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Industrials & Electronics Practice

Enabling renewable energy with battery energy storage systems

The market for battery energy storage systems is growing rapidly. Here are the key questions for those who want to lead the way.

This article is a collaborative effort by Gabriella Jarbratt, Sören Jautelat, Martin Linder, Erik Sparre, Alexandre van de Rijt, and Quan Han Wong, representing views from McKinsey's Industrials & Electronics Practice and McKinsey's Battery Accelerator Team.

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With the next phase of Paris Agreement goals rapidly approaching, governments and organizations everywhere are looking to increase the adoption of renewable-energy sources. Some of the regions with the heaviest use of energy have extra incentives for pursuing alternatives to traditional energy. In Europe, the incentive stems from an energy crisis. In the United States, it comes courtesy of the Inflation Reduction Act, a 2022 law that allocates $370 billion to clean-energy investments.

These developments are propelling the market for battery energy storage systems (BESS). Battery storage is an essential enabler of renewable-energy generation, helping alternatives make a steady contribution to the world's energy needs despite the inherently intermittent character of the underlying sources. The flexibility BESS provides will make it integral to applications such as peak shaving, self-consumption optimization, and backup power in the event of outages. Those applications are starting to become more profitable as battery prices fall.

All of this has created a significant opportunity. More than $5 billion was invested in BESS in 2022, according to our analysis—almost a threefold increase from the previous year. We expect the global BESS market to reach between $120 billion and $150 billion by 2030, more than double its size today. But it's still a fragmented market, with many providers wondering where and how to compete. Now is the time to figure out where the best opportunities will be in the rapidly accelerating BESS market and to start preparing for them.

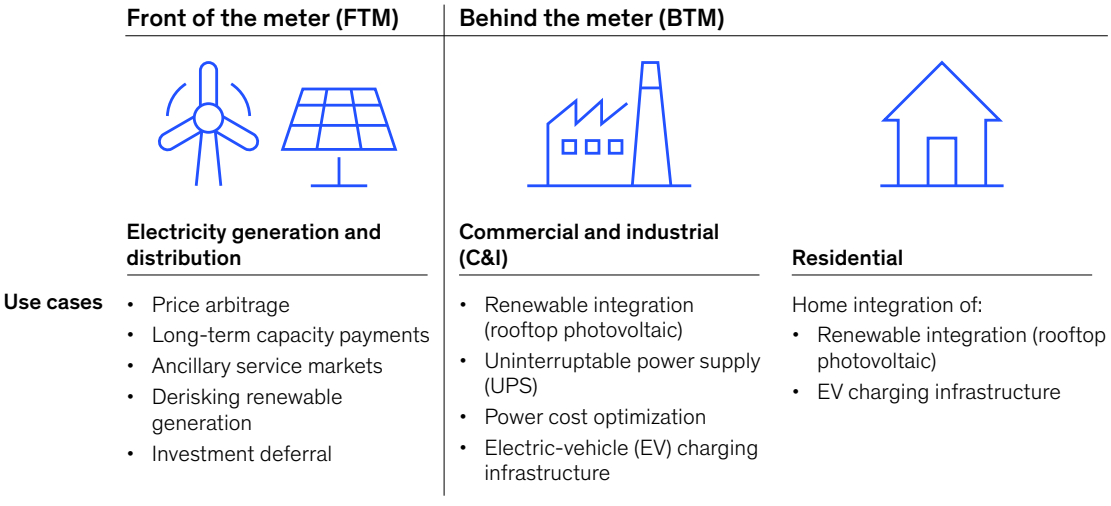
Here are some questions—and answers—to help BESS players formulate their strategies.

What are the main opportunities?

The best way to get a sense of the opportunities associated with BESS is to segment the market by the applications and sizes of users. There are three segments in BESS: front-of-the-meter (FTM) utility-scale installations, which are typically larger than ten megawatt-hours (MWh); behind-the-meter (BTM) commercial and industrial installations, which typically range from 30 kilowatt-hours (kWh) to ten MWh; and BTM residential installations, which are usually less than 30 kWh (Exhibit 1).

Exhibit 1

Battery energy storage systems are used across the entire energy landscape.



