

## **Paper 73**

### **Comparing Different Energy Storage Solutions: A Comprehensive Review**

With the rapid development of renewable energy, efficiently storing energy has become a key factor in promoting the transition to clean energy. Energy storage technologies not only balance energy supply and demand but also enhance the stability and reliability of power systems. Currently, the main energy storage solutions available include battery storage, compressed air energy storage (CAES), pumped hydro storage (PHS), and hydrogen storage, each with its unique advantages and challenges.

Firstly, battery storage technology, particularly lithium batteries, is widely used in residential and commercial energy storage systems. Lithium batteries, with their high energy density, long lifespan, and low self-discharge rate, are among the most common storage devices. However, lithium batteries face challenges such as high costs and limited resources, especially the reliance on rare metals like cobalt. Additionally, solid-state lithium batteries, as the next generation of storage technology, offer higher safety and energy density, and are expected to become mainstream in the future.

Secondly, compressed air energy storage (CAES) is a mature storage technology. It works by using excess electricity to compress air and store it in underground caverns or containers. When needed, the compressed air is released to drive turbines and generate electricity. CAES is suitable for large-scale energy storage but has high infrastructure costs and is highly dependent on specific geographical conditions.

Pumped hydro storage (PHS) is one of the most widely used storage technologies globally. It involves pumping water from a lower elevation to a higher one for storage, and then releasing the water to generate electricity during peak demand. PHS has high efficiency and a mature technology base, but it requires large amounts of water and specific geographical environments.

Hydrogen storage technology is also gaining attention, especially for long-duration and large-scale storage. Hydrogen can be produced through water electrolysis and stored through compression, liquefaction, or chemical methods. When needed, hydrogen can be converted back into electricity or used in other industrial applications. The advantages of hydrogen storage lie in its high energy density and virtually unlimited storage duration, but challenges such as high production and storage costs, as well as efficiency issues, still remain.

In conclusion, each energy storage technology has its own advantages and disadvantages. Battery storage is suitable for small-scale, high-efficiency applications, while compressed air and pumped hydro storage are ideal for large-scale energy storage. Hydrogen storage holds potential for long-duration, high-capacity storage. In the future, with continued technological advancements and cost reductions, energy storage solutions will play a stronger role in supporting global energy transitions and sustainable development.