A deep dive into behind-the-meter battery storage economics: PG&E territory in California

1. Overview

The California Public Utilities Commission (CPUC) passed a mandate in 2013 that requires the state's Investor-Owned Utilities (IOUs) to procure 1,325 MW of electricity storage capacity by 2020. Three years later, CPUC issued another order that requires each of the IOUs to procure additional 500 MW of Behind-The-Meter (BTM) storage. This robust regulatory environment has further been bolstered by the creation of an independent body to resolve interconnection disputes, provide support for long duration bulk storage and encourage the expansion of funding incentives for customer-sited storage. The results have been impressive; California currently rules the US BTM storage market, and saw deployment of 45 MW in non-residential BTM, 43 MW in Front-of-the-Meter (FTM) projects, and 6 MW in residential BTM applications in 2017.

California has established its position as one of the leading states in renewable energy deployment. Most recently, it passed another unprecedented ruling that requires all new constructions to come installed with solar, as well as a landmark 100% clean energy goal.

Traditionally, energy storage has been viewed as a mechanism to circumvent the challenge of variability in renewable energy production. Now, storage is increasingly being viewed as a standalone asset, capable of benefiting from diverse revenue streams. These revenue streams, and the economics of energy storage for different end-users, are dependent on the interplay between tariff structures, incentive programs, renewable energy production and the overall costs of deploying storage systems. This article explores these variables in detail and outlines the trends and expectations of BTM storage economics. It begins with discussion of the value proposition storage brings to the grid and goes on to examine the factors that govern success of battery storage projects. Qualitative and quantitative analyses are presented to highlight the various drivers of success in California's battery storage market.

2. Why is storage necessary?

Before diving into the specifics of battery storage projects, it is important to appreciate the myriad of problems storage seeks to solve.

2.1. The Duck Curve

Historically, California has always been a leader in deploying renewable energy. The efforts to meet Renewable Portfolio Standard (RPS) goals and improve overall grid reliability have resulted in one of the most interesting case studies in the modern energy industry; the infamous 'duck curve' (see Figure 1 below). High penetration of solar during the day results in a significant reduction in load on the grid during those hours. However, when the sun stops shining and people return home and switch on lights, run washing machines or turn on air-conditioners, there is a sudden spike in demand from the grid.

