

## Utility-scale energy storage guatemala city

The battery storage technologies do not calculate levelized cost of energy (LCOE) or levelized cost of storage (LCOS) and so do not use financial assumptions. Therefore, all parameters are the same for the research and development (R& D) and Markets & Policies Financials cases.

The 2024 ATB represents cost and performance for battery storage with durations of 2, 4, 6, 8, and 10 hours. It represents lithium-ion batteries (LIBs)--primarily those with nickel manganese cobalt (NMC) and lithium iron phosphate (LFP) chemistries--only at this time, with LFP becoming the primary chemistry for stationary storage starting in 2022. There are a variety of other commercial and emerging energy storage technologies; as costs are characterized to the same degree as LIBs, they will be added to future editions of the ATB.

The National Renewable Energy Laboratory's (NREL's) Storage Futures Study examined energy storage costs broadly and the cost and performance of LIBs specifically (Augustine and Blair, 2021). The costs presented here (and for distributed residential storage and distributed commercial storage) are based on that study. This work incorporates base year battery costs and breakdowns from (Ramasamy et al., 2022) (the same as the 2023 ATB), which works from a bottom-up cost model.

Battery cost and performance projections in the 2024 ATB are based on a literature review of 16 sources published in 2022 and 2023, as described by Cole and Karmakar (Cole and Karmakar, 2023). Three projections for 2022 to 2050 are developed for scenario modeling based on this literature.

For a 60-MW 4-hour battery, the technology innovation scenarios for utility-scale BESSs described above result in capital expenditures (CAPEX) reductions of 18% (Conservative Scenario), 37% (Moderate Scenario), and 52% (Advanced Scenario) between 2022 and 2035. The average annual reduction rates are 1.4% (Conservative Scenario), 2.9% (Moderate Scenario), and 4.0% (Advanced Scenario).

Between 2035 and 2050, the CAPEX reductions are 4% (0.3% per year average) for the Conservative Scenario, 22% (1.5% per year average) for the Moderate Scenario, and 31% (2.1% per year average) for the Advanced Scenario.

**Projected Utility-Scale BESS Costs:** Future cost projections for utility-scale BESSs are based on a synthesis of cost projections for 4-hour-duration systems as described by (Cole and Karmakar, 2023). The share of energy and power costs for batteries is assumed to be the same as that described in the Storage Futures Study (Augustine and Blair, 2021). The power and energy costs can be used to determine the costs for any duration of utility-scale BESS.

**Definition:** The bottom-up cost model documented by (Ramasamy et al., 2022) contains detailed cost

components for battery-only systems costs (as well as batteries combined with photovoltaics [PV]). Though the battery pack is a significant cost portion, it is a minority of the cost of the battery system. The costs for a 4-hour utility-scale stand-alone battery are detailed in Figure 1.

Within the ATB Dataspreadsheet, costs are separated into energy and power cost estimates, which allows capital costs to be calculated for durations other than 4 hours according to the following equation:

Base Year: (Cole and Karmakar, 2023) assume no variable O& M (VOM) costs. All operating costs are instead represented using fixed O& M (FOM) costs. The FOM costs include battery augmentation costs, which enables the system to operate at its rated capacity throughout its 15-year lifetime. FOM costs are estimated at 2.5% of the capital costs in \$/kW. Items included in O& M are shown in the table below.

The cost and performance of the battery systems are based on an assumption of approximately one cycle per day. Therefore, a 4-hour device has an expected capacity factor of 16.7% ( $4/24 = 0.167$ ), and a 2-hour device has an expected capacity factor of 8.3% ( $2/24 = 0.083$ ). Degradation is a function of the usage rate of the model, and systems might need to be replaced at some point during the analysis period. We use the capacity factor for a 4-hour device as the default value for ATB because 4-hour durations are anticipated to be more typical in the utility-scale market.

Round-trip efficiency is the ratio of useful energy output to useful energy input. Based on Cole and Karmakar (Cole and Karmakar, 2023), the 2024 ATB assumes a round-trip efficiency of 85%.

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