

What are base year costs for utility-scale battery energy storage systems?

Base year costs for utility-scale battery energy storage systems (BESSs) are based on a bottom-up cost model using the data and methodology for utility-scale BESS in (Ramasamy et al., 2023). The bottom-up BESS model accounts for major components, including the LIB pack, the inverter, and the balance of system (BOS) needed for the installation.

How much energy does a battery storage system use?

The average for the long-duration battery storage systems was 21.2 MWh, between three and five times more than the average energy capacity of short- and medium-duration battery storage systems. Table 1. Sample characteristics of capital cost estimates for large-scale battery storage by duration (2013-2019)

Do battery costs scale with energy capacity?

However, not all components of the battery system cost scale directly with the energy capacity (i.e., kWh) of the system (Feldman et al. Forthcoming). For example, the inverter costs scale according to the power capacity (i.e., kW) of the system, and some cost components such as the developer costs can scale with both power and energy.

Are battery storage costs based on long-term planning models?

Battery storage costs have evolved rapidly over the past several years, necessitating an update to storage cost projections used in long-term planning models and other activities. This work documents the development of these projections, which are based on recent publications of storage costs.

How are battery storage cost projections developed?

The projections are developed from an analysis of recent publications that include utility-scale storage costs. The suite of publications demonstrates wide variation in projected cost reductions for battery storage over time. We use the recent publications to create low, mid, and high cost projections.

How much does gravity based energy storage cost?

# COST OF LARGE-SCALE BATTERY ENERGY STORAGE SYSTEMS PER KW



Looking at 100 MW systems, at a 2-hour duration, gravity-based energy storage is estimated to be over \$1,100/kWh but drops to approximately \$200/kWh at 100 hours. Li-ion LFP offers the lowest installed cost (\$/kWh) for battery systems across many of the power capacity and energy duration combinations.



For example, a lithium ion battery might cost around \$150/kWh (\$600/kW), but a grid-scale lithium ion battery is shown at \$300/kWh (\$1,200/kW). Utilization also strongly determines the costs of grid-scale storage. A nice simplifying assumption for benchmarking different batteries is that they might be lucky to charge and discharge precisely



current and near-future costs for energy storage systems (Doll, 2021; Lee & Tian, 2021). Note that since data for this report was obtained in the year 2021, the comparison charts have the year 2021 for current costs. In addition, the energy storage industry includes many new categories of

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"Energy independence is one of the biggest reasons people install home battery storage systems," says Gerbrand Ceder, professor at UC Berkeley and faculty staff scientist at Lawrence Berkley National Laboratory. "It's seamless, so you don't even notice when power switches from the grid to your battery backup system."



However, the cost of large-scale battery storage, like Hornsdale (which has been recently expanded), has already fallen to about US\$300/kWh and the price tag today may be about half that in 2017. Future battery costs may depend very much upon the cost of metals and of fossil fuels used in mining.



Capital cost of utility-scale battery storage systems in the New Policies Scenario, 2017-2040 - Chart and data by the International Energy Agency. Free and paid data sets from across the energy system available for download. Policies database. Past, existing or planned government policies and measures. Chart Library

# COST OF LARGE-SCALE BATTERY ENERGY STORAGE SYSTEMS PER KW



A decade ago, the price per kilowatt-hour (kWh) of lithium-ion battery storage was around \$1,200. Today, thanks to a huge push to develop cheaper and more powerful lithium-ion batteries for use in electric vehicles (EVs), that cost has dropped to between \$150 and \$200 per kWh, and by 2025 it had been predicted to fall to under \$100/kWh



The future of renewable energy relies on large-scale energy storage. Megapack is a powerful battery that provides energy storage and support, helping to stabilize the grid and prevent outages. Megapack delivers more power and reliability at a lower cost over its lifetime. Each battery module is paired with its own inverter for improved



The cost of a 1 MW battery storage system is influenced by a variety of factors, including battery technology, system size, and installation costs. While it's difficult to provide an exact price, industry estimates suggest a range of \$300 to \$600 per kWh.



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Table 1. Hydrogen Energy Storage Costs by Component ??? 2018 and 2030 Values, Adapted from Hunter et al. (In Press) Mode Component 2018 Assumption 2030 Estimate Charging PEM electrolyzer (kilowatt Electric [kWe]) \$1,500 \$440 Rectifier ???



Palchak et al. (2017) found that India could incorporate 160 GW of wind and solar (reaching an annual renewable penetration of 22% of system load) without additional storage resources. What is grid-scale battery storage? Battery storage is a technology that enables power system operators and utilities to store energy for later use.



Flow Batteries: They offer long cycle life and are excellent for large-scale storage but come with higher initial costs and lower energy density. System Size and Capacity. The scale of your commercial & industrial battery energy storage system also plays a crucial role in determining the cost per kWh. Larger systems generally benefit from

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In this work we describe the development of cost and performance projections for utility-scale lithium-ion battery systems, with a focus on 4-hour duration systems. The projections are ???



These systems have lower costs per kilowatt and higher costs per kilowatthour. For example, a \$12 million battery system with a nameplate power capacity of 10 megawatts and nameplate energy capacity of 4 megawatthours would have relatively low power costs (\$1,200 per kilowatt) and relatively high energy costs (\$3,000 per kilowatthour).