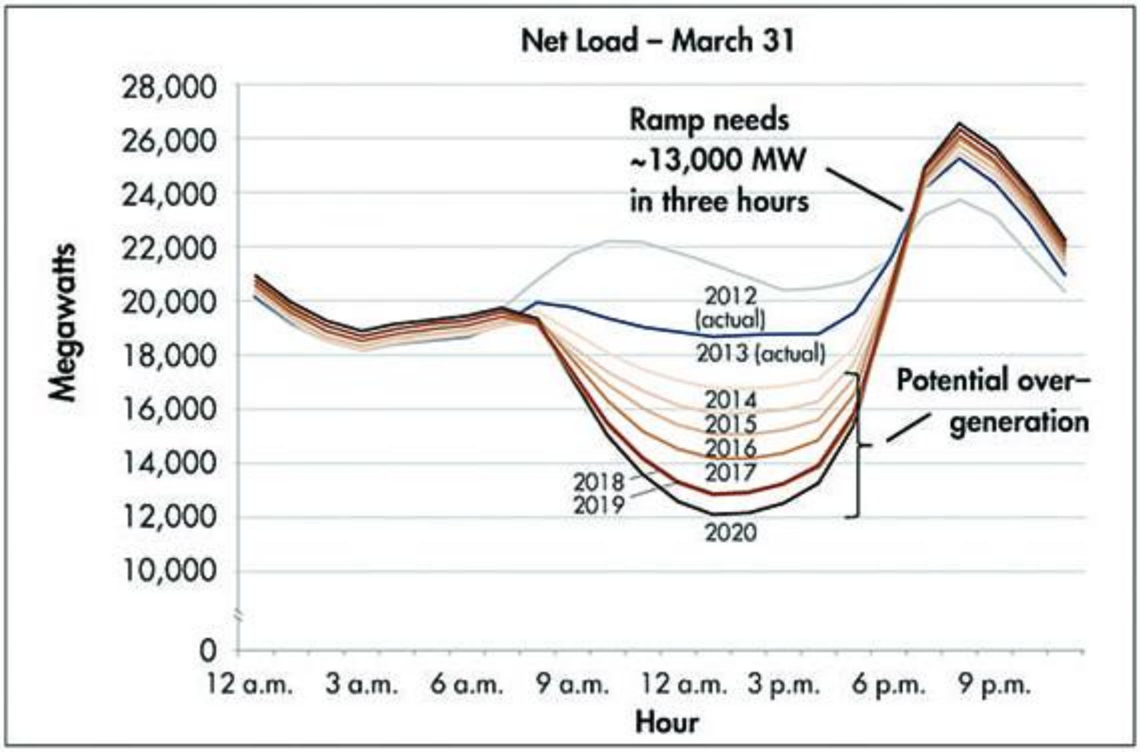

Figure 1: Illustration of the "duck curve" in California: Source CAISO

This has proved to be a significant issue for grid-operators that they manage in the following ways:

- **Deploy quick response, expensive peaker plants**
  These plants are capable of ramping up quickly and meeting the sudden spike in demand from the grid. However, they add significant costs as the plants have a relatively low utilization factor.
- **Modify rates based on time of use to "teach the duck how to fly", i.e. flatten the demand curve**
  This may mean making it relatively less expensive to use grid electricity during the day. This is almost certain to harm the economics of solar electricity, by making it uneconomical to use when it is most abundant.
- **Incentivize energy storage**
  By storing the excess solar energy and deploying it when the sun isn't shining, battery storage is increasingly being seen as an alternative to peaker plants. Essentially, battery storage keeps the duck fit; it trims the belly and transfers that energy to its head.

2.2. Maintaining the competitiveness of solar

The new ruling on mandatory solar for future construction has several societal benefits. However, critics have argued that it will also impose further costs on the system, primarily in the following ways:

- **A 'fatter duck'**
  More solar is likely to deepen the belly of the duck and further exacerbate the stresses on the grid in the evening when the system peaks.
- **Cannibalized value of FTM solar**

Variable renewable energy (e.g. solar or wind) floods the wholesale power market all at once, driving the market clearing price down to zero and sometimes requiring CAISO to actually pay other states to absorb excess generation. Solar, in particular, tends to be coincident with demand, rising and peaking at midday, right when demand is highest. It replaces expensive power with free power, reducing prices. The more solar energy there is on the grid, the lesser the value of each kWh of solar energy produced.

- **Diminished value for BTM solar**
  This challenge extends directly from the previous one. While BTM solar installations are likely to be insulated from wholesale market prices, an overall increase in solar is likely to result in a regulatory response that may redefine time-of-use blocks and energy pricing across the day. California is actively pursuing time-of-use rate structures for residential customers. Currently, the peak period (12 pm - 6 pm) coincides with solar production; if the peak time was redefined to occur in the evening when solar isn't being produced, then solar systems will begin to appear less attractive economically. Figure 2 depicts planned changes to PG&E TOU blocks, Peak Day Pricing (Demand Response) events and electricity prices.

