Energy
Storage
Association

Storage Technology Primer

Technology Review

Storage technology is rapidly evolving. Currently, there are more than half-a-dozen electricity storage technologies at or near commercial viability, with many more at various stages of development. Figure 1 catagorizes current technologies.

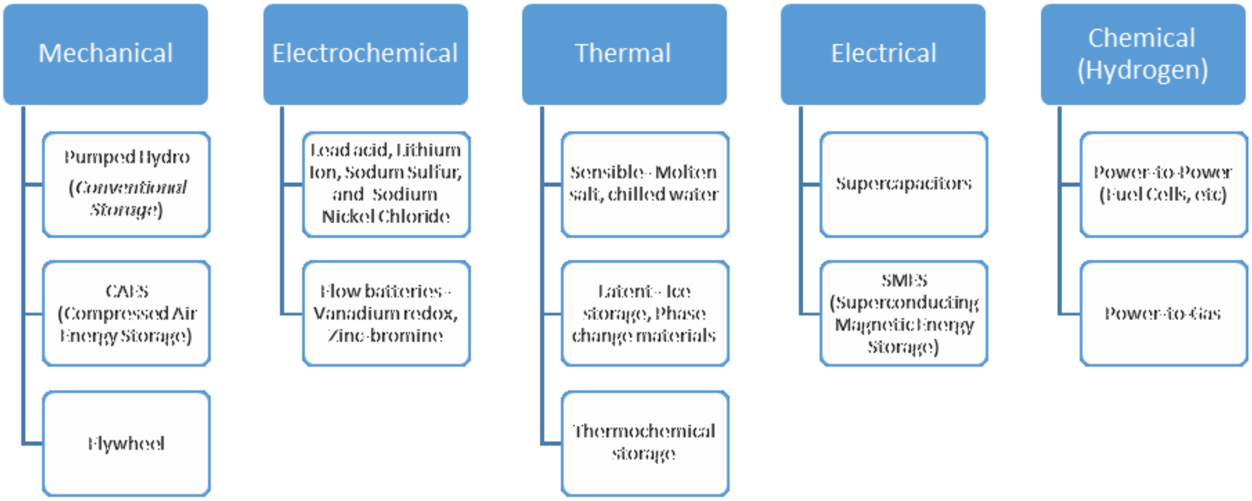


Figure 1: Classification of Storage Technologies

Mechanical storage holds energy through momentum, pressure, or simply by lifting heavy things. Types of mechanical storage include:

- Pumped Hydro, which stores energy by lifting water. Pumped Hydro is the most mature grid-scale storage technology. Because grid-scale pumped hydro requires moving vast quantities of water—storing one MWh is equivalent to lifting an Olympic swimming pool 500 feet—pumped storage facilities are usually reservoirs on the top of a mountain or hill. Finding appropriate sites can be challenging.

- Compressed Air Energy Storage (CAES), stores energy as high pressure air in rock formations or, at small scale, tanks. Current CAES technology requires favorable geology and offers relatively low efficiency. Development projects underway aim to improve efficiencies and/or allow more flexible siting.

- Flywheel Storage Systems store energy as spinning masses.

Electrochemical storage uses electricity to drive a chemical reaction while charging, then reverse that reaction to release electricity when discharging. This is the classic battery. Types of battery include:

- Lead Acid. The oldest type of rechargeable battery. Low cost, but cycling limits prevent them from competing for some applications.

- Lithium-Ion. Currently the dominant storage technology. Moderate cost, high efficiency, and long lifetime make Li-Ion batteries well suited for the frequency regulation market. Costs are approaching, but have yet to reach, the level to broadly compete in other power markets.

- Sodium-Sulphur (NaS). Another efficient battery technology, NaS projects have been widely deployed over the last 10-12 years, especially in Japan. However, NaS costs have not fallen as quickly as Li-Ion. That, combined with some engineering challenges—NaS batteries operate at 300-350C—have reduced their market share in recent years.

- Flow batteries. Unlike the solid-state batteries above, flow batteries store energy in liquids chemicals that are pumped through a reaction area for charging and discharging. This has the advantage of allowing the storage capacity to be easily increased simply by increasing the reservoirs. Whereas most other battery storage technologies have an intrinsic power/energy ratio, flow batteries can be designed with whatever ratio is appropriate for their application.

Thermal storage stores energy as heat. Many thermal storage technologies are once-through, where electricity is converted to heat, stored for a period, then used without being converted back to electricity. Technologies that do convert power back into electricity are under development, including:

- Molten Salt. As the name implies, these systems store power in very high temperature (~1000F) molten salt. The hot salt is used to create steam to drive conventional turbines. Given the efficiency of turbines, this makes molten salt an inefficient storage method if electricity is used to heat the salt. However, if primary heat is used to melt the salt without first being converted to electricity, molten salt systems are very efficient. They are commonly used in conjunction with concentrated solar systems.