This will require an increased uptake of home batteries across Australia, which as mentioned earlier, is lagging significantly behind when compared to the uptake of rooftop solar. Currently, the typical cost of a household battery ranges from around \$1000 per KW for large systems, to around \$2000 per KW for smaller batteries ??? around 5KW [vii]

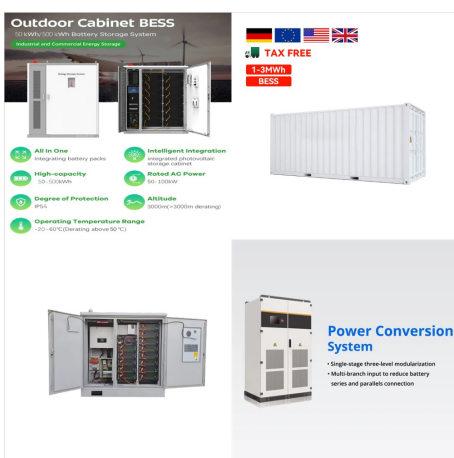
# COST OF LARGE-SCALE BATTERY ENERGY STORAGE SYSTEMS PER KW



Where  $P_B$  = battery power capacity (kW) and  $E_B$  = battery energy storage capacity (\$/kWh), and  $c_i$  = constants specific to each future year; Capital Expenditures (CAPEX) Definition: The bottom-up cost model documented by (Feldman et al., 2021) contains detailed cost buckets for both solar only, battery only, and combined systems costs. Though



result in the cost per kilowatt-hour of stored energy. Figure 2. CAES systems classifications (adapted from [3]) \$0.11/kWh; however, that estimate includes \$0.03/kWh in energy costs. The 2030 LCOS estimates Cavern Storage 6.84 Base cavern storage cost (\$/kWh) O& M Costs 16.12 Base fixed O& M (\$/kW-year)



(e.g. 70-80% in some cases), the need for long-term energy storage becomes crucial to smooth supply fluctuations over days, weeks or months. Along with high system flexibility, this calls for storage technologies with low energy costs and discharge rates, like pumped hydro systems, or new innovations to store electricity economically over longer

# COST OF LARGE-SCALE BATTERY ENERGY STORAGE SYSTEMS PER KW



Energy storage system costs stay above \$300/kWh for a turnkey four-hour duration system. In 2022, rising raw material and component prices led to the first increase in energy storage system costs since BNEF started its ESS cost survey in 2017. Costs are expected to remain high in 2023 before dropping in 2024.



\$/kWh. However, not all components of the battery system cost scale directly with the energy capacity (i.e., kWh) of the system (Fu, Remo, and Margolis 2018). For example, the inverter costs scale according to the power capacity (i.e., kW) of the system, and some cost components such as the developer costs can scale with both power and energy.



Average battery energy storage capital costs in 2019 were \$589 per kilowatthour (kWh), and battery storage costs fell by 72% between 2015 and 2019, a 27% per year rate of decline. Most large-scale battery energy storage systems we expect to come online in the United States over the



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Storage Capacity (kWh) System Mass (kg) System Cost (2016\$) ??? Monte Carlo uncertainty analysis was completed for all systems investigated ??? Results for 700 bar Type 4 systems show that baseline projections (represented by the black, dashed line and data label) reflect best case scenario for all parameters studied.



U.S. Energy Information Administration | US. Battery Storage Market Trends 5 Executive Summary Large-scale battery storage systems are increasingly being used across the power grid in the United



The U.S. Department of Energy's (DOE) Energy Storage Grand Challenge is a comprehensive program that seeks to accelerate the development, commercialization, and utilization of next-generation energy storage technologies. In support of this challenge, PNNL is applying its rich history of battery research and development to provide DOE and industry with a guide to ???

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Battery capacity is in kW DC. E/P is battery energy to power ratio and is synonymous with storage duration in hours. Battery pack cost: \$283/kWh: Battery pack only : Battery-based inverter cost: \$183/kWh: Assumes a bidirectional inverter, converted from \$/kWh for 5-kW/12.5-kWh system: Supply chain costs: 6.5% (U.S. average)



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We also consider the installation of commercial and industrial PV systems combined with BESS (PV+BESS) systems (Figure 1). Costs for commercial and industrial PV systems come from NREL's bottom-up PV cost model (Feldman et al., 2021). We assume an inverter/load ratio of 1.3, which when combined with an inverter/storage ratio of 1.67 sets the BESS power capacity at ???



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Rs 0.7-0.8/kWh by 2030 4-6 hours of storage system is found to be cost-effective in 2030 These cost estimates warrant a closer examination of future investments in the power sector However, significant regulatory interventions would be needed for ???

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The U.S. electricity system is changing rapidly with the large-scale addition of variable renewables, and or total volume and weight of the battery energy storage system (BESS). For this report, volume was Capital Cost ??? Energy Capacity (\$/kWh)  
400-1,000 (300-675) 223-323 (156-203) 120-291  
(102-247) 520-1,000 (364-630) 265-265 (179