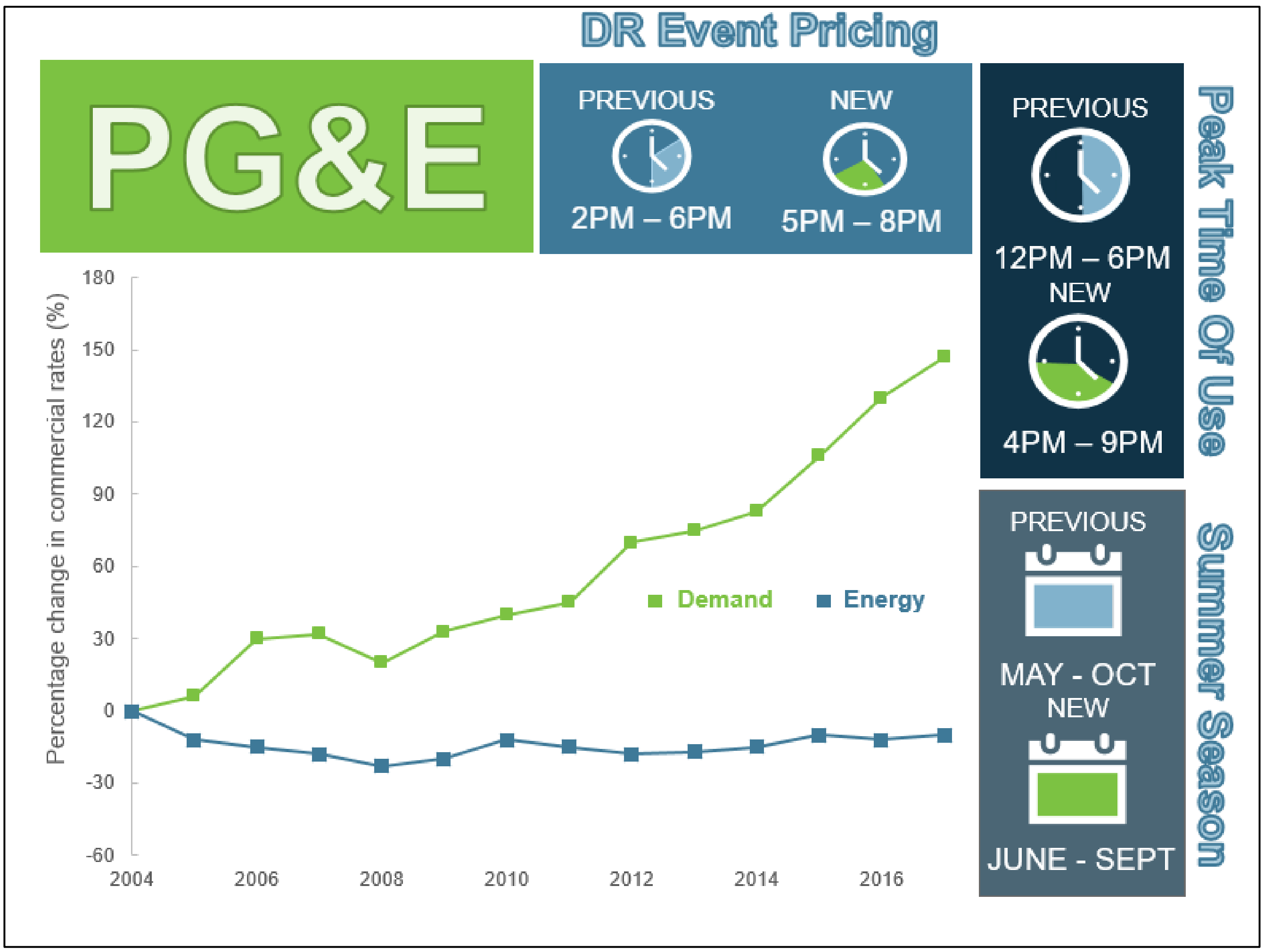

Figure 2: Proposed changes in TOU blocks, PDP events and electricity prices in PG&E territory: Source: PG&E & STEM research

Energy storage is no doubt the most promising solution to managing the issues highlighted above. In fact, the primary reason behind all storage supporting mandates in California is to mitigate the growing imbalance between renewable energy generation and the system peak.

3. Factors that shape the battery storage market

3.1. Declining installed Costs

A McKinsey study published in June 2018 highlighted that the costs of battery storage (assuming a utility scale 1MW/1MWh system) fell 72% over 5 years, from $2,100/kWh in 2012 to $587/kWh in 2017. This is primarily driven by the decline in Balance of System (BOS) costs.

The study goes on to present two plausible scenarios: one was just a continued decline in installed costs leading to an all-in cost of $270/kWh in 2025; the other assumes additional efficiency gains and innovation that results in a 70% decline from 2017, (all-in cost of $170/kWh).

A 2016 NREL study found the installed costs of a commercial scale 500KW/1000kWh containerized Li-ion battery system to be $883/kWh. Other studies and papers have made similar projections; the latest Lazard study suggests capital cost to be ~$283/kWh for utility scale, $576/kWh for commercial scale and $749/MWh for residential scale installations (Li-ion batteries).

These studies are varied in the precise projections and estimates of installed costs per unit capacity, primarily due to differences in underlying assumptions and the nature of component costs considered. However, the message is consistent; storage costs are falling rapidly and will continue to do so as more players gain the necessary scale and experience to swiftly deploy these systems.

3.2. Jurisdiction and policy

Falling installed costs however, play only a part in the overall uptake of storage technologies. The cost projections are also subject to change depending on the local jurisdiction and policies. For example, any regulations around the interconnection and permitting processes that increase complexity are likely to drive costs up and reverse the projected trends.

A prime example of this has been experienced in New York City. Prior to the release of the Energy Storage Permitting and Interconnection Process Guide for New York City: Lithium-Ion Outdoor Systems, little progress had been made in the deployment of energy storage. The lack of data on how these systems would perform under different scenarios has resulted in unforeseen delays in permitting and an overall increase in costs associated with battery storage projects. Thankfully, California has maintained its leadership status in this regard and in September 2017 passed a bill that significantly streamlines the permitting process, clarifies good permitting practices and calls for the entire process to be digital by 2019.

3.3. Diverse value streams

Battery storage projects are capable of providing unique revenue streams to each major stakeholder in the California electricity market:

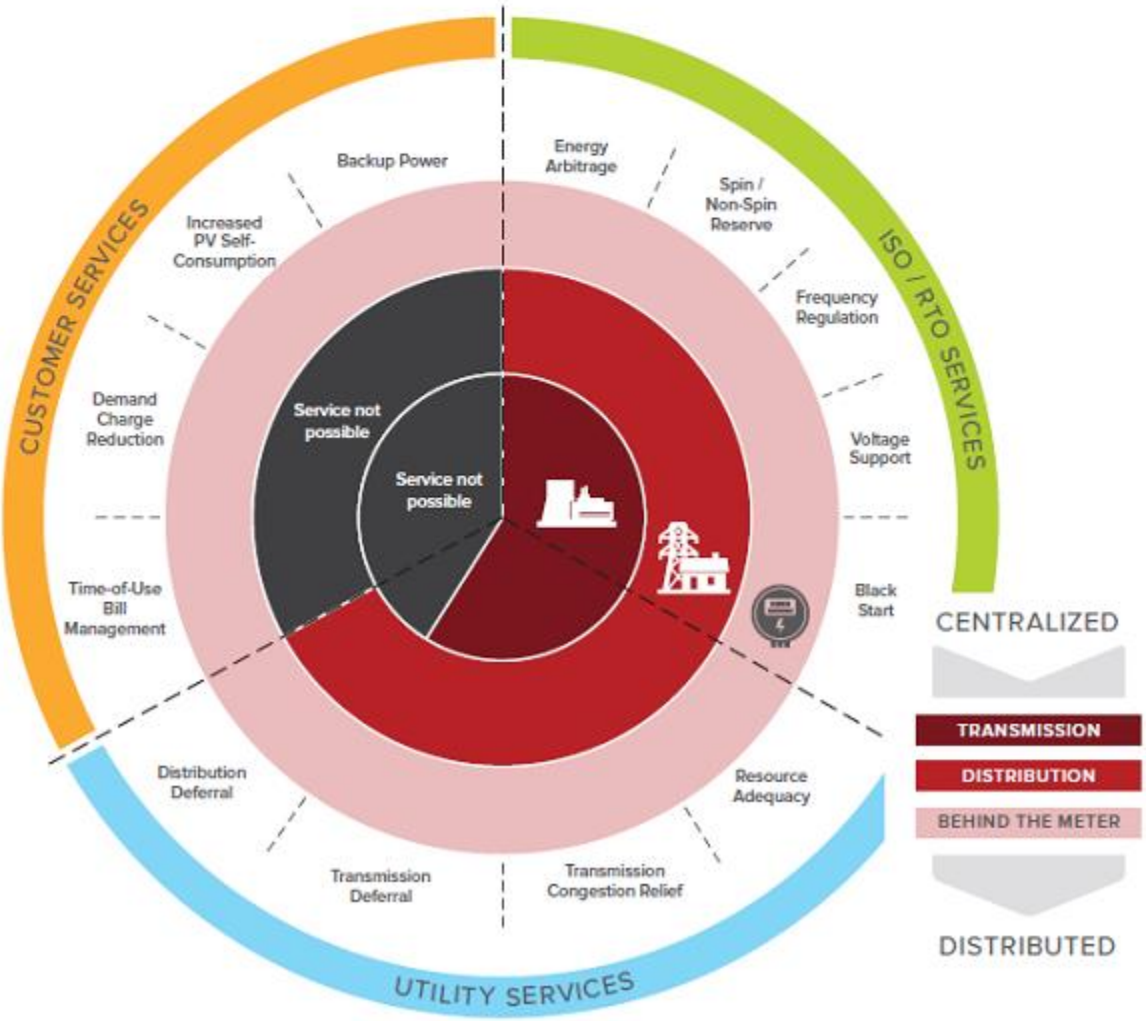

Figure 3: Source - The Economics of Battery Storage, Rocky Mountain Institute

A 2015 Rocky Mountain Institute paper titled *The Economics of Battery Storage* concluded that BTM energy storage offered the greatest spread of the aforementioned suite of services (i.e. in theory all of the above can be offered through BTM solutions). However, current market conditions do not permit BTM batteries to participate in all of the quantifiable value streams.

Within the BTM market, Demand Response programs have a significant role to play in allowing end users to extract the most out of demand charge reduction efforts. California has a wide array of demand response programs in place that cater to various types of end users. A few examples of such programs in operation include:

Peak Day Pricing rate: Provides discounted rates during the summer in exchange for an energy (kWh) surcharge on specific event days.

Scheduled Load Reduction Program: Pays the customer to use less energy by reducing electric load during pre-selected time periods.

Typically, the impact of these programs on the economics of battery storage is dependent on the certainty with which the battery can be used to respond when the utility calls for a reduction in load/declares an event day. For example, under Peak Day Pricing, the battery is likely to achieve lesser value under normal operating conditions (discharging during peak or part peak times) because of the discounted rates. The goal under this scheme would be to operate the battery to ensure that the battery has enough capacity to respond on the event day and avoid the surcharge. If the battery is able to shave peaks as usual but not have enough capacity to respond when it matters (i.e. on an event day), the returns are likely to be diminished.

BTM batteries would also be capable of participating in ancillary services markets, though current market rules prevent them from doing so in some cases. In terms of specific market participation rules, California offers the following models:

Non- Generator Resource Model (NGR): Allows smaller, energy constrained resources to provide energy, frequency regulation and operating reserve services

Proxy Demand Resource Model (PDR): Allows BTM batteries to perform load curtailment. The participation resembles a bid into the ISO market as supply

Reliability Demand Response Resource (RDRR): Enables emergency demand response resources to offer energy into the day ahead market. Participation is modelled like a supply resource and takes advantage of processes and infrastructure set up for the PDR model.

The PDR and RDRR models do not permit the battery to inject energy onto the grid or participate in other ancillary services (even if they are technically capable of doing so).

The availability of diverse value streams coupled with the projected cost decline result in project developers being able to offer a variety products and services with batteries. However, the reality is that often the rules and regulations that govern the participation in any revenue stream outside of lowering on-site demand are difficult to decipher and add to costs. Broadly speaking, the following barriers exist in California:

- There is no centralized capacity market, which can result in the lack of a transparent price signal and hence impede the realization of generation capacity value streams
- There are often limitations on net exports to the grid
- In the event where batteries operate to capture multiple value streams across markets, the dispatch control priority (i.e. who controls the battery and at what time) is ambiguous.

