STORAGE FOR POWER SYSTEMS

Growing levels of wind and solar power increase the need for flexibility and grid services across different time scales in the power system. There are many sources of flexibility and grid services: energy storage is a particularly versatile one. Various types of energy storage technologies exist, addressing flexibility needs across different time scales.

What are the benefits of storage?

Storage shifts energy in time. Storage can act as either generation or consumption, helping to maintain the balance between supply and demand at different time scales. For example, storage can provide capacity which contributes to resource adequacy during stress periods on the system. It can provide diurnal load shifting to help balance the diurnal production profile of solar. It can provide fast responses such as primary and secondary frequency reserves which help maintain system balance in the seconds to minutes time scale. Storage can also help postpone transmission and distribution upgrades.

It may be possible to stack these value streams, increasing total revenue for the storage owner (see Figure 1). However, unlocking these values relies heavily on effective market design and regulation.

Storage can be located at a power plant, as a stand-alone resource on the transmission system, on the distribution system and at a customer's premise behind the meter.

Do wind and solar need storage?

All power systems need flexibility, and this need increases with increased levels of wind and solar. There are many sources of flexibility such as from improved system operations, generators, demand, interconnections to other regions, power-to-X, and electrical and thermal storage. Storage competes with these other sources of flexibility. Figure 1 in the Flexibility for Power Systems factsheet shows the time scales and markets that energy storage and other flexibility resources can operate in.

Storing fuels, or water in reservoirs, is the most cost-effective form of storage today. Thermal (hot water) storage is also more cost-effective than electrical storage.

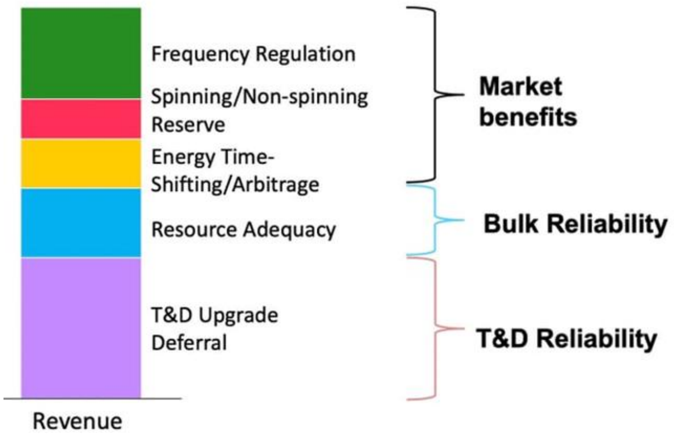

Figure 1. *A potential stacking of storage value streams. Frequency regulation and reserve markets have a limited need before the markets saturate. T&D: transmission and distribution.*

Declining costs and easy siting make lithium-ion batteries an increasingly attractive flexibility source. On the other hand, lithium-ion batteries incur losses, in contrast to some other flexibility sources such as demand flexibility. In the case of hydropower reservoirs, storage can help reduce water that otherwise would have been wasted.

The fact that "the wind doesn't always blow, and the sun doesn't always shine" is often used to suggest the need for dedicated energy storage to handle fluctuations in wind and solar production. Dedicated energy storage ignores the realities of both grid operation and the performance of a large, spatially diverse renewable energy source. Because power systems are balanced at the system level, no dedicated backup with energy storage is needed for any single technology. Storage is most economical when operated to maximise the economic benefit of an entire system.

Don’t we need storage to reduce curtailment?

Curtailment of variable renewables is wasted energy. That said, the goal is not necessarily to reduce curtailment to zero. It may be more cost-effective to have some amount of curtailment than to procure enough storage to reduce curtailment to zero. Furthermore, curtailed wind and solar can provide upward reserves, so curtailment, if used properly, need not be simply wasted energy. Curtailment is a way to provide flexibility from wind and solar.

How many hours of storage are needed?

The needs depend on the particular power system and type of grid service being provided. For example, the first commercial application of battery storage in the US was 15-minute duration batteries to provide fast secondary reserves. Today, 4-hour batteries are most commonly installed to provide capacity services and load shifting.

It is important to note that as more storage is added to the system, its capacity value—representing the fraction of the installed capacity that can be relied upon during system stress—declines (Figure 2). The first 4-hour battery installed provides the highest capacity value to the system. The hundredth may provide much less capacity value. At some point, longer duration energy storage will be needed to continue providing significant capacity value.

There is a complementarity between solar and 4-hour storage in summer-peaking systems as seen in Figure 3. Depending on the wind regime, storage needs may vary. Storage can be used to mitigate down ramp events. Longer duration storage can mitigate against lulls in variable renewables.

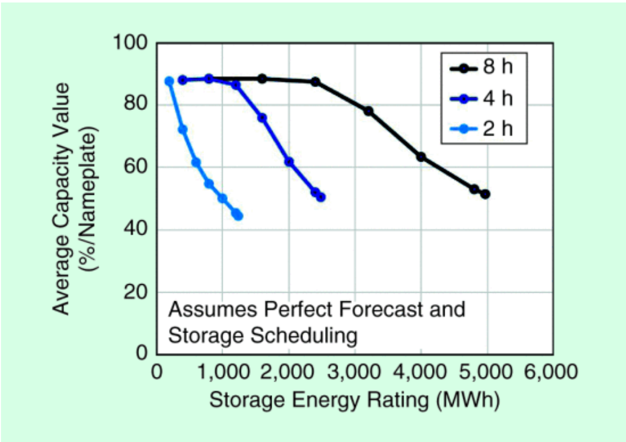

Figure 2. *Longer durations are needed for storage to maintain significant capacity value (example from Hawaii). (Source: Stenclik et al., 2018).*

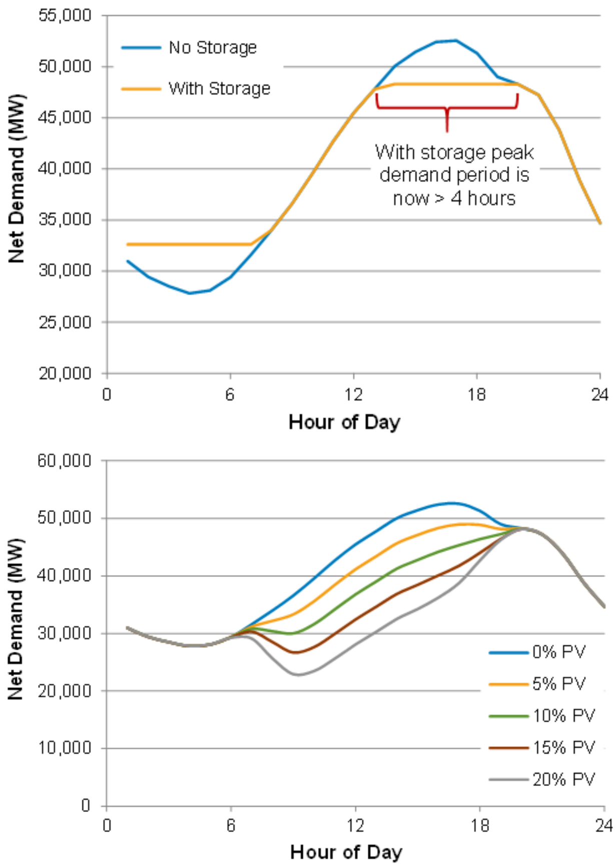

Figure 3. *Top shows the simulated impact of increased 4-hour storage deployment on the net load shape. Bottom shows how solar increases the opportunities for 4-hour storage as peaking capacity in California. (Source: Denholm et al., 2023).*

Associated publications

- Holttinen, H. et al. (2021). **Design and operation of energy systems with large amounts of variable generation**. Final summary report, IEA WIND TCP Task 25. https://doi.org/10.32040/2242-122X.2021.T396
- Stenclik, D. et al. (2018). **Energy Storage as a Peaker Replacement**, IEEE Electrification Magazine. https://doi.org/10.1109/MELE.2018.2849835
- Denholm, P. et al. (2023). **Moving Beyond 4-Hour Li-Ion Batteries: Challenges and Opportunities for Long(er)-Duration Energy Storage**. https://doi.org/10.2172/2000002
- Easac (2017). **Valuing dedicated storage in electricity grids**. www.easac.eu
- Greening the Grid (2015). **The Role of Storage and Demand Response.** https://greeningthegrid.org/Grid-Integration-Toolkit

More information

This Fact Sheet draws from the work of IEA Wind TCP Task 25, a research collaboration among 17 countries. The vision in the start of this network was to provide information to facilitate the highest economically feasible wind energy share within electricity power systems worldwide. IEA Wind TCP Task 25 has since broadened its focus to analyze and further develop the methodology to assess the impact of wind and solar power on power and energy systems.

See our website at

https://iea-wind.org/task25/

See also other fact sheets

How Do We Ensure Long-Term Reliability of Future Power Systems?
Balancing Power Systems with Large Shares of Wind and Solar Energy
Impact of Wind and Solar on Transmission Upgrade Needs
Variability and Predictability of Large-Scale Wind Power
Wind and Solar Integration Issues