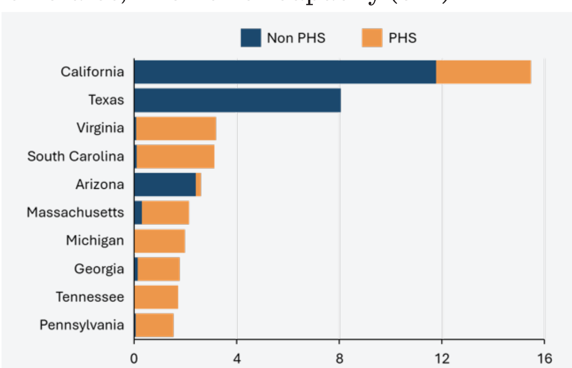
U.S. Grid Energy Storage

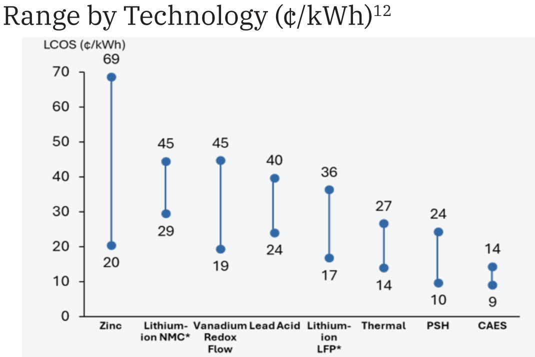
Electrical Energy Storage (EES) systems store electricity and convert it back to electrical energy when needed.[1] Batteries are one of the most common forms of electrical energy storage. The first battery, Volta's cell, was developed in 1800.[2] The U.S. pioneered large-scale energy storage with the Rocky River Pumped Storage plant in 1929.[3] Energy storage research accelerated dramatically [2] after the 1970s oil crisis,[4] driving significant improvements in battery cost and performance.[5] Energy storage is a critical component for current and future sustainable energy grids.[6]

Top Ten States, EES Power Capacity (GW)[8]



- EES systems are characterized by rated power (W) and energy storage capacity (Wh).[7]
- The U.S. energy storage market achieved record growth in 2024 with 12.3 GW of new installations[43] and is projected to add another 15.2 GW in 2025.[44] Total rated power reached 50 GW in the U.S.[8] and 178 GW globally.[10]
- Of the 1,643 operational energy storage projects worldwide, 49% are located in the U.S., with another 131 projects under construction.[10] California leads U.S. capacity with 15.5 GW, followed by Texas.[8]
- Levelized cost of storage (LCOS)—which includes taxes, financing, and operations and maintenance costs per output kWh—varies significantly by technology.[11] Compressed Air Energy Storage (CAES) offers the lowest costs, while zinc and lithium-ion batteries are more expensive.[12]

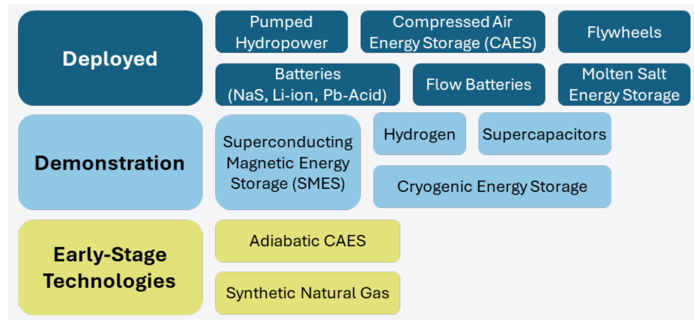
LCOS Range by Technology (¢/kWh)[12]



Deployed Technologies

Key EES technologies include Pumped Hydroelectric Storage (PHS), Compressed Air Energy Storage (CAES), Advanced Battery Energy Storage (ABES), Flywheel Energy Storage (FES), Thermal Energy Storage (TES), and Hydrogen Energy Storage (HES).[16] PHS and CAES are large-scale technologies with power capacities up to 1G W and discharge times of tens of hours, but are geographically limited.[17] ABES and FES have lower power and shorter discharge times (from seconds to 6 hours), and are often not limited by geography.[17]

Maturity of Energy Storage Technologies[13]



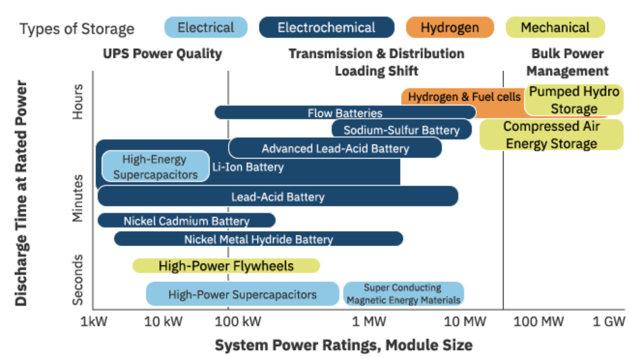
Pumped Hydroelectric Storage (PHS)

- PHS systems pump water from lower to upper reservoirs, then release it through turbines using gravity to convert potential energy to electricity when needed. These systems have 50-60 year lifetimes and operational efficiencies of 70-85%. [17, 18]
- Annual PHS additions have nearly doubled since 2022. PHS provides 90% of global EES capacity,[19] and 96% in the U.S.[20] PHS share of U.S. utility-scale power capacity dropped from 93% in 2019 to 70% in 2022 due to battery facility growth.[20]

Compressed Air Energy Storage (CAES)