Furthermore, the realization of these value streams is highly dependent on the following characteristics of the host site:

Load profile

A "peaky" load profile indicates an opportunity to use the battery to peak shave and reduce demand charges. A "block" load profile (typically what one would expect from a manufacturing facility) is likely to be better-suited to take advantage of energy resiliency or self-PV consumption benefits. This is best illustrated below:

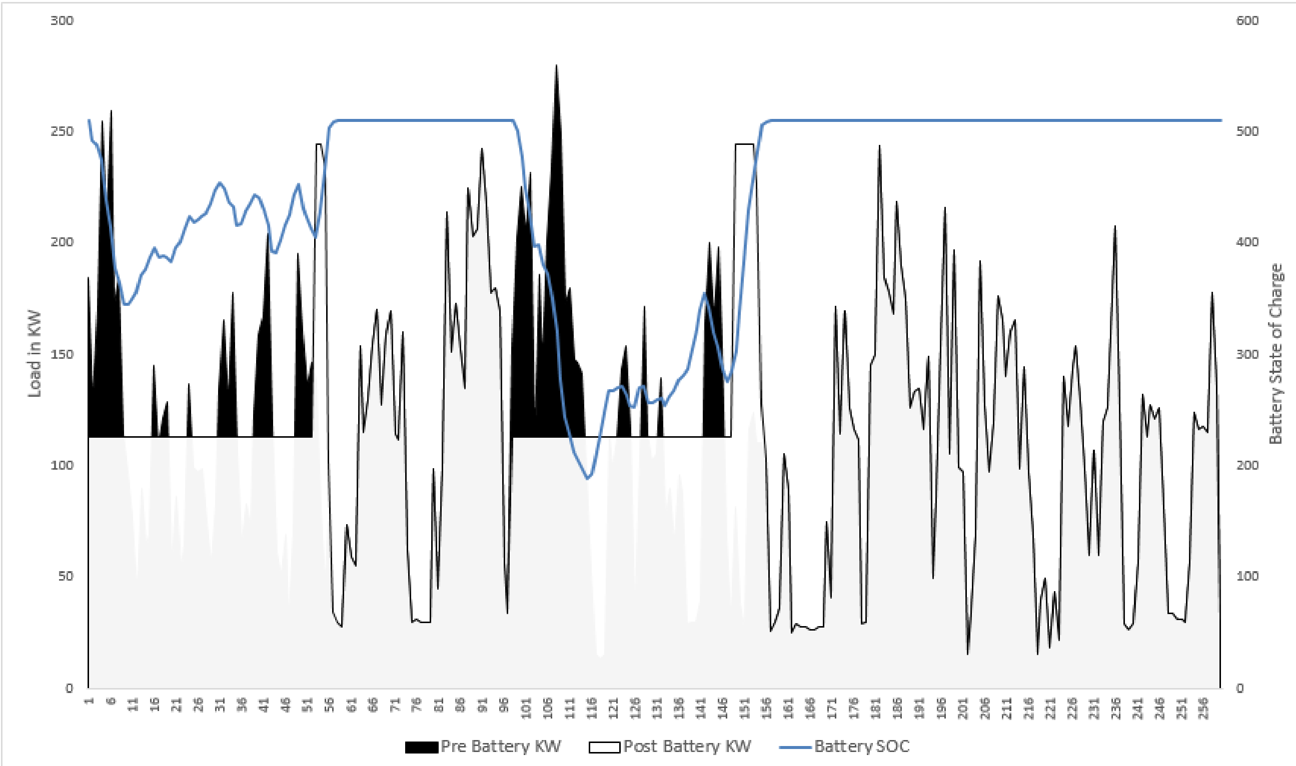

Figure 4: Illustration of battery operations for a typical "peaky" load profile (sample 360 "15 min" intervals) : GI Energy

The figure above illustrates a snapshot in time of battery operations at a site with a "peaky" load profile. The battery is able to discharge initially to reduce the peak down to a target level of 113 KW. In subsequent time intervals where the pre-battery load was less than this target (i.e. the "troughs" in the load profile), the battery charges itself. In this way, a battery will be capable of discharging at a later time once again, thereby shaving the peaks.

