Whitepaper

Unlocking the Hidden (Capacity) Value in Energy Storage

Insights from ICF

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Shareables

1. Capacity value of energy limited resource should not be overly discounted.
2. A one-hour Energy Storage device provides nearly half the Capacity Value, and a four-hour device provides almost full Capacity Value.
3. Recognizing the capacity contribution of energy storage improves resource adequacy planning.
4. A consistent framework should be adopted to characterize the capacity contribution of energy storage systems.

Executive Summary

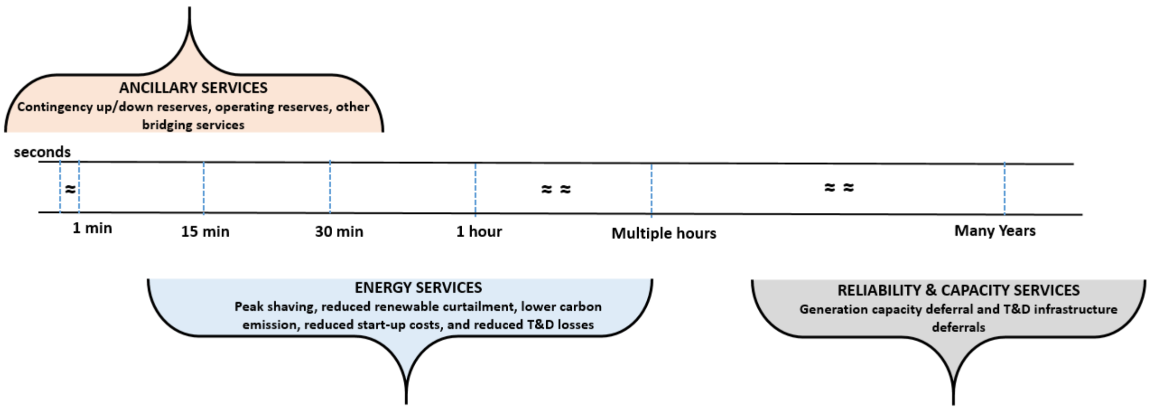
Recognizing the capacity value of energy storage is important to send the right economic incentives to the resource also ensure that an optimal amount of generation capacity is procured to meet resource adequacy needs, which is important from a grid planning perspective. The topology of the U.S. power grid is undergoing a rapid and fundamental change, with natural gas and renewables replacing traditional sources based on cost effectiveness. Environmental policies are also further accelerating the change in the generation resource mix.

Energy storage is one of the many options for improving the operational and planning flexibility of the power grid. Figure 1 shows how energy storage can provide different grid services in different time scales. Some of these services, in particular peak shaving and mitigation of renewable curtailment risk, are widely recognized[1]. Ancillary services from energy storage, such as frequency regulation and spinning reserves, are also gaining industry attention. For instance, the PJM regulation market has seen record deployments of energy storage resources, which currently contributes a capacity of 265 MW (or nearly 40%) of the required regulation capacity of 700 MW[2].

[1] There are currently 82 installations of electro-chemical Energy Storage systems in US, with 1-hour or more of stored duration and more than 1 MW of capacity.

[2] Andrew Levitt, Energy Storage Global Innovation Forum, Sep 12 2016 “Storage: What’s Beyond Regulation?”

FIGURE 1. GRID SERVICES FROM ENERGY STORAGE IN DIFFERENT TIME SCALES



Source: ICF

What is less acknowledged, or not properly accounted for, is the reliability and capacity benefits of energy storage. Today some regions do not recognize the capacity value of energy storage, while some regions account for capacity benefits only if the duration of stored energy is above a mandated threshold. While there is a need to have a consistent approach in valuing capacity benefits from Energy Storage, such an approach should not penalize or overly discount the capacity value of energy-limited resources like energy storage.

Most Markets Don't Account for Capacity Value of Energy Storage

Capacity value or capacity credit of a resource is the capability to provide firm energy in the hour of need, typically during the peak load period or when adequate generation is not available. A combined cycle unit with a forced outage rate of 5% will be accounted as a resource with 95% capacity value: it is available on a firm basis for 95% of the hours. Reliability planning in most regions enforces a certain reserve margin requirement[3], and capacity value of a resource plays a crucial role in determining the amount of generation capacity required to meet this requirement. If capacity value is not properly assessed and undervalued, the actual amount of resources procured to meet resource adequacy needs increases. Procuring excess resources will affect market efficiency and increase customer payments. Recognizing the capacity value contribution and properly compensating storage resources for the service will provide revenues that will be an incentive for the deployment of storage.

Energy-limited resources often contribute to reserve margin on a discounted basis. However, the important consideration here is that the discount must be appropriate. The fact that storage

[3] Reserve margin is the amount of additional generation over and above the peak load.

technologies are energy neutral[4] and have limited energy availability complicates the measurement of capacity value using standard reliability assessment protocols. Some regions have established a capacity value for energy storage systems provided that their duration is greater than a certain threshold, and therefore completely ignoring the capacity credit for shorter-duration storage. Figure 2 shows that there is a lack of consistency across markets, and some regions are still in the process of establishing the requirements for energy storage to qualify as a capacity resource. A consistent and standardized approach across regions will help to recognize the capacity benefits of Energy Storage from a grid planning perspective, while also enabling the right incentives for reliability services from such resources.

FIGURE 2. ELIGIBILITY RULES FOR ENERGY STORAGE VARIES IN DIFFERENT REGIONS

Market	Storage Eligibility	Minimum Availability / Operating Capacity
CAISO	Yes	At least 4 consecutive hours for over three consecutive days[1]
PJM	Yes	No minimum time, but storage resources must be able to offer capacity whenever PJM determines an emergency condition exists to qualify as Capacity Performance or during weather operations to qualify as Base Capacity[2]
ISO-NE	Yes	No minimum time, but a penalty is applied if the storage resource is called on in a shortage event and cannot provide energy for the entire period. Maximum output must be greater than 1 MW. [3]
NYISO	Yes	Energy Limited Resources must be able to provide at least 1 MW of grid injection for at least 4 consecutive hours[4]
ISO	No	MISO aims to clarify the rules for energy storage participation in the capacity and/or energy and ancillary service markets by the end of 2016 through early 2017[5]

Source: ICF

[4] Energy Storage has a round trip efficiency losses and in this sense it is not “truly” energy neutral

[1] CAISO, Energy Storage Interconnection: Draft Final Proposal, November 18, 2014 Available at http://www.caiso.com/Documents/DraftFinalProposal_EnergyStorageInterconnection.pdf

[2] PJM, PJM Manual 18: PJM Capacity Market, April 01, 2016, Available at http://www.pjm.com/~/media/documents/manuals/m18.ash

[3] ISO-NE, How Energy Storage Can Participate in New England’s Wholesale Electricity Markets, March 31, 2016, Available at http://www.iso-ne.com/static-assets/documents/2016/01/final_storage_letter_cover_paper.pdf

[4] NYISO, Energy Storage: Market Integration and Optimization, March 01, 2016, Available at http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_miwg/meeting_materials/2016-03-01/Energy%20Storage%20-%20Market%20Integration%20and%20Optimization%20MIWG.pdf

[5] MISO, Energy Storage Feedback and Next Steps, March 1, 2016, Available at https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/MSC/2016/20160301/20160301%20MSC%20Item%2004h%20Energy%20Storage%20Feedback%20and%20Next%20Steps%20v4%20.pdf

To understand the benefits of correctly accounting for energy storage's reliability and capacity benefits, ICF performed a case study on a representative model of the ERCOT grid, using ICF's Stochastic Resource Assessment Model (ICF SRAM). The tool quantifies the risks associated with uncertainties related to supply and demand, and determines the capacity value of Energy Storage by its ability to cover the shortage event or lower the Loss of Load Expectation (LOLE)[5].

Energy Storage Acts As a Generator During Peak Hours: Improves System Reliability

An energy storage system that operates on the well-established functionality of peak shaving or energy arbitrage is typically available at full capacity during the peak load conditions. However, its capability to lower the risk of shortage events (or LOLE) is highly dependent on the duration of stored energy. In other words, an energy storage system with one hour of stored energy, which is available every day during the peak load hour, will only be able to mitigate the risk in that hour and unable to provide any reliability benefits for the shoulder peak hours. Because it is able to provide some reliability benefits, a one-hour storage system therefore qualifies for partial capacity credit.

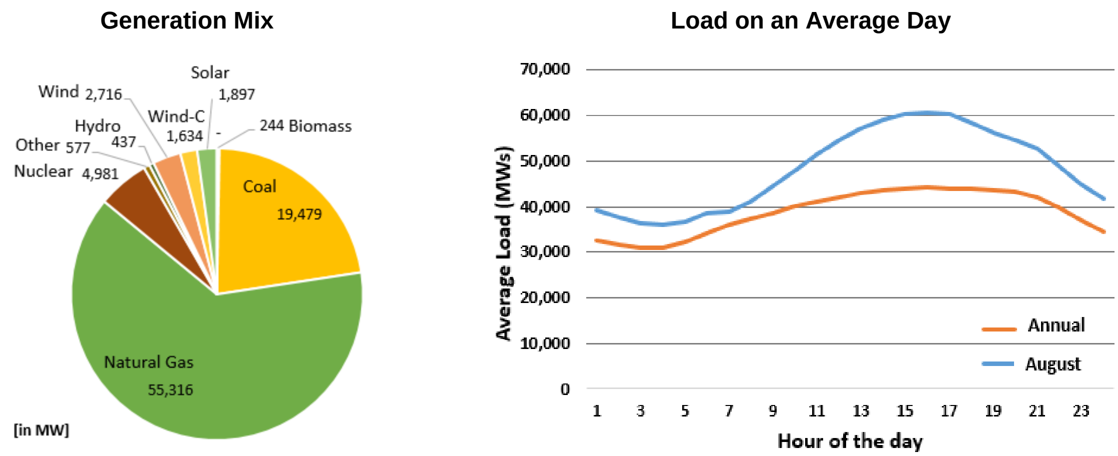
Evaluating the reliability benefits of limited-duration energy storage systems helps planners determine the appropriate capacity credit (and associated payments) for each resource, and also procure optimal generation capacity to meet established reserve margins. In this paper, we assume that energy storage systems are operated as peak shaving or energy arbitrage resources – the typical modus operandi for many storage systems. The approach presented here provides quantitative rigor to characterize the reliability and capacity benefits of energy storage systems based on their operational characteristics.

How to Capture the Capacity Value of Energy Storage

The ICF SRAM tool was used to quantify the capacity value of energy storage on a representative model of the ERCOT grid. We modeled a future year (2018) with generation mix and load data from the Report on the Capacity, Demand and Reserves (CDR) in the ERCOT Region, 2017-2026. The 2018 peak load forecast was approximately 72 GW. The hourly profile shows that the load peaks between 3pm and 4pm during the peak day in August.

[5] LOLE is the probability of not having adequate generation to meet the load demand. A typical planning requirement is to design the system with a LOLE of 0.1 days/ year. This implies that there is an expectation that one day in 10 years may not have adequate generation to meet load.

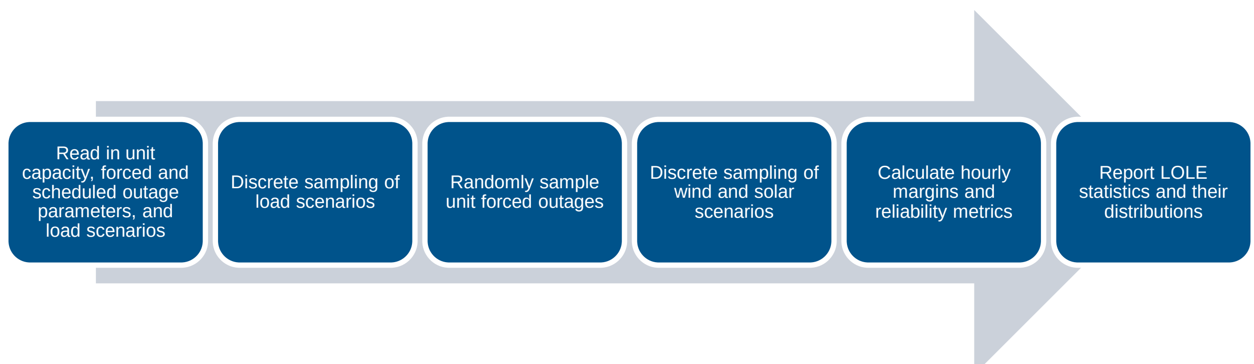
FIGURE 3. GENERATION MIX AND LOAD PROFILE ON THE ERCOT GRID



Source: Report on the Capacity, Demand and Reserves (CDR) in the ERCOT Region, 2017-2026

A step-by- step description of the ICF SRAM simulation is shown in Figure 4. The tool simulates the availability of the generation to meet load while accounting for unit forced outage rates. The model is run for thousands of years, and it calculates the LOLE in days/year based on the number of days of generation shortage during the simulation period. The capacity value of a resource can then be calculated through well-established reliability methods like effective load carrying capability (ELCC)[6] or the ideal-generator method (IGM)[7]

FIGURE 4. OPERATING FRAMEWORK OF THE ICF SRAM



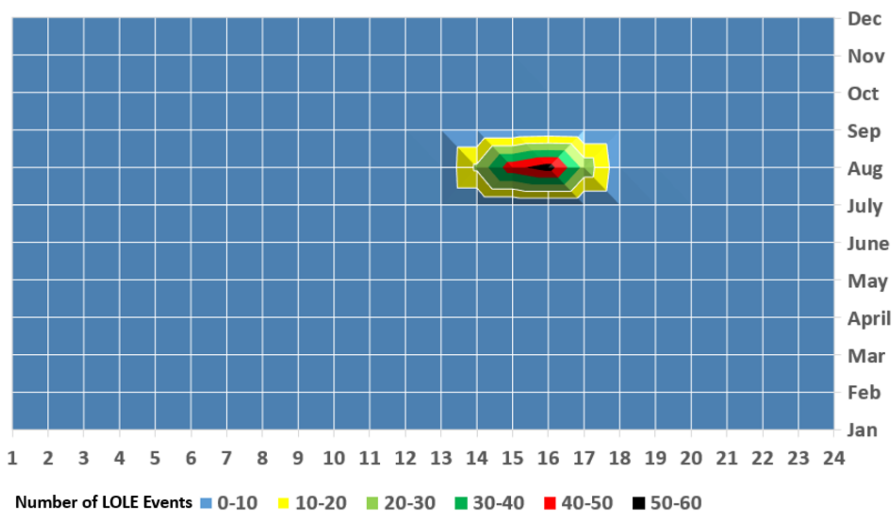
[6] ELCC is defined as the additional increase in system load that can be sustained with the addition of a resource to the grid.

[7] The Ideal-Generation method accounts for the capacity value of a resource equivalent to a generation resource with no outage rate.

We first assess the hours of the day that have the highest risk of having a LOLE event. Identifying the profile of these hours will inform how effective energy storage can be in reducing this risk, based on the assumed operational characteristics that mimic an arbitrage function[8].

Figure 5 shows a heat map of hours that have high probability of LOLE events. Darker colors show higher incidence of such events, which occur in the month of August and in the hours from 2-5pm. This is consistent with the load profile (Figure 3) that also peaks in these hours in the month of August. The risk of not having adequate generation to meet the load is therefore higher in these hours.

FIGURE 5. HEAT MAP



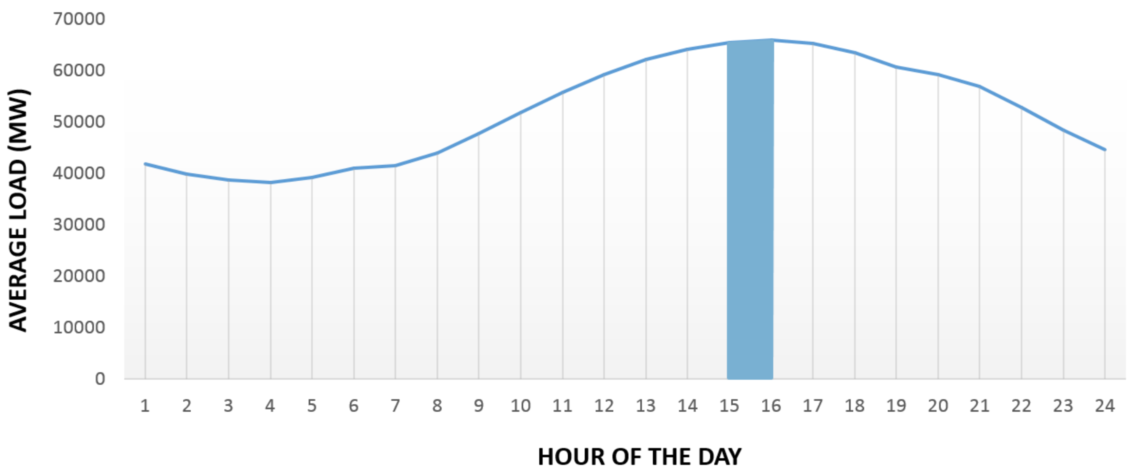
Source: ICF

To assess the capacity value of an energy storage resource, we assume the resource is available during the period(s) with the highest load. For example, as shown in Figure 6, the peak load occurs at hour-ending 4pm. This is the period during which the risk of not meeting load is highest. We calculate the capacity value of a one-hour storage system by evaluating the improvement in LOLE assuming it is available during that hour.

Similarly, when analyzing a two-hour storage device, we assume it is available to meet system needs during the top 2 peak hours, hour-ending 3pm and 4pm. The process is repeated with a 3-, 4-, 5- and 6-hour energy storage system.

[8] Peak hours are typically associated with the high prices, and therefore assuming such an availability pattern closely mimics the market arbitrage function

FIGURE 6. ENERGY STORAGE AVAILABILITY IS BASED ON THE RISK HOURS



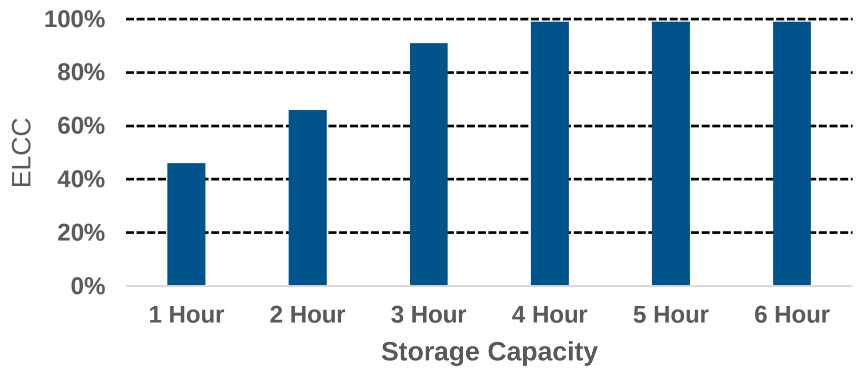
Source: ICF

What Duration of Energy Storage System Can Provide 100% Capacity Value?

The higher the duration of stored energy, the higher the capacity value of the Energy Storage system – this is quite intuitive. An energy storage system with a duration of many hours would behave similarly to a thermal generator in terms of its ability to provide firm energy to the grid at the time of need. Our analysis on the modeled grid indicates that an energy storage system with 4 hours or higher of stored energy could obtain almost 100% capacity value[9]. More importantly, our analysis indicates that smaller duration of energy storage provides partial capacity benefits (i.e. it is a non-zero value). In other words, a 100 MW energy storage system with 1-hour of stored energy can provide 46 MW of firm capacity, while a 100 MW storage resource with 4-hour of stored energy can provide 99 MW of firm capacity.

[9] Capacity value of Energy Storage is highly correlated with the underlying load and generation mix. In the case of the ERCOT grid, our analysis indicates that a 4-6 hour storage system should be able to capture a capacity value of 100%.

FIGURE 7. CAPACITY VALUE OF STORAGE AS A FUNCTION OF STORED ENERGY



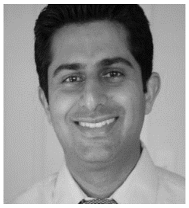
Source: ICF

It is also noteworthy that the first one-hour block of stored energy provides the maximum capacity benefits, and the incremental benefits from subsequent blocks of stored energy provide begin to diminish (suggesting decreasing marginal returns). In this example, the first one-hour block provides 46% capacity value, while the second one-hour block provides 20% additional capacity value (for a total of 66% capacity value for a 2-hour storage system). This occurs because the value of the first one-hour block of energy storage captures the maximum risk (or LOLE events) in the system. The subsequent blocks of energy operate in shoulder hours and therefore capture a lower number of LOLE events. This discussion strengthens the argument that capacity benefits of energy storage system should be recognized at all levels of stored energy duration, and not just at the level that provides 100% capacity value. The framework applied in this paper presents an approach that can be used to refine existing standards or develop new mandates for considering capacity contribution of energy storage, based on their operational function.

Concluding Thoughts

A resource such as energy storage that can operate for the expected duration of “shortage” events can meet capacity needs and be eligible to receive full capacity credits (or a fraction proportional to the time period they are able to operate). Current approaches or requirements to establish capacity value undervalue the capacity benefits of storage resources. We have outlined a methodology based on traditional resource adequacy planning, which can capture the capacity value of storage systems by explicitly taking into account their operational characteristics. Although the framework presented here can be consistently applied across market boundaries, the results of the analyses and respective conclusions may vary depending on the underlying resource mix and load shape.

About the Authors



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About ICF

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