Source: McKinsey Energy Storage Insights

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We expect utility-scale BESS, which already accounts for the bulk of new annual capacity, to grow around 29 percent per year for the rest of this decade—the fastest of the three segments. The 450 to 620 gigawatt-hours (GWh) in annual utility-scale installations forecast for 2030 would give utility-scale BESS a share of up to 90 percent of the total market in that year (Exhibit 2).

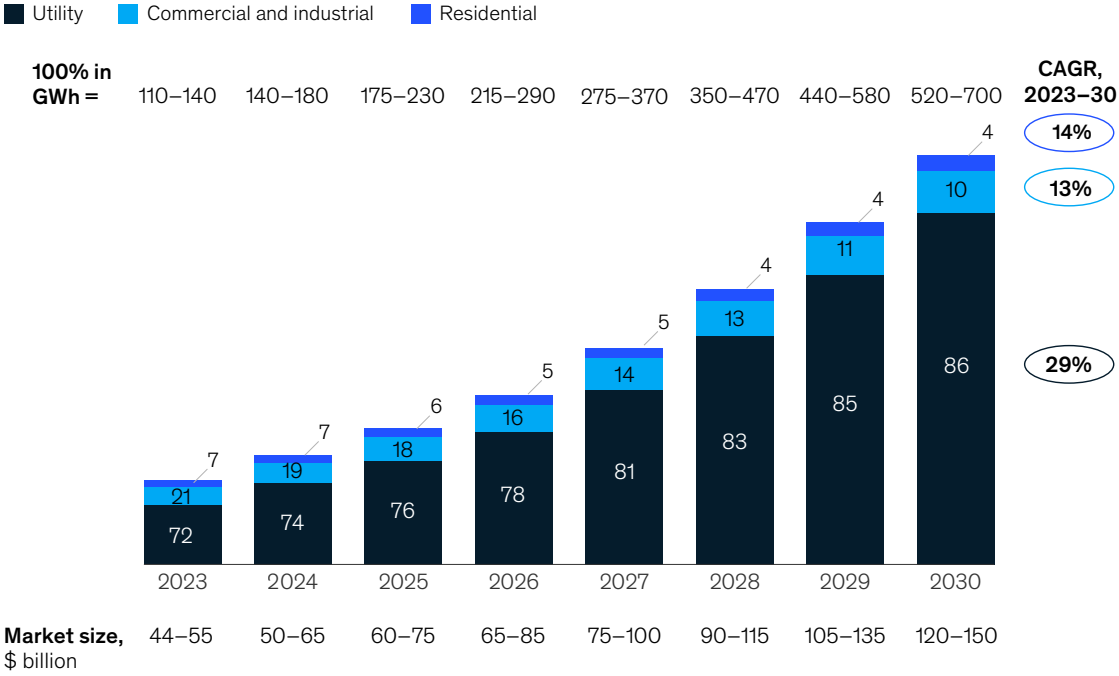
Customers of FTM installations are primarily utilities, grid operators, and renewable developers looking to balance the intermittency of renewables, provide grid stability services, or defer costly investments to their grid. The BESS providers in this segment generally are vertically integrated battery producers or large system integrators. They will differentiate themselves on the basis of cost and scale, reliability, project management track record, and ability to develop energy management systems and software solutions for grid optimization and trading.

BESS deployments are already happening on a very large scale. One US energy company is working on a BESS project that could eventually have a capacity of six GWh. Another US company, with business interests inside and outside of energy, has already surpassed that, having reached 6.5 GWh in BESS deployments in 2022. Much of the money pouring into BESS now is going toward services that increase energy providers' flexibility—for instance, through firm frequency response. In the long run, BESS growth will stem more from the build-out of solar parks and wind farms, which will need batteries to handle their short-duration storage needs.

Exhibit 2

Battery energy storage system capacity is likely to quintuple between now and 2030.

Annual added battery energy storage system (BESS) capacity, %



Note: Figures may not sum to 100%, because of rounding.
Source: McKinsey Energy Storage Insights BESS market model

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Revenue models for FTM utility-scale BESS depend heavily on the dynamics of the regions that providers are entering. Most utility-scale BESS players pursue a strategy of revenue stacking, or assembling revenues from a variety of sources. They might participate in ancillary services, arbitrage, and capacity auctions. For instance, many BESS installations in the United Kingdom currently revolve around ancillary services such as frequency control. Italy has BESS players that have broken through by winning one of the country's renewables-focused capacity auctions. The opportunities in Germany revolve more around avoiding costly grid upgrades. The BESS players that have gotten traction in the FTM utility segment have understood the value of responding individually to countries and their regulations versus using one monolithic strategy.

Where is the value in the commercial and industrial segment?

Commercial and industrial (C&I) is the second-largest segment, and the 13 percent CAGR we forecast for it should allow C&I to reach between 52 and 70 GWh in annual additions by 2030.

C&I has four subsegments. The first is electric vehicle charging infrastructure (EVCI). EVs will jump from about 23 percent of all global vehicle sales in 2025 to 45 percent in 2030, according to the McKinsey Center for Future Mobility. This growth will require rapid expansion of regular charging stations and super chargers, putting pressure on the current grid infrastructure and necessitating costly, time-consuming upgrades. To avoid this, charging station companies and owners may opt to put a BESS on their properties. Partnerships have already formed between BESS players and EV producers to build more EVCI, including in remote locations.

The next subsegment of C&I is critical infrastructure such as telecommunication towers, data centers, and hospitals. In this subsegment, lead-acid batteries usually provide temporary backup through an uninterruptible power supply during outages until power resumes or diesel generators are turned on. In addition to replacing lead-acid batteries, lithium-ion BESS products can also be used to reduce reliance on less environmentally friendly diesel generators and can be integrated with renewable sources such as rooftop solar. In certain cases, excess energy stored on a battery may allow organizations to generate revenues through grid services. Several telecommunication players and data center owners are already switching to BESS as their uninterruptible power supply solution and for the additional benefits BESS provides.

The third subsegment is public infrastructure, commercial buildings, and factories. This subsegment will mostly use energy storage systems to help with peak shaving, integration with on-site renewables, self-consumption optimization, backup applications, and the provision of grid services. We believe BESS has the potential to reduce energy costs in these areas by up to 80 percent. The argument for BESS is especially strong in places such as Germany, North America, and the United Kingdom, where demand charges are often applied.

The final C&I subsegment consists of harsh environments—applications for mining, construction, oil and gas exploration, and events such as outdoor festivals. The source of the growth will be customers moving away from diesel or gas generators in favor of low-emission solutions such as BESS and hybrid generators. A main factor driving adoption in this segment is upcoming regulations (including the European Commission's sustainability-focused Big Buyers initiative and Oslo's plan for net zero on construction sites by 2025). Many of the companies that make the switch will start by converting to hybrid genset solutions rather than immediately moving completely to BESS.

What about the BESS residential consumer play?

Residential installations—headed for about 20 GWh in 2030—represent the smallest BESS segment. But residential is an attractive segment given the opportunity for innovation and differentiation in areas ranging from traditional home storage to the creation of microgrids in remote communities. From a sales perspective, BESS can be bundled with photovoltaic panels or integrated into smart homes or home EV charging systems. Tailored products

will help residential customers achieve goals such as self-sufficiency, optimized self-consumption, and lower peak power consumption—and they may mean higher margins in this sector. Our recent consumer survey on alternative energy purchases suggests that interest in a BESS product will come down to a few factors, starting with price, safety, and ease of installation (Exhibit 3).

How might we think about our strategic positioning?

In a new market like this, it's important to have a sense of the potential revenues and margins associated with the different products and services. The BESS value chain starts with manufacturers of storage components, including battery cells and packs, and of the inverters, housing, and other essential components in the balance of system. By our estimate, the providers in this part of the chain will receive roughly half of the BESS market profit pool.

Then there are the system integration activities, including the overall design and development of energy management systems and other software to make BESS more flexible and useful. We expect these integrators to get another 25 to 30 percent of the available profit pool.

Finally, between 10 and 20 percent of the profit pool is associated with sales entities, project development organizations, other customer acquisition activities, and commissioning (Exhibit 4).

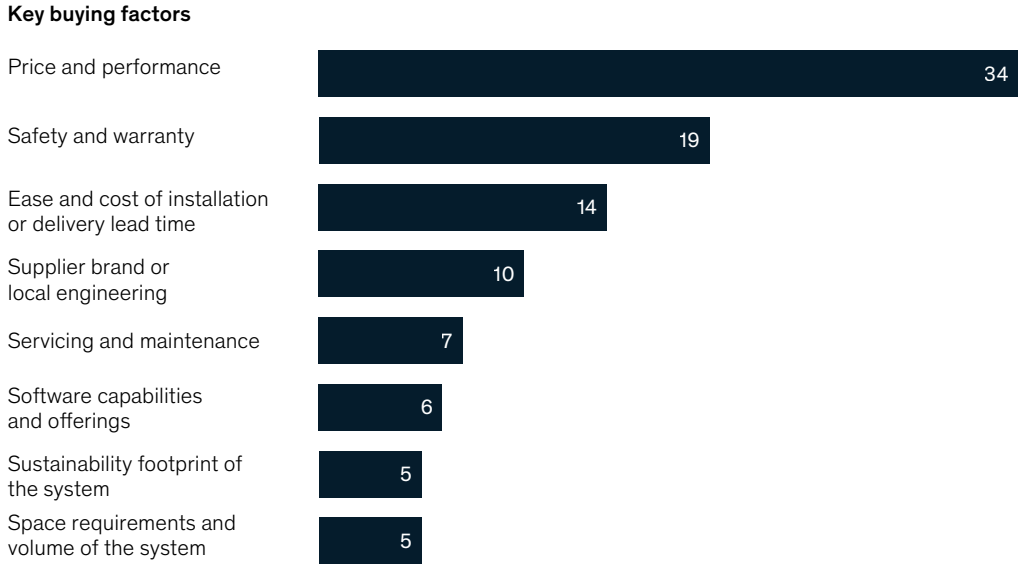
What's going on in the area of battery technology that we need to know about?

From a technology perspective, the main battery metrics that customers care about are cycle life and affordability. Lithium-ion batteries are currently dominant because they meet customers' needs. Nickel manganese cobalt cathode used to be the primary battery chemistry, but lithium iron

Exhibit 3

Price, performance, safety, and good warranties top the list of what home buyers seek in a battery energy storage system.

2023 BESS[1] Germany Customer Survey, perceived as most important, % of respondents



[1]Battery energy storage system.
Source: McKinsey BESS Customer Survey, 2023, German market (n = 300)

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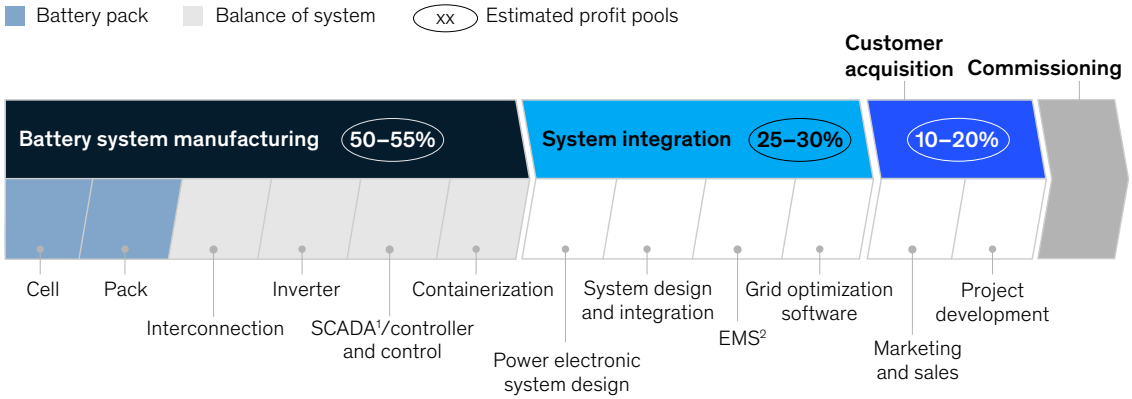
Exhibit 4

The battery energy storage system value chain includes manufacturing, system integration, and customer acquisition.

Value chain breakdown of battery energy storage systems (hardware only)



[1]Supervisory control and data acquisition.
[2]Energy management system.
Source: GTM Research; McKinsey Energy Storage Insights BESS market model

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phosphate (LFP) has overtaken it as a cheaper option. (Lithium iron phosphate customers appear willing to accept the fact that LFP isn't as strong as a nickel battery in certain areas, such as energy density.) However, lithium is scarce, which has opened the door to a number of other interesting and promising battery technologies, especially cell-based options such as sodium-ion (Na-ion), sodium-sulfur (Na-S), metal-air, and flow batteries.

Sodium-ion is one technology to watch. To be sure, sodium-ion batteries are still behind lithium-ion batteries in some important respects. Sodium-ion batteries have lower cycle life (2,000–4,000 versus 4,000–8,000 for lithium) and lower energy density (120–160 watt-hours per kilogram versus 170–190 watt-hours per kilogram for LFP). However, sodium-ion has the potential to be less costly—up to 20 percent cheaper than LFP, according to our analysis—and the technology continues to improve, especially as manufacturing reaches scale. Another advantage is safety: sodium batteries are less prone to thermal runaway. There's also a sustainability case for sodium-ion batteries, because the environmental impact of mining lithium is high.

All of this makes it likely that sodium-ion batteries will capture an increasing share of the BESS market. Indeed, at least 6 manufacturers are expected to launch production of sodium-ion batteries in 2023. Clearly, providers will have to make decisions about which technology to bet on. Integrators may want to set up their systems so that their transition to sodium-ion batteries is straightforward as the batteries become widely available.

Is there a recipe for success in the BESS market? If so, what is it?

This is a critical question given the many customer segments that are available, the different business models that exist, and the impending technology shifts. Here are four actions that may contribute to success in the market:

— *Identify an underserved need in the value chain.* In a nascent industry such as this, it pays for companies to think about other products and services that they could get into, whether through organic moves or inorganic ones. For instance, is there anything to stop a system

integrator from doing battery packaging in-house? Or from codeveloping a new cell chemistry with a battery manufacturer? For that matter, is there anything to keep a battery manufacturer from adding system-integration or service capabilities to appeal to a specific BESS segment, such as utilities?

Software is a particularly critical area to explore. The value of storage systems will likely evolve from just hardware into the software that controls and enhances the system, unlocking the opportunity to capture larger customer segments and higher margins. BESS players need to develop these capabilities early.

— *Build resilience in supply chains.* Many critical BESS components (ranging from battery cells to semiconductors in inverters and control systems) rely on complex supply chains, which are susceptible to supply shocks from a multitude of sources, including raw material shortages and regulation changes. Strategic partnerships, multi-sourcing, and local sourcing are all levers to consider when defining a supply chain strategy, while not forgetting to plan for potential technology shifts. In addition to BESS components, another bottleneck for those in the market is engineering, procurement, and construction (EPC) capability and capacity, particularly for front-of-the-meter applications. Strategic partnerships with large EPC players ready for large-scale BESS installations are crucial to ensure successful execution of BESS projects.

— *Focus on the product features that matter most.* Product specifications should reflect what customers care about. Having a customer segment strategy that informs the road map will increase the odds that every feature matters to customers. Such an approach is especially important given that price competition is likely to remain a permanent reality in the BESS market. The right product road map will also increase the odds of having a unique selling proposition in any segment a company happens to be in. For example, making the right decision on system architecture and integrating with existing customer infrastructure (say, by coupling direct current with photovoltaic technology) could reduce the barriers to entry for many customers.

— *Think big and move fast.* With BESS in the spotlight and revenues starting to increase rapidly, now is not a time to play it safe. While it's true that the market is highly fragmented, it's also true that some bigger players are starting to amass market share. This raises the stakes for all companies, especially for small ones that may have started a decade ago as research projects and now find themselves sitting on top of valuable intellectual property. These companies will likely need to take some risks to have a chance of gaining share and avoid being muscled out by bigger companies.

The BESS market is in an explosive stage of development; players that don't move now will miss out. The winners in the market will be the companies that exhibit the four things required for success. These winners will create value in a new market as the energy transition accelerates.

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