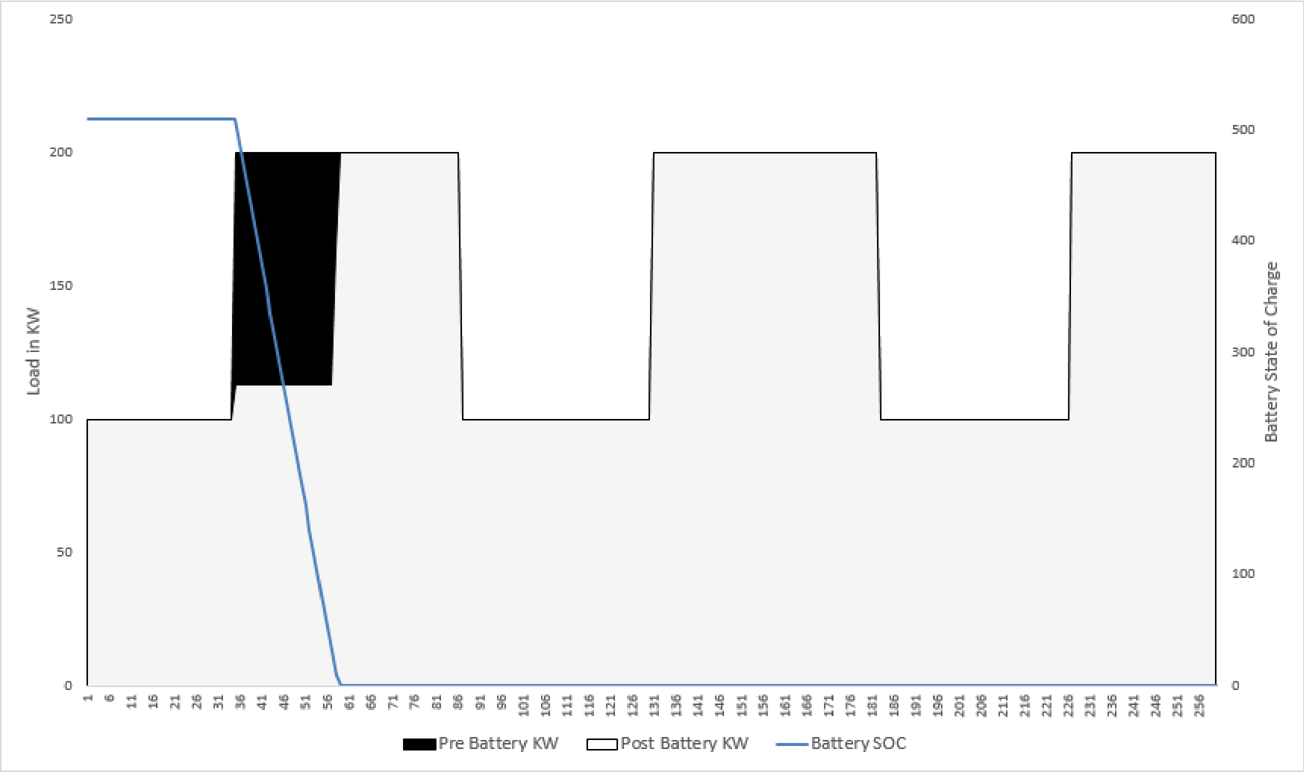

Figure 5: Illustration of battery operations for a typical "block" load profile (sample 360 "15 min" intervals): GI Energy

The figure above illustrates how a battery would perform, ceteris paribus, if the site had a "block" like load profile. The battery rapidly discharges to shave the peak but is unable to find an opportunity to recharge itself, since there aren't any "troughs" in the load profile where the pre-battery load is lower than the battery's target (thereby allowing it to charge up without resetting the peak). A battery at such a site would yield better results when paired with a solar plant.

Rate structure

IOUs in California offer a variety of tariffs that include Time-of-Use (TOU) rates and demand charges. Value streams such as demand charge reduction and energy arbitrage are highly dependent on the price signals created by TOU rates. PG&E's definition for TOU blocks for commercial and industrial customers is unique in that it contains two part-peak periods (8:30 AM to 12 PM and 6 PM TO 9:30 PM) around the peak period (12 PM to 6 PM) with the entirety of the night being the off-peak period. Furthermore, weekends and holidays are considered off-peak throughout.

Interaction between load profile and rate structure

Ultimately, both the aforementioned factors together will help determine the viability of a battery project. A "peaky" load profile is likely to derive the most value if the peaks coincide with the "peak" demand period under a TOU rate structure. The magnitude of benefits is further determined by the value assigned to each demand charge. For example, the max demand (measured across the day) for a PG&E E-19 rate is approximately $17.56/kW, while the part peak demand charge is $ 5.18/kW. Is it worth going after the more expensive "max demand" saving (which would likely mean the battery has to charge up in the more expensive, part peak period) or shave the less valuable "part peak demand" (which would mean charging up in the cheaper off-peak period)? The answer to this question is highly circumstantial and would require iterative simulations to determine the best battery dispatch protocol.

3.4. Incentives

The Self-Generation Incentive Program (SGIP) in California is one of the leading programs across the nation that actively incentivizes stand-alone advanced energy storage systems. The SGIP is often the deciding factor in making any battery storage project make financial sense.

The extent to which the SGIP plays a decisive role in pushing battery storage projects over the finish line depends on the projected value that the battery is able to bring to the table. This is further dependent, as detailed out in the preceding section, on the site's load profile, rate structure and regulatory environment.

This is best illustrated using a hypothetical example: for a small manufacturing site located in PG&E territory (on a E-19 tariff) with a fairly flat (block-like) load, using battery storage to pursue various BTM value streams such as energy arbitrage or demand charge reduction is likely to be difficult, unless the battery is significantly oversized. This is because PG&E peak, part peak and max demand is measured as the highest demand in a 15-minute interval. In a block like load profile, a battery will be discharged initially and will succeed in lowering the demand during the times it is capable of discharging. However, the rest of the time the "plateau-like" shape of the load profile will remain and the effective max demand value will remain unchanged (Refer Figure 2 above).

For such a site, other value streams such as increased self-PV consumption or resiliency during outages are more likely to be drivers for battery storage adoption. Assuming a 1 MWh system which costs (per the 2017 costs highlighted in the McKinsey study cited in an earlier section), $587,000, the SGIP amount (assuming Step 2 is active @ $ 0.40 /WH) is likely to be $400,000. That's almost 70% of the installed costs! (*Note: The SGIP follows a sophisticated process of computing the eligible incentive amount. The numbers quoted here are purely directional to highlight the trend).* It is reasonable to expect that without the SGIP, this hypothetical site is not likely to pursue a battery storage project.

The SGIP does require the battery to meet certain operating characteristics, including an equivalent of 52 full cycles per year. A site with a "peaky" load profile is typically better-suited for adopting battery storage, being eligible for the SGIP and maximizing the value they derive from the battery. It is also likely that the SGIP will play a less decisive role in the project, since a "peaky" site will be able to capture the benefits of demand charge reduction effectively.

4. Conclusion

Battery Storage projects are subject to several uncertainties despite that fact that theoretically their value to end users and the health of the grid has been proven time and time again. These uncertainties range from the ever-evolving market participation rules to permitting hurdles that can significantly inflate costs.

Broadly speaking, the factors that every potential battery storage owner must consider are:

- Does my tariff structure allow me to generate financial savings by reducing demand?
- Is my load profile conducive to using battery storage (i.e. peaky vs block profiles)?
- Does my usage pattern coincide with my rate structure in a way so as to realize maximum savings?

Nonetheless, California is poised to demonstrate the success of battery storage projects here in the United States. It is however, important to unpack all the studies and numbers that suggest that batteries are good investments before coming to a conclusion on the best way forward for individual projects. The exact nature of benefits will vary depending on the end user. GI Energy has gathered extensive experience in developing battery storage projects and can help prospective battery owners determine the feasibility and navigate the regulatory landscape. The authors may be reached at achandar@gienergyus.com and jrobinson@gienergyus.com for any further discussion.

Additional Sources

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