HYBRID RESOURCES

Resource Adequacy and Capacity Accreditation

FACT SHEET

Hybrid resources are a combination of generation, storage, and/or flexible load that share a common point of interconnection and are operated as a single integrated resource. These resources can participate in a wider range of electricity markets than their component technologies can alone. Regarding capacity markets, for example, while stand-alone solar and wind resources often have a lower capacity value because their generation may not align with the periods when the system needs it most, hybrids can be configured to maximize their value in (and revenue from) capacity markets. In such markets a resource is "on call" and earns revenue from being available to feed electricity onto the grid during periods of peak demand. The capacity revenues for hybrid projects will likely continue to increase as a portion of their overall revenue mix. As a result, capacity rules, and specifically resource adequacy and accreditation methods, will become increasingly important for hybrid resources.

Participation of Hybrid Resources in Capacity Markets

The capacity revenues of a resource are typically dependent on its capacity accreditation (or capacity value)—its likelihood of availability during times of system need. Resources' capacity values are determined through resource adequacy analysis and requirements that ensure that there are sufficient resources available to serve load under a wide range of conditions, including unpredictable weather, unexpected generator outages, and fluctuating loads. Adding storage to wind and solar plants allows these renewable resources to shift the energy they supply to the grid to time periods when it is needed most, thus increasing their capacity credit. As a result, all other things being equal, a hybrid resource can receive higher overall revenues from providing capacity (participating in capacity markets) than can stand-alone wind or solar resources.

NREL/Dennis Schroeder (58013)

However, there are numerous challenges that must be considered for capacity accreditation of hybrid resources. Six of these challenges are highlighted in Figure 1 on page 2.

As the reliability of power systems becomes more dependent on variable renewable energy and energy-limited resources such as batteries and load flexibility, the system will become less capacity-constrained and more energy-constrained—while it may have sufficient total capacity on an annual basis, the resources are not always generating energy when it is needed. The availability of a hybrid resource to the system is dependent on the availability of energy to charge the storage resource and shift production to later hours when sun and wind are less abundant. Since the capacity credit of a resource diminishes as the installed capacity of the resource increases (known as the saturation effect), rising levels of variable renewable resources will lead to decreases in their capacity credit. However, the timing of scarcity events will likely change, either by time of day or seasonally, as the energy system evolves. Hybridization

This fact sheet is adapted from ESIG's report Unlocking the Flexibility of Hybrid Resources.

FIGURE 1

Challenges for Quantifying Capacity Value for Hybrids and Energy-Limited Resources

Saturation Effects

Daily load profile flattens, any additional shift of energy will reduce reliability during charging.

Multi-Day Events

Sustained low output of wind or solar limits ability to charge battery.

Unexpected Outages

An unexpected generator outage could occur after storage discharge (not just about peak load).

Forecast Uncertainty

Wind and solar forecast errors could yield sub-optimal storage scheduling.

Competing Objectives

It is likely that assets are used for multiple services (arbitrage, reserves, transmission and distribution, etc.), which may compete with capacity needs.

Energy for Charging

Capacity value of storage is dependent on availability of resources to charge.

Six challenges associated with resource adequacy modeling and capacity accreditation methods for wind, solar, storage, and hybrid resources.

Source: Stenclik et al. (2018); GE Energy Consulting.

can help mitigate, or slow, the diminishing capacity credits over time and ensure that hybrid resources are available when scarcity events occur.

The Reliability Benefits of Combining Complementary Resources

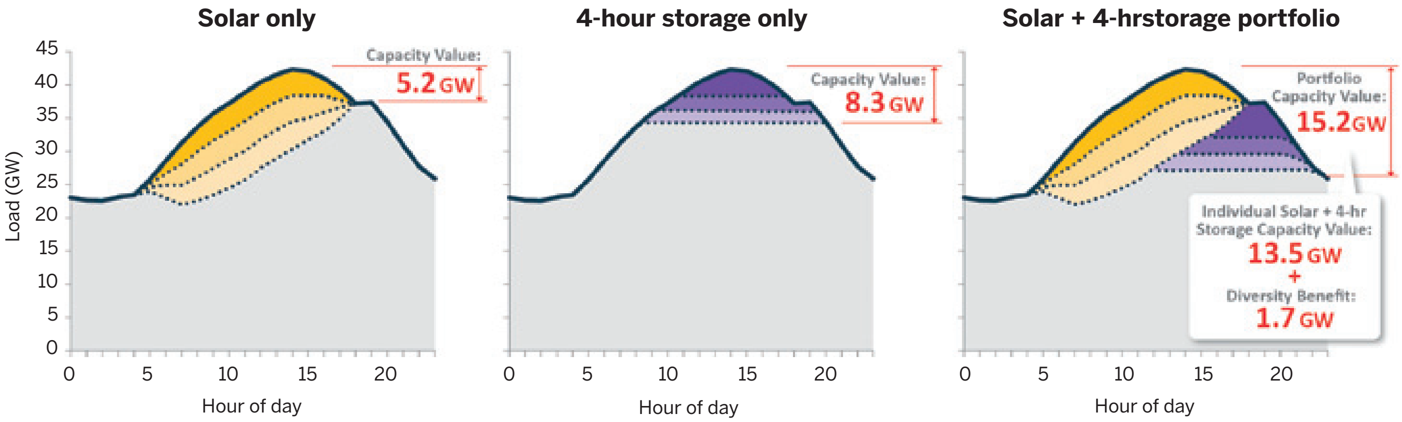
Hybrid resources bring unique, complementary benefits for system reliability through resource-coupling and diversity—both within an individual hybrid resource and at the system level. Whereas when resources are of a similar type, their value for the system goes down as their numbers rise, when resources are complementary, their value goes up. The interactive effects of combinations of resources can yield additional capacity value benefits that are not captured when the individual resources are evaluated independently.

For example, the complementary resources in solar + storage projects yield multiple benefits, as shown in Figure 2 (page 3). First, the addition of solar narrows the system net peak load, and this increases the ability of the battery storage to cover the peak load risk. In addition, the solar adds energy to the system that can be used by the battery to charge.

But disentangling these portfolio effects can be a challenge. Which resource type receives the reliability credit (and payment) when portfolio capacity value is greater than the sum of its parts? Whereas allocating the capacity accreditation of the portfolio benefits is relatively straightforward for an individual hybrid resource and single owner, it is more complex when the benefit allocation is across many different resources and owners. The allocation of portfolio benefits at the system level becomes increasingly important as the system becomes more energy limited, because the exact timing of shortfall events is less of a driver than the total amount of energy available across the day. In contrast to allocating portfolio benefits on a system level assuming separate renewable and storage resources, the hybrid resource "brings its own energy" for capacity accreditation (in a sense, looking like a self-charging battery of a sort); therefore, determining which resource type gets the credit is unnecessary. In addition, the hybrid resource can include extra amounts of renewable capacity (in excess of the injection limit at the point of interconnection) to ensure that the storage system is available nearly every day at 100 percent of its available capacity, regardless of the overall larger system conditions, and ensures the resource is available during scarcity events.

FIGURE 2

Portfolio Benefits for Solar + Storage in Capacity Accreditation



An illustration of the complementary benefits of solar and storage resources for capacity accreditation. The gray area indicates the amount of load that needs to be served by other resources in each case.

Source: N. Schlag, Z. Ming, A. Olson, L. Alagappan, B. Carron, K. Steinberger, and H. Jiang, *Capacity and Reliability Planning in the Era of Decarbonization: Practical Application of Effective Load Carrying Capability in Resource Adequacy* (San Francisco, CA: Energy and Environmental Economics, 2020).

Two Options for Calculating Hybrids' Capacity Accreditation

There are two options for calculating the capacity accreditation for hybrid resources. The first is a "sum of parts" approach that calculates the effective load-carrying capability (ELCC) of each hybrid component separately, sums the individual pieces together, and limits the total capacity accreditation to the injection limit at the hybrid's point of interconnection. This approach is attractive because it is simple to implement (provided that the individual capacity credits are calculated correctly) and does not require hybrids to be modeled across many different potential configurations (e.g., with different inverter-loading ratios, relative battery to solar sizing, and plant-level export constraints). However, the approach does not, by itself, account for the portfolio effects at the resource or system level, because the plant configuration can be designed specifically to maximize its resource adequacy value. In addition, it does not consider potential charging constraints (for example, if the storage resource cannot be charged from the grid) or the benefits of high inverter-loading ratios (the ratio of installed DC capacity to the inverter's AC power rating), which add increased energy from the wind and solar resources.

A second option is to evaluate the combined hybrid resource as a single, coordinated plant in the resource adequacy analysis—as a distinct resource type. In this approach the resource is modeled with its specific configuration, charging constraints, and other plant-level parameters to calculate the resource's ability to be available during time periods when the system is most likely to need it most. The benefits of this approach are that it explicitly captures the portfolio effects, allows higher inverter-loading ratios, and accounts for potential charging constraints. However, given the large number of potential unique configurations of hybrid resources, each plant requires an individual analysis (as opposed to evaluating groups of resource classes together), which can be computationally burdensome and analytically time-consuming. More research is needed to determine which of the capacity accreditation methods is appropriate for hybrid resources given the trade-off between accuracy and complexity (see Table 1, page 4).

Recommendations for System Operators on Resource Adequacy and Capacity Accreditation

Resource adequacy and capacity accreditation are an integral component of a hybrid resource's economic

TABLE 1
Two Options for Hybrid Resource ELCC Calculations

OPTION A	OPTION B
Individual Resource Accreditation	**Aggregate Resource Accreditation**
Is a sum of ELCC individual hybrid resources, capped at the point of interconnection	Evaluates the hybrid plant ELCC at the aggregate plant level as a unique resource
Advantages	
• Is simple to implement and understand • Does not require unique modeling for all hybrid configurations	• Evaluates the specific characteristics of the hybrid plant • Considers charging constraints • Considers benefits of higher inverter loading ratios and DC coupling
Disadvantages	
• Does not account for portfolio effects at the plant level • Does not consider charging constraints • Does not consider benefits of higher inverter load ratios and DC coupling	• Requires individual analysis of each hybrid resource on the system • Is computationally burdensome and analytically time-consuming

Note: ELCC = effective load-carrying capability.

Source: Energy Systems Integration Group.

value. Therefore, there are several important aspects for system operators to consider when developing resource adequacy programs and capacity accreditation methods for hybrid resources.

Capacity accreditation methods should consider portfolio effects, in which interactive effects of resources added in conjunction with one another increase their capacity value and thus their benefits for resource adequacy. This is true for resource combinations system-wide as well as resources within an individual hybrid plant. Further research and analysis are needed to understand whether hybrids' capacity accreditation should be based on the sum of individual resources, capped at the point of interconnection limit, or done on an aggregate basis encompassing the entire hybrid plant.

Adapted from *Unlocking the Flexibility of Hybrid Resources,* a report by the Energy Systems Integration Group's Hybrid Resources Task Force. Four fact sheets and the full report are available at https://www.esig.energy/unlocking-the-flexibility-of-hybrid-resources.

To learn more about the recommendations described here, please send an email to info@esig.energy.

The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. Additional information is available at https://www.esig.energy and info@esig.energy.