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How Batteries and Solar Power Are Disrupting Electricity Markets

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AT A GLANCE

The market potential of renewable energy, and of solar power in particular, has increased dramatically in the past few years, mainly because of improvements in battery storage, which allows solar customers to store energy generated on sunny days and use it at night and on cloudy days.

Different Strategies for Different Continents

In Europe and Australia, where electricity prices are higher, many of the advances in battery storage have centered on "behind the meter" residential and small-commercial uses, which allow customers to generate and store their own electricity rather than buying it from the local utility. In the US, much of the growth is occurring "in front of the meter," with larger installations and batteries located in the transmission or distribution grid in order to balance fluctuating loads from intermittent renewable generators, such as solar arrays or wind farms.

The Disruption Begins

The proliferation of both types of battery storage is disrupting the traditional utility model and laying the foundation for a cleaner, more reliable energy future. But fundamental changes in the energy landscape are needed, and these will create both opportunities and challenges for stakeholders in energy markets across the world.

THE BATTERY PACK MAY be the least glamorous component in the electricity delivery network, but it is on the verge of transforming electricity markets worldwide.

Solar power produces plenty of electricity on sunny days, but not during peak usage in the evening or when the sky is cloudy. Storage systems such as lithium-ion (Li-ion) batteries, combined with photovoltaic (PV) generation, can address the intermittency of renewables without the expense of expanding the power grid. Batteries reduce the short-term disparity between supply and demand by storing excess electricity during sunny periods (such as at midday) and then delivering it at times of high demand but little or no sunlight (such as at night).

Around the world, retail power prices are rising and the cost of PV-generated and stored electricity is declining, creating potential savings for consumers and small businesses. (See *Distributed Energy: A Disruptive Force*, BCG report, July 2014.) As companies and consumers adopt these new technologies, they are unlocking billions of dollars in potential value while at the same time becoming more self-sufficient. With batteries, consumers and small businesses can use as much as 80% of their PV-generated electricity, compared with 30% to 40% without battery storage. If the cost of generating and storing electricity is less than the cost of electricity from the grid, this can reduce electric bills substantially.

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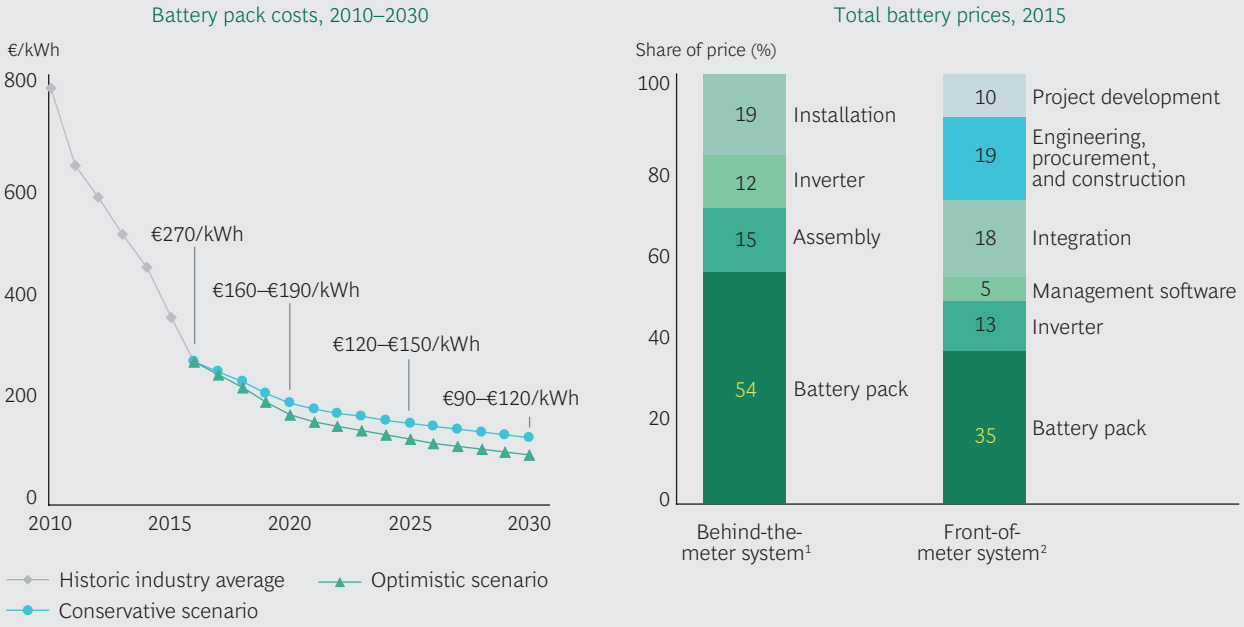
The proliferation of storage options is disrupting the traditional utility business model and laying the foundation for a cleaner, more reliable energy future. The role of traditional utilities in many markets is shifting from control over all aspects of generation and distribution to one in which utilities are primarily grid operators and service providers. This represents a fundamental shift that will affect investors and participants in energy markets around the world.