- CAES systems compress air in underground caverns.[21] The pressurized air is heated and expanded in a natural gas combustion turbine to drive a generator.[22] As of 2024, the U.S. only had one CAES plant operating, a 110 MW plant in AL.[8]
- Existing CAES plants separate compression and combustion processes.[22] This method generates three times the output per unit of natural gas input, reducing CO_2 emissions by 40-60% and achieving 42-55% efficiency.[22]

Characteristics of Energy Storage Technologies[14, 15]



Advanced Battery Energy Storage (ABES)

- ABES stores electricity as chemical energy.[23] Batteries contain two electrodes (anode and cathode) separated by an electrolyte. The electrolyte enables ion flow between electrodes while external wires carry electrical current.[23]
- The U.S. has 431 operational battery energy storage projects,[8] using lead-acid, lithium-ion, nickel-based, sodium-based, and flow batteries.[10] These projects totaled 27 GW of rated power in 2024,[8] and have round-trip efficiencies between 60-95%.[24]

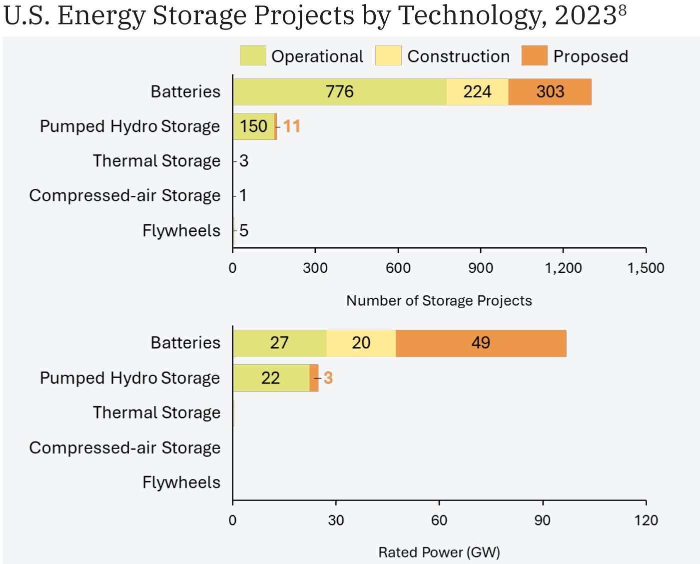
Flywheel Energy Storage (FES)

- FES systems store kinetic energy by spinning a rotor in a low-friction enclosure, and are used mainly for grid management rather than long-term energy storage.[22] The rotor changes speed when moving energy to or from the grid.[17]
- In 2024, FES systems provided 47 MW of rated power in the U.S.,[8] and have efficiencies between 85-87%.[24]
- FES systems excel in high-power, low-energy applications. Low-speed systems rotate up to 10,000 RPM while high-speed systems reach 100,000 RPM.[22]

Applications

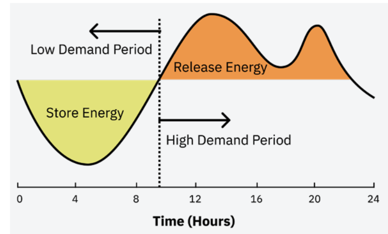
- EES systems have many applications, including energy arbitrage, generation capacity deferral, ancillary services, ramping, transmission and distribution capacity deferral, and end-user applications (e.g., managing energy costs, power quality and service reliability, and renewable curtailment).[26]
- EES can operate at partial output levels with low losses and can respond quickly to changes in demand.[27] Storing energy in off-peak hours and using that energy during peak hours saves money and prolongs the lifetime of energy infrastructure.[25]

U.S. Energy Storage Projects by Technology, 2023[8]



- Round-trip efficiency, annual degradation, and generator heat rate have a moderate to strong influence on the environmental performance of grid connected energy storage.[28]
- Energy storage accelerates adoption of variable renewable sources like solar and wind by storing excess energy for use when these sources are unavailable.[29]

Daily Energy Storage and Load Leveling[25]



Solutions

Research & Development

- Energy storage boosts electric grid reliability and lowers costs,[47] as storage technologies become more efficient and economically viable. One study found that the economic value of energy storage in the U.S. is $228B over a 10-year period.[27]
- Lithium-ion batteries are one of the fastest-growing energy storage technologies[30] due to their high energy density, high power, near 100% efficiency, and low self-discharge.[31] The U.S. holds 1.8 Mt of lithium reserves, 6% of global reserves.[32]
- A zero-carbon future by 2050 would require 930 GW of storage capacity in the U.S[33], and the grid may need 225-460 GW of long duration energy storage (LDES) capacity.[34] Hydrogen, CAES, and PHS are the most viable technologies for LDES.[35]
- When designing EES, it is important to ensure system deployment results in a net reduction in environmental impacts.[36]

Policy & Standardization

- 12 states have statewide energy storage deployment targets,[37] including Michigan's goal of 2.5 GW by 2030.[38]
- The U.S. DOE disbursed $185M of American Recovery and Reinvestment Act funding to support 16 large-scale energy storage projects with a combined capacity of over 0.53 GW.[39]
- DOE's Long Duration Storage Shot sets an LCOS target of 5¢/kWh by 2030, a 90% reduction from 2020 costs.[41]
- The Federal Energy Regulatory Commission (Order No. 841) requires wholesale electricity markets to establish participation models recognizing energy storage's physical and operational characteristics.[40]
- California implemented one of the largest financial incentive policies through its Self-Generation Incentive Program, authorizing $280M for residential solar and storage.[45]
- The 2022 Inflation Reduction Act provided a 30% Investment Tax Credit for energy storage technologies through 2032. Recent legislation reverts this to 2027.[42,46,48]

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Sources for this factsheet are here, help with units and abbreviations is here.