The table below summarizes the technologies at or near commercial use:

Technology	Cost ($/kWh)	Eff. (DC-DC)	Duration (hours)	Lifetime (cycles)	Siting	Maturity
Lead Acid	$100 -$300	70-85%	2 – 6	500 -2000	Easy	Mature
Li-Ion	$200 -$1000	85-95%	0.25 – 4	2000 – 6000+	Easy	Commercial
NaS	$400 - $600	70-80%	6 – 8	3000 – 5000	Moderate	Commercial
Flow Battery	$500 - $1000	60-75%	4 and up	5000+	TBD	Early
Flywheel	$1000 - $1400	60-80%	0.25 – 4	Nearly unlimited.	Easy	Early
Pumped Hydro	$50 - $150	70-80%	6 -20	10,000+	Hard	Mature
Molten Salt		90%+	6 – 15		Specialized	Early

Cost: Capital cost of storage components. Excludes “remainder of system” costs such as inverters and interconnection.

Eff.: Round trip efficiency. For DC technologies, this excludes AC-DC and DC-AC conversion losses.

Duration: How long a system can maintain full output from a full charge. For many technologies, duration can be increased by reducing the maximum output of the system.

Siting: How difficult finding a site for a new project is.

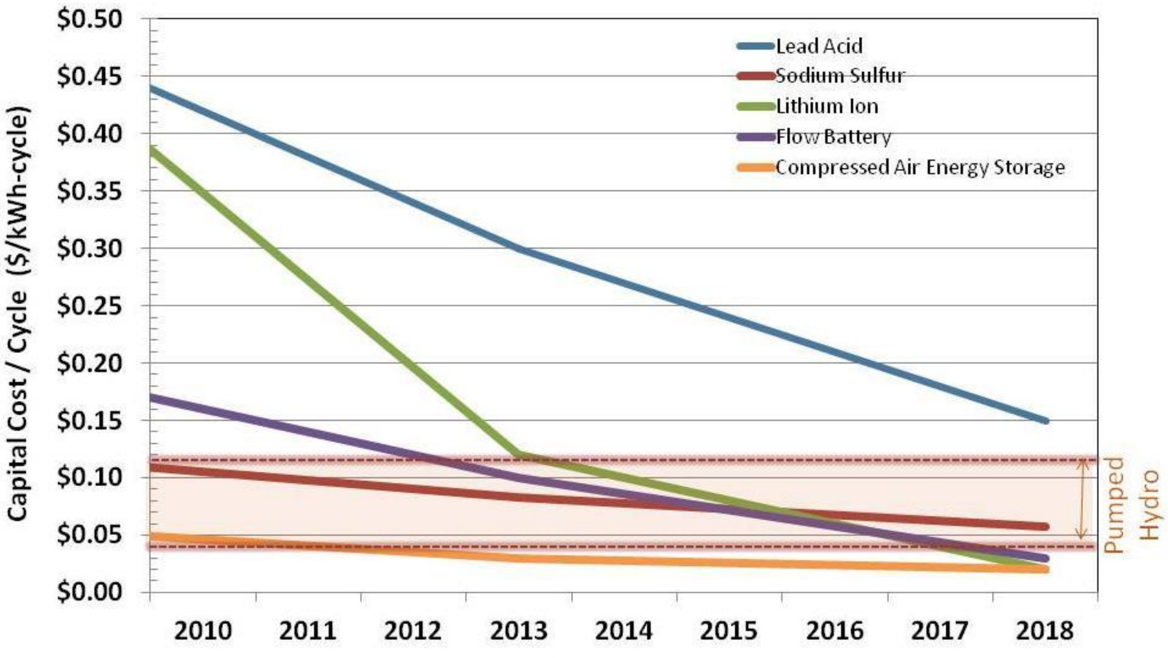
Maturity: Technology level of development. “Mature” technologies are considered fully development, with no major improvements expected. “Commercial” technologies are in commercial operation, but may not yet be fully developed and could see improvements. “Early” technologies may be in limited commercial or pilot deployment, but further development is needed before widespread commercial viability.

Energy Market Outlook

The viability of storage in energy markets depends on three factors: cost of storage, efficiency of storage, and energy price spreads. The revenue from a charge-discharge cycle is the difference in energy prices between the charge and discharge period, less losses due to inefficiency. Storage will become economic in energy markets once this revenue sufficiently exceeds capital costs.

Costs of many storage technologies has been dropping rapidly, especially Li-Ion. Li-ion batteries cost nearly $1,000/kWh in 2010, and have dropped to around $200/kWh today. Industry analysts predict Li-ion prices to hit $100/kWh by 2020 – 2022. That price level is considered a rough estimate of the point where energy arbitrage becomes economically viable.

Levelized capital costs per kWh have also dropped. The graph below shows capital costs per kWh-cycle over the life time of the storage device. This sets a lower bound on energy price spreads needed to support storage in energy markets.



SOURCE: Customized Energy Solutions

Figure 2: Estimated Levelized Capital Costs of Storage

The levelized cost is a function of both system cost and expected life. Even though lead acid batteries are relatively inexpensive, their low cycle life makes each charge/discharge cycle expensive, precluding them from energy market participation under most circumstances.

Low efficiency inhibits other technologies. CAES, in particular, is quite inexpensive, with capital costs only $25.00/MWh. But, the high round trip losses inherent to current CAES systems prevent them from profiting from energy markets under most circumstances.

Near-term improvements in Li-Ion and flow batteries may well push the levelized capital cost of these systems below $15/MWh delivered.