RESOURCE PLANNING FOR ELECTRIC POWER SYSTEMS

KEY INSIGHTS

- As intermittent capacity expands, energy storage will become increasingly important to balance demand and generation.
- Different energy storage technologies offer varying advantages and disadvantages, and the electric grid of the future is expected to leverage these diverse technologies for specific applications.

Energy Storage Technologies in Energy System Resource Planning

by Romey James

Historically, energy storage has played a crucial role in real-time balancing, supporting baseload generation, meeting peak demands, and responding to unforecasted fluctuations in load. For example, nuclear units have utilized pumped storage energy to pump water during off-peak hours for later use. Such storage technologies have provided flexibility and reliability to the grid, addressing variability of weather and customer demand.

The increasing penetration of variable renewable resources is necessitating greater energy storage capacity to manage the challenges posed by higher levels of intermittent generation. Future strategies to manage the grid will likely involve a combination of various energy storage technologies, advanced grid management systems, demand response programs, and low-carbon peaking generation.

Considerations for Different Energy Storage Technologies

Technology Readiness Level (TRL)

TRL is a measure of the technical maturity of a technology. This is an important factor when considering technologies in a resource plan as low TRL options could take significant time to become commercial. Pumped hydro storage and lithium-ion batteries (Li-ion) have high TRLs, while newer technologies, including several novel battery chemistries, thermal, mechanical, and chemical energy storage options, have lower TRLs.

Leveraging Existing Technology

Though many non-battery solutions have low TRLs, they are often comprised of technologically mature components such as compressors, turbines, and tanks, which reduces reliance on future scientific breakthroughs to reach market.

Round Trip Efficiency (RTE)

RTE quantifies the ratio between the energy discharged by an energy storage system and the energy used to charge it considering conversion losses. Li-ion batteries, flywheels, and some gravitational systems have among the highest RTEs. Pumped hydro can also be relatively high. Compressed air energy storage (CAES), flow batteries, and pumped heat energy storage tend to be somewhat lower. Thermal energy storage systems that integrate with existing power cycles can have lower efficiencies due to the losses.

Value Stacking: An energy storage asset can serve more than one purpose, providing additional value on investment. Beyond arbitrage, energy storage systems can provide key ancillary services including peak load management, voltage and frequency regulation, and even black start capability.

Duration: Li-ion batteries are well-suited for quick response services and daily load shifting, but the growing need for longer duration storage is driving investment in thermal, chemical, and mechanical energy storage technologies that can more economically store grid-scale capacity for longer periods with potentially lower standby losses.

Siting and Scaling: An important advantage for Li-ion batteries and other standalone AC-to-AC energy storage systems are their ability to be installed in a wide variety of locations and sizes. On the other side of the spectrum, systems like pumped hydro and CAES need specific geological and geographical conditions. Siting flexibility is due in part to energy density. Higher energy density systems such as batteries and thermal and chemical energy storage systems have smaller footprints. Also, some energy storage systems can have safety concerns relevant to siting. Li-ion batteries and hydrogen carry the risk of fire, and other battery chemistries and thermal energy storage systems require high temperatures or hazardous materials.

Critical Minerals: An advantage for many non-battery energy storage technologies is their lack of critical mineral requirements, as the supply chain and availability of the minerals needed for battery manufacturing have become a topic of concern. For example, Li-ion batteries rely on lithium, copper, nickel, cobalt, manganese, and graphite which could have supply chain concerns in the future. There are efforts to improve the TRL of alternative battery chemistries, some of which rely on abundant and cheap materials, including sodium-ion and liquid metal batteries. Other novel battery chemistries offer their own advantages, such as solid-state batteries which offer such potential benefits as enhanced safety, higher energy density, and longer cycle life.

Costs: Pumped hydro storage could be a cost-effective energy storage option, but its siting and regulatory challenges make it difficult in many locations. While companies developing chemical, mechanical, and thermal energy storage systems have set aggressive price targets, most of these products are not commercially available yet. Due to advances driven initially by the consumer electronics industry, Li-ion batteries have seen costs fall over the past three decades, making it the most cost-effective energy storage solution for shorter-duration applications today. Batteries using newer chemistries are generally more expensive than Li-ion currently, but like the non-battery solutions, costs are expected to decline as the technology matures and experience is gained. Though market demand is expected to drive continued cost reductions, resource planning may benefit from including analysis of some scenarios with conservative cost reduction assumptions.

Inflation Reduction Act (IRA) of 2022: In the United States, section 48E of the IRA makes investment tax credits (ITC) available to standalone energy storage projects. Previously, energy storage was only eligible for the ITC if coupled with solar. The new ITC offers a base credit of 6% of a project's capital costs, with a bonus rate of 30% if labor requirements regarding prevailing wages and apprenticeships are met, plus stackable bonuses of an additional 10% each for domestic content and energy community requirements. Tax exempt entities are eligible for a direct pay option. These credits in the United States, along with similar government programs and subsidies in other regions in the world, could further drive demand, investment, and cost reductions in the energy storage industry.

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