Costs and Pricing of Battery Storage

Li-ion batteries are the storage technology of choice because of their technical and economic advantages, including an annual decline in manufacturing costs of 10% to 15%. (See Exhibit 1 and "Solar PV Plus Battery Storage: Poised for Takeoff," BCG article, July 2013.) Currently, it costs about €270 per kilowatt hour (kWh) to produce a Li-ion battery pack. Sodium-sulfur batteries are less suitable for applications such as small-scale residential use, while lithium-sulfur and other battery types are not yet commercially viable. Lead-acid batteries, while still cost effective, are quickly losing their investment cost advantage against Li-ion because of their shorter lifespan. (See the sidebar, "Battery Cost Comparisons Defined.")

Exhibit 1 | The Economics Favor Battery Storage



Sources: GTM Research; BTM Navigant; Bloomberg New Energy Finance; press search; Nykvist and Nilsson, "Rapidly Falling Costs of Battery Packs for Electric Vehicles," *Nature Climate Change,* March 23, 2015; BCG analysis.
Note: Battery costs assume a constant exchange rate of €0.891 per $. The conservative scenario assumes an annual decline in costs of 6% after 2020; the optimistic scenario assumes an annual decline in costs of 8% after 2020.
[1]Pricing is based on a 7 kWh system for residential use; the battery pack includes cell replacement costs after 10 years (given a 50% cost reduction spread over the 10-year period).
[2]Pricing is based on a 20 MW system of one-hour duration.

BATTERY COST COMPARISONS DEFINED

Battery costs play a crucial role in the debate about the viability of energy storage. Typically, they are determined by looking at price versus costs or cell costs versus system costs, but the calculations can vary.

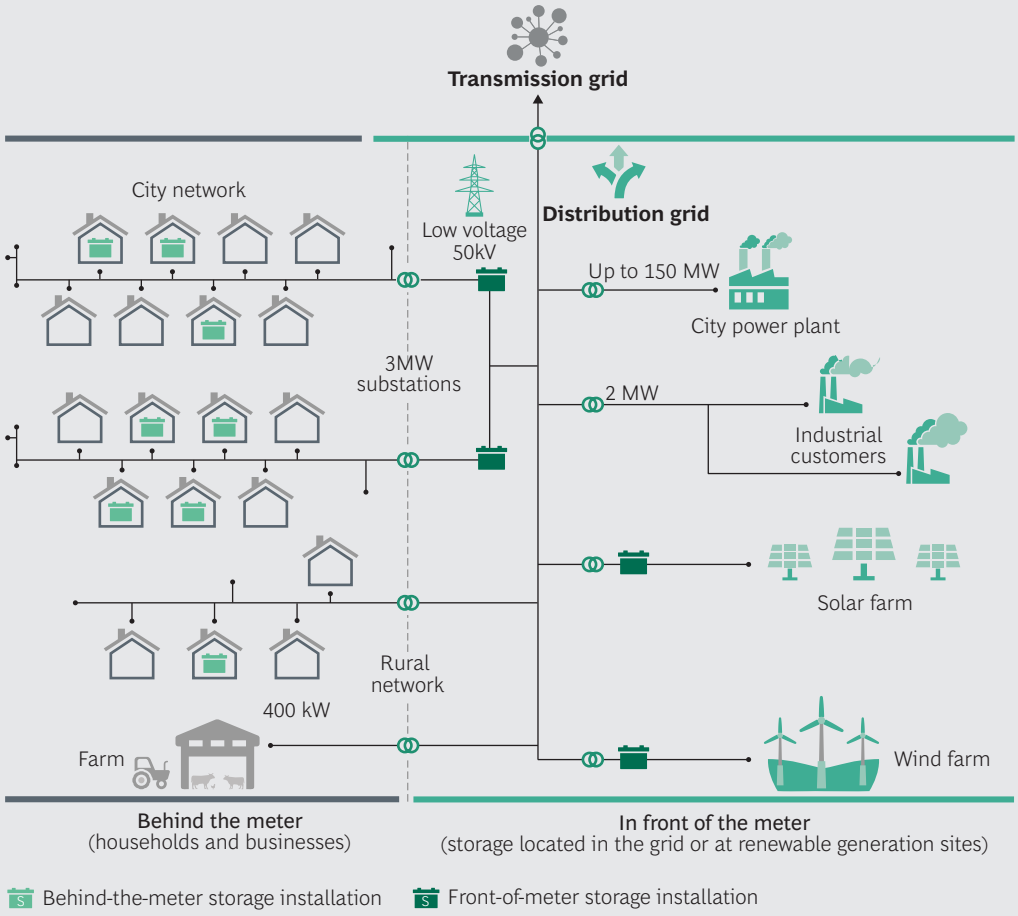
Price Versus Costs. Costs refer to production and logistics costs, while prices also include the margins of equipment manufacturers and wholesalers. In the behind-the-meter section of this report, we examine the economics from the customer's perspective, so the calculations include prices. In general, however, we refer to total system costs. (Exhibit 1 provides an overview of manufacturers' battery pack costs and total component pricing for the customer.)

