



What To Look For In ENERGY STORAGE SYSTEMS

When selecting a technology for an energy storage project, it's essential to consider several key factors



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The integration of renewable energy sources like wind and solar power into the power grid introduces challenges related to their intermittent nature. Unlike traditional power plants that can provide a steady output, the energy production from renewables depends on environmental conditions, such as sunlight and wind availability. This variability can affect grid reliability, particularly during peak demand periods when the energy supply from these sources might be insufficient. Grid operators must, therefore, carefully plan and manage the capacity to ensure a balance between supply and demand.

To address the challenges of intermittency, various strategies are employed. Energy storage systems, such as batteries, play a crucial role in storing excess energy generated during periods of high production and releasing it when demand exceeds supply. Additionally, the concept of a smart grid, which involves advanced technologies and communication systems, allows for more flexible and efficient management of energy resources. By leveraging real-time data, grid operators can better predict demand patterns and adjust the energy mix accordingly.

Demand response plans are another key tool in maintaining grid stability. These



plans incentivise consumers to reduce their energy usage during peak times, thereby alleviating strain on the grid. Smart meters and thermostats enable precise control and monitoring of energy consumption, allowing for a more responsive and adaptable grid system. As the share of renewable energy in the grid continues to grow, the development of these technologies and strategies becomes increasingly important in ensuring a reliable and sustainable energy future. In a conversation with Chloe Herrera, Analyst, Lux Research, we gained the insights on how critical these integrated technologies and strategies are.

Energy storage solutions for modern needs

Energy storage systems play a crucial role in contemporary energy infrastructure, offering solutions for the efficient storage and management of energy. They assist in balancing the grid's supply and demand, ensuring stability and facilitating the integration of renewable energy sources.

Closed electrochemical batteries. Closed electrochemical energy storage systems, like lithium-ion batteries, are sealed units where the chemical reactions occur in a controlled environment. This closed design prevents external elements from interfering with the battery's operation, leading to more stable and reliable performance. In contrast, open systems, such as metal-air batteries, are exposed to the external environment, which can introduce variability in performance due to changes in air quality or humidity.

Lithium-ion batteries are the cornerstone of modern energy storage due to their high energy density, long lifespan, and rapid charging capabilities. Their widespread adoption in consumer electronics and electric vehicles has led to signifi-

Choosing the right energy storage technology

When selecting a technology for an energy storage project, it's essential to consider several key factors:

- **Technology maturity.** Choose a proven technology for long-term reliability, as energy storage systems are expected to last 20-30 years.
- **Performance.** Match the technology with the specific requirements of the intended application, ensuring it can meet the necessary performance criteria.
- **Cost.** Assess both the upfront capital expenditure (CapEx) and the lifetime costs, including system components and ancillary systems like enclosures, HVAC, and power components.
- **Application-specific needs.** For applications such as grid support, peak shaving, or renewable integration, evaluate the technology's ability to meet the unique demands of each use case. For instance, peak shaving requires a technology that can respond quickly and efficiently for short durations.

While choosing an energy storage technology, prioritise proven maturity, performance alignment with application needs, and a thorough cost analysis. Additionally, tailor your selection to the specific requirements of the intended application for the best project fit.

cant advancements in manufacturing processes, making them more affordable. However, challenges such as the limited availability of lithium and concerns over battery degradation and safety remain. As the industry continues to grow, addressing these challenges will be crucial for maintaining the sustainability and reliability of lithium-ion technology.

Redox flow batteries. Redox flow batteries are unique in their ability to separate energy storage capacity from power generation. This separation allows for greater flexibility in system design, enabling the optimisation of each component for specific applications. For instance, increasing the size of the electrolyte tanks can extend the duration of energy storage without affecting the power output. This makes redox flow batteries particularly well-suited for applications that require long-duration storage, such as stabilising renewable energy sources or providing backup power for critical infrastructure.

The main challenges facing redox flow batteries are their relatively low energy density compared to solid-state batteries and the high initial costs associated with their complex system architecture. Innovations in electrode materials, membrane tech-

nology, and electrolyte chemistry are being explored to enhance the energy density and reduce costs. Additionally, modular design approaches are being developed to allow for easier scalability and integration into existing energy infrastructure.

Air energy storage technologies. Compressed and liquefied air energy storage technologies offer alternative solutions for large-scale energy storage. By leveraging the energy stored in compressed or liquefied air, these systems can provide grid-scale energy storage without the geographical constraints of pumped hydro storage. Advances in thermal management and system efficiency are key to making these technologies more competitive and scalable.

Metal-air batteries. Metal-air batteries hold promise for ultra-long-duration energy storage due to their high theoretical energy density and the abundance of metals like zinc and iron. However, their practical application is hindered by efficiency losses and material degradation. Research is focused on developing more robust electrolytes and catalysts to improve the longevity and efficiency of these batteries, paving the way for their use in applications that require extended energy stor-



Key to more renewables

The rise of renewable energy sources like solar and wind brings a greater need for energy storage solutions due to several factors:

- **Intermittency.** The variable nature of renewable energy sources leads to intermittent power generation, creating a demand for energy storage to maintain a stable and reliable power supply.
- **Grid inertia.** Decommissioning fossil fuel plants reduces grid inertia, which is crucial for grid stability. Lithium-ion batteries, with appropriate power components, can potentially provide the necessary inertia.
- **Frequency and voltage stability.** Renewable energy integration can challenge grid frequency and voltage stability. Energy storage solutions are essential for managing these fluctuations and maintaining grid stability.

The increase in renewable energy sources introduces challenges such as intermittency, reduced grid inertia, and frequency and voltage instability, all of which drive the need for advanced energy storage solutions to ensure a stable and reliable power grid.

age, such as disaster resilience and off-grid power systems.

Pumped hydro. Pumped hydro storage remains a vital component of the energy storage landscape, providing large-scale, long-duration storage capabilities that are crucial for grid stability. While its deployment is limited by geographical and environmental considerations, ongoing research into innovative designs and site selection methodologies aims to expand the feasibility and reduce the environmental impact of new pumped hydro projects.

Measuring energy storage project costs

The levelised cost of storage (LCOS) is a crucial metric for assessing the economic viability of energy storage projects. It encompasses all costs associated with a project, including capital expenditures (capex), operation and maintenance (O&M) costs, and replacement costs, divided by the total energy output. This calculation provides a standardised way to compare different storage technologies by presenting costs in terms of US dollars per kilowatt-hour (\$/kWh).

When evaluating the LCOS, it is essential to consider the specific characteristics of each storage technology. For instance, lithium-ion

batteries require accounting for their cycle life and replacement frequency, whereas compressed air energy storage systems need to factor in the O&M costs for their mechanical components. By using the LCOS metric, developers can make informed decisions about the most cost-effective storage solution for their needs.

The upfront costs of energy storage projects can be categorised into several key components:

Storage system costs. For electrochemical systems, this includes the cost of cells or electrolytes, while for mechanical systems, it involves the cost of reservoirs or caverns.

Power components. Expenses related to power electronics, HVAC systems for temperature control, and housing for batteries.

Construction and engineering costs. Costs associated with building the storage facility and its engineering design.

Grid connection costs. The cost of connecting the storage system to the electrical grid.

The cost efficiency of an energy storage system is influenced by various factors, including the technology type, operational costs, efficiency, and lifespan. For example, flow batteries have significant costs in electrolytes and power components, while compressed air systems have

high excavation and construction costs.

O&M costs and replacement costs play a crucial role in determining the total cost of ownership of an energy storage system. For example, while lithium-ion batteries may have lower upfront costs, their shorter cycle life compared to flow batteries can result in higher replacement costs over time. Therefore, it is vital to consider these costs when evaluating the economic viability of different energy storage technologies for specific applications.

Texas energy storage: Meeting peaks, creating opportunities

The need for significant peaking capacity in Texas, highlighted by the winter storm outages, has driven a surge in energy storage deployment. The state's experience with massive power outages due to frozen infrastructure and reduced solar generation has underscored the importance of having dispatchable assets for grid resiliency. As a result, lithium-ion batteries have been increasingly implemented in Texas to provide reliable power during peak demand periods and outages.

Local energy requirements also play a crucial role in shaping grid needs and the utilisation of energy storage. For example, a grid with a high percentage of distributed solar energy may require energy storage solutions at the customer's home or distributed storage to address regional issues. Conversely, a region reliant on offshore wind may need energy storage at grid connections to prevent transmission congestion and longer-duration storage to manage the seasonal intermittency of wind.

The growth in energy storage is primarily driven by the ancillary services market and the expanding microgrid sector. Ancillary services, although becoming saturated in some areas, still offer lucrative opportunities for short-duration energy storage.



Microgrids are gaining popularity as a reliable solution for keeping lights on in communities, commercial operations, and utilities, with energy storage being a natural fit when paired with renewables. Additionally, energy shifting, where excess solar energy produced during the day is stored for use at night, is emerging as a significant application for energy storage.

Equipment and materials suppliers can play a pivotal role in developing lower-cost energy storage technologies. By forming development partnerships or supply agreements with startups or technology developers, these suppliers can offer alternative materials or advice to reduce costs. Their involvement can provide pathways towards more affordable energy storage solutions, addressing one of the critical challenges facing early-stage technologies.

EV batteries in fixed energy storage

The integration of electric vehicle (EV) batteries into fixed energy storage systems, commonly known as vehicle-to-grid (V2G) technology, presents a range of opportunities and challenges. This approach allows EV batteries to power homes or export energy to the grid, providing a valuable asset for grid resilience. It is applicable not only to residential customers but also to commercial fleets, offering substantial energy storage capacity.

However, this integration requires buy-in from automakers to incorporate bidirectional charging capabilities in their vehicles, allowing energy to be both stored and discharged. Additionally, software and visibility into users' energy usage are necessary to optimise the utilisation of the EV battery.

Recycling plays a crucial role in the life cycle of EV batteries, impacting sustainability. While the process can vary, car manufacturers see

value in recycling to extract valuable materials from batteries for resale. Although driven more by material recovery than circularity, recycling contributes to sustainability by reclaiming plastics, circuitry, and metals like aluminium and copper.

Used EV batteries are assessed for second-life applications through visual inspection and cycling tests to determine their state of health. Batteries with capacity below a certain threshold are disqualified. Those that pass undergo further testing to determine their suitability for second-life energy storage, where their performance is carefully managed to ensure safe operation.

Capacity degradation in EV batteries affects their performance in fixed energy storage applications. As capacity decreases, voltage characteristics change, requiring intelligent management of the remaining capacity. Second-life battery systems often throttle performance to operate safely within these constraints.

The repurposing of EV batteries for energy storage systems is governed by safety standards such as UL 1974 certification. Thermal management is crucial in both EV and stationary storage systems to mitigate external environmental effects. EVs use passive and active cooling, while stationary storage relies on HVAC systems to maintain optimal temperatures.

The growing stockpile of EV batteries with residual capacity is driving their use in fixed energy storage systems. This market is expanding as companies seek to monetise second-life batteries in short-duration energy storage applications.

The effective use of EV batteries in stationary energy storage is not solely technology-driven but is influenced by the increasing volume of end-of-life EV batteries. Early attempts at repurposing, such as Toyota's work with Prius batteries,

were deemed unviable due to low volumes. However, the expanding EV market has made second-life applications more feasible, with software and testing protocols evolving to ensure safe and efficient operation.

The integration of renewable energy sources like wind and solar power into the power grid necessitates innovative solutions to address their inherent intermittency. Energy storage systems, smart grid technologies, and demand response plans are key strategies that help maintain grid reliability and balance supply and demand. These approaches enable the efficient management of energy resources, ensuring that renewable energy can be effectively integrated into the grid without compromising stability. As the share of renewables continues to grow, the development and deployment of these technologies become increasingly vital for a sustainable and reliable energy future.

Emerging trends and technologies in energy storage, such as sodium-ion batteries, offer promising avenues for further enhancing the integration of renewables into the grid. While sodium-ion batteries may have a lower efficiency compared to lithium-ion, their potential for lower cost materials and similar manufacturing processes make them an exciting area of development.

Ultimately, reducing costs remains a critical goal across all energy storage technologies, as affordable solutions will be key to widespread adoption and a successful transition to a renewable energy-dominated grid. **EFY**

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