining on full retail-value net metering[14]. For SCE customers who missed that deadline but still install solar systems before the new TOU rates come into effect, NEM 2.0 applies, and offers limited grandfathering of TOU rate periods for five years from their permission to operate, up to July 31, 2022. In addition to paying more fees, these customers will move to a new TOU rate when their grandfathering expires. For customers who install solar after the new TOU rates come into effect, one of the new rates will apply.

All in all, because the production of solar energy has increased, and the costs of production have fallen, the prices of solar energy have fallen. The value of midday solar energy has fallen most of all. The new TOU rates reflect these changes, so the output of residential solar systems is generally less valuable than it once was.

However, these challenges for solar energy have greatly increased the potential value of energy storage, both for SCE and its customers. Solar and storage together now prove to be worth more together than either would be on its own. Residential energy storage can collect intermittent, non-dispatchable residential solar energy during midday peak production, when the energy isn't needed. Residential energy storage can supply continuous, dispatchable residential solar energy during early evenings, when it is most needed. Once again, customers and utilities can both benefit.

For customers, solar+storage is a larger investment than solar alone, but the new residential economics of solar+storage can be better than those of solar on its own. Residential storage can provide revenues from the time value of electricity under properly designed TOU rates. Energy from the afternoons could help in the evenings, either for use in the household or for export to the grid. Early SolarCity, Tesla, and SCE tests had suggested that residential solar+storage systems might be feasible. Today, in these new market circumstances, residential solar+storage is not only feasible, it is valuable as well. The cases for converting older solar systems to solar+storage is more complex, but many are also positive.

Early in 2019, with SCE's support, the CPUC explicitly approved energy storage as eligible for export credit[15], so long as the storage system has the proper inverter communications and controls to manage export, charges entirely from solar, and can demonstrate that it has done

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[14] In marketing materials, SCE has encouraged NEM 1.0 customers to switch to one of the new TOU rates. Installers called out SCE for making this suggestion and urged solar customers to avoid the new rates. Run on Sun Monthly Newsletter, February 2018, Vol. 9, No. 2.

[15] Rulemaking (R.) 14-07-002 *DECISION GRANTING PETITION FOR MODIFICATION OF DECISION 14-05-033 REGARDING STORAGE DEVICES PAIRED WITH NET ENERGY METERING GENERATING FACILITIES*

so[16]. One of the new SCE TOU rates, the TOU-D-PRIME rate, has been designed for these purposes.

The TOU-D-PRIME rate is only available to those residential customers who own or lease an electric or hybrid vehicle, or an electric heat pump, or a residential battery. The TOU-D-PRIME rate is based on a 4-9 PM peak and offers a peak/off-peak differential of 24-cents/kWh in the summer and 21-cents/kWh in the winter, seven days a week. Under the TOU-D-PRIME rate, residential storage can charge entirely from solar until 4 PM on off-peak rates, remaining compliant with Investment Tax Credit and SGIP rules. The storage can then discharge directly into the 4-9 PM peak, aiding ramping and benefiting from the higher rates.

Initial analysis confirms that solar customers on the TOU-D-PRIME rate benefit from adding energy storage.[17]

Solar economics are experiencing more and more challenges, in addition to changes in utility demand. Solar systems costs have fallen 34% in the last five years, but costs are now leveling out. In 2020 the federal solar investment tax credit begins to step down from 30%, and lapses entirely in 2022. Meanwhile, costs have fallen 70% for Li-ion batteries in the last five years and continue to decline. California SGIP state rebates for residential energy storage have now been extended through 2025, by the so-called "Million Solar Roofs of Energy Storage" bill, SB 700, signed late in 2018, by Governor Jerry Brown. California now aims to move from 176 MW of behind-the-meter energy storage to over 3,000 MW by 2025.

Market changes have made residential energy storage more important to solar, and more important to SCE, than it ever was before. As noted earlier residential energy storage is also key to the new California Building Code provisions, has a role in SCE's customer experience, and may have a role in SCE's electrification strategy. These considerations increase the value of residential energy storage systems, and the value will continue to increase as:

- the systems perform better (e.g., much longer at higher capacity)
- power at certain times of day becomes much more valuable (i.e., expensive)
- grid outage increased in frequency and duration
- rebates, incentives, and credits increase

more households discover and cultivate related values (e.g., energy independence, the security of backup power), and attribute these values to residential storage.

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16 As Adam Gerza of Energy Toolbase noted, "this decision will likely drive more demand for retrofitting ESS to existing solar systems for residential customers, once they lose their grandfathering protections and are forced onto the new TOU rates." https://www.energytoolbase.com/newsroom/PolicyUpdates/cpuc-approves-energy-storage-net-metering.

17 "A Historic Moment for Residential Energy Storage Economics: California's new Time-of-Use Rates", by Adam Gerza, Energy Toolbase, 3/28/2019: https://www.energytoolbase.com/newsroom/Blog/. The model assumed a Santa Ana customer using 12,000 kWh/year with an annual utility bill of $2,549. The model suggested a 7 kW DC residential solar system would cost $21,000 all-in and installed (utilizing the ITC), and would generate utility bill savings of $1,492 annually. The solar project pays for itself in 9.0 years. Adding an 8.3 kWh LGChem RESU10H residential storage system would cost $11,000 all-in and installed (utilizing the ITC and SGIP), and ***assuming only local TOU arbitrage mode with no grid export***, would generate utility bill savings of $2,131 annually. The storage project pays for itself in 8.5 years. The advantages of solar+storage as an investment over solar alone arose in all cases across a 3-8 kW range of solar systems.

SCE's plans and strategies for residential energy storage will depend on some combination of these changes coming to pass. We note SCE is in control of few of these changes, but SCE can influence all of them. To understand how, we will review the products, players and markets for residential energy storage in California.

2 THE SUPPLIERS AND THEIR PRODUCTS

We discuss residential energy storage as it is deploying in Southern California. We focus our attention on the market-leading systems and components, and we mention a few others.

Residential energy storage has less standardization around components and product models than most fast-growing markets moving across early adopters to the mainstream. If the category grows, it will be on the basis of more standardization. At present, preemptive designs aren't in evidence, and the list of leading vendors is subject to change. In such a young fringe market, where economics are dubious and performance varies, a single innovation could lead an entrant or also-ran to become dominant.

2.1 Key Components of a Standard System

Residential energy storage systems include three key components: secondary batteries, inverters, and battery energy control systems. These components are on separate innovation and development tracks in the industry and are combined only in system manufacturing. The individual capabilities and performance of these components determine the value of a system, and the system's prospects in the market.

Secondary Batteries

Batteries are essentially packaged chemical reactions, and as such are more high-maintenance than most of the products deployed throughout the electric grid. As meter experts know, individual batteries vary in performance, lifetimes, and failure modes; battery operations can be difficult to sense properly; and the costs of replacing batteries can add up. In residential energy storage today these challenges are managed, but not solved.

Battery performance, lifetime, and failure modes are inherently difficult to predict. Secondary (rechargeable) batteries are based on the conversion of electrical energy into chemical energy (charging) and the reverse (discharging), as electrons are exchanged, electrode to electrode. Charging and discharging may take place at different rates, and for different periods of time. As they age, batteries lose capacity, and have lower capacity limits (termed State of Health, or SoH) for charging. The actual level of charge in a battery is referred to as State of Charge, or SoC, and is a percentage.

Battery capacity is primarily determined by energy density and power density, which relate to battery chemistries. Both battery chemistry and battery design also influence energy efficiency, life-cycle tolerance, the SoC operating window, and temperature range tolerance. As a result, battery capacity can be difficult to anticipate. Furthermore, the dynamic nature of battery chemistry can occur at different places within individual batteries, so sensors can be misleading.

While battery design has greatly improved in recent years (e.g., more efficiency through closer electrodes), pushing batteries to their limits is still a failure concern. For example, the recommended SoC is still generally 20-90% for Li-ion batteries. High-temperature operation will reduce battery life expectancy, while low temperature operation reduces efficiency. For typical batteries, experience with power electronics and auxiliary systems suggests 90% efficiency for charging and discharging, with 3,000-14,000 full cycles completed across lifetimes of 12.5-20 years. Better cell quality and oversizing can both help reduce aging, but deeper cycling will result in faster aging.

Secondary battery manufacturers provide 1-2 year warranties, and also sell 5 and 10 year (SGIP-compliant) extended warranties. The manufacturers prefer to warranty throughput (energy production) over a certain number of years, with restrictions on cycling levels temperature of operation, and the state of charge range. Such data is available from the systems and provides for warranty claims. But data or no data, batteries may fail suddenly, and the costs of replacement will vary depending on backup availability, replacement availability, access, and workforce skills.

It might seem that more progress should have been made in improving secondary batteries, but we must keep in mind that the technology is still relatively new, and many chemistries have been commercialized. The lithium-ion (LI-ion) battery was invented and commercialized in the 1980s[18], and the lithium cobalt oxide ($LiCoO_2$), cell became the base case for a variety of batteries distinguished by the different transition metals (e.g., Mg, Fe, Co, Ni) used in their cathodes, and their different cell shapes and sizes.

Sony introduced the Li-ion cellphone battery in 1991, which led to large-scale Li-ion battery manufacturing for consumer electronics[19]. Meanwhile, the California Air Resources Board (CARB) pushed the auto industry toward electric vehicles in the 1990s, but the automakers fought back, and commercial Li-ion batteries seemed decades away. It took the announcement of the Tesla *Roadster* in 2004 to convince major automakers to recommit to Li-ion development. In 2015, the Tesla *Powerwall* debuted, announcing the residential energy storage market we know today.

Today, the residential storage battery market is led by a range of chemistries: lithium nickel manganese cobalt oxide (NMC - $LiNi_{1/2}Mn_{1/2}CoO_4$) used by Panasonic (Tesla), LG Chem, and Pika; lithium iron phosphate (LFP - $LiFePO_4$) used by SimpliPhi, Sonnen and Enphase; lithium-ion manganese oxide (LMO - $LiMn_2O_4$) used by NantEnergy; and lithium nickel cobalt aluminum oxide (NCA - $LINiCoAlO_2$) used by TrinaBESS. Lead-acid alternatives are still in use, especially for backup power in remote locations e.g., the Pika Absorbent Glass Mat (AGM) *Coral Smart Battery*™).

Even when properly used in good designs, all the major lithium chemistries involve tradeoffs. NMC is relatively inexpensive and reliable, and excels on specific energy, but includes cobalt, so it can be risky (e.g., thermal runaway, conflict-nation sourcing). NCA offers higher capacity, power, and lifespan, but is expensive and includes the risks of cobalt. LFP offers safety (it lacks cobalt) and a reasonably-long life, but it has lower specific energy, lower energy density, high levels of self-discharge, and is too slow for fast-response frequency management. LMO offers fast charging and discharging, and high power, but has lower capacity. NMC and LFP dominate the market.

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[18] John Goodenough (Oxford University) and M. Stanley Whittingham (Exxon) pioneered the concept, that reached the market through the efforts of researchers and engineers from Exxon, Asahi Kasei, Sony, and others.

[19] Murata Manufacturing acquired Sony's battery business in 2017, ending an era.

Alternative battery technologies under test today include Aquion Energy's sodium-based Aqueous Hybrid Ion™ *Aspen* batteries, the Eos Energy zinc-air *Zynth*® aqueous battery, the Seeo lithium batteries with its non-flammable polymer Dry-Lyte™ electrolyte, the Sakti3 solid-state technology (acquired by Dyson), and the Sila Nanotechnologies silicon-based chemistry. Other promising chemistries moving toward secondary battery commercialization include Lithium-Sulfur, magnesium, and nickel-iron formulations.

The leading suppliers of residential energy storage systems source their secondary batteries from different sources. Tesla has allied with Panasonic and employs Panasonic batteries manufactured at Tesla's factories. Pika also uses Panasonic batteries. LG Chem uses their own batteries and provides them for Sunrun. Sonnen sources Murata batteries. Enphase sources from ELIIY Power. Some systems are completely integrated (e.g., Pika, Sonnen), and some are assemblies (e.g., Tesla, LG Chem).

These relationships may change as global battery manufacturing scales up, and new capital flows into the industry. Li-ion battery supply is expected to remain tight through next year, with much new capacity arriving throughout 2020. China-based Contemporary Amperex Technology (CATL), BYD, Envision Energy, Funeng Technologies, China Aviation Lithium Battery (CALB) and Lishen Battery are building new gigafactories at home and overseas. LG Chem, Samsung, SK Innovation, and Panasonic are investing similarly. Residential energy storage will benefit from these investments as newer and better batteries are introduced, especially when solid-state battery technology becomes commercial. But these developments across the decades to come will also make current residential systems obsolete.

The differences in battery chemistry and design indicate that homeowners are installing a range of quite different batteries. Different batteries from different manufacturers will perform differently. Furthermore, batteries are also continually improving in both chemistry and design. This year's battery will perform differently from last year's battery. Finally, and most important, residential energy storage systems are assembled electrochemical products installed, used and maintained differently by their owners, and located in different conditions. Batteries from the same product batch will differ. Not all cycling is the same. No one battery is asked to perform like any other battery.

These differences in battery performance are magnified by differences in the performance of software, electronics, and other components of residential energy storage appliances. The net result is that the owners of these systems can't be sure of the productivity and lifetime of their appliances -- and neither can anyone else (including utilities).

As in the case of other appliances, warranties provide benchmarks, and some products have been tested in laboratories by third parties. But unlike other appliances, residential energy storage systems are new, with very little operating history. The operating routines for these appliances to provide value to homeowners, the grid, or the climate aren't yet well-defined. The tradeoffs between initial price, maintenance, and lifetime haven't yet been worked out in the marketplace.

Homeowners should be aware that they are installing a range of different energy storage appliances, and they should expect the performance of these devices to vary greatly. It is an irony that the performance of an appliance acquired primarily for reliable performance is still so variable.

Battery technology and batteries are an obvious candidate for competition among residential home storage systems. However, despite real differences, battery features have not yet evolved into one of the accepted terms of competition among systems providers. LG Chem has noted that their NMC cells are available, while Tesla's have not been. Tesla stresses that the Panasonic batteries they use are manufactured in the United States, and their volume gives them more experience than anyone else. Both Sonnen and SimpliPhi have touted the safety of the LFP chemistry in their batteries.

Inverters:

Residential solar and storage systems need inverters to convert the direct current (DC) power from solar panels into alternating current (AC) for household use. Inverters used with residential energy storage systems include products from ABB (used with Tesla), Delta (used with Tesla and LG Chem), Enphase (used with Tesla), Fronius (used with Tesla), KACO (Siemens), OutBack Power (EnerSys), Pika Energy, Schneider, SMA America (used with Tesla and LG Chem), SolarEdge *StorEdge* (used with Tesla and LG Chem), Sonnen, Tabuchi Electric America, and others.

Table 2-1:
Leading Inverter Suppliers to the California Residential Solar Energy Industry: 2018

Rank	Name	Market Share (%)
1	SolarEdge	29
2	Enphase Energy	15
3	SMA America	13
4	SunPower	10
5	Delta Electronics	5
6	Chint Power Systems	5
7	A Renewables	4
8	Huawei Technologies	4
9	Sungrow	2
Source: Brad Heavner, Policy Director, CALSSA		

The industry does not yet track the top ten inverter suppliers in residential energy storage, however, as shown above in Table 1, many of them are also leading inverter suppliers to the solar energy industry[20].

Most existing solar systems are unsuitable for traditional DC battery storage connection. As a result, residential storage systems have used AC-coupled inverters that store energy when called upon to do so: these expensive, inefficient, and complex systems can work, but they have losses averaging 12-14% due to conversion. Residential storage systems that charge and discharge regularly (e.g., to manage under TOU rates), function better with a DC-coupling system that has a single hybrid inverter managing both the solar and the storage system: these only have 8-9% conversion losses.

[20] It is beyond the scope of this report to consider IEEE 1547 and California's Rule 21 inverter standards, or to discuss the differences between solar and storage inverters. EPRI has led the industry in helping to standardize inverters, and has many insightful reports discussing inverter technology and development.

Intelligent hybrid inverters (e.g., the Pika *Islanding Inverter*), are capable of connecting to the battery bank and the grid at the same time, storing energy only when production exceeds consumption, and also offering off-grid, on-grid (exporting), grid boosting and backup modes. The intelligence of these inverters allows programming for peak load shaving, solar power consumption ahead of grid power, and power exporting schemes. Intelligent hybrid inverters are most common in Europe, Australia, and China (e.g., IMEON Energy *IMEON 9.12*, KACO (Siemens) *blueplanet*, Schneider Electric *Conext*™).

Many residential energy storage systems suppliers have offered both systems with built-in inverters, and systems compatible with inverters purchased separately and installed alongside. Installers have appreciated the alternatives. Inverter manufacturers have also offered choice, in the form of special programming features. For example, SMA's *Sunny Boy* line of storage inverters has Integrated Secure Power Supply, connecting from the battery manually into individual loads: a key function to lengthen the life of selected loads in the event of grid failure. Enphase's intelligent micro inverters support many advanced functions through their enhanced programming capabilities.[21]

Inverters have stressed simple functionality and broad compatibility to date, and many of them have been adapted from solar models, or strictly with existing solar rooftops in mind. The SolarEdge *StorEdge* inverter line has been the best example of simple, reliable inverters for residential energy storage applications. As distributed resources become more and more common, inverter performance has become more and more important, and inverter design and commissioning has become more and more complex.

Inverters are a natural feature for competition in residential storage systems, and built-in or plug-and-play intelligent hybrid inverters will change the terms of competition in the category. As battery control systems depend more on inverter capabilities, residential energy storage systems will become more integrated and intelligent.

Battery Energy Control Systems

Within a household, battery energy control systems have internal and external functions. Beyond the household, battery energy control systems have a role in larger energy management strategies.

Internally, Battery Management Systems (BMS) must monitor the health of the battery itself. The power conversion system (PCS) needs SoC data to prevent excessive charging and discharging. Multiple stacks need to perform as one. Stack connections need to be protected against voltage, current and temperature problems. Failsafe processors need to trigger switches protecting the battery if other components break down. As issues arise, performance data must be delivered to the fire control system early enough to take action.

Residential battery control systems lack the complexity of CII battery control systems that need to support renewable generation and energy storage across day-ahead and real-time market strategies. Residential energy storage systems should have basic internal controls in place, but assembled systems and customized systems may not. Many early residential energy storage

[21] With the launch of its *Ensemble* product line including *Encharge* and *Enpower* late in 2019, Enphase is looking forward to a complete home microgrid capability based on solar and storage. Pricing isn't yet finalized.

systems in Southern California arrived through a collection of novices: confident contractors, committed customers, and inexperienced inspectors. On the other hand, more modern integrated all-in-one systems have standardized internal controls across design and manufacturing, in some cases with innovative approaches (e.g., the Pika *REbus ™ DC* nanogrid, a smart 380VDC bus).