Cells Versus Systems. The cost of storage cells tell only part of the story, because it excludes the costs of casing, cabling, power electronics, control systems, and other components that are needed to operate stationary storage units. The numbers cited in this report refer to complete behind-the-meter or in-front-of-the-meter storage systems.

Li-ion battery production capacity is expected to triple worldwide by 2020, which would reduce manufacturing costs to between €160 and €190 per kWh. However, potential buyers must consider the full price of the system, including balancing costs. Moreover, component prices differ in behind-the-meter and front-of-the-meter systems, as illustrated in Exhibit 1.

The market for PV-generated electricity storage is determined by the cost of adding batteries to PV installations, as well as by the cost advantage of PV over grid electricity, the PV market size, and the regulatory framework of individual countries. In recent years, battery storage has been developing differently in Europe and Australia than in the US. In Europe and Australia, where electricity prices are higher, most advances have centered on residential and small-commercial uses, known as "behind the meter." In the US, much of the growth is occurring "in front of the meter," with larger installations and batteries located somewhere in the transmission or distribution grid in order to balance fluctuating loads from intermittent renewable generators, such as solar arrays or wind farms. (See Exhibit 2.)

EXHIBIT 2 | Battery Storage Can Be Deployed Behind or In Front of the Meter



Source: BCG analysis.
Note: The transmission grid carries high-voltage electricity over long distances, such as between cities; the distribution grid carries low-voltage electricity to end users.

