$250 per kWh: The battery price that will herald the terawatt-hour age

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Key takeaways

- The AC-installed price of an energy storage system will fall below $250/kilowatt-hour (kWh) in 2026, making batteries competitive with the cost of constructing and installing a natural gas peaker plant.
- This price point will open the US natural gas peaker market to batteries.
- By 2030, installed battery capacity will reach 500 gigawatt-hours (GWh) in the US and more than 2 terawatt-hours (TWh) globally.

Contents

By 2025, the US electrical grid will be fundamentally and forever changed by batteries as a tidal wave of new stationary energy storage systems is installed. E Source expects that wave will encompass 111 GWh and 33 gigawatts (GW) of batteries. By 2031, the number is even more staggering: the US will have installed and be operating more than 500 GWh and 150 GW of batteries.

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Underlying this transformational change is the plummeting cost of batteries. In 2017, it was common to spend more than $1,000/kWh to install a stationary storage system. In 2022, that number fell to $312/kWh, even amid a hyperinflationary environment for battery materials like lithium. It will drop to $248/kWh by 2026.

Breaking the $250 barrier will mark an inflection point in grid battery usage. At that price point, a utility can build a four-hour system for $1,000/kilowatt (kW), which makes it competitive with the capital cost of constructing and installing a natural gas peaker plant. The California ISO defines a four-hour system as being sufficient to supply reserve power for the grid. In other words, a four-hour battery looks and feels like a natural gas peaker plant and operates under similar parameters. Thus, the entire US natural gas peaker market will be open to batteries. By the end of the decade, we'll start measuring the US battery power plant market not in GWh but in TWh.

The history of the grid: From San Francisco to San Francisco

In 1879, a priest connected the first electrical grid when he linked a coal-fired boiler to a string of outdoor lights in San Francisco. In the following century and a half, grids grew, but they continued to resemble that first version: a generator hooked to a load with simultaneous production and consumption of electricity.

Most other networks transfer their content with the help of storage. The internet has data centers. The road and highway system has parking lots. Even the brain has neurons whose job is to retain memories.

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But the electrical grid has operated for more than 140 years without a means for storing electricity. This is possible for two reasons. The first is that the fuel (coal, natural gas, and petroleum) functions as storage. It's burned when needed. That proposition will start to disappear as we move to fuel-free technologies like wind and solar.

The second reason the grid works without electricity storage is that it's built out significantly larger than necessary for the average load. The extra production comes in the form of peaker plants, usually powered by natural gas burned in relatively inefficient combustion turbines. These peaker plants come on only when the peak of the load exceeds the power requirements of an average daily load. In other words, we built the grid to meet the absolute highest load. If, as occurs more than 90% of the time, the load is below peak, then the generation assets designed for the peak period stay silent, sometimes still burning fuel (this is called spinning reserve) but not making electricity.

Fast forward to the summer of 2022, 143 years later, when Vistra Energy installed more than 1 GWh of batteries at Moss Landing in Monterey Bay, just south of San Francisco. The batteries are divided into three separate projects owned and operated by three separate power plant operators, but they all occupy the space of an abandoned former natural gas–fired power plant.

The future of energy storage in the US looks like Moss Landing: endless rows of containers filled with batteries, sitting seemingly inactive but working feverishly on the molecular scale charging and discharging. How soon will Moss Landings fill the country? To answer that, we must take battery costs into account.

The shrinking cost of a battery system

Through E Source Battery Next, we model battery costs from the atomic layer (how many atoms of lithium, nickel, etc.) up to a finished system level (energy storage system or EV battery pack). We itemize costs on three layers:

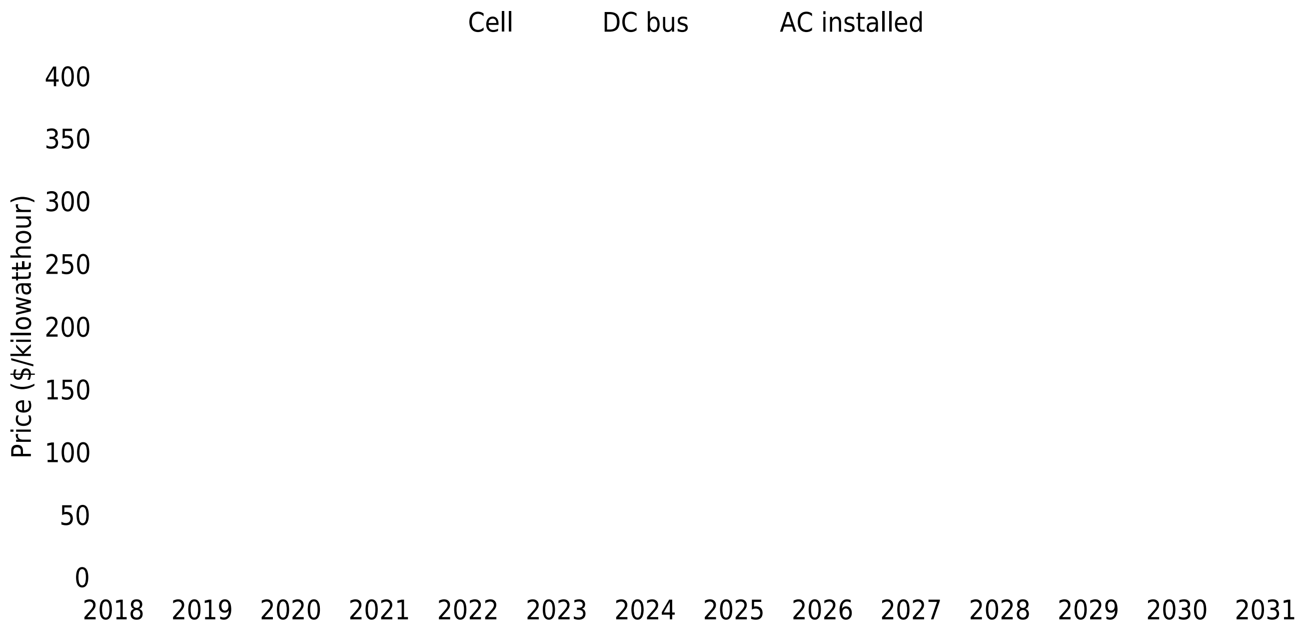
- *Cell:* The cost of manufacturing the battery cell, plus the profit margin of the manufacturer, shipping, and taxes.
- *DC bus:* The finished container filled with batteries, including all power electronics and control systems needed to work on the DC level.
- *AC installed:* The cost of installing DC systems at a site, including the power control system (also called an inverter) needed to receive and produce AC power, and construction costs.

Experts commonly discuss battery costs at the cell level, where they've proposed a magical threshold price of $100/kWh as an important milestone. We believe this will happen in 2027, but it won't, by itself, cause any significant changes to demand. A far more meaningful number is the cost of AC-installed systems. And the break-even price point of $250/kWh will indeed present an inflection point in demand because it means that a four-hour system will cost $1,000/kW.

E Source tracks and forecasts battery prices for all applications—from EVs to power tools and consumer electronics. On the stationary storage front, the price forecast shown in **figure 1** represents utility-scale energy storage systems—installations like the one at Moss Landing. We expect that the AC-installed price for battery systems will drop below $250/kWh in 2026.

Figure 1: Utility-scale energy storage system pricing forecast

The AC-installed price will drop below $250/kWh in 2026, marking an inflection point for battery installations.



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In other words, the coming three-year wave of battery installations is just a warm-up. Most battery systems built out to 2025 will happen in New York, Texas, and California—each a market that's especially predisposed to batteries (New York because of subsidies, California because of state-mandated energy storage requirements, and Texas because of the lucrative nature of providing peaking power).

After the cost of a full battery power plant installation drops below $250/kWh, the rest of the US will open—from New England to the Midwest to the Southwest. At that point, storage as a foundational part of a functioning grid will become ubiquitous throughout the country.

> **What's happening to cause prices to fall? It starts with cell pricing but doesn't end there.**

What's happening to cause prices to fall? It starts with cell pricing but doesn't end there. As we move to bigger factories, economies of scale take over and reduce equipment, labor, and energy costs. Likewise, a switch to lithium iron phosphate (LFP) batteries as the cathode chemistry of choice will deliver a lower-cost cell.

But cell costs are not just heading downward. Since 2020, prices have gone up as hyperinflation affected input materials (most notably lithium, which increased in price by more than tenfold in three years). Although the inflationary trend is starting to subside for most battery materials, we expect a second inflationary bubble to increase cell pricing in 2025.

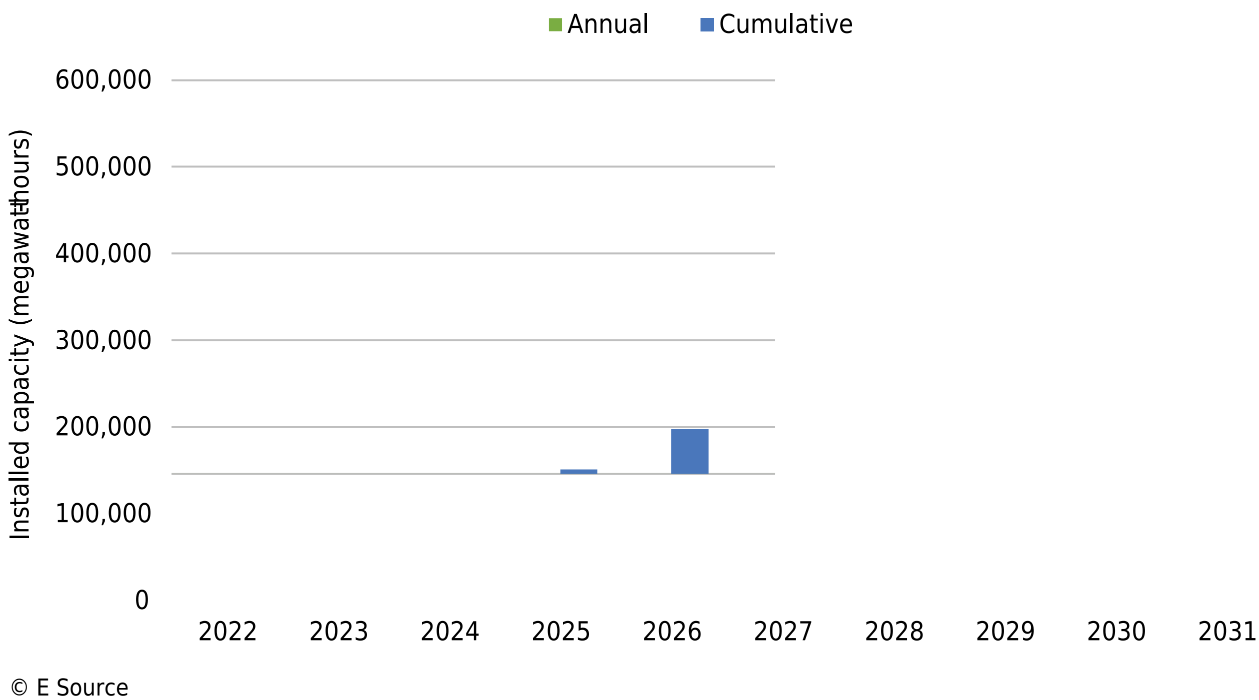
So, if battery cells are getting more expensive, how can system prices decrease so much in the coming three years? The answer lies in system design and engineering. Manufacturers now design DC bus systems for speed and ease of installation, dramatically reducing construction costs on the AC-installed level. Systems like the Tesla Megapack, Powin Centipede, and Fluence GridStack are designed to lower construction costs at the installation site. In most cases, manufacturers are placing the inverter inside the container and doing AC-to-DC inversion on the module level, which lowers the installation costs by eliminating the need to build an external inverter system.

The result: We’ll measure installed capacity in TWh instead of GWh

These cost savings will lead to widespread adoption of batteries throughout the world. The US will be at the vanguard of this trend thanks to its diversity of grid-balancing structures. As shown in **figure 2**, the US will install more than 500 GWh of batteries by the end of the decade. Globally, the number will be over 2 TWh of installed batteries.

Figure 2: US energy storage system installations

By 2030, we expect installed battery capacity to reach 500 GWh.



By 2031, the role of the grid will be noticeably differently than it is today. Batteries will serve as a critical buffer between solar insolation lows, natural gas price spikes, and wind doldrum periods. The world will have significantly more renewables powering the grid, and batteries will allow all power sources to interact smoothly and efficiently.

What happens beyond 2031? At that point, we expect annual installations of batteries will reach a relative plateau, but the installed base will continue to grow. By 2050, the US will have 3 to 5 TWh of installed battery capacity (likely a combination of lithium ion and flow batteries) and the world will probably reach close to 20 TWh. Batteries will become the most important nodes in global power networks and will enable extremely high penetration of renewables. At that point, experts will look back at the moment when this TWh age started to appear in earnest, and they will probably point to 2026—the year battery system costs dropped below $250/kWh.