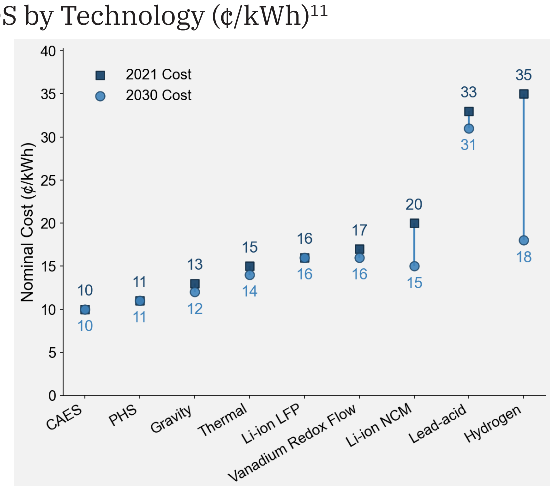
U.S. Grid Energy Storage

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.[2] The first battery, Volta's cell, was developed in 1800.[3] The U.S. pioneered large-scale energy storage with the Rocky River Pumped Storage plant in 1929.[4] Energy storage is a critical component for current energy grids,[5] and will be needed to manage variable energy from renewable generation as renewables generate greater amounts of power.[1]

- EES systems are characterized by rated power (W) and energy storage capacity (Wh).[6] This is different than electricity generators like wind, solar, and fossil fuel power plants, which only have an output power rating. EES systems cannot output electricity that exceeds their storage capacity.
- U.S. energy storage achieved record growth in 2025 with 18.9 GW of new installations, led by California with 700 MW.[7] Total rated power reached 69.5 GW in the U.S. by April 2026, of which 46.5 GW was battery storage.[2] In 2025, the U.S. accounted for 47% of global utility-scale battery storage.[2,8]
- The U.S. is projected to reach 200 GW of rated power and 655 GWh of energy storage capacity by 2031.[9]
- California leads U.S. rated power with 14.4 GW, while Texas leads energy storage capacity with 21.8 GWh.[2]
- Levelized cost of storage (LCOS)—which includes taxes, financing, and operations and maintenance costs per output kWh—varies significantly by technology.[10] Compressed Air Energy Storage (CAES) offers the lowest costs, while zinc and lithium-ion batteries are more expensive.[11]

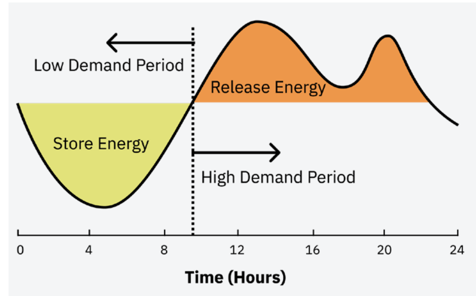
LCOS by Technology (¢/kWh)[11]



Applications

- EES systems serve many purposes: delivering backup power, decreasing the variability of renewables, and arbitrage applications such as peak shaving, load leveling, and load following.[1] Peak shaving is when EES is used to supplement power at peak demand.[1] Load leveling involves shifting demand to off-peak times.[1,13] Load following stabilizes the grid in real time by quickly charging and discharging.[1]

Daily Energy Storage and Load Leveling[15]

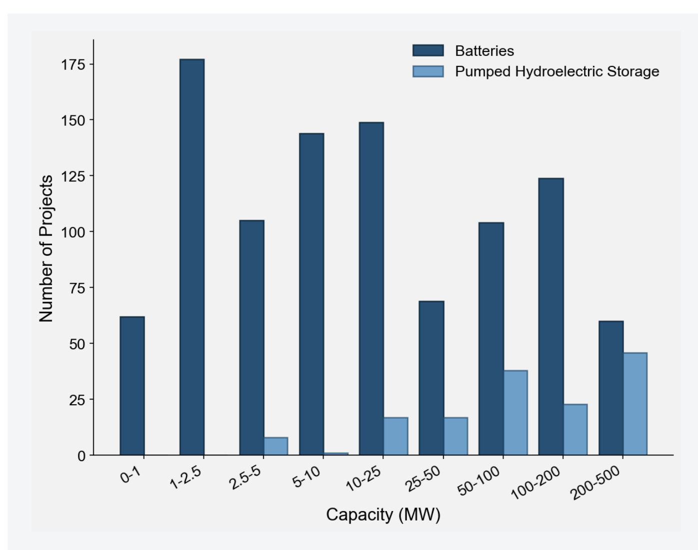


- No energy storage system is desirable for all applications in part due to differences in power rating, response time, and energy storage capacity.[1]
- EES can operate at partial output levels with low losses and can respond quickly to changes in demand.[14] Storing energy in off-peak hours and using that energy during peak hours saves money and prolongs the lifetime of energy infrastructure.[15]
- Energy storage accelerates the adoption of variable renewable sources like solar and wind by storing excess energy for use when these sources are unavailable.[16]

Deployed Technologies

Key EES technologies include Advanced Battery Energy Storage (ABES), Pumped Hydroelectric Storage (PHS), Compressed Air Energy Storage (CAES), Flywheel Energy Storage (FES), Thermal Energy Storage (TES), and Hydrogen Energy Storage (HES).[17] PHS and CAES are large-scale technologies with power capacities up to 3 GW and discharge times of tens of hours, but are geographically limited.[2,18] ABES and FES have lower power and shorter discharge times (from seconds to 21 hours),

U.S. Energy Storage Projects by Technology[2]



and are often not limited by geography.[2,18] The conversion efficiency from input energy to output energy, termed round-trip efficiency, and the rate of energy storage capacity losses and round-trip efficiency losses as the EES system ages, termed annual degradation, have a moderate to strong influence on the environmental performance of grid-connected energy storage.[19]

Advanced Battery Energy Storage (ABES)

- ABES stores electricity as chemical energy.[20]
- The U.S. has 749 operational battery energy storage projects,[2] using lead-acid, lithium-ion, nickel-based, sodium-based, and flow batteries.[8] These projects totaled 43.6 GW of nameplate capacity in 2025,[2] and have round-trip efficiencies between 60-95%.[21]
- Lithium-ion batteries are one of the fastest-growing energy storage technologies due to their high energy densities, high power, near 100% round-trip efficiency, and low self-discharge.[22,23]
- Cost decreases due to larger manufacturing scales and technology breakthroughs are driving lithium-ion battery adoption and have resulted in the cheap lithium iron phosphate (LFP) chemistry to constitute 90% of lithium-ion grid additions.[24,25]
- Companies are investigating sodium-ion batteries, which have a lower energy density than LFP, but perform well in cold environments and do not contain lithium, which is subject to price swings.[26]

Pumped Hydroelectric Storage (PHS)

- PHS systems pump water from lower to upper reservoirs, then release it through turbines to convert potential energy to electricity when needed.[18,27] These systems have 50-60 year lifetimes[18] and operational efficiencies of 70-85%.[27]
- PHS provides 201 GW of global EES capacity.[28] and 22.2 GW in the U.S.[29] PSH generation has remained relatively stable for the last two decades.[29] PHS was overtaken by ABES as the biggest contributor of EES in the U.S. in 2024.[29]

Compressed Air Energy Storage (CAES)

- CAES systems compress air in underground caverns.[30] The pressurized air is heated and expanded in a turbine to drive a generator.[31] As of 2025, the U.S. only has one CAES plant operating, a 110 MW plant in Alabama.[2]
- Existing CAES plants separate compression and combustion processes.[32] 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.[32]

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.[32] The rotor changes speed as a result of moving energy to or from the grid.[18]
- In 2025, FES systems provided 47 MW of rated power in the U.S.,[2] and have efficiencies between 85-87%.[21]
- 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.[32]

Solutions

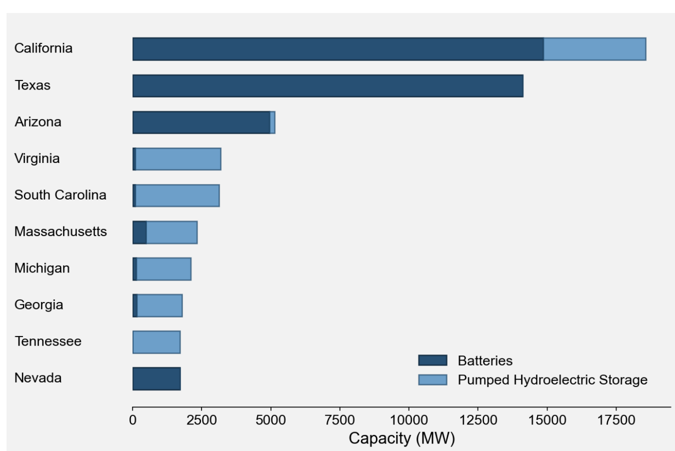
Research & Development

- Energy storage boosts electric grid reliability and lowers costs,[25] as storage technologies become more efficient and economically viable.[14] Major power outages are estimated to cost Americans $67B per year.[33]
- A zero-carbon future by 2050 would require 930 GW of storage capacity in the U.S.,[34] and the grid may need 225-460 GW of long duration energy storage (LDES) capacity.[35] Utilizing multiple sources of ESS on the grid, like PHS, CAES, ABES, and hydrogen, improves technically feasibility and economic viability.[36]
- When designing EES, it is important to ensure system deployment results in a net reduction in environmental impacts.[37]

Policy & Standardization

- 13 states have statewide energy storage deployment targets,[38] including Michigan's goal of 2.5 GW by 2030.[39]
- California implemented one of the largest financial incentive policies through its Self-Generation Incentive Program, authorizing $280M for residential solar and storage.[12]
- The 2022 Inflation Reduction Act provided a 30% Investment Tax Credit for energy storage technologies through 2032.[40] Recent legislation changed the end date to 2027 for many technologies,[24,26] although tax credits for PHS remain.[29]

Top Ten States, EES Power Capacity (GW)[2]



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