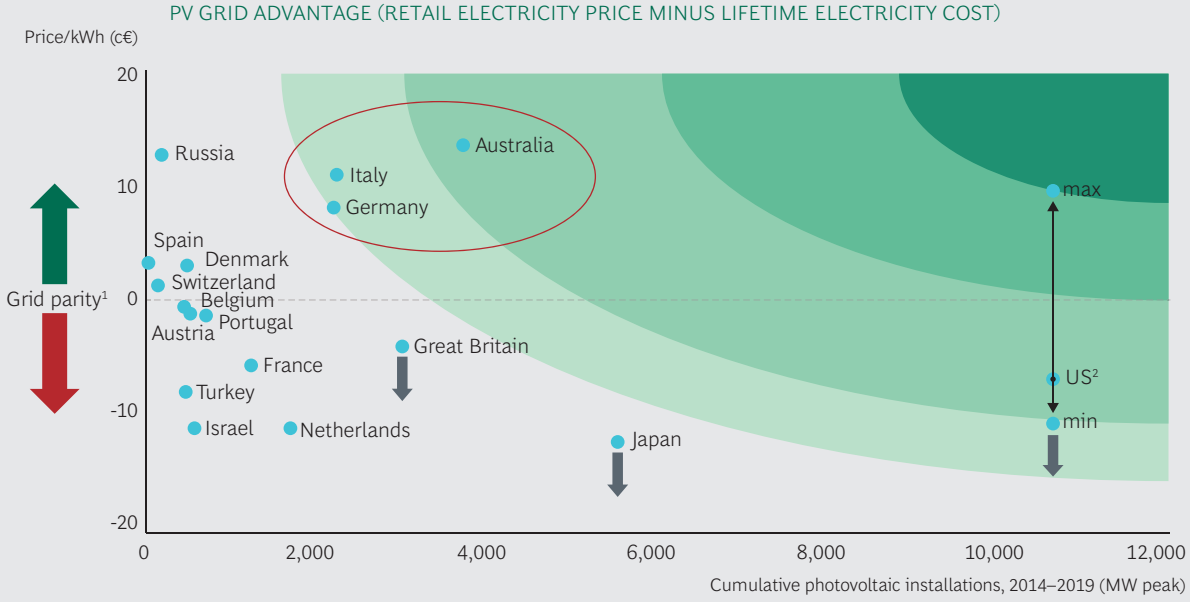
Behind the Meter

Most European countries have few regulations governing residential electricity generation in private homes, and battery storage is consistent with popular energy initiatives such as those encouraging the use of smart-home technologies and electric vehicles. Residential and small-commercial users can generate and store their own electricity rather than buying it from the local utility.

Covering the Costs of Battery Storage. Demand for behind-the-meter storage is a function of the PV grid advantage, which determines how quickly battery owners can cover their costs. The PV grid advantage is the difference between the retail price that customers pay for electricity from the grid and the cost of generating electricity over the lifetime of a PV installation. It also accounts for local electricity prices and the amount of sunlight an area typically receives. The greater the grid advantage, the faster battery owners can cover their costs and the more likely that residential and small-commercial customers will be willing to upgrade their PV system with a battery.

A battery storage system for a home or small business currently costs about €1,000 per kWh. As those costs decline and the economics become more compelling, more new PV installations will be combined with battery storage. Even in countries where existing PV systems are not supported by guaranteed incentives, many residents may reduce the lifetime costs of their PV systems with storage retrofits. Australia, Italy, and Germany currently have the most attractive economics for battery storage. (See Exhibit 3.) Beginning in 2018, buying a bundled system in these countries will be more advantageous than buying a standalone PV unit.

Exhibit 3 | Several Countries Have Attractive Economics for Residential Battery Storage



Sources: IHS; European Photovoltaic Industry Association; Eurostat; Joint Research Centre of the European Commission; International Energy Agency; Photovoltaic Geographical Information System; BCG analysis.
Note: The PV grid advantage also takes into account local electricity prices and the amount of sunlight an area typically receives.
[1] Grid parity occurs when an alternative-energy source generates power at a cost less than or equal to the price of power from the grid.
[2] US residential electricity price varies across states from c€8.2 to c€28 per kilowatt hour.

Support for Battery Storage. Some countries have financial incentives that encourage battery storage. As of July 2016, for example, Germany has offered a 22% investment subsidy for PV plus storage.[1] By contrast, in October 2015, the UK announced a drastic cut in feed-in tariffs, or payments to consumers and commercial users for the renewable energy they generate. This reduction triggered a sharp decline in the PV market and shattered investor confidence. Ultimately, however, it may increase the use of battery storage, because customers will find it more economical to use the electricity they generate rather than feeding it into the grid. In Italy, meanwhile, the grid advantage is large but the government provides no specific support for battery storage.

In Australia, customers are becoming more aware of the benefits of PV and storage, and local investment support is growing in places such as Adelaide City. Sunshine levels in most of the country are also favorable, and Australia is emerging as an attractive battery storage market, drawing interest from companies such as Tesla, Panasonic, Enphase, Solarwatt, Samsung, and Sonnen.

In addition, battery makers are continually developing new business models in support of behind-the-meter systems. For instance, Sonnen allows residential battery owners to sell their self-produced electricity over an energy trading platform (sonnenCommunity), further increasing the independence of small customers from utilities, and Lichtblick has launched a similar platform (SchwarmEnergie/SchwarmDirigent).