Externally in the household control systems for residential battery energy storage have much more complicated roles. In operation, the BMS must respond to household generation resources, household loads, and the householders themselves. In each of the use cases for residential energy storage, these elements must interact safely and reliably. Regulations, rates, grid requirements, household activities, household appliances and devices, occupants and the weather all change. Communications and control must be accurate, secure and private. Upgrading, maintenance, and trouble diagnostics all pose their own issues.

The challenge of continual dynamic control has loomed over home automation, demand response, and net metering for decades. Electricity reaches throughout the household, but household loads haven't been designed to communicate. Retrofitting capabilities for communications (let alone control) has been prohibitively expensive, and only provided primitive signals. Developing standards for communications and control has taken decades and is not yet complete. Residential energy storage may solve many important problems, but it only adds to the challenge of controlling residential electricity.

Energy storage system providers cannot resolve all of these external communications and control issues on their own, so they have resorted to building in software that might evolve over time. Software for utility-scale and CII installations has received the most attention, but software for use in residential installations has also advanced in the direction of home automation and smartphone control.

In thermostats, market-leading Honeywell consistently lagged innovative rivals while building established relationships with builders and contractors. Similarly, in residential energy storage, the market leaders, Tesla and LG Chem, have moved more slowly toward innovative controls than the smaller players. For example, as noted, all Pika products are managed through the patented *REbus ™ DC* nanogrid, a smart 380VDC bus that can transmit power, data, and control signals across the same wires. Generac is developing storage optimization software across its Pika and Neurio platforms and integrating the Neurio home energy monitoring and appliance monitoring software into the Pika offerings.

Sonnen *ecoLINX* interfaces across energy storage, solar panels, a mobile application, home automation software and controllable circuit breakers to manage individual household loads. The system links with utility rates and programs, weather forecasting, and emergency services. The Silicon Valley startup Energyiq, which has ambitions in Southern California but no established market channels or track record of installations, features its smartphone controls.

Beyond the household, residential battery energy control systems must help the household respond to the grid, working according to changing regulations, rates, program requirements, and grid requirements. In the United States, these applications are emerging as residential energy storage develops its role in peak management, due to NEM and TOU rates. In addition, residential energy storage systems have been nominated to provide grid services, engage in peer-to-peer transactive networks, support the growth of electric transportation, and aid the grid in the event of emergencies. The latter use case has some urgency, given California's wildfire situation, now that the CPUC will boost SGIP incentives for households threatened by fire risk.

European experience shows where Southern California may be headed. Germany has over 130,000 grid-connected residential battery storage systems installed, and over 1,100,000 homes hosting solar energy systems. Germany has pioneered the use of residential batteries to provide control reserves for ancillary services (e.g., frequency control and balancing). These services require very rapid primary response (<30 seconds), with lesser value for secondary (<5 minutes) and tertiary (<15 minutes) response. The German primary control reserves (PCRs) have been modeled[22] to be accessed continually and autonomously in 15-minute intervals, recharging the batteries in the two-hour following periods.

The German application has many requirements that control systems must enable: e.g., state of charge and availability levels during nominal and extreme conditions, with limited degrees of freedom; appropriate capacity sizing, availability confirmation, and performance testing over time as the battery ages; and confirmation of market contract terms and transactions scheduled to manage State of Charge (SoC). The application has proven feasible.

U.S. initiatives to follow the German example, and access residential energy storage for grid purposes beyond the household, encounter two problems. First, the residential energy storage resources available in the U.S. are small and widely distributed. These resources have great impacts on individual households, but a small impact on overall grid operations. At current scale, even in locations where residential energy storage resources are concentrated, it's not yet clear how these resources could best help the grid. Second, residential energy storage installations are in place in few U.S. households. Investing in policies or programs specifically targeted to residential energy storage can't be expected to directly benefit many customers and will be less valuable than many other investments.

However, the suppliers of residential energy storage systems are greatly motivated to add value to their installations through enabling these grid-related services. As demand response has shown, households will participate in well-designed programs, and most households will enjoy participating. Most important, environmental threats such as fires and floods have intense local impacts, and the ability of even a single household to remain energized might turn out to be critical. Local outages might offer milder opportunities to similarly add value. Local voltage issues might even be positively addressed. The value for residential energy storage beyond the household is focused near the household, in unusual conditions. It remains to be discovered how households hosting residential energy storage systems can be compensated for these services.

Battery energy control systems will be a major area of competition for residential energy storage systems suppliers in the years to come. As customers become more interested in system economics, use cases will become better defined, and will be built around settings, testing, and the savings software can trigger. Furthermore, battery energy control systems will be crucial to the customer experience, to confirm these savings and help customers develop valuable habits.

Batteries, inverters, and control systems differentiate both the custom systems developers create, and the standard residential energy storage systems leading the Southern California

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[22] 'Fundamentals of Using Battery Energy Storage Systems to Provide Primary Control Reserves in Germany," by Alexander Zeh et al, Batteries 2016, 2, 29, doi:10.3990/batteries2030029.

market. We now briefly profile these leading systems, noting that new entries could leap to this list at any time.

2.2 Tesla Powerwall

In March, 2019 Elon Musk claimed that 2019 was "definitely going to be the year of the solar roof and *Powerwall*."[23] In late April, 2019 Musk claimed 5-10% of Tesla's battery cell production would soon be allocated to the firm's energy storage products (*Powerwall* and *Powerpack*), adding that he expected a 300%+ year-on-year growth for Tesla's energy storage business lines.[24] By the end of June, 2019, energy storage cell production in 2019 has climbed 30% above Q4 2018 levels, and Tesla recommitted to its larger goals. But market interviews indicate that Tesla's engineering and battery cell resources remain stressed.

2018 was a difficult year for the Tesla *Powerwall*. Product economics favored vehicles over storage systems, so almost all the 24 GwH of Tesla's Nevada Gigafactory battery cell production was routed to automobiles. Product economics also favored international markets over the United States, so any small lots left over were routed overseas. As a result, 2018 *Powerwall* supply in North America could not meet demand, and backorder delays became 6-10 months. By mid-year 2018 Tesla promised to reduce these delays to one month before the year was out, but in April 2019 some customers still reported *Powerwall* delivery waits of four months or more. All channels are still short of product.

Tesla's *Powerwall* production problems have been impacted by the uneven demand for its vehicles, which has contributed to a shortage of cash. When Tesla's auto inventories increased earlier this year, and cash reserves dwindled, Tesla and Panasonic jointly announced that expansion plans for both the Nevada and the Shanghai Gigafactories were on hold, postponing the expansion of Nevada capacity from 35 to 54 GwH. When auto demand picked up recently, Tesla translated the revenues into cash reserves, and kept a lid on capacity.

It might seem that stationary energy revenues could buffer the swings in auto sales, but Tesla's stationary energy storage target for 2019 is only 2 GWh/yr. Furthermore, this target is mostly comprised of overseas commercial, industrial, and utility-scale storage projects anticipated years in advance. Sales in stationary energy take too long to ramp up to balance volatility in auto sales, and sales in the U.S. *Powerwall* market are too small to make a difference. If Tesla had more cash, enough production could easily be allocated to such a small market, if only to avoid customer dissatisfaction, but *Powerwall* margins are narrower than other Tesla products, and the firm can't justify the allocation.

Tesla claimed to have shipped more than 3,000 Powerwalls worldwide in 2016. In 2017 and 2018, the company provided no numbers, but continued to publicize the product, and claimed to have shipped many Powerwall units to Puerto Rico, Hawaii, South Australia, and Europe. Green Mountain Power's trumpeted a residential storage program with plans for over 2,000

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[23] Elon Musk, Model Y Crossover SUV launch event quote, March 11, 2019.

[24] "Tesla Redoubles Efforts to Expand its Energy Business in 2019," by Kyle Field, 26 April 2019, https://cleantechnica.com/2019/04/26/

Powerwalls, yet interviews suggest only about 400 units have been installed, and many of the original 2,000 units were rerouted to Sunrun.

We can confirm that at least 1,455 Powerwalls were deployed under the California Self-Generation Incentive Program (SGIP) to date.25 Tesla quickly reached its SGIP limits for a single developer, but Powerwalls have been available under the SGIP through many Tesla partners. We estimate that Tesla's Powerwall shipment numbers in North America were about 4,000 units per year in 2017 and 2018.

Tesla claims that demand has been very high for the Powerwall; it is certain that interest in the product has been great. Over 56% of installers surveyed by EnergySage report Tesla is the most requested brand in residential energy storage (far ahead of LG, in second place at 32%)26. Today, some Tesla partners report little or no delays in supply while others report wait times of six months or more. There is no data available on cancelled Tesla reservations.

Consumers interested in the Powerwall can learn about it online or through word of mouth. They can buy the product through Tesla's own ex-Solar City installers and selected third parties. However, channels are limited: fewer than 12% of North American solar installers carry the Tesla Powerwall line, Tesla's short-lived Home Depot partnership has ended, and Tesla has reduced the number of its own 300+ retail stores. Builders seeking talks with Tesla about storage's potential for new residential construction under the California Building Code changes can reach out: Tesla says they will be responsive.

Tesla does not provide information about service and support issues, but among Tesla's 10,000+ Powerwall customers, there are many online reports of system problems post-installation. For example, Tesla systems off-grid in cold climates can fail to function.

Tesla's residential sales strategy remains an enigma to the industry. Certainly, Tesla's manufacturing constraints were real and remain serious, and Tesla has other serious problems in its residential businesses. The solar business has spiraled down from an industry-leading 34% market share to third-place status at 9%, and the much-delayed solar rooftop product is still struggling against regulatory barriers. Tesla may be doing its best to maintain any kind of position in North American residential markets.

Another explanation might be that Tesla knows its customers. Tesla lets its installers explain residential energy storage to curious prospects. These prospects then discover that residential energy storage systems are expensive, and they don't yet pay for themselves. Early adopters decide that it's too early; few of them ever request a solar bid including storage, and few of these solar+storage bids ever become projects. The few fringe market customers who elect to proceed are willing to wait for a Powerwall. While they are waiting, Tesla's installers wait with them, and keep reassuring the customers that the system is worth the wait. To date, Tesla doesn't try to change that dynamic.

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[25] While Tesla quickly reached its 20% developer cap for reservations in all incentive stages under the SGIP, some independent Tesla Certified Installers still have SGIP allocations available for Steps 3-5 ($4,060 – 2,900).

[26] EnergySage and the North American Board of Certified Energy Practitioners. Storage may be a showcase product for the 69% of installers who offer it today (and the 9% who say they will add storage products to their lines in 2019).

Tesla holds themselves out to the customers who are passionate about energy independence, or preparing for outages, and are ready to invest $10,000 or more into those passions. Orders arise only among the most committed and wealthy households. Tesla customers have been willing to advance deposits and endure expensive delivery delays in order to acquire systems they don't know how to use.

Tesla isn't misleading these customers; the company says that it has never marketed Powerwall to its customers on an economic basis. But Tesla isn't leading these customers either. Here's the system, Tesla seems to say, buy it if you're smart enough and cool enough to know that you should. It could be that Tesla has met the market where it is.

Is the Powerwall worth waiting for? Since their introduction, Tesla Powerwall systems have been the most popular brand installed under the California SGIP. Introduced in 2015 in an earlier, smaller version as a backup battery, the Tesla Powerwall I was undersized at 10 kWh, and noisy. In October 2016, Tesla launched the 7kW/13.5 kWh[27] Tesla Powerwall II, which has been on backorder since that time. Tesla claims the 13.5 kWh Powerwall II doesn't exceed 58 decibels while in operation.

The Powerwall II is based on at least one solid-state LI-ion Panasonic battery pack, a liquid thermal control system, an integrated inverter (which may be from SMA, SolarEdge, Fronius, Enphase, Delta, or ABB), a backup gateway, and management software. Customers also need standard electrical hardware (e.g., breaker panels, junction boxes, and conduit).

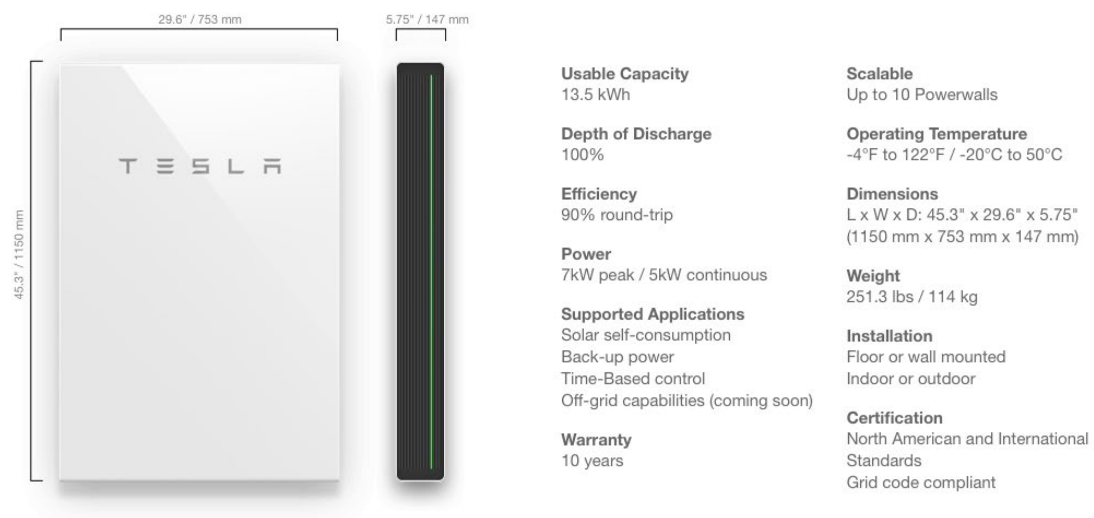

Figure 2-1:
The Tesla Powerwall

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[27] *Powerwall II* energy retention is warranted at 70% of initial energy capacity at ten years following the initial installation date. The *Powerwall* is expressly prohibited from use as primary or backup power for life-support systems. Any repair, replacement, or refund (the market price of an equivalent product at the time of claim) is at Tesla's option. The warranty is void if Internet access for software upgrades is unavailable. claims are subject to arbitration or Small Claims Court.

The list price for a single *Powerwall II* is $6,700 as of April 2019. Additional supporting hardware is also required ($1,100). Installation typically costs $2,000-8,000, independent of solar energy, and depending on electrical upgrades, permits, and fees. Thus, the installed price of a Tesla residential energy storage system with a single *Powerwall* will be $9,800-15,800 before any incentives are applied.[28]

Tesla's suggests an operating standard of 100% self-power from solar, with the capability to support normal household usage through a week-long outage. These criteria mean that multiple *Powerwalls* are indicated for most installations. For households with average daily usage more than 25 kWh (most homes over 1,200 square feet, or any home with air conditioning) Tesla advises two *Powerwalls*.

For homes averaging more than 48 kWh daily (most homes over 3,600 square feet with air conditioning) Tesla advises three *Powerwalls*. Each additional *Powerwall* adds $6,700 to the estimated cost, so a larger household using at least 66 kWh daily, and planning to use air conditioning, EV charging equipment, and a pool pump during outages, will need at least four *Powerwalls*, and will spend $30,000-36,000 on a residential energy storage system, before incentives.

Table 2-2:
***Powerwall II* Technical Specifications**

Usable capacity	13.5 kWh
Depth of discharge	100%
Efficiency	90% round-trip
Power	7kW peak/5kW continuous
Scalability	9 *Powerwalls* in one system
Dimensions	45" L x 30" W x 6" D
Weight	251 lbs.
Warranty	10 years
Estimated Cost	$600/kWh[29]

2.3 LG Chem Resu 10H

LG Chem is part of the South Korean giant LG, a global consumer products, chemicals and industrial materials conglomerate, and a leading Li-ion battery manufacturer. To date, we estimate LG Chem has supplied over 170,000 residential energy storage systems worldwide, at least 6,000 – 8,000 of these in California.

Like Tesla, LG Chem has recently suffered a crisis in its distribution channels for residential energy storage systems. Shortly after the *Resu10H* was introduced in 2017, LG Chem and other South Korean transportation suppliers diverted all of their battery semiconductor production to

[28] In comparison, according to EnergySage, "an average 5 kilowatt (kW) solar energy system costs anywhere from $8,500 to $16,000 depending upon where you live and the type of equipment you choose." https://www.energysage.com/solar/solar-energy-storage/tesla-powerwall-home-battery/. In California, most other estimates would be at the high end of that range.

[29] Cost estimates depend greatly on individual site conditions and operating assumptions. SolarPowerRocks provides general figures for simple cases in the United States. See "Should you get a home solar battery in 2019?" by Ben Zientara, https://www.solarpowerrocks.com/affordable-solar/get-home-solar-battery-2018/. Similar Australian data is reported in Clean Energy Reviews, https://www.cleanenergyreviews.info/blog/2015/11/19/complete-battery-storage-comparison-and-review.

electric vehicle production, responding to a surge in demand. Residential energy storage batteries were cut off from semiconductor supply. By the second half of 2018, LG Chem had to cease distribution of the *Resu10H* in North America. Production and distribution returned to normal in early 2019.

LG Chem claims that they simply make better batteries. The unique LG Chem flat-laminated polymer pouch design for its battery cells offers much higher energy density, with increased stability and safety due to even heat dissipation across the layered battery sections. The cells stack easily in the battery pack.

LG Chem's Safety Reinforced Separator (SRS®) also increases cell stability and safety.

Figure 2-2:
LG Chem Resu10H

Because LG Chem sees itself as a battery manufacturer first, and a system supplier second, the firm has chosen to integrate with various inverters, private label the *Resu10H* for Sunrun, and share installers with Tesla and other brands. LG Chem's partnering strategy entails many stresses. One partner, Sunrun, has kept its options open, working with Tesla and other providers from time to time.

Another LG Chem partner, SolarEdge, whose *StorEdge* inverters are a favorite of installers to combine with the LG Chem *Resu10H*, recently acquired another South Korean battery manufacturer, Kokam. Kokam has specialized in larger systems to date, but SolarEdge has refused to rule out extending the Kokam battery line to smaller systems, in the event LG Chem's distribution problems arise again.

LG Chem's systems have been easier to acquire, install, and afford than Tesla's *Powerwall* systems. However, installers report dissatisfaction with LG Chem's product reliability and customer service. One installer claims LG Chem staff advised installers to "keep the box" after installation, in case problems arose. The nature of the fringe market, Tesla's brand, and its own distribution problems have also interfered with LG Chem's progress.

It might seem that LG Chem's positioning should be favored as the market includes more and more early adopters, but the value proposition for a *Resu10H* is just as unclear as the value proposition for a *Powerwall*. In fact, as the market grows, LG Chem risks being outflanked by residential energy storage offerings with stronger designs, safer chemistry, and more sophisticated controls.

Although still 2-3X the cost of lead-acid battery backup systems, the LG Chem *Resu10H* has often been priced in the market at a discount to other Li-ion residential storage systems, and it offers a well-known brand. LG Chem systems are the second most popular brand installed under the California SGIP. LG Chem also offers a range of configurations to satisfy different situations, e.g., AC and DC-coupled residential systems with SolarEdge, Delta and other inverter brands. The LG Electronics ESS home energy management system is compatible with the *Resu10H.*

The *Resu10H* pricing is about $6,000 for the battery system and another $3,000 for the inverter. Installation typically costs $2,000 – 4,000, independent of solar energy, and depending on electrical upgrades, permits, and fees. The installed price of a *Resu10H* residential energy storage system will be $11,000 – 13,000, before incentives are applied.

Table 2-3:
***Resu10H* Technical Specifications**

Usable capacity	9.3 kWh
Depth of discharge	100%; 80% after 10 years
Efficiency	95% round-trip
Power	7kW peak/5kW continuous
Scalability	multiple combined batteries
Dimensions	36" L x 29" W x 8" D
Weight	214 lbs.
Warranty	60% of nominal discharge for 10 years
Estimated Cost	$645 - 800/kWh

2.4 Sunrun Brightbox ™

Sunrun is currently the largest solar installer in the U.S., and a Wall Street favorite, despite its $1.8 B in debt and $246 MM of cash on the books. The company buys residential solar systems and leases them to customers, and it sells customers systems over time. These systems depreciate in financial and technical value. Sunrun says solar panel costs have declined 64% since 2010 and will decline another 61% by 2030; battery costs have declined 85% since 2010 and will decline another 49% by 2030. As Sunrun's leases and contracts run out, customers will consider replacing Sunrun's older systems with much cheaper, higher-performing alternatives. Even if Sunrun achieves renewals, its revenues per household will decline substantially.

Sunrun needs to increase its revenues per household and lengthen its contracts, hence the more Sunrun can offer, the better: enter the Sunrun *Brightbox™.* Essentially a private-label version of LG Chem's popular *RESU10H* system, the *Brightbox™* is unusual in that it is a residential energy storage system that households can lease or buy. Sunrun describes their service as "solar battery storage," and claims its primary performance is to intelligently and remotely optimize savings based on proprietary software. In California, Sunrun is making every effort to include residential storage with every residential solar contract. The Sunrun *Brightbox™* service has been in the market since 2016 and is only available to Sunrun's new solar customers.

For customers who lease, Sunrun can assume responsibility for financing, installation, monitoring and maintenance. *Brightbox™* is offered as an add-on to Sunrun's *brightsave monthly* lease plan, or Sunrun's *brightsave prepaid* lease plan. For customers who buy, Sunrun can take on these responsibilities for an extra charge. *Brightbox™* is then offered as an add-on to Sunrun's *brightbuy purchase* plan, or Sunrun's *brightadvantage* monthly loan.

Potential customers are invited to contact Sunrun and learn if they "qualify" for *BrightBox™*. The service is claimed to be sized so that customers can power the key appliances and outlets they choose for over 10 hours during an outage. Sunrun also claims that *BrightBox™* customers can avoid using grid electricity when rates are highest. While these services are also offered through other residential energy storage systems, Sunrun features them.

Sunrun doesn't quote California prices, but EnergySage reports some prices elsewhere: $6,500 – 8,000 in addition to solar installation costs in New York State, but $1,000 as an introductory offer in Massachusetts under the MassSave program. The *BrightBox™* service is also available in Arizona and Hawaii.

Sunrun views the *BrightBox™* service as extending its enterprise value in several directions. First, *BrightBox™* increases Sunrun's capital at work in an individual household by extending solar to storage. With proof of concept installations in place through *BrightBox™*, Sunrun can address the potential of storage retrofit to its existing solar homes, a considerable engineering challenge. Sunrun can also anchor its customers more firmly by providing a larger value proposition.

Figure 2-3:
The Sunrun *Brightbox*

Second, *BrightBox™* enables Sunrun to offer grid services to utilities, which not only add a revenue stream, but help anchor Sunrun's installations into the grid itself. Sunrun is already working with utilities in Hawaii and the Northeast to provide basic two-hour services to perform like demand response. By controlling utility relationships, Sunrun also positions itself between the system suppliers and the utilities, which will be particularly important if more utilities elect to become system suppliers themselves. In that event, Sunrun can continue as a financial partner.

Third, *BrightBox™* makes Sunrun more capable and competitive in its traditional solar business. Sunrun has been pursuing the advantages of scale and leadership in the solar energy business for many years. Currently, Sunrun is actively seeking to lock up production builders and customer builders into its program to handle the new California Building Code provisions. By bundling storage easily with solar, and offering the builders construction options as a result, Sunrun reinforces its leadership position in solar energy.

Fourth, once *BrightBox™* is established, public market investors can mark-up Sunrun's ongoing customer base reflecting the potential for new services. Small changes in the firm's business model can add up to significant changes in expected earnings and share price. Sunrun is well-aware of the connection and has adjusted its investor presentations accordingly.

The *BrightBox™* service offers the LG Chem *RESU10H* system (see above) with Sunrun's particular marketing claims and levels of support. Because *BrightBox™* is based in turn on Sunrun's solar services, *BrightBox™* is squarely aimed at customers and channel partners who are most interested in financing, and can accept a standardized approach.

Table 2-4:
Sunrun *BrightBox™ (Resu10H)* Technical Specifications

Usable capacity	9.3 kWh
Depth of discharge	100%; 80% after 10 years
Efficiency	95% round-trip
Power	7kW peak/5kW continuous
Scalability	multiple batteries with the combiner unit
Dimensions	36" L x 29" W x 8" D
Weight	214 lbs.
Warranty	60% of nominal discharge for 10 years
Estimated Cost	$645 - 800/kWh

2.5 Pika *Harbor*

Pika Energy, headquartered in Westbrook, Maine, was founded in 2010, and initially focused on wind energy power electronics before shifting its focus to solar energy and energy storage. Pika products are currently manufactured in Maine and Massachusetts.

Pika's early innovations were its patented REbus™ DC nanogrid, a smart 380VDC bus, and its DC *Islanding Inverter™*. Pika began working with Tesla *Powerwall* systems in 2015, helping Green Mountain Power to create a solar-powered state park.

Pika partnered with Panasonic Eco Solutions to develop its *Harbor™ Smart Battery* line, which was introduced late in 2017. The line was upgraded to the *Harbor Plus™ Smart Battery* early in 2018, increasing performance while reducing prices by up to $1,700. At the same time, Pika also introduced new AC-coupled solutions to broaden its DC Pika *Energy Island*™ solar+storage line, and developed a California-compliant smart inverter communications solution, partnering with Kitu Systems and San Diego-based Sullivan Solar.

Figure 2-4:
The Pika *Harbor*

Pika Energy was acquired in early 2019 by Generac Holdings (NYSE: GNRC), a Wisconsin-based manufacturer of industrial power products and residential standby generators, with $2+ B in annual revenues, and a history of successful acquisitions. Terms were not disclosed. Earlier in the year, Generac had acquired Neurio, an energy management venture specialized in metering and home energy analytics. Generac will add Pika to its Clean Energy Solutions unit and has signaled it will continue to invest in these businesses.

The Pika *Harbor Plus ™ Smart Battery* is a Panasonic battery developed for Pika and integrated with the Pika *Islanding Inverter ™* to comprise the firm's residential "storage platform". Pika emphasizes its system flexibility: the batteries can be configured in different combinations (e.g., 8.6 kWh, 13.4 kWh, 14.3, 17.1 kWh). The larger *Harbor 6* now comprises over 50% of its installations.

As an organic system developed by MIT engineers, the Pika system has its share of unusual capabilities and features. For example, the Rebus BEacon™, which manages the inverter automatically configures to TOU rates. Pika offers remote mobile control through the Pike REview™ Dashboard. Also, Pika and Panasonic do not warranty system capacity over time but do warranty total system output at 45.36 MWh.

At present, the installed cost for the Pika *Energy Island*™ is $12,000 – 18,000 before any incentives are applied. Little supporting hardware is usually required, and installation is straightforward. Solar energy, electrical upgrades, permits, and fees are extra.

Pika claims to have over 1-2,000 systems installed nationwide, and over 100 systems installed in California to date. SCE hosts a Pika system in a Mosaic Gardens multifamily project. While Pika may have been in limited distribution before, its new parent company is known for its superb product distribution and channel management, and Pika has had none of the battery distribution issues Tesla and LG Chem have faced. Pika is looking to partner with Sunrun in Massachusetts and elsewhere, believing the market is growing quickly.

Pika's small-town, US branding coupled with its strong design and technical performance sets it as a Tesla alternative. Pika cannot yet compete on price, but Panasonic has been willing to pass on cost reductions to Pika, and Pika has passed them on to its customers. Furthermore, new performance features should emerge as improved analytics based on cooperation with Neurio are added to Pika's superior software and communications.

Table 2- 5:
***Harbor 6™ Smart Battery* Technical Specifications**

Usable capacity	17.1 kWh
Depth of discharge	84%
Efficiency	97% round-trip
Power	10.0kW peak/9.0kW continuous
Scalability	3-6 battery "modules" at once
Dimensions	68" L x 22" W x 10" D
Weight	445 lbs.
Warranty	10 years, extends to 20 years; 45.36 MWh
Estimated Cost	$960/kWh

2.6 Sonnen *Sonnen* ecoLinx

Although Sonnen is arguably the world leader in residential energy storage, and its systems have been manufactured and assembled in the United States since 2015, only a handful of the German firm's premium-priced systems have been installed in Southern California to date. Sonnen was acquired by Shell earlier this year, and its US operations remain headquartered in Atlanta.

Sonnen deliberately positions itself as the industry leader in residential energy storage, according to six criteria: a history of global leadership, product superiority, the sonnen community of customers, sonnen innovation (e.g., *ecoLinx*), philanthropy, and high-quality partners. Sonnen does have global leadership, and it could be argued that its product architecture is among the safest, most durable, and most long-lasting in the industry. In the U.S., its communities are yet to be established, its philanthropy is less well understood, and its partners are less familiar.

Since 2010 Sonnen has installed more than 35,000 *sonnenBatterie eco* systems, spanning eight product generations. The latest Sonnen introduction is the *ecoLinx* system, which arrived in late 2018 priced in the neighborhood of $22,000 for a typical 10kW system. Supporting hardware, electrical upgrades, permits, fees and installation can add another $2,000 - 8,000, independent of solar energy. Thus, the installed price of a mid-sized *sonnen ecoLinx* energy storage system will be at least $24,000 - 30,000 before any incentives are applied.

The premium *ecoLinx* pricing and design reflects a deliberate 2017 repositioning at the high end of the market, just as Tesla was cutting its prices slightly on the *Powerwall*. Targeted at custom new home construction and renovation since then, the *ecoLinx* system has found some traction in the showcase luxury projects of production homebuilders.

The *ecoLinx* customer interface is consistent with its luxury positioning. A relatively quiet system with sound output under 25 decibels, the *ecoLinx* automatically networks across Amazon's Alexa and Google Home, links with Eaton's smart circuit breakers, and is compatible with the Crestron and Control4 home automation systems.

The *ecoLinx also* offers two significant top-end performance upgrades: (1) a 15 year/15,000 cycle battery lifetime warranty, courtesy of its LFP battery technology, and (2) courtesy of improved software and power electronics , backup power kicking in after only 100 milliseconds rather than the industry-standard 30 seconds,.

In Prescott Valley, Arizona, Sonnen has partnered with Mandalay Homes and Arizona Public Services to create what it calls the Jasper sonnenCommunity, a virtual power plant (VPP) of 2,900 sonnen-equipped homes. Patterned after its European VPPs, the Jasper VPP will be the first set of what Sonnen plans to total 40,000+ new homes nationwide across the next several years.

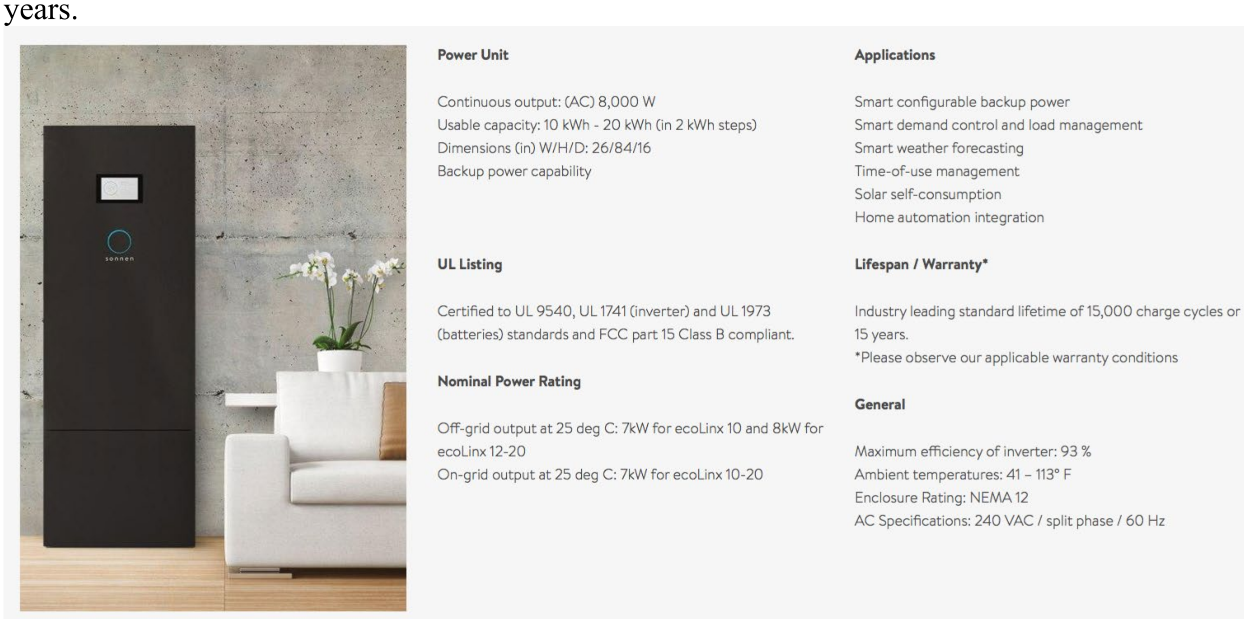

Figure 2-5:
The sonnen *ecoLinx*

Sonnen had seen several changes in senior management in the years leading up to the Shell acquisition. After the opening of its Los Angeles Sonnenbatterie center in 2014 in partnership with SK Solar USA, sales were slow in the competitive California market. A Southern California distribution deal with solar installer Sungevity and the retailer Lowe's was established just prior to Sungevity's spectacular 2017 bankruptcy and created more problems. Since then, Sonnen staff in North America have worked to establish financing relationships, but haven't found major partners, and have struggled to establish premium prices in California and Arizona.

Currently Sonnen is managed out of an operating unit, but it is one of many such smaller acquisitions Shell has been making (e.g., First Utility, MP2 Energy, New Motion, Greenlots, Limejump). Shell is investing broadly in its return to renewable energy, but the global giant is not known for setting its venture investments on a consistent course. Some ventures are managed out of a dedicated venture unit, while others are assigned to operating businesses. It is not evident how much priority North American markets will be given. Nevertheless, Sonnen's long-term bet on the upper reaches of the market is less risky with Shell's resources and brand in place.

Table 2-6:
***Sonnen ecoLinx* Technical Specifications**

Usable capacity	10-20 kWh (2 KwH battery modules) (90% of total)
Depth of discharge	100%
Efficiency	93% round-trip
Power	*7kW peak/3-8 kW continuous*
Scalability	10-20 kWh
Dimensions	84" L x 26" W x 16" D
Weight	622-900 lbs.
Warranty	15 years or 15,000 cycles
Estimated Cost	$2,450/kWh

2.7 SimpliPhi AccESS™

A small company based in Oxnard, California, SimpliPhi began by creating mobile power solutions for film and television production, and then backed into the opportunity to create environmentally friendly residential energy storage systems. Already global through its entertainment industry connections, SimpliPhi quickly became a small-scale but well-known supplier of backup power systems around the world.

Unlike the other established players in the residential energy storage system category, SimpliPhi has remained small and independent. The firm is not competing in global markets for batteries, vehicles, or energy. Its systems offer little design elegance and a rudimentary information interface. The brand is widely known, but its systems are expensive by comparison. But the SimpliPhi AccESS™ system has a reputation for safety, long life, reliability and satisfied customers.

Since 2007 the firm has offered backup generators based on LFP chemistry, which has allowed SimpliPhi products to gain the reputation for longest-life (10,000+ cycles) and best capacity retention in the industry. Recently, SimpliPhi has also strongly emphasized the relative safety of its battery chemistry, and its potential role in the California Public Safety Power Shutoff program.

The SimpliPhi AccESS™ residential energy storage system includes proprietary elements in its cell and battery architecture, power electronics, battery management system, and manufacturing methods. SimpliPhi says it designed the system with installers, to simplify design choices but preserve site adaptability.

Price quotes from installers range from $21,000 – 23,000, including the inverter but not supporting hardware, electrical upgrades, permits, fees and installation, independent of solar energy. These additional costs can add another $5,000-10,000 to a SimpliPhi system, since it usually requires custom site work. Thus, the installed price of a household-sized AccESS™ energy storage system will be in the range of $26,000 – 33,000 before incentives are applied.

There are versions of the *AccESS™* system for both Schneider and Outback inverters, AC and DC coupling, and a variety of charge controllers. Basic system performance monitoring and operating settings are built into the software. SimpliPhi asserts that their systems require no maintenance.

SimpliPhi claims that their systems are preferred for AC-coupled solar retrofits, through a combination of installer care in installation and battery robustness.

Figure 2-6:
SimpliPhi *AccESS*

In 2010, SimpliPhi expanded into Optimized Energy storage offerings, and custom residential systems (e.g., a 21-kWh system in Palos Verdes, a 11 kWh system in Miami, a 163 kWh battery bank for a New York State ZNE residence). SimpliPhi's premium prices and small installer network have limited growth, but the firm has established an extensive training and certification program.

Table 2- 7:
SimpliPhi *AccESS™* Technical Specifications

Usable capacity	14 kWh
Depth of discharge	up to 100% (80% recommended)
Efficiency	92% round-trip
Power	6.8kW peak
Scalability	four PHI 3.5 kWh batteries
Dimensions	76" L x 30" W x 20" D
Weight	600 lbs.
Warranty	10 years/10,000 cycles
Estimated Cost	$700 - 857/kWh

2.8 Others

Because the market for residential energy storage systems is still young, and the value propositions are marginal, the market is still open, both to familiar names and new entrants. The leaders discussed above have challengers. We note several of the more notable ones here. There are also a number of other firms with relevant positions in European markets who have the resources and energy storage expertise to enter the North American markets. We list many of them below.

Sunverge

A market leader in residential energy storage from its 2009 launch, Sunverge boasted an array of investors including AGL, Mitsui, Kokam, Siemens, and Softbank China VC. By 2013 the firm's flagship product was the *Sunverge One™*, a 500+ lb. assembly of Kokam and other batteries, various power electronics, and proprietary software that required installation by Sunverge specialists.

Over 1,000 of the DC and AC-coupled *Sunverge One* system were installed worldwide, many in utility pilot projects (e.g., at SMUD, AGL, Arizona Public Service, Alectra, the Glasgow Electric Plant Board, PowerStream, Puget Sound Energy, and Xcel). Sunverge, having long ago proclaimed itself "utility-centric", continues to win bids for these pilots, including a recent award Consumers Energy, and an award from Con Edison that replaces a project cancelled several years ago.

Sunverge's early dominance among utilities didn't translate into substantial revenues. In 2017 several Sunverge projects were postponed or scaled back as a result of independent utility decisions. The direct-to-consumer channel was emerging on its own, and utilities reconsidered whether or not to own residential energy storage systems. Overextended, Sunverge suffered a financial crisis, laid-off staff, and reduced manufacturing. Today Sunverge specializes in supplying software and services (e.g., the *Sunverge Energy Platform*).

Swell Energy

Given its formal relationship with SCE, Swell Energy would nominate itself as a future market leader. Launched in 2016 offering generous financing to its customers, Swell Energy has faced major challenges. Its initial SCE contract took a long time to complete, and *Powerwall* delays have been costly. Management's history with Tesla didn't speed *Powerwall* deliveries, and relationships with LG Chem and Sonnen haven't progressed. Resources have been limited: the field sales force is small, the company's blog is outdated, and outreach to new home builders is rare. Swell Energy has shallow ties to the solar industry, a deep dependence on Tesla and SCE for brand pull, and a short history as a company.

Swell Energy has committed to deliver 7,000+ homes to SCE, but since 2016, has only provided systems to a few hundred customers. There are another ~1,000 signed-up households awaiting delivery on their *Powerwall* reservations, according to the firm, but it is unclear how many of these commitments will cancel. The entire fleet of assets was to have been in place and operational by mid-2019, so the project is behind schedule. Swell has only recently contracted with Autogrid to supply the software necessary for managing the fleet of residential assets, and the software is not yet installed and tested. While there may be few consequences from falling behind its schedule with SCE, unlike its rivals, Swell Energy has no other lines of business to support the firm as it tries to move ahead.

Nevertheless, management is confident that business is about to accelerate. Management notes *Powerwalls* are available again. Fires and new utility rates are causing customers to investigate residential energy storage. The SGIP has been renewed. A long-delayed seed financing round is nearing completion and will underwrite Swell's new customer financing program. While few of these resources are unique to Swell Energy, and management is aware that Swell's rivals are larger, more experienced, and closer to the construction community, the company believes its models for targeting prospects (1 in every 40 households qualifies), and serving customers are superior[30].

SunPower (Total)

SunPower is one of the largest residential solar panel manufacturers and leasing companies in the U.S., with more than 236,000 customers. In 2015 CEO Tom Werner predicted that lithium-ion batteries combined with solar power would inaugurate a new era of control and cost management for commercial customers. Since then, SunPower has led the commercial segment in both solar and energy storage solutions. SunPower is majority-owned by Total, one of the world's largest and most ambitious energy companies. In a related move, Total recently acquired French global battery leader Saft.

Despite Total's ambitions, SunPower has been thoughtful about its approach to energy storage. In order to offer households a choice for "solar storage batteries," in 2018 SunPower "handpicked" Tesla and Sonnen as partners, citing IHS Markit research predicting that the residential energy storage market will grow fourfold by 2022. More quietly, SunPower has been working with Tendril (now merging with Simple Energy to form Uplight) to address energy storage data and control requirements.

In its *Bottle the Sun®* residential marketing campaign, SunPower cites the advantages energy storage provides, and offers tools for households to see if "solar+storage is a good fit." Its solar salespeople are ready to add storage to any solar bid in California or elsewhere. The SunPower positioning (i.e., bottle the sun, enjoy peace of mind, take control of your monthly bill, be prepared for anything) speaks directly to consumer benefits. SunPower has thought through use cases (e.g., outage management, EV powering), and has conducted its own research with 18 leading residential Californian homebuilders about the upcoming building code changes.

Although SunPower has the product design and manufacturing experience to extend itself into energy storage, the firm has to be careful about product lines due to financial stresses. SunPower continues to develop premium-quality and premium-priced solar cells and panels, but in 2018 it sold its line of microinverters to Enphase, and so far, SunPower has declined to enter the residential energy storage market. For SunPower, solar+storage extends its *Equinox*™ residential solar system, and its new *A-series* line of solar panels, through "compatibility" between its products and those from Tesla and Sonnen.

Other Entrants

Other market entrants in North America include solar, battery, inverter, and electric vehicle firms extending their reach:

- Sunnova Energy now offers its *SunSafe*™ EasyOwn 25-year solar+storage warranties to solar homes across the California IOUs, including both Sunnova and non-Sunnova systems. With

[30] Swell's approach to customer targeting is professional, but it does not lead the industry. To address similar customer targeting challenges, Sunrun employs Google, as well as Google's latest data-analytics acquisition, Looker, to inform its algorithms.

65,000+ customers, the fourth-largest solar energy provider in the U.S. introduced *SunSafe*™ solar+storage in late 2018, featuring Panasonic batteries.

- In 2017, Vivint Solar, currently the second-largest solar installer, announced a joint venture with Mercedes Benz to develop a residential energy storage system reaching across EV and smart home capabilities: in 2018, when Mercedes Benz exited the market, Vivint quickly partnered with LG Chem for its solar+storage offering.

- Enphase has recently launched its *Ensemble* solar+storage line; the firm's 1.2 kWh Enphase *Storage System*, designed specifically to increase self-supply and use of solar, continues to gain traction overseas. Enphase also has a scalable AC battery designed for use with residential storage and its inverter line.

- The Palo Alto venture ElectrIQ has introduced a 10kWh system including an inverter and a handheld mobile control system, but the venture has had manufacturing challenges.

- Toronto-based Eguana Technologies expanded from power electronics, inverters, and controls into its commercial *Elevate* and its residential *Evolve Energy* Storage System lines. *Evolve,* a 5 kW/6.5 kWh wall-mounted system based on Eguana's proprietary controls and LG Chem batteries, has few installations. Eguana also developed a home battery system for the short-lived Mercedes-Benz storage venture. Eguana has been short of capital for some time.

- Blue Planet Energy's *Blue Ion* LFP system has had some success in Hawaii and in the San Francisco multifamily Sol-Lux-Alpha Passive House apartment building.

- The 4.2 kWh Nissan *XStorage* has been sold overseas, and the company has reviewed residential markets in North America, but Nissan has also denounced residential energy storage as inferior to vehicle-to-grid (V2G) and vehicle-to-home (V2H) applications based on its notably long-lived EV batteries.

- Adara Power (once known as Juice Box) still offers its 20 kWh residential system in California, which includes its Adara *Pulse* smart controller sitting atop a LG Chem RESU10 battery and a Schneider *Conext XW+* inverter; but the firm has discontinued its 8.6 kWh and 17.2 kWh systems, and is concentrating on larger-scale markets.

- Enel X has experimented in California, linking 6,000 residential and commercial JuiceBox EV chargers via Enel's JuiceNet cloud software to create a CAISO-linked 30 MW/70 MwH storage asset to balance day-ahead and real-time markets.

- Fresh off a $5 MM Initial Public Offering (IPO) in May, NeoVolta has introduced the NV 14, a residential home storage system powered by a 14.4 kWh LFP battery, monitored 24/7 via a "web-based energy management system." Now developing its distribution network, NeoVolta says it has capacity in its San Diego manufacturing plant for 10,000+ units annually.

- In 2017, the Northern Pacific Group (NPG) acquired the assets of bankrupt Sungevity, the California-based designer, financier, and installer of residential solar systems. Under the Sungevity brand NPG then acquired Southern California installer Horizon Solar Power, and two small Hawaiian firms with expertise in solar+storage, Energy Connection and E-Gear, aiming to provide solar+storage nationwide.

A number of initiatives overseas in residential energy storage have could impact residential energy storage in the United States:

- BMW investigated entering the North American market with Solar City, and later proposed using its 22 kWh and 33kWh *i3* EV batteries redeployed in residential energy storage systems, based on successful deployment of used *Mini E* batteries in a University of California – San Diego microgrid, and a PG & E pilot. Since 2018, BMW has been focused on V2G work in PG &E's EPIC *ChargeForward* program.

- The Siemens *Junelight Smart Battery* has been trialed in Austria and Germany: the system scales in 3.3 kWh modular units up to 19.8 kWh, takes account of local weather forecasts, and can be controlled by a mobile smart app.

- The 6 kWh *Powervault 3* is an inexpensive UK system of some technical note. EDF is now backing Powervault.

- In 2017, EDF and Lightsource Labs researchers partnered to create Sunplug, consumer software combining solar+storage and energy management. In 2018, BP invested in what became Lightsource BP, and acquired Ubiworx, the technical contractor behind most of the Sunplug work.

- In 2017, retailer IKEA teamed with Solarcentury, LG Chem and Sonnen to offer a residential solar+storage package in the United Kingdom.

- In Germany, inverter manufacturer Huawei created the *FusionHome* smart energy solution to combine residential solar with the management of household appliances. The system included a DC-coupling storage interface for retrofitting batteries.

- German utility subsidiary E.On Solar and Storage has supplied and financed residential solar+storage systems to customers in the U.K., Germany, and Sweden since 2017. The firm has yet to come to North America.

- German solar leader Solarwatt markets its solar+storage systems across Europe and Australia, but also has yet to come to North America.

The diverse and volatile range of aspirants in residential home energy storage indicates that the market remains young and speculative.
We have profiled the leaders supplying systems to Southern California's residential energy storage market. The roster going forward includes Tesla, LG Chem, Sunrun, Pika, Sonnen, and SimpliPhi. Sunverge, Swell Energy, and SunPower would also expect to be considered. Literally dozens of other players have the potential to package systems together and offer them, or to wait for new technology to transform the market. In the meantime, we emphasize that despite Elon Musk's rhetoric, Southern California's residential energy storage market is not driven by

suppliers alone. Customers, builders, installers, regulators, and utilities all have significant roles to play. We now describe these other market players.

2.9 Other Market players

Customers

We discussed suppliers first in order to describe their products, but customers and their demands are equally fundamental in any market, including residential energy storage. Customers determine the nature, level, intensity, and dynamics of demand, and do so on a young market under a number of influences. Suppliers market to customers, installers plan with customers, regulators speak for customers, utilities influence the value proposition for customers, and customers communicate among themselves. Customers decide what to buy and when to buy it, but their purchasing decisions are affected by many interactions.

Our assignment was conducted without the voices of SCE residential energy storage customers. In order to profile the overall market, we relied instead on what other industry players and observers could tell us about these customers. We have also called upon our own extensive research among the customers of new energy products, services, and programs.31

Installers report that customers for residential energy storage have generally been wealthier homeowners who already have solar on the roofs of their single-family homes. Their homes tend to be larger than average. These customers are more concerned about power outages than most households. Some of them live in remote areas. Our research would indicate that these customers are more likely to own an electric vehicle or be intending to buy an electric vehicle than other households. They are comfortable with technology. They like to have "things"; some of their things they lease, and some they buy. Some of them understand their electric bills. And in almost every case, these customers' choices to acquire residential energy storage are based more on principles than economics.

The "principle of the thing" is generally what's most important to the first customers in a young fringe market. These first customers have enough money to get what they want. They are innovative and demanding. They try things. They create fads. They like to know things other people don't know, and do things other people don't do, and often, being among the first matters a great deal to them. They generally know who they think they are, and they can identify goods and services that suit them. In fact, they identify with the goods and services they select, and they feel their lives are larger for it. The first customers for residential energy storage weren't comparison shopping. They were aspiring.

These early fringe customers are iconoclastic and particular. Many of them would identify with Elon Musk, because when Musk didn't see what he wanted, he decided to build it himself. These first customers aren't merely innovative and unconventional. When permitted, they are antagonistic and hostile to convention, choosing differently simply because they can literally make a difference. These fringe customers arise across the spectrum of traditional

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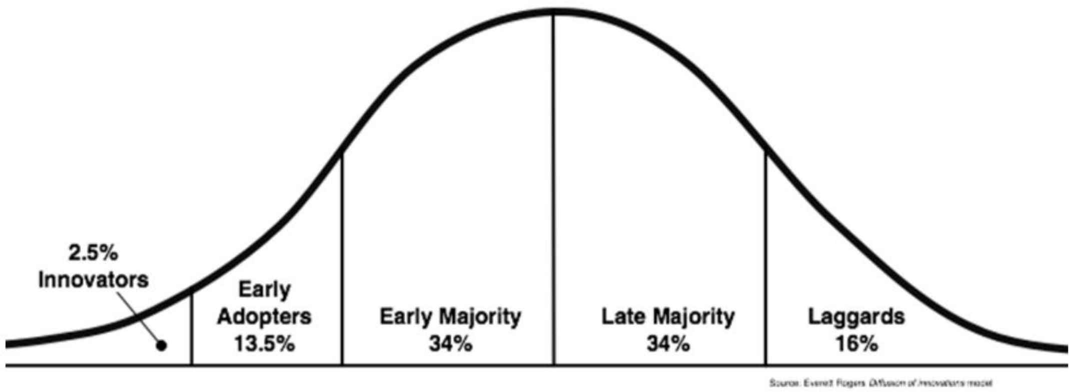
[31] Our work among residential customers in California, Oregon, Washington, Nevada, and Arizona across the last three decades has included more than thirty focus groups, over one hundred in-home interviews, and over ten thousand survey responses. Several assignments were in SCE franchise territory.

demographics, e.g., age, sex, family structure, income, politics, size of home, and occupations. Some of these customers may be survivalists, and some may be socialists, and some may be homemakers. But they all know what they want when they see it, even if no one else sees it, let alone wants it.

As a market grows, it transitions away from fringe customers to early adopters.[32] In his classic model described in Diffusion of Innovations, Everett M. Rogers referred to the early fringe customers as "innovators," although in fact they were the customers most receptive to innovation:



Source: http://blog.leanmonitor.com/early-adopters-allies-launching-product/

Figure 2-7:
Consumer Customer Segments – Innovation Adoption

First noticed by these earliest customers, the 2.5% or less who originated the market, the innovation then becomes a topic of interest for the 13.5% of the population who see themselves as on the cutting edge. In fact, these early adopters are very different from the fringe customers who really live on the frontiers. Early adopters usually care that they are early adopters: they want to be in front of other people, but they don't want to make bad or peculiar choices. They *don't want to be making bad or peculiar choices.* Early adopters may identify with the innovation and they may not. The cause may or may not matter to them, but the label certainly does. Most important, early adopters prefer their purchases to make sense as purchases. Price matters to them. A reasonable story about value matters to them.

A fringe customer doesn't care much about use cases and warranties, because the very act of acquisition is a statement of identity. The product simply becomes part of their life. An early adopter, on the other hand, generally wants to experiment with a purchase to see if it works out, if it fits. Adoption is a process: it can happen very quickly, or it can take time; it can be very deliberate, or very casual. But there will be an interval of coming to embrace a product after it is purchased. Often, this interval is based on collecting opinions from other people, which may be more important than how well the product is performing. Early adopters want to be cool, and

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[32] We are using a framework established by Everett M. Rogers in Diffusion of Innovations (Simon & Schuster, New York City: 1962, Fifth Edition 2003), updated by more recent work (e.g., The Deviant's Advantage: How Fringe Ideas Create Mass Markets, by Ryan Mathews & Watts Wacker (ibid).

they want to be perceived as cool, so they try to make it work. The fit may not be perfect, but it's good enough. When the purchase has found its place in the early adopter's life, and how the early adopter is perceived by others, adoption is complete: the early adopter will identify with the purchase.

It is very important for the residential energy storage market if the product is expensive, or not well understood in advance of the purchase, or if it's not too clear how cool it really is, the more an early adopter will look for an economic rationale. If adoption doesn't work out, at least the experiment was a good deal. Fringe customers often care about price only to the extent that there's only so much they can afford. Early adopters don't want to overpay for the risks they are taking.

The chasm between fringe customers and early adopters has been well documented.[33] What works with fringe customers doesn't work with early adopters, and many firms fail to make the transition. Driven by Building Code changes, TOU rates, the growth of solar energy, and environmental concerns, the residential energy storage market has already been pushed to the edge of the chasm.

To attract early adopters, residential energy storage will need a reasonable story about value. Energy storage has found a place supporting solar energy, and may become very important for electrification as well, but these roles won't lead one in seven households to consider acquiring a residential energy storage system. The economics of residential energy storage are better than they ever were, but the question arises: are the customer economics good enough?

It might seem that things have worked out for solar energy, so maybe they can work the same way for residential energy storage. Costs fall, incentives persist, customers like the category: maybe residential energy storage hops easily over the chasm. However, several market characteristics indicate the chasm for residential storage may be wider and deeper than first imagined.

First, solar energy began with a much bigger and stronger fringe market than residential energy storage, due to basic differences between the products. For the last thirty years, solar energy has had a very broad set of initial customers, who had a cultural and visceral appreciation of generating clean energy from the sun. Distributed solar energy had intrinsic appeal. Households were waiting for costs to fall enough so they could afford to install solar energy, even if that upfront investment never paid for itself. For these initial customers, solar energy was an end. They had some economic concerns: they didn't want their utility to profit from their investment, especially when they weren't, and they weren't above earning a little on the side from NEM rules. But the point of solar energy for them was to have personal solar energy. Solar was more about personal identity than investment returns.

Energy storage, on the other hand, is much more of an acquired taste than solar generation. There are only so many wealthy, environmentally inclined households, who crave the experience of installing expensive new branded energy storage technology in their garages,

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[33] See as noted above Geoffrey Moore's Crossing the Chasm (ibid), Inside the Tornado ((ibid), and Living on the Fault Line ((ibid); Eric Ries' The Lean Startup (ibid) and in particular The Deviant's Advantage: How Fringe Ideas Create Mass Markets, by Ryan Mathews & Watts Wacker (ibid).

simply because they can. Storing energy has always been appealing to customers, whether as a woodpile or a coal bin or a battery: stored energy provides security, safety, and flexibility. Storing energy also has intrinsic appeal just because customers see it as *their* energy. Through energy storage, fringe customers can hold onto it just because they want to. Early adopters can store energy until it's time to use it or sell it. But the perceived value of energy storage is based much more on the energy than the storage. A solar system is a badge of honor of energy awareness and environmental sensibility, visible on the roof to neighbors. An electric car is a mobile status symbol of power and innovation. A residential energy storage system is usually a battery hidden in a garage.

We shouldn't be surprised that energy is more interesting than energy storage systems: most of the time the beer in the refrigerator will be of more interest than the refrigerator. In this case, we should also note that most residential energy storage systems are even less engaging than refrigerators. Residential energy storage is a particularly difficult investment for homeowners to love, because the systems offer little opportunity for interaction and engagement. An energy storage system processes and stores energy like a water heater processes and stores water. There isn't much to watch, or listen to, or manage. There aren't many stories to tell: energy arbitrage is hard to observe, bill savings show up and get noticed occasionally, outages that need backup are uncommon. For most early potential customers and owners, residential energy storage systems won't hold much interest.

Residential energy storage already has a small set of early fringe purchasers, who are motivated by identification, or impulse, or what they might describe as destiny and this may not be sustainable moving forward.

Second, the chasm for energy storage may be wider and deeper than it was for solar energy because the economic value proposition and incentives for solar energy were much larger than those for residential energy storage. Today's residential energy storage value proposition in California may pay off after nine years, which is a long time to wait given the technical problems, rate changes, and lifestyle changes that can transform a household in the meantime. The attractive long-term investment returns claimed for solar+storage systems depend on these same factors remaining reasonable not only for nine years, but for another 15 or 20 years. Many homes are too small, many lives are too inflexible, and many customers are too impatient for these economics to work.

Solar energy always had a self-supply value proposition, and early on had a strong energy exporting value proposition as well. Residential energy storage's value is merely incremental to those two cases, and modest. It is true that early adopters will make excuses for marginal investments that they find appealing, and they admit their investments might not work out. But early adopters recognize that they are investing, and they need functional, economic, or entertainment performance in return. Residential energy storage might mean that a residential solar investment is less damaged by TOU rates than it otherwise would be, but the downside is that solar+storage is a much larger investment. The larger the investment, the better and safer it needs to seem to early adopters. Today, energy storage economics may be interesting, but they aren't compelling.

Another problem arises because not only is the solar+storage investment larger than an investment in solar alone, solar+storage is also a longer investment. Installers have told customers that under prevailing rules and rates (e.g., NEM 2.0), "a customer who is financially driven is better off with a simple PV system,"[34] given that installing solar alone has had a payback of 4.0-4.5 years, vs. 5.6-6.2 years for solar+storage._A solar+storage combination requires a 20-30 year system lifetime that involves replacing batteries at least once over the span, and also takes advantage of state SGIP and federal ITC incentives, which may not be available to everyone in the future[35]. Installers are simply unfamiliar with selling systems that take so long to justify themselves.

Yet another problem arises because federal and state regulations intend residential storage systems to meet household load from time to time, rather than to enable rate arbitrage. Prospective customers may assume that they can empty their batteries into the grid when power is scarce, and fill them when power is abundant, but systems that receive a 30% federal Investment Tax Credit (ITC) must charge 100% from solar resources, rather than from the grid. Systems that receive state SGIP incentives must charge up from solar and discharge to the home often enough and deeply enough to meet an annual onsite cycling/usage requirement.[36]

The chasm grows wider and deeper still, as California incentives for residential storage can't yet let customers share in the value created by grid services. The original NEM permitted solar energy providers to be paid for helping solve a utility problem. SCE's TOU rates have pushed solar energy and residential storage into a relationship that benefits the grid, and California's new Building Code provisions are pushing solar and storage together to address climate change, but these provisions don't add up to incentives. Just because ratemakers and regulators think that these technologies are good for the grid and the climate doesn't mean that early adopters will respond to them. Early adopters will seek specific incentives if their energy is supplying specific services, and right now, these incentives aren't evident.

Finally, the third reason the chasm for energy storage may be wider and deeper than it was for solar energy is that solar energy, which has always led the way for energy storage, is now moving beyond its substantial set of early adopters to the mainstream. To do so, solar energy will need to become not merely justifiable, but attractive as an investment. The benefits from solar+storage may be captured by solar providers, rather than storage providers, because the solar providers are continuing to take the lead in attracting customers.

On its own, solar energy takes some explanation, although it yields value in an immediate and predictable pattern. Energy storage takes more explanation, and yields episodic value that may take a long time to become evident. Solar energy systems are now being streamlined and simplified for the mass market (e.g., with smart inverters), and these mass market solar+storage customers won't be the early fringe who seek out products, and tolerate delays, inexperience, regulation, and high costs to achieve their goals. Solar+storage customers from the mass market will expect a mature, integrated system that delivers attractive investment returns.

These expectations will come into sharp focus as the California Building Code changes come into effect. The changes require solar energy for new residential construction, indicating to early adopters that regulators have verified value, yet energy storage is only an option, indicating that

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[34] Deep Patel, Gigawatt, private communication and "Energy Storage Adoption and Payback," 2018 NABCEP Conference.

[35] Solar+storage can be marginally more economical than solar alone under the new SCE TOU-D-PRIME rate.

[36] SGIP-backed systems cannot be employed solely as backup systems.

its value might be more doubtful or risky. To date, only about 15% of California's new single-family homes have included solar energy, and very few have included storage; these have been built by a small sliver of the construction industry. Now, by the tens of thousands, builders, contractors, architects, installers, bankers, and customers who have never dreamed of themselves as being part of an early fringe, and hesitate to call themselves early adopters, will be required to address the option of residential energy storage.

These are the reasons why residential energy storage is facing a forbidding chasm in moving across to its potential early adopters. We should note that none of today's category leaders will find the jump easy to make. The adoption challenges faced by residential energy storage are inherent to the nature of the category and can't be met easily[37]. Clever marketing or brand names will be unlikely to provide enough lift, because residential energy storage has little compatibility with past consumer experiences. The new grid-interconnected battery systems have relative advantage over traditional backup generators, but only a small fraction of the population has experience with any backup system. The new systems are complex to understand and use and can't be trialed in advance. There is no way to anticipate what it will be like to live with a residential energy storage system, except through the testimony of others. Finally, residential energy storage systems produce tangible results (e.g., power during an outage, credits for energy exports), but these results are episodic and uncommon.

Residential energy storage may well leap across the broad and deep chasm that lies ahead. Scale, experience, and innovation may continue to reduce costs, attract entrants, and produce better offerings. Customers may see a backup power value proposition as reasonable, or even essential. But residential energy storage may also struggle to grow beyond a fringe community and reach enough early adopters. If the market stalls in a niche, vendors may struggle and exit, and offerings will age. The value propositions for customers (financial, environmental, and emotional) may erode, and residential energy storage will become an optional feature of some solar energy systems.

2.10 Builders

The California Energy Commission (CEC) says that the new 2020 California Building Code solar energy requirements will apply to all the 74,154 new homes permitted in 2020. In contrast, in 2017 only an estimated 15,000 new homes had solar energy installed on a voluntary basis. SCE has estimated 36,878 new residential meter sets for 2020.

SCE already has over 300,000 residential single-family homes with solar energy, adding more than 31,000 in 2018 (mostly retrofits on existing homes). Requiring solar energy in new residential construction will boost the number of new homes with solar, but installers believe SCE's new TOU rates will slow the pace of retrofit solar substantially. As these trends balance, it is reasonable to expect that SCE will see an overall jump in the number of solar residential interconnections of at least 15-20,000 homes per year.

The CEC estimates the solar design, materials, installation, and verification costs of compliance with the new code will average $9,365 per home (a range from $7,933 - $17,730 across climate

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[37] Diffusion theorists maintains that relative advantage, compatibility, complexity, trialability, and observability are the leading factors influencing adoption of an innovation, across all customer segments.

zones). This investment is a 1.7% increase in the median home cost of $561,000. The CEC has asserted that these residential solar systems should repay this investment twice over the life of a typical 30-year mortgage, through electricity bill savings.

The new code provisions require every new single-family home to include solar energy, but the provisions also require consideration of residential energy storage as an option. Including residential energy storage offers builders some flexibility in meeting the code's energy efficiency and solar energy requirements. But as noted above, residential energy storage will still require an additional investment added to solar energy, and the additional investment in energy storage will not pencil out on an operating basis for decades, even under the best of the new TOU rates.

Many builders affected by the new code have worked with solar energy to a limited degree, and many of them have not worked with energy storage at all. None of them have worked with the new software that is supposed to validate levels of energy efficiency, required solar, and useful storage. Our interviews indicate builders are taking three different approaches to the situation. With rare exceptions builders were unwilling to have these conversations on the record.

First, some builders still haven't dealt with the new code provisions, even as 2020 nears. We interviewed builders large and small who assured us that there was still time to prepare, even as they demonstrated in conversation that they didn't understand how the new code worked. After providing their perspectives, these builders admitted they had little experience with solar or storage, but they were confident they would recognize good enough solutions when they saw them. These builders explained that they had bigger things to worry about than yet another compliance item. Two builders separately said they would take meetings with experts to better understand solar and storage, if the meetings could be brief, with no obligations. Some builders said that compliance would have to get worked out, jurisdiction by jurisdiction, as new projects progressed.

Second, some builders are expecting to rely on third parties to specify how to deal with the new code provisions. Larger builders have been targeted by installers and suppliers who are offering solar and storage solutions from design through permitting, interconnection, installation, and testing. Sunrun and others are telling these builders that solar and storage can be handled in standard configurations that offer economies of scale and worry-free integration. Builders have limited time, resources, and expertise; they are used to relying on the trades to mitigate risk. Sunrun, for example, is insisting that solar should automatically be combined with storage, and neither the builder nor the homeowner should be required to make decisions about these systems. These builders are expecting to select and approach to solar and storage, and stick with it, much as they might generally use a certain brand of water heater, or automatic garage door.

Third, a few builders are trying to figure out how to make the new code provisions work for them. These proactive builders tend to have experience with solar energy already, or their homes are at the high end of the market, or both. High-end customers for new homes are usually more concerned about customization and performance than cost. These customers expect their builders to offer them options at every turn. Solar energy and energy storage are merely additional technical areas like home automation, electric vehicle support, and custom lighting that require builders and specialty contractors to be prepared. Builders reported that functional solar and storage systems were available, although expensive. The builders were concerned that the solutions had limited lifetimes and warranties and might require significant maintenance only a few years into ownership.

One high-end builder had figured out how to avoid high-efficiency attic construction through the new code provisions. Another builder was determined to oversize solar+storage on the theory that the prospects for grid export would lead homeowners to see solar and storage as an investment, rather than a requirement. Two builders noted that new homes included so many expensive components that no single system received detailed attention from the homeowner, unlike renovation projects, where the budgets might be scrutinized. Another builder noted that solar+storage could be financed as a package, either separately or bundled with the rest of the home, and its actual use could be figured out later. A couple of builders agreed with one another that homeowners didn't really know what good-quality solar+storage systems should cost, so wide profit margins and margins for error could be built into new home prices.

Builders across the spectrum of preparedness noted that solar + storage could be financed below the $50,000 ceiling most renovation projects dealt with, and the contractors who completed those projects were the ones to start with for new construction. One builder also noted that because customers didn't know what they wanted out of either solar or storage systems, minimally functional systems were preferable. Another builder noted that proven systems and installers were essential, because builders didn't like to experiment. One of the nation's largest production builders said their decision to proceed in California with both solar energy and home security as standard systems, but not energy storage, came after they had seriously examined the economics of all three types of systems.

No California builder we spoke with was aware of the 86-home Hunters Point project (Cortez, FL), which features Sonnen systems. No one was aware of the 62-home Signature Homes Reynolds Landing project (Birmingham, AL), which includes community energy storage within a microgrid. No one was aware of the Pulte Homes Altus at the Quarter development (Atlanta, GA) that will include residential electric storage. No one outside of Meritage was familiar with Meritage's Buckeye or Fontana projects. Builders generally dismissed demonstration projects (e.g., the Advanced Energy Communities) as non-commercial showcases.

Builders are aware that electrification, and the all-electric home, has returned to prominence after a nearly 50-year absence in California. But most builders haven't connected the dots to understand how solar energy, much less energy storage, fits within electrification. If the solar+storage story helped overcome any of electrification's downsides (e.g. electrification can cause demand peaks, and storage can help smooth them) the builders would be very interested, but that message has yet to be delivered.

2.11 Installers

To date, some residential storage has been installed by electricians working directly with motivated customers, but the vast majority of residential storage has been installed by solar installers working with guidance from product suppliers. Suppliers are advising installers that energy storage systems can be a high-margin addition to new solar installations.

As listed below, there are dozens of residential solar installers working across California. Most are preoccupied with creating business among homeowners looking to add solar, although some also extend to small-scale commercial/industrial work, and a few are part of larger firms who also take on major commercial-industrial and utility-scale projects.

Among homeowners, there are three potential market segments for energy storage to address: (1) new homes, (2) conversion to solar, and (3) solar to solar+storage.

First, California's new building codes will require all new homes to include solar and to consider adding storage. SCE has estimated approximately 37,000 new residential meter sets in 2020, and each of the following years, about 185,000 homes across the next five years. The new homes segment is distinguished by complex code requirements and financing. In terms of complex code requirements, new home buyers must install solar, and may install storage. To estimate these costs, builders must assess how to balance requirements for energy efficiency, solar array size, and potentially, storage systems.

Table 2- 8:
2018 California NEM Residential Solar Interconnections by Installer

Rank	Name	Total Capacity (kW)	Number of Systems
1	Tesla	91,219	16,385
2	Vivint Solar	71,105	11,398
3	SunRun	44,379	6,927
4	Sunpower	29,151	7,631
5	Horizon Solar Power (Sungevity)	20,781	3,247
6	Semper Solaris	19,550	3,214
7	Petersen Dean	18,181	2,778
8	Baker Electric	14,734	1,959
9	Infinity Energy (TLP Electric Integrations)	14,305	2,331
10	Freedom Forever	10,778	1,673
11	REC Solar	10,144	1,751
12	V3 Electric	9,445	1,433
13	Solcius	8,555	1,694
14	Solarmax	7,692	1,114
15	Renova Energy Corporation	7,389	744
16	Sun Solar Energy Solutions	7,286	758
17	Sunstreet Energy Group	7,161	2,666
18	Sullivan Solar Power	6,544	911
19	Complete Solar	5,591	1,094
20	Hooked on Solar	5,057	660
21	Quick Systems	4,954	840
22	Grid Alternatives	4,941	1,402
23	Quality Home Services	4,806	566
24	West Coast Solar	4,707	678
25	Shorebreak Energy Developers	4,602	25
26	1st Light Energy	4,527	662
27	Southwest Sun Solar	4,468	740
28	LA Solar Group	4,325	633
Source: Brad Heavner, Policy Director, CALSSA			

The addition of energy storage enables builders to receive flexibility in solar array size and other design elements. The tradeoffs are still unclear for all parties. In terms of financing, new home prospects are considering solar (and solar+storage) as part of a major investment, where the addition of these technologies is one small aspect of a larger project and is easiest and most economical to incorporate in new construction. Most independent installers wait for builders or system suppliers to bring them in to new home construction.

The new homes segment is difficult for solar installers to access because few installers have close partnerships with new-home builders.[38] Prior to the building code changes, the new homes segment has only been about 15% of solar installers' business. Production builders, who supply the bulk of the new homes segment, have first turned to system providers (both manufacturers and lessors), rather than installers, to help define their energy storage solutions. So far, few

[38] There are exceptions. The production builder Lennar has its own solar installation subsidiary, which serves Lennar and 11 other builders nationwide. The roofing contractor Petersen-Dean is a major solar installer and is active with home builders. Xero Solar works with custom builders.

production or custom builders have yet decided whether to utilize the storage option under the new building code.

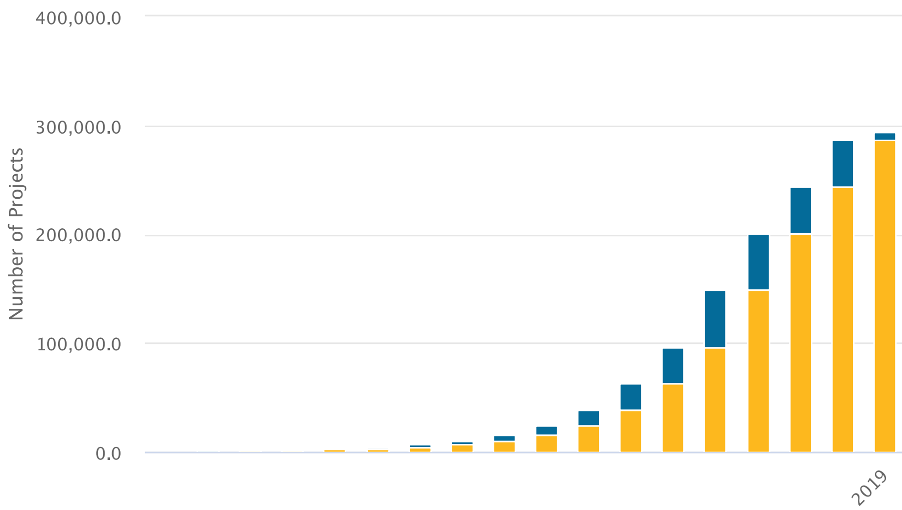

Figure 2-8:
SCE Solar PV Residential NEM Interconnection Applications: 1993 – 2019
Source: California Distributed Generation Statistics, https://www.californiadgstats.ca.gov/charts/

Second, almost 44,000 homes in SCE's territory added solar last year, a total that has been increasing at a declining rate. Although the impact of TOU rates on this segment of the market is still unclear, we estimate solar conversion will add at least 180,000 new solar homes in SCE's territory across the next five years. The conversion to solar segment is notable because it involves a choice, and a choice with an option. In terms of a choice, the conversion to solar is voluntary, and the timing is up to the homeowner, so personal circumstances, deals offered in the markets, and the arrival of new technologies all come into play. In terms of the choice with an option, in conversion, homeowners must choose between solar alone, or solar+storage. Unlike new construction, where builders are involved, in conversion to solar it is installers and solar system owners (who lease to homeowners) who often take the lead in the financial modeling.

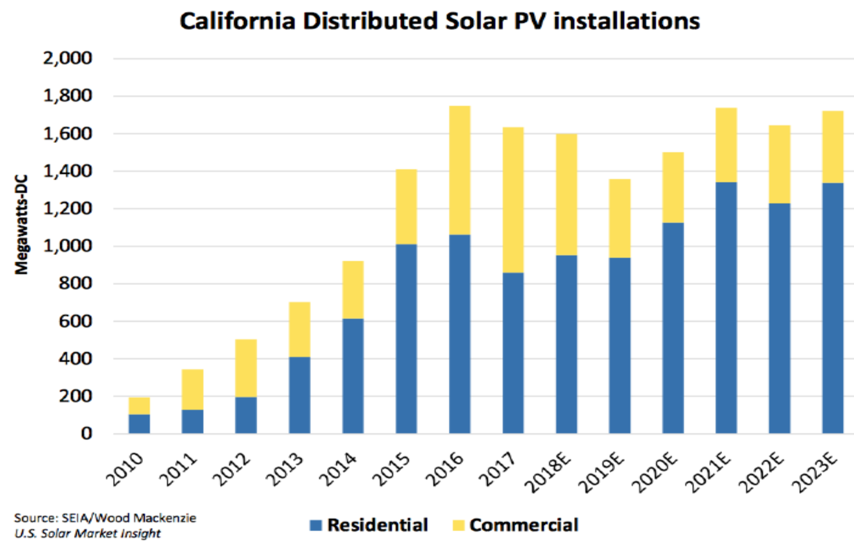

Figure 2-9:
California distributed solar PV residential installations
Source: California Distributed Generation Statistics, https://www.californiadgstats.ca.gov/charts/

Third, approximately 300,000 existing homes in SCE's territory already have solar in place. Approximately one-third of these systems are more than five years old. Only about 1% of these homes already have energy storage. The solar to solar+storage segment is distinguished by rate impacts and the challenges of conversion. In terms of rate impacts, homes with solar in place are grandfathered under older NEM rates for now, but the addition of storage could make the new TOU rates economical. In terms of conversion challenges, many older solar systems have inverters and control software that cannot integrate with energy storage. It would be economically prohibitive to replace these components before end of life, but as they age, replacement may be required in any case.

Although Outback Power and other veteran suppliers have recommended it, few installers have accessed the solar to solar+storage segment, because storage requires outreach and an upsell. Customers with existing solar systems require maintenance and repair, but upgrades are optional. Also, while installers can access their own limited list of past customers, they can't easily access other customers to propose upgrading systems they didn't install in the first place.

Looking across the next five years, the residential storage market in SCE's territory is likely to include almost all the 300,000 homes that already have solar, about 180,000 homes converting to solar, and about 185,000 new homes, making a total of roughly 660,000 prospects. These are large numbers, but, most solar installers are focused on their fast-growing base business of homes converting to solar, with less emphasis on new homes and existing solar homes.

Residential solar installers find many prospects to be curious about energy storage, so they try to be ready to help. They become certified installers for residential storage products, they include residential storage on their websites, and they provide residential storage if that's what it takes to win solar business. Beyond all the effort, most installers have found residential energy storage to be a challenging. As educating prospects about the operations and economics of residential storage is difficult, time-consuming, and has usually been fruitless. Once a job is won, it may be difficult to obtain product from the manufacturers. Once a system is in hand, field staff must complete a complicated and unfamiliar installation. Once the system is in place, it can be difficult to get paid: California SGIP rebates involve so many filings, verification requirements, and payment delays that frustrated installers may give up on the incentive and merely credit the customer for it. Time is money, and residential energy storage systems have taken a lot of time for installers. The projects that are completed can easily lose money for installers and customers alike.

It isn't surprising that over half of the SGIP residential storage projects have been developed by firms with major sources of revenue beyond solar or storage installation. Sunrun and Swell Services extend into solar+storage installation through their primary business as system owners and financiers. Tesla also manufactures systems, and Petersen-Dean is a roofing contractor.

Those installers who have pursued residential energy storage generally have close relationships with one or two residential storage system providers. Tesla is a solar installer itself, and has a roster of certified *Powerwall* storage installers, including Xero Solar, Swell Services, Solar Optimum, Renova,[39] Baker Electric, Solar Forward Electric, and Infinity Solar. Swell indicates it installs systems other than the Tesla *Powerwall* but can cite few examples. LA Solar Group,[40] Semper Solaris and Sunlux are large installers who offer both Tesla and LG Chem products. In addition to Tesla and LG Chem products, Sunlux also features the Enphase Storage System. Sullivan Solar Power is LG Chem's top installer in the United States. Sunrun's *Brightbox*™ solution is built around LG Chem's batteries, and Sunrun is a Horizon Solar Power partner. Petersen Dean is another LG Chem partner.

As shown below, the SGIP database identifies fifteen solar installers in SCE's territory who have combined for at least 2,675 residential energy storage installations on existing homes across 2017-2019, over 90% of the projects on record where payments have been made. Most of these installers are also active statewide. There is a significant overlap with the list above of leading NEM residential solar installers.

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[39] Renova Energy features Tesla, but also includes the Sonnen trademark and pictures on its website. A company spokesperson doesn't know why Sonnen is included.

[40] LA Solar includes a photo of a Sonnen product on its website but does not discuss the product.

Table 2- 9:
All CA and SCE SGIP Residential Project Rebates Applied for by Leading Developers: 2017-4/2019

Developer	CA Incentive Amount ($ Total)	SGIP Projects (# Total)	SCE Incentive Amount ($ Total)	SCE SGIP Projects (# Total)
Sunrun	7,062,402	2,525	2,719,308	943
Tesla/SolarCity	8,391,002	1,445	2,551,533	451
Petersen-Dean	3,074,278	1,056	765,308	262
Swell Services	5,620,060	850	1,530,881	229
Xero Solar	1,374,075	196	1,299,255	185
Sullivan Solar Power	2,207,635	765	438,265	126
Solar Optimum	1,191,100	234	628,140	123
Renova Energy	578,260	100	578,260	100
LA Solar Group	1,526,071	277	528,047	91
Horizon Solar Power	*		276,660	37
Baker Electric	748,669	181	150,390	31
Solar Forward Electric	419,340	49	244,760	27
Infinity Solar (TLP)	*		137,460	23
Semper Solaris	459,025	136	101,440	27
Sunlux	*		60,366	20
All Others	*		*	248
Total		9,760		2,923

**Data not reported in public source*
Bolded and in italics also a leading statewide NEM solar installer
Public data may be incomplete or inaccurate. Table includes applications as well as completed payments in order to include completed projects with administrative payment delays or abandoned applications

Solar installers can be suspicious of utilities due to changing regulatory tariff issues, and in one recent instance, the installers urged solar customers to opt-out of Clean Power Alliance (CPA) energy supply. CPA, as the Community Choice Aggregator (CCA) for Los Angeles County, has offered jurisdictions in its territory three default energy supplies to choose from: “lean” (36% renewable), “clean” (50% renewable), and “green” (100% renewable). The CCA consumer offers vary from place to place, and provide only modest savings in any case, because they affect only the energy charge on a consumer’s bill, and not the SCE delivery charge. The solar installers noted that a CPA switch could trigger two true-up bills in a single year (one from CPA, one from SCE), outweighing any savings[41].

Installers are crucial to the prospects for residential energy storage, but many of them aren’t familiar with the category. System suppliers offer certification and training courses, but installers haven’t prioritized their efforts towards what they consider a sideline. Now that storage may lead to solar business as well as the other way around, many installers are investing more time in understanding residential energy storage. But there are still many solar installers who don’t do any storage installations, or don’t do them often, or do them only with a single supplier’s proprietary system.

[41] Run on Sun Monthly Newsletter, April 2019, Vol. 10, No. 3.

2.12 Regulators

Elsewhere in this report we discuss SCE's rates, a vital regulated aspect of residential energy storage in Southern California. In this section we discuss the broader roles of federal, state, and local regulators in providing direction to the market.

Federal Legislation & Regulation

The Federal Energy Regulatory Commission (FERC) oversees the nation's bulk power system (CAISO in California), and has focused various rulemakings on energy storage since 2011, FERC has enabled storage in frequency regulation (Orders 755, 819), ancillary services (Order 784), and ISO/RTO storage tariffs (Order 841). FERC's interventions are very significant for energy storage as an industry, but by opening large-scale bulk power applications, the value of residential storage in grid services to local issues is limited.

For example, Order 841, to be implemented by December 2019, has required each RTO/ISO to create a tariff model for energy storage resources, spanning its system. CAISO has extended its non-generator resource (NGR) model and will allow storage resources to be dispatched as generation or load across their entire capacity range. CAISO has also created a five-minute ramping product and a scarcity pricing structure to add flexibility. Within these CAISO plans, individual California utilities are actively working to create 'non-wires' solutions including aggregated residential storage in some cases. But most market activity across "non-generator resources" will be larger-scale. For example, CAISO is experimenting with 2 MW/8MWh vanadium redox flow batteries.

More significant for residential energy storage, the 30% federal tax credit on the purchase of a residential solar system is scheduled to begin its stepdown in six months. In place since 2005 and extended in 2015, the 30% solar ITC falls to 26% in 2020, 22% in 2021, and then expires. The IRS has allowed the ITC to be applied to the storage elements in solar+storage systems, if the scale of the storage is small-scale and the storage is charged entirely by the solar system. Residential energy storage has benefited.

Federal legislation has been introduced to extend the 30% level of the residential solar ITC for a longer period, and explicitly include residential energy storage systems as well, but passage into law would require bipartisan support. On the one hand, the solar ITC made sense to Congress well before climate change became an issue, and the solar industry has grown to be an important employer in many Congressional districts. On the other hand, Congress has changed, the nation's energy policies have changed, and the solar ITC has become caught up in debates about fossil-fuel subsidies and the "Green New Deal".

California Legislation & Regulation

Earlier we discussed some of California's many state-sponsored utility initiatives that led to the growth of residential energy storage. The larger context for these rates and programs was set by the California Energy Storage Bill (AB 2514) of 2010.

Following the passage of that fundamental legislation, the CPUC set forth to determine how investor-owned utilities should support energy storage. A Storage Working Group and a Storage Roadmap guided a series of mandates and rulings between 2013 and 2017, in which the CPUC addressed who can own energy storage; how storage can operate; the services storage can provide; storage procurement processes; storage's dispatch priority; how the benefits of storage are valued; how net metering, aggregation, and utility programs can work; and how storage-related rates are designed. While none of these topics was addressed in final, comprehensive form, the series of overlapping rulings allowed SCE and other utilities to create storage strategies and programs.

Today, California is well ahead of the 2013 mandate to PG & E, SCE, and SDG & E to collectively acquire 1,325 MW of storage by 2020. SCE's allocated portion is 580 MW, 85 MW of which is customer-interconnected storage (CII and residential). The Aliso Canyon experience gave SCE and the CPUC confidence that SCE could manage energy storage, so SCE has forged ahead with several large-scale storage procurements (see above).

In 2016, AB 2868 added another 167 MW of distribution-connected or behind-the-meter energy storage to each IOU's requirements. These new requirements are not subject to the 2020 deadline. SCE filed plans in 2018 to hit these new targets largely through distribution-connected resources, with a $10 MM, 4 MW allocation to storage in low-income multifamily housing.

Supporting storage market development in Southern California, another 2016 bill, SB 388, required local publicly-owned utilities, including those neighboring SCE, to consider storage in meeting peak loads. As noted above, the CPUC has now approved energy storage as eligible for export credit. In 2017, AB 546 required all local California governments to make their permitting applications for behind-the-meter storage available online. For CII projects, in 2018 California became the first state to issue revenue-stacking rules (i.e., "multiple use applications").

The specifics of many of these rulings are beyond the scope of this report, but we should note that the net impact on residential storage in Southern California has been substantial. Not only must SCE sponsor behind-the-meter storage (e.g., through its contracts with Swell Energy), but neighboring utilities (including LADWP) must support storage as well.

Furthermore, the grand scope of California's storage initiative means that many energy storage resources of different sizes will arise in many different locations. Some of these resources will also reflect CAISO's policies within FERC's jurisdiction. The situation for energy storage will parallel demand response, where utility peaker plants, CII facilities, and residential program participants all can be called on to meet peak demands. As the utility industry and its regulators learned from demand response, it is no small issue to decide which resources should be called on in which circumstances, with what compensation.

If we turn to the residential markets, SB 700 has now extended California SGIP state rebates for residential energy storage through 2025. The $57 MM available through the SGIP has been California's primary vehicle for incenting residential energy storage with an allocation of about $14 MM annually to support residential energy storage projects 10kW or less in size. The CPUC is in the process of establishing new incentive levels and procedures under SB 700. Looking ahead, earlier this year the SGIP Program Administrators requested CPUC approval for several streamlining improvements, e.g.:

- providing public access to the SGIP's statewide list of manufacturers' equipment that had completed technical reviews;

- eliminating the duplicate submission of manufacturer equipment specifications at different stages of the application process
- permitting virtual compliance inspections eliminating the requirement for submitting a copy of the application fee check
- allowing host customers to opt out of "non-critical" e-mail communications with developers
- eliminating the requirements for itemized cost submissions, replacing them with a simple attestation
- eliminating the requirement for separate customer data authorization for third party non-utility administrators (e.g., CSE)

The requested changes eliminate some of the SGIP's more complicated procedures, but the changes focus on making compliance simpler to confirm, rather than making compliance less burdensome for customers.

The initial comment period is now closed on the SB 700 SGIP modifications, and the Commissioner's replies will be issued soon. The SGIP extension is very important in SCE's market, as SCE's SGIP allocation for residential systems was reaching its last step, with several major developers/installers already capped out of the program. SCE will also be influenced by enhanced SGIP provisions applying to low-income customers and customers in fire zones.

Beyond the SGIP's details, the CPUC has much larger ambitions, as it begins to design the details of the 2030 Preferred System Portfolio, which will include 12 GW of new solar, wind, geothermal and battery storage resources. The Preferred System Portfolio is California's path to reach 100% zero-carbon energy by 2045.

Local Ordinances & Regulation

Local jurisdictions have a role in permitting residential energy storage that complicates many installations. Localities look to the utility interconnection process for some direction, yet they realize that interconnection standards have a narrow focus. Every California jurisdiction is different in the scope of its concerns (e.g., Los Angeles County is much more restrictive than most), but there are some common local regulatory factors that influence the residential energy storage market.

First, permitting for battery installation is simpler for residential installations than commercial units, but can still take a minimum of two weeks for streamlined consideration with no issues, and much longer if any issues arise. Given the system's weight, structural and seismic support for the system on the wall or the floor can be one of those issues. Fire safety is another major issue: California Fire Code Section 608 recommends exterior installation, but most jurisdictions allow interior installation with much attention to location, fire setbacks, heat sensors, and panel connections[42]. The most common issue is previous on-site code violations that come to light during the design and installation of residential energy storage.

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[42] Other jurisdictions outside of California have investigated the fire safety of residential electric storage systems in some detail. The New York City Fire Department is noted for its opposition to most installations. The Salt River Project and Maricopa County, Arizona have reviewed residential energy storage safety under high temperature exposure.

Second, many inspectors, electricians, and other building professionals are new to electricity storage, so the approval process can differ from case to case. NREL and others (e.g., Sunrun, SunPower, Vivint Solar, and Tesla) are at work on the Solar Automated Permit Processing Platform, which will provide standardized streamlined permitting software for solar and storage, but deployment will take years. Today, documentation varies across system suppliers and jurisdictions. Bundled systems like the Tesla *Powerwall* avoid many issues of custom connections but may be inflexible. Replacing panels may seem necessary to one inspector, but not to another. System sizing, metering, testing, and warranty requirements may be unfamiliar to one installer, but not to another. Architects may be particularly uninformed. Few building professionals have much if any experience with residential energy storage systems that have problems or create problems.

Third, the revised Building Code, solar+storage, and EV connections have all complicated the approval process for local jurisdictions. While localities are supposed to aid in the deployment of new technologies, their limited resources and familiarity with advanced components (e.g., smart inverters) mean that commissioning and approval in single-family homes is more complicated than it has been for some time. Outdated building and fire safety codes in some jurisdictions effectively restrict the installation of certain products, and incomplete installation instructions can lead to failed inspections.

The market impacts of local regulation are predictable: divergent rules, standards, and tests to be mastered by building professionals; inconsistency in administration; and unfamiliarity with energy storage lead to extra time, expense, and risk for all concerned, and fewer successful installations. Many installers say that delays and debates with local jurisdictions are a much bigger problem for them than interaction with utilities.

2.13 Utilities

Our market analysis of residential electric storage in Southern California does not contrast utility approaches, or review the strategies employed in other states: SCE has considered these topics elsewhere. It is also beyond the scope of this report to discuss the strategic value or operational effectiveness of SCE's interventions to date in the residential energy storage market, or to compare SCE's activities to those of its neighboring utilities. Those may be under assessment by regulatory evaluators.

Utilities propose regulations, comment on proposed regulations, and administer many regulations once they are established. We have discussed the broad course of California regulatory policy regarding residential energy storage across the past decade. Here we note policy initiatives underway that will influence the Southern California market for residential energy storage. At the end of this report we will suggest some specific initiatives SCE could consider.

Interconnection

Utilities have mandated interconnection requirements for distributed resources such as residential energy storage, and SCE is intensely focused on them. Interconnection is the key utility relationship for suppliers, builders, and installers, because the ease or difficulty of interconnection has a substantial impact on profit margins.

Installers and utilities in California have been embroiled in a long dialogue about the grid impacts of large-scale solar+storage. A final resolution will take time. Similar issues have arisen in Massachusetts, Nevada and elsewhere, generally arising from use cases. Developers prefer to retain flexibility in how their energy storage assets might be used, so they would rather not agree to rigid use cases. Utilities respond that without specified use cases, they must assume the storage asset might be used in modes that would have maximum grid impacts, so they must require the more rigorous interconnection standards that address those possibilities. Related concerns about interconnecting EV charging systems are also arising.

Residential solar interconnection was greatly aided by the California Solar Initiative Guidebook, but solar+storage has proven to be more complicated. The large-scale storage interconnection controversies filter down to the residential energy storage markets. Household processes that used to take a few days for solar-only now can take much more time. Utilities require a great deal of information about a site, and then ask for more. SGIP requirements add their own burdens. Communication can be slow and repetitive. Residential solar+storage interconnection can take a few days, but it can also take much more time. Time is money for suppliers, builders, installers, and ultimately, customers, who one way or the other are going to pay for these problems.

Of course, interconnection does raise all of the familiar issues about who owns the grid, and who is entitled to interact with the grid in what ways. To a utility, interconnection does sound like a call to be the protector of safety and value. Yet there are ways to make progress. Facing the immense and immediate demands of electric transportation, SCE simplified EV charging station interconnection by training utility staff, setting clear application requirements, providing process flowcharts, maintaining reliable schedules, and opening communications channels. Speed and predictability improved greatly.

As one of our scenarios described in a related study, residential energy storage may well face similar immense and immediate demands for interconnection. As volume rises, streamlining interconnection would be profitable for all concerned.

Public Safety Power Shutoffs (PSPS)

After the severe wildfires of recent years, California's utilities and regulators took stock of what lay ahead and were concerned that it might be many years before older utility lines could be inspected and insulated. In the meantime, they concluded, drastic steps were necessary to avoid more wildfire disasters. One of those steps is the imposition of PSPS.

SCE and other utilities are now implementing PSPS policies. PG & E has already imposed PSPS events. As noted above, the practice of de-energizing lines through in emergencies may lead to outages of undetermined duration. A PSPS is a blackout by another name, although it is not rolling, it may not be a surprise, and allegedly utilities can start and stop a PSPS at will. From a customer standpoint, despite any advance notification, a PSPS is relatively unpredictable in many respects,

Most important for residential energy storage, as SCE's website indicates:[43]

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[43] For a reasonably complete description of SCE's approach to conducting a PSPS, see https://www.sce.com/safety/wildfire/psps.

"when utility power is shut off, your solar energy system is designed to immediately shut down for safety reasons (to avoid "backfeeding" the grid; refer to Rule 21). A grid-tied solar electric system does not provide power during outages unless it includes a battery storage system and transfer switch. Your power will typically be reinstated moments after grid power is restored. However, you may need to manually reset your solar system's inverter back to service after your power is reinstated (most systems automatically reset after power is restored)."

Through these provisions, SCE has mandated a customer experience that may be less than most residential energy storage customers had hoped for. Even large residential energy storage systems will only provide power for a few applications across several hours, or a whole household for two hours or less. These systems are designed to be recharged from solar daily and need that ability to be useful in multi-day outages.

If a residential storage system has been sized, installed, and tested to switch properly, then discharge and charge locally, it could be a vital resource for a customer in a PSPS event. It could function day after day, recharging from solar. If it could reset automatically after the PSPS, so much the better. But if the system is inadequate, or the household isn't informed properly about what to do, the PSPS could cause an outage precisely when the household believed it was protected.

The customer experience of relying on residential energy storage during a PSPS hasn't yet been thoroughly assessed, and it remains one of the largest questions about customer demand.

Grid Services Trials

In another kind of intervention in residential electric service, SCE and other utilities are studying how to employ virtual networks of residential energy storage systems to supply grid services. Swell Energy's PRP with SCE is one example of these grid services trials. The Swell PRP contract specifies that its resources must be ready with 15 minutes warning to dispatch up to 5 MW for a continuous 4-hour period.

The storage-to-grid services theory is very similar to demand response, where large numbers of residential households would reduce electric usage slightly during peak periods and be paid for doing so. The argument runs that software is just as comfortable managing 100 small distributed residential sites as it is managing a single commercial site. The risk of failure or non-compliance is spread.

However, the analogy with demand response is not as strong as it needs to be. Accessing residential energy storage actively employs the batteries, unlike demand response that merely curtails use. Grid services may require repetitive and immediate access, while demand response is usually based on wholesale market needs or day ahead congestion that can be somewhat anticipated. Grid services are faster acting, and may require most of what a battery can do at any given moment, and leave the battery in need of recharging; demand response usually requires modest temporal and impactful adjustments and leaves household appliances unaffected. It isn't yet clear how grid services from residential storage will work, or how customers will need to be compensated for providing them.

As noted above, an active and profitable set of grid services based on residential energy storage would constitute a new revenue stream for customers. But the technical and operating feasibility of these services remains speculative. Furthermore, utilities currently have other sources of grid services (e.g., ramping dispatchable generation, larger storage resources or automated distribution equipment) that may prove to be comparatively cheaper and more durable.

Rates & Incentives

Rates are one form of tariff regulation that utilities propose and administer. We have described SCE's new TOU rates, noting how they will impact residential energy storage. Here we discuss future market impacts of these rates and other incentives.

Based on the current price and schedule design, the market for residential electric storage will focus on the benefit opportunities offered by the TOU-D-PRIME rate. As noted above, initial analysis confirms that solar+storage is preferable under the rate to solar alone, but there will be prospects considering retrofit storage, despite its difficulties. Based on previous studies on customer experience with dynamic pricing, we can expect there will be households who work to maximize exports from their energy storage, and then publicize their results, with advice for others. There will be inquires and service calls to ensure proper solar operations, inverter communications to assure proper system operations, export control management, and schedules for charging only from solar. PRIME rate customers may be natural targets for EV and electric heat pump marketing due to the rate benefits for off peak charging and water heating. For most PRIME rate customers, the high peak/off-peak differential will also prove enough to motivate household behavioral change.

If previous experience with dynamic pricing is a guide, some PRIME households will initially be inattentive to what the rate asks of them and will see their electric bills rise. Other households will find their routines and the construction of their homes don't lend themselves to avoiding peak usage. These households will seek guidance. There may be households badly impacted by other TOU rates who do the math and decide it's time to add solar+storage to avail themselves of the PRIME rate. There may be households who have EVs or electric heat pumps but not energy storage, who decide that they would like to benefit even more from their new rate. The PRIME rate could become the baseline residential rate for SCE, and an example for neighboring utilities.

The residential energy storage market in Southern California could also be boosted by an opportunity to provide incentives beyond those that SGIP delivers. One example is the Bring Your Own Device (BYOD) incentives offered by Green Mountain Power (GMP) of Vermont[44] in its new Resilient Home trial, The 500 Resilient Home customers each receive two *Powerwalls*, leasing the set for $30 per month, or participating by acquiring their own *Powerwalls*. All participants agree to let GMP access the system to manage demand peaks.

In GMP's original 2015 Powerwall leasing program customers were offered a *Powerwall* for $37.50 per month, if they were willing to let GMP access the system to manage demand peaks. Alternatively, customers could buy their own *Powerwall* for $6,500 (obtained from GMP, or obtained and financed through a third-party retailer under the GMP BYOD feature), and then receive a monthly $31.76 GMP bill credit if they were willing to let GMP access the system to manage demand peaks. Several hundred customers took advantage of the program (out of 2,000

[44] GMP also claims its patent-pending technology allows the *Powerwall* battery software to function as a household electric meter. Participants can also elect a "subscription pricing" plan, receiving electricity at a flat monthly rate.

authorized), and GMP achieved significant savings while maintaining reliability during summer peaks.

The GMP incentive programs illustrate the value of small-scale targeted resources, and the perceived customer service value of aiding customers in financing the acquisition of residential energy storage. If utilities can see their way clear to offer some customers deals that other customers can't qualify for, don't qualify for, or don't take up, households could be targeted for residential energy storage (e.g., low-income households in critical fire zones). A combination of discounts and financing could make the systems affordable.

Utilities may enhance the value of residential energy storage through customer friendly TOU rates, which add value to both self-supply and energy exporting. SCE's TOU-D-PRIME rate will play that role in Southern California. But the Southern California market could also be enhanced even more through targeted incentives that expand the set of customers who could afford residential energy storage.

3
THE MARKET OBSERVED

3.1 Economic Value Proposition

As noted above, the early fringe market for residential energy storage in Southern California has served innovative committed customers, through their solar installers. System supply has now improved as hardware distribution has been restored, and company acquisitions have provided resources to smaller players. Storage system performance continues to rise as batteries, inverters, and control systems improve, and system components integrate more successfully. But performance and price points are not yet standardized.

Demand for storage has improved with the growth of solar systems, concerns about climate change and wildfires, new TOU rates, ongoing regulatory support (e.g., the SGIP extension) and the anticipation of California Building Code changes. Market forces are leading more customers to appreciate the perceived value of residential energy storage. The number of residential energy storage installations will rise due to the California 2020 building code changes that require solar in new construction. Installations may also rise as potential solar energy retrofit customers learn that residential energy storage can make solar bundled with storage more attractive, but there will be fewer of these solar retrofit customers due to the impacts of TOU rates.

It may be that a significant number of the customers building new homes will reveal themselves to be fringe market partisans of energy storage. There may be many more of them than it seemed. It may be that in the process of complying with the new Building Code requirements that others will succeed in persuading these newly revealed partisans to choose solar+storage. If so, the wavelet of new homes with energy storage that results may provide support to the early fringe storage market until the system suppliers are ready to deal with the more numerous early adopters.

However, we believe that the needed dynamic regarding the persistence and growth of residential energy storage demand would be a successful leap from fringe customers to early adopters. A successful leap is not assured but would be essential to eventually address the early mass market. The early mass market is much larger but is even more concerned about finding an economic value proposition than early adopters. As the long-term economic value proposition goes, so goes the long term market.

The upcoming market of early adopters will find it very challenging to understand the economic value proposition for residential energy storage. System costs are site specific, and higher in comparison to other household purchases. Revenues are specific to household behavioral response and to rates, which are new and may not be easily understood. Information sources about residential energy storage can be very general, valid only for certain systems, or generalized and misleading. Builders and utilities provide little help in clarifying details and installers are narrowly informed. Government regulators are more concerned about meeting safety and legal compliance than communicating economic paybacks. Even once the value proposition is clear, the early adopters will be hesitant: the beneficial use cases arise sporadically, the returns are limited, and the financial payoff takes a very long time.

Earlier, we specified five drivers of the residential energy storage value proposition:

- Better system performance to lower the lifetime cost of ownership (an *investment* value), and handle more frequent and longer outages (an *insurance* value)
- More valuable power to increase the value of self-supply (a *savings* value) and energy cost management (an *investment* value)
- More common and severe outages to increase system utilization (an *insurance* value)
- Increased financial incentives to lower the lifetime cost of ownership (an *investment* value)
- Development of other value streams such as utility grid services, to increase system utilization (an *investment* value)

These value drivers differ in terms of what they deliver, and what they depend on.

Better system performance delivers *investment* value. *Investment* value arises from the system's operations over its life. Increase the system's operating performance or its lifetime, and its value as an investment rises. In the case of residential energy storage, the returns on investment arise as the system becomes more powerful, reliable, flexible and fast. Outages and conversions from grid to household power are less noticeable and less stressful. These *investment* values depend upon what value the household places on uninterrupted power. For more and more households more and more of the time in California, uninterrupted power service can no longer be assured due to planned outages, even with an investment in solar generation.

More valuable power delivers *savings* value and *investment* value. *Savings* value arise when the system's operations reduce household spending that would otherwise have been made. Spend less due to the system's operations, and the net value is savings. In the case of residential energy storage, the actual savings level depends upon both utility rates and customer behavior. The higher the rates, and the rate differentials from period to period, the larger the potential for savings. The more customer loads arise in peak periods, the more savings can arise from serving those loads through energy stored earlier. In California, the extraordinary mid-afternoon/evening ramp is well-documented, and the new TOU rates will either help serve it or will be revised in a subsequent rate case.

More incidents of everyday and severe outages deliver an *insurance* value. *Insurance* value arises when the system mitigates a real or perceived risk. Increase the risk or the level of mitigation, and the system provides more insurance value. In the case of residential energy storage, the insurance value arises with outage risks and the perception of those risks[45]. Major disasters (e.g., hurricanes, fires) and everyday incidents (e.g., auto accidents) increase both

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[45] Residential truck owners in focus groups agreed that one important reason to own a pick-up truck was to be perceived by neighbors as the go-to family to be relied when big or unusual jobs needed to be done. The perception was valuable *whether or not any jobs actually needed to be done*. The perception of being prepared for a risk, such as a power outage, can be valuable in and of itself, whether or not an outage occurs.

insurance value and the perception of that value. Customer concerns about major electrical outages are very high in California.

Development of other values delivers *investment* value. In the case of residential energy storage, the returns on investment arise when the system can deliver compensation from grid services. Grid services include functions such as local voltage ride-through and support, frequency stability, soft starts, ramp management, and emergency curtailment. The *investment* value of these services supplied through residential energy storage depends upon what the utility will pay for grid services, which depends in turn on what alternatives the utilities have for supplying them. If and when utility grid services can be designed around a large amount of distributed and possibly aggregated resources, the value will be significant and the compensation consistent.

The long-term prospects for residential energy storage are strong, given the direction and intensity of value drivers at work. Over the long-term, suppliers can continue to improve performance, reduce system costs, and market more effectively. As the solar energy industry has shown, there's a lot to be said for better, cheaper products that customers understand. However, the storage market's short-term situation is more difficult in three respects:

First, the value proposition for residential energy storage still leaves most households at a loss. The systems don't pay for themselves over battery lifetimes.

Second, the value drivers of residential energy storage are largely out of the system suppliers' control. The storage industry can't control solar adoption, utility design of rates, the utility's need for grid services, customer behavior, or the incidence of outages. To a large degree, the value proposition for residential energy storage must be forecast rather than produced.

Third, the value drivers for residential energy storage have their limits. The value of self-supply and time-based rate arbitrage is unlikely to rise substantially now that TOU rates are in place. Outage management is a key focus of utilities today, and any increase in natural disasters will only enhance that attention, and perhaps lead to a stronger utility interest in the grid value of residential storage.

If the economic value proposition for residential energy storage drives the market among today's early adopters, then we conclude that the Southern California market for residential energy storage is young and growing, but weak[46]. We also observe that even if system suppliers reduce costs, improve their marketing, explain their use cases more clearly, the value of residential energy storage will still largely result from other factors: solar adoption, utility rates, customer behavior, and customer outage experiences.

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[46] Growing technology-based markets can still be weak as they grow, as airlines, computer manufacturers, software, and high-performance materials firms have discovered. Like residential energy storage, these industries require substantial, ongoing technical investment and constant redesign of their offerings. Costs can't decline fast enough to pay for all of the necessary innovation. Unless all of the investment in innovation can drive up customer value, and therefore pricing, margins remain thin. Some troubled firms will price at a loss to make some kind of contribution to fixed and sunk costs. As the market expands to include more and more customers who require better and better economics, pricing remains low, and cash flow comes from investors. Until it doesn't. At that point, consolidation occurs.

3.2 Terms of Competition

SCE has an interest in understanding the terms of competition among suppliers in the residential energy storage market, because SCE aims for market stability, prosperity, and adaptability to SCE's needs. Diffusion and development of residential energy storage provides SCE with more options for the future. As a result, while SCE isn't interested in picking winners, SCE is very interested in anticipating winners, and may develop early relationships with leaders (such as Tesla, Sunrun, LG Chem, etc.) to better understand their value propositions.

Marginal market conditions like those we have described in residential energy storage usually argue for a consolidation of suppliers, the development of standardized products, and a battle for channel control. Well-financed, economical and reliable suppliers get larger and win. Suppliers taking too many risks based on too few resources lose. In growing weak markets, the terms of competition are oriented to survival rather than first-mover advantage. Slow and steady wins the race.

However, second-rate and smaller category competitors may be owned by firms with considerable resources, strategic reasons for being in the category, and other lines of business that support the firm. All the players in residential energy storage that we profiled earlier meet one or more of those conditions. Second-rate and smaller category competitors may also remain in the market if the market is growing, closely related to other markets they must be in (e.g., solar, electric vehicles) or if factors out of their control may yet save them. The California residential energy storage market meets these conditions.

These conditions may postpone consolidation in the residential energy storage market as the market continues to absorb capital. During this interval, suppliers will try to reduce costs and improve features to offer better residential energy storage systems. Because the category is young, the market hasn't established its own set of competitive metrics. Rather, suppliers are competing across a range of technical performance metrics, as this material from Pika indicates:

System Specifications

The Pika Energy Island is the most powerful solar plus storage system on the market. Compared to the leading residential battery brands, we offer as much as 2x the continuous power and 70% more capacity. Our super efficient system means that you will get to put more of the solar power you produce to use in your home. Enjoy more power when you need it with the Pika Energy Island.

SPECIFICATIONS	Pika Energy Island	Competitor A	Competitor B
Battery Type	DC battery	AC battery	DC battery
Usable Energy @ 30C	17.1kWh	13.5kWh	9.3kWh
Capacity Ratio**	1.2	1	1.1
Continuous Rated Power	6.7kW	3.3kW	3.3kW
Maximum Continuous Power	9.0kW	5.0kW	5.0kW
Surge Power (islanding)	12.0kW	7.0kW	7.0kW
Surge Power (single battery)	10.0kW	7.0kW	7.0kW
Roundtrip Efficiency – PV to ES to AC	93.00%	86.00%	91.70%
Roundtrip Efficiency – AC to ES to AC	90.70%	90.00%	89.80%
Warranty Period	10 Years	10 Years	10 Years
Warrantied Throughput (MWh)	45.36	37.8	22.4
UL9540 (Certified Home Energy Storage)	Yes	Yes	No
UL1973 (Stationary Applications)	Yes	Yes	Yes
UL1642 (Standard for Lithium Batteries)	Yes	Yes	Yes

*It is important to have a local user interface. If access to the internet is disrupted by a power outage, system controls are still available.

**Capacity Ratio = Total Capacity / Usable Capacity

Figure 3- 1:
Pika Product Comparisons

System Capabilities

Power and capacity are important, but far from the whole story. When shopping for a car, do you look for the fastest car or the car with the biggest gas tank? Usually, people buy the car with the best features to meet their needs: AWD to get to the mountains more frequently, or airbags to carry their family safely to school. The Pika Energy Island comes with a range of unique capabilities that put its power and capacity to better use for you. These capabilities are what sets our system above the rest.

CAPABILITIES	Pika Energy Island	Competitor A	Competitor B
Self-Supply Capability	Yes	Yes	Yes
Backup Power Capability	Yes	Yes	Yes
Off-grid Capability	Yes	No	Yes – Limited
Time of Use (TOU) Capability	Yes	Yes	Yes
Multiple Battery Capability	Yes – up to 4 batteries per inverter	Yes – up to 10 batteries per service	Yes – up to 2 batteries per inverter
Grid Export Capability	Yes – "Sell" mode	Not at this time	Yes
Zero Export Capability	Yes – "Zero Export" mode	Not at this time	No
Peak Avoidance Capability	Yes – "Demand Charge Management" mode	Not at this time	No
Grid Charge Capability	Yes – "Priority Backup" mode	No – not if solar is installed	Yes
Manual Control Capability*	Yes – control the battery from the inverter	No – cannot control battery without internet connection	Yes – control the battery from the inverter
"Dark Start" Capability	Yes – restarts with PV power	Yes - restarts with PV power	No – full discharge requires service

Figure 3- 2:
Pika System Comparisons (may be "Competitor A" is Tesla and "Competitor B" is LG Chem.)

While in some cases the Pika data may be for a larger (and thus apparently more capable) system than the rival system specified, the capability table does indicate that Pika supplies a more complete system than others.

Pika is asserting competitive advantage based on the range and values of its technical performance metrics. However, there is no evidence that the market understands these metrics, agrees that they are relevant, or purchases systems based on them. Pika is arguing that these metrics ought to predict competitive success, but there is no evidence that they do. Other suppliers also focus on technical performance metrics, similarly, arguing that it stands to reason that bigger, more, and longer are likely to be valuable. But the market is still so young that the tradeoffs across metrics aren't evident, and it's not clear how much of a good thing (e.g., energy density) is enough, or too much.

It also turns out that there's more to competition among residential energy storage systems than reducing costs and improving features. However, there are three other aspects of the residential energy storage market that will also have a great influence on how market consolidation will proceed, once it arrives.

<u>Enabling options</u>

The first relationship offering competitive advantage in the residential energy storage market is the relationship between residential storage and other categories.

Steve Jobs once defined his quest as introducing the next great product in the home. Examples of these rare innovations might include the home computer, the television, the microwave, the sound system, air conditioning, the home security system, and the swimming pool. Earlier a range of appliances transformed living at home. Today, solar energy, the heat pump, and electric vehicle charging are candidates. Residential energy storage is not such a transformative category.

Even if residential energy storage becomes typical, and even if regulations make it useful, for most households, it will not be an essential category for life at home. We might compare it to advanced water filtration systems, or computer printers, or large-scale backup generators. According to their lifestyles, a few households find these products necessary and some households find them preferable.

To the degree that solar+storage becomes its own category, and residential energy storage is positioned merely as a component of a solar energy system, the picture changes. In some cases, residential energy storage increases the size of the upfront investment but helps make solar energy more valuable during evenings and emergencies. In other cases, retrofit storage offers installers more revenue from customers they have already acquired, and who have already bought into the solar value proposition. While not every solar system and not every solar household are good candidates for retrofit storage[47], many are.

To the degree that solar+storage+EV charging becomes an integrated offering, the picture changes even more. The package is an even larger investment, but now electric transportation is enabled through evening and emergency charging. Fueling charges drop substantially, and mobility during a long-term outage is feasible. The EV market is moving into early adoption on a grand scale, including many households who haven't adopted solar or considered storage.

The value of enabling options through residential energy storage is particularly important in weak market conditions, because it allows residential energy storage to take advantage of willingness-to-pay in other categories. A customer who is making an investment in solar energy may be willing to invest even more in better, more useful solar energy. A customer who wants to invest in electric transportation may invest even more in order to have better, more useful electric transportation. For the high-end of the market, the scale of investment (especially as part of a homebuilding project) can be less important than the ability of the incremental investment to make something they've already decided to do (e.g., invest in solar energy, invest in electric transportation) even more attractive.

A category's value proposition that is carried by certain value streams (e.g., clean and economical transportation) may be bundled with other enabling investments. If clean and economical transportation means an EV, and an EV needs a home charging system, and the home charging system delivers on the clean and economical claim in that it is powered by a solar+storage system, then the entire investment proposition stands on its own.

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[47] Replacing grid-tied inverters and reconfiguring arrays requires experienced technicians and may also require new regulatory approvals. AC-coupling is less efficient, is still complicated, and can be very hard on the batteries unless charging is managed carefully.

Therefore, in the run-up to market consolidation, the residential energy storage firms who can provide collaborative functionality, integrate systems, and eventually become essential to other categories will have a competitive advantage.

External Drivers

The second relationship offering competitive advantage in the residential energy storage market is the relationship between the market and outside drivers. We have noted above that market suppliers can't control solar adoption, utility rates, the utility's need for grid services, customer behavior, or the incidence of outages. Instead, market suppliers need to forecast these factors.

Builders are very familiar with the need to forecast well and build accordingly. Across land, labor, materials, regulation, economic health, local development, design fads, finance, technology and many other factors, builders have to estimate what the value will be, a few years in the future, of these kinds of homes built on these particular lots. Builders know that people need to live somewhere, that homes will find a market value, and that much of their job is simply to comply with plans, codes, and regulations. Builders try to understand human nature, to identify what will hold constant as other factors are changing. But in the end, builders have to forecast well, and live by those forecasts.

Suppliers of residential energy storage systems may make the mistake of assuming that because their category is relatively new, and understood by few, they can design to whatever specifications they think best. Nothing could be further from the truth. Certain system features will best support solar adoption. Certain system features will best adapt to utility rates. Certain system features will best enable utility grid services. Certain system features will best an increased incidence of outages. Most important, certain system features will be best aligned with how customers will use a residential energy storage system. To date, none of the major market players have designed their offerings to take best advantage of these outside forces. It is beyond the scope of this report to suggest how designs might change if they did.

But we can note that in weak, growing markets driven by outside forces, often one of the outside forces will become dominant, and in that moment, a market player may seem suddenly preferable to others. In that moment, that market player may offer a well-timed redesign built around technical, digital, design, or customer experiences. The category leader emerges with a product that just fits, and other products seem obsolete and awkward by comparison.

Therefore, in the run-up to market consolidation, the residential energy storage firms who best anticipate and adapt to changing outside forces will have a competitive advantage.

Value vs. Perceived Value

The third relationship offering competitive advantage in the residential energy storage market is the relationship between value and perceived value.

Unlike the value perceived by a fringe market purchaser, who is self-identifying with a purchase, the value perceived by an early adopter arises to a great extent from an economic value proposition. But the values of the variables in that proposition may not be measured. They may be perceived, or forecast, or merely assigned. For example, for a single-family homeowner, the value of having a fallout shelter in the backyard can't be measured through experience or test data. Its unclear which scenarios should be tested, or how the models would be validated to test them. Most important, the construction specifications of the fallout shelter assert a certain level of protection under certain conditions, and the insurance value of that protection can't be marked to market. Apart from the fact that we can't ever objectively know if it proved worthwhile as a shelter, as a precaution, does the fallout shelter provide peace of mind? The value of that peace of mind will be quite real and will differ greatly for different households. In the resale market, the fallout shelter will make all the difference for a few prospective buyers and will be an irritant or worse for other prospects.

There are other less extreme examples of how real perceived value can be. There are homes on the regular path of hurricanes, tornadoes, and floods; there are homes near prisons, waste sites, fault lines, and electric transmission lines. How dangerous are these locations? There are homes near hospitals, and police stations, and military bases. Are these homes safer? There are homes in the forests, and brush land, and mountain hillsides near Los Angeles. What's the risk of fire for these homes? There are homes with and without residential energy storage. What's it worth to have residential energy storage in an emergency? The answer is that it's worth what people will pay for it, and what people will pay for it depends upon how they perceive both the risk and the mitigation.

Residential energy storage is certainly worth more to some households than others, depending on the home, its location, and the habits of those who live there. These objective values can be measured. But residential energy storage is also worth more to some households than others, depending on how those households perceive risk and risk mitigation. These perceived values are no less real and no less economic simply because they are perceived. Customer attitudes are every bit as important as product features in determining value.

Therefore, in the run-up to market consolidation, the residential energy storage firms who segment and understand customer attitudes will have a competitive advantage.

In the young, weak market for residential energy storage, suppliers are setting the current terms of competition based on technical performance. Certainly, technical performance is a means of comparing systems, but we maintain that competition for purchases depends on other factors: enabling options in other markets, anticipating forces from outside the market, and addressing perceived values.

3.3 Outlook

The market for residential energy storage in Southern California is a young, weak, growing market. The systems are of marginal, speculative, or perceived value to almost all the 10,000+ households who have installed grid-interconnected residential energy storage. Suppliers recognize that new residential construction may reveal more energy storage partisans, but beyond them, early adopters will demand economic value, and there are many alternatives for household spending[48].

Residential energy storage suppliers will continue to compete based on improving system performance, but system sales in residential markets will remain too low to amortize research,

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[48] Solar energy and electric transportation reduce GHG levels and save money. LCD lighting and double-paned windows reduce the cost of living at home to a greater degree than rate arbitrage. Even surge suppressors can claim to lengthen the life or improve the performance of household appliances.

development, and marketing costs. Capital is more likely to support utility-scale and CII storage, which can credibly offer grid services. We expect a consolidation of suppliers, the development of standardized products, and a battle for channel control in residential energy storage.

In the search for advantage, residential energy storage suppliers may come to recognize that their category is driven by outside forces, i.e., solar adoption, utility rates, the utility's need for grid services, customer behavior, and the incidence of outages. These forces may prove positive: e.g., solar power may continue to decline in price, increasing the investment returns of self-supply, and the savings from energy cost management. Local grid services from distributed residential energy storage may prove to have a distinctive value.

Some of these forces will be accessible to suppliers who are already positioned in adjacent categories (e.g., solar energy, electric vehicles), and can integrate residential energy storage more closely with their other offerings. The perceived insurance value of residential energy storage may extend well to these larger investments. Suppliers outside of these adjacent categories will be disadvantaged.

The fundamental challenge for residential energy storage is that it does one thing, and that one thing has limited value, even when bundled and extended to other categories. Residential energy storage offers households the opportunity to believe that they are independent from the grid, to a degree. An energy storage system does not clean up the electrons, or improve their comfort, or make them more entertaining. Residential energy storage is a young category with an uncertain future, and unlike home computing, or cable television, or the microwave, residential energy storage does not have the prospect of transforming how households live in their day to day lives.

Except in emergencies when the power goes out.

Residential energy storage has outsized value in a grid outage, and strong value in anticipating an emergency. Some system suppliers (e.g., Sonnen) are already describing these use cases and their value, e.g., how essential it might be to have medications refrigerated through an extended outage. In outages, a properly designed battery storage system can power lighting, appliances, telecommunications, and a variety of end uses. Prior to the emergency itself, peace of mind is also significantly valuable. After the emergency, the stories live on, and impart their own significant value. Residential energy storage can be valuable to have, as well as to use.

Customer perceptions of high-impact, unfamiliar and speculative events shape many markets across our economy (e.g., in health care, education, insurance, wagering, politics). Wildfires, earthquakes, and climate change are examples. Residential energy storage falls in a sector of home health, safety and security products that are not required by code, but that offer significant insurance value. There are many good examples of category leaders who attract customers with claims that "we're all in this together." The benefits emphasized are customer control, peace of mind, and responsibility ("clean power", "doing everything possible").

The next step in residential energy storage market development will be led by the suppliers who identify these customers, figure out how to reach them, and what stories to tell them. The bridge across the market chasm from the fringe market to early adopters will be the enhanced perception of insurance value some customers attribute to the category. There should be enough time to build the bridge, because of the market boost created by TOU rates and the new Building Code requirements.

In the run-up to market consolidation, price and feature competition will continue among

residential energy storage suppliers, as those who segment and understand customer attitudes develop their competitive advantage. Based on customer research, we expect improvements in specific performance and performance tradeoffs regarding system lifetime costs, size, weight, capacity, efficiency, acquisition, installation, operations, noise, control, and maintenance. Initial system designs based on system components will be replaced by designs based on residential customer use cases (e.g., outage management through backup power, self-supply, energy cost management, grid services supply).

The leaders in residential energy storage will also be searching for economic value propositions early adopters can believe in. Because belief in value depends upon beliefs about what might happen in the future, these leaders will also be investigating which stories about the future have the most resonance with customers.

SCE can help the residential energy storage market to broaden and prosper by providing these stories.

3.4 Policy and Program recommendations

The Southern California market for residential energy storage has rushed to the edge of a chasm. As customers investigate residential solar retrofit, they ask their installers and contractors about energy storage. In response, these customers have been receiving incomplete or discouraging information about the systems' economics. As a result, few expressions of interest have led to installed systems. Customers for new residential construction could follow a similar unclear path under the new Building Code provisions.

While residential storage system economics are improving, they are still marginal in general, and are highly dependent on both system selection and the local circumstances of installations. One site's story doesn't necessarily translate to another site. Some sites prove to be economic, and some don't. Given that detailed analysis of site economics occurs in few cases today, it stands to reason that many promising installations are overlooked, and some unsuitable installations are built. It's also the case that many customers purchasing residential energy storage understand that the suppliers, installers, regulators, and utilities may be unsure about the category.

SCE could mitigate these problems, and influence the customer adoption for residential energy storage, by taking steps in five areas: active community outreach, online information and analytics, strategic intent, SGIP improvements, and installer support. SCE is active in some of these areas already; discussing these current activities is beyond the scope of this report. However, there continue to be opportunities for policy and program improvement, and what follows are recommendation for future consideration.

Active Community Outreach

The residential energy storage market is small enough that in-person community outreach can make a significant difference. Target audiences are many: e.g., construction professionals, firstresponders and emergency services personnel, health care workers, schoolteachers, students living at home, mortgage bankers and realtors, green cause supporters, EV owners, and more.

The content could be as simple as distributing fact sheets with "Ten Questions to Ask Your Installer", describing how to understand and take advantage of TOU (e.g., TOU-D-PRIME) rates, explaining how to prepare for and live through a wildfire, discussing GHG mitigation. Many encounters could include homeowners who have successfully installed residential energy storage and are willing to share their experiences. The outreach could be at many different locations: e.g., schools, offices, parking lots, malls, farmers' markets, parks, hotels, sporting events. The outreach could target particular feeders. Social media networking would expand reach and encourage more events.

As a research project, SCE could design a set of these outreach events, conduct them, and then measure the customer impact (e.g., attitudes; communications, inquiry and purchasing behaviors). Potential customers could better understand the value proposition, the perceived insurance value, and the connections with storage and EVs through active community outreach.

Online Information and Analytics

SCE could partner with system suppliers, installers, and software providers to offer online information and analytics. SCE could either make the analytics possible directly over an SCE website, or could link customers to SGIP-approved industry, installer or system supplier sites for analysis conducted in an objective framework according to inputs supplied by the installers and suppliers. In standing behind objective information and analytics, SCE would be serving customers as a trusted energy advisor.

Most potential customers new to the category need to begin with basic information about residential energy storage: what it is, how it works, what it costs, why others have chosen to install it, what's involved in the permitting and installation process, and what would be expected of them should they decide to acquire such a system. If there are differences of opinion, SCE could explain them (e.g., AC-coupled vs. integrated DC systems, alternative battery chemistries, indoor or outdoor locations). Customers have had a very long relationship with SCE as their electricity provider, which may lead them to trust SCE's expertise.

SCE already takes a similar approach for electric vehicles. SCE's website offers information about EV rebates and incentives, rates & savings, and EV charging. The website includes tips about checking home infrastructure, getting a charging station installed, and working with electricians. The website includes cost estimates. Most important, by encouraging analytics, the website initiates a dialogue with SCE about the specific purchase.

As a research project, SCE could make available inexpensive, software-based site analytics (e.g., Energy Toolbase™) to see if such analyses increase customer inquiries, solicitation of bids, and approvals of bids for residential energy storage. Online information and analytics would help potential customers better understand the value proposition, the perceived insurance value, and the connections with storage and EVs,

Strategic Intent

SCE has chosen to strategically support the residential market through incentive programs and innovative rate strategies (e.g., SGIP, resiliency adders, storage net metering, TOU rates), and provide advocacy in the background, through its emerging technology experiments and its own large-scale investments in energy storage.

Despite its notable innovative research into residential energy storage (e.g., the Fontana project, the Irvine Smart Grid Demonstration project), its sponsorship of multifamily residential energy storage (e.g., Mosaic Gardens), and its major commitment to electrification, SCE hasn't communicated a clear position on the category. Customers, suppliers, policymakers and industry observers are left to interpret tariff rules and regulatory filings to better understand SCE's strategic direction and preferences. Should homeowners invest in energy storage alongside solar? Should EV owners invest in energy storage alongside their vehicles? Should residential electric storage system owners anticipate SCE will draw on those systems for grid services? Should residential electrification include storage as a matter of course?

As research projects, SCE could (1) analyze the value and roles of residential energy storage for grid services; and (2) identify the explicit value and roles of residential energy storage in electrification. Builders, installers and regulators could understand residential storage's role in grid services and electrification and develop confidence in SCE's strategic intent and long-term policy interests.

SGIP Improvements

In order to provide more reliability and resiliency for the electricity grid, California legislators have encouraged utilities to offer incentives for customers to install renewable generation. Residential energy storage is following in the footsteps of solar energy, and could be straightforward, but market feedback indicates that the SGIP is time-consuming, burdensome, and difficult for many of SCE's residential customers.

The SGIP Program Administrators and the program evaluator have been required to focus on CPUC regulatory compliance in their administration of the program. As a result, the SGIP has become internally focused. What was intended as a market transformation initiative to increase the adoption of renewables has posed challenges for participants seeking to install residential storage.

As a research project to improve the SGIP's focus on customers, SCE could conduct baseline customer research among its own SGIP recipients, and across installer/customer experiences. Satisfaction surveys, definitions of the customer journey, process mapping of customer/installer/ program interaction, and consideration of alternative methods of achieving program objectives would also be helpful. Customers, installers, builders could get behind SGIP improvements, while building confidence for the CPUC in how SCE is meeting the strategic intent of the legislators. SCE has always valued the voice of the customer in establishing its strategies, and residential energy storage offers another opportunity to listen.

Installer Support

The residential solar + storage community has viewed SCE tariffs and interconnection rules and requirements with caution. Many in the community would choose to deal with SCE as little as possible, because they suspect SCE's motives, capabilities, and reliability. However, both parties would benefit from improvements in the relationship, and SCE can deliver them.

SCE's relationships with solar and storage installers spans bidding, the SGIP, interconnection, and local approval. During bidding, installers need to estimate how long permitting, installation, and interconnection will take, and what steps they will need to complete. Jurisdictions and locations differ, as SCE knows better than anyone. SCE can improve their communications and help installers understand specific situations. In their bids, installers also need to describe how customers should use and maintain their residential energy storage systems. SCE understands these behaviors.

During SGIP application, SCE could actively help the installers file and accelerate applications, rather than merely processing applications. During interconnection, SCE could help installers anticipate requirements and execute on them properly and quickly. During local approval SCE may seem to have no formal role, but informally, SCE could help installers anticipate local issues and requirements.

The most important step SCE could take to improve its relationships with installers would be helping to align attitudes. It is natural for a utility to measure itself by its success in protecting the grid from substandard projects, and it is natural for installers to measure themselves by how many worthy projects they connect to the grid. Each party needs to understand and embrace both metrics. SCE must guard the grid, train others to respect the grid, and actively support interconnection. In training others to respect the grid, SCE must look after its partners, especially by providing information, skills, and improvements to develop a timelier process. Interconnection seems threatening, but it is also an opportunity to improve the grid. Installers must expand the grid, train others to understand the projects they are developing, and accomplish disciplined and safe interconnection.

As an internal process improvement project, SCE could engage a team of external stakeholders to assess and map its residential energy storage interconnection processes, identify potential improvements in dialogue with installers, and then test these potential improvements in practice. The customer adoption rate could rise through installer support, as bidding would be based on better information, and the SGIP, interconnection, and local approval would all be easier -- making for more profitable projects. This would develop improved customer and installer satisfaction, regulatory and legislative compliance, and more customer and industry support for residential energy storage.