Gaining Scale. For the residential and small-commercial battery storage market to achieve meaningful scale, it must account for a sufficient share of the PV market. This will require an economic advantage for the end user; that is, a PV system with batteries must enable customers to save more than they would with a standalone system. When battery installation costs are well below this breakeven point, few buyers will purchase batteries. Close to breakeven, purchases will increase because customers who are interested in PV will be willing to bear a small portion of the cost of the battery. Once the breakeven point is reached, the market will gradually gain momentum until it reaches saturation at more than 80% penetration. (See Exhibit 4.) From then on, the demand for batteries will develop in parallel to the demand for PV installations.

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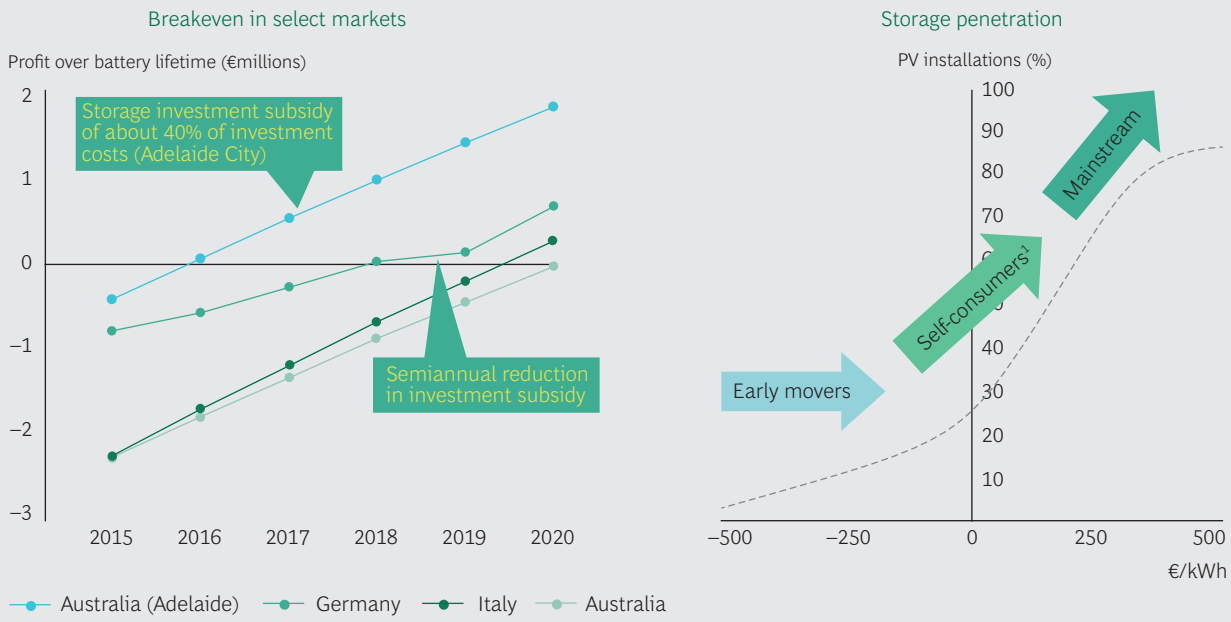
As Exhibit 4 shows, the breakeven rate for residential and small-commercial battery storage varies by country. Germany, for example, achieved breakeven in 2016. We expect the German battery storage market to grow significantly until 2020, with installations of about 350 megawatt hours (MWh), corresponding to a €275 million market volume. (See Exhibit 5.) Battery penetration of the PV market is expected to reach more than 50% within the next four years. Penetration of new installations of residential solar PV systems is already about 40%, according to the German Federal Ministry for Economic Affairs and Energy.

Italy and Australia should reach the breakeven threshold by 2018. Battery penetration in those countries has not reached Germany's level, but we expect rates of about 30% to 40% for new installations by 2020, resulting in markets of €250 million and €190 million, respectively.

Exhibit 4 | Breakeven Battery Costs Drive Market Growth



Source: BCG analysis.
[1] Self-consumers are willing to bear a portion of battery costs before the market reaches breakeven.

Exhibit 5 | The Behind-the-Meter Market Is Growing in Key Countries

Sources: BCG market model; IHS; expert interviews; BCG analysis.

In some cases, battery demand can increase even before the breakeven point is reached, owing to customers' desire to avoid power price increases, to disconnect from the power grid, or to adopt green-energy alternatives and smart-home technologies.

In Front of the Meter

The US is one of the largest PV markets, but a lack of government support for behind-the-meter battery storage and net metering, which allows customers to offset consumed grid electricity with self-produced electricity, has directed storage development mainly to front-of-the-meter applications.[2]

We predict that by 2020, the installed base of US grid battery capacity will increase to more than 2.5 GW, from about 300 MW in 2016. During this period, increased competition will lower the costs of battery storage by about 25%, from approximately $800 per kWh to $600.[3] Costs are expected to decrease by another 20% to 25% from 2020 to 2025.

Declining system costs and growing experience in the large-scale battery business will create a variety of attractive opportunities associated mainly with grid services, such as balancing loads to account for the intermittency of renewables. Batteries offer a fast response to short-term imbalances by storing and releasing electricity within seconds.

Companies such as AES, RES, NextEra Energy Resources, BYD, and S&C Electric have deployed customized battery storage systems in response to the needs of specific utilities and independent power producers (IPPs). However, manufacturers of these systems have struggled to find consistent value in the market given relatively high levels of competition and persistent undercutting of prices by companies seeking a foothold. In contrast to behind-the-meter battery storage, utility-scale storage requires a significant amount of custom engineering for specific sites and applications. While many companies are trying to standardize the market, it remains project based, which increases the number of companies—and the markups—involved.

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BCG found potential opportunities in utility-scale battery storage for five types of companies.

Battery Manufacturers. Expanding capacity—exemplified by Tesla's Gigafactory—will characterize Li-ion battery manufacturing for the next few years. The resulting overcapacity and low margins are prompting some manufacturers, including Tesla, BYD, and Toshiba, to develop standardized battery storage systems. Given their scale and R&D capabilities, battery manufacturers will enjoy a cost advantage over other potential storage providers, but they must develop more expertise in end-user applications and grid integration and improve their sales relationships with utilities and IPPs. To capture downstream value, battery manufacturers will rely on partnerships with developers and engineering, procurement, and construction (EPC) companies.

Power Equipment Manufacturers. Power equipment manufacturers such as S&C Electric, ABB, Schneider Electric, and GE have extensive experience and expertise

integrating products into the distribution infrastructure. Given their credibility and existing sales channels, these companies are well positioned to sell batteries to utilities. They could capture the EPC market as well, but low-cost solar inverter manufacturers are also likely to enter this market as it grows, increasing competition and causing margins to fall. Like battery manufacturers, power equipment makers will need strong sales relationships with utilities and IPPs to develop standardized, cost-competitive battery storage.

Legacy Software Providers with Turnkey Solutions. Capturing value from battery storage requires software capabilities to manage the system across multiple applications while maintaining battery life. With their established solutions, energy management software companies such as Greensmith Energy and Younicos are integrating vertically by developing standardized storage systems. This will further increase competition, but these companies will still be able to capture the highest margins in the utility-scale battery market by offering effective, user-friendly software and integrating it with various storage technologies. Battery software companies will benefit from end-market knowledge and proven performance, but concerns about their "bankability" will be a significant hurdle, particularly for utility customers.

Integrators and Developers. Leveraging their purchasing power and supply chain knowledge, companies such as AES and RES are providing utilities and IPPs with integration, EPC, and development services. However, their advantage in this market will likely diminish with increasing competition from upstream players moving downstream. As the number of modular and standardized solutions in the market grows, software, warranty quality, performance guarantees, and reliable track records will be the biggest differentiating factors, in addition to costs.

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Project Developers and Owners. Traditional renewable-energy developers and IPPs, such as NextEra Energy Resources and Invenergy, are developing storage applications as standalone offerings or in combination with renewable generation. Over time, they will need to expand their software and system integration capabilities. Emerging competition from integrators will require greater risk tolerance and access to low-cost financing for project developers and owners.

Financing will be critical for developing front-of-the-meter batteries. Utility-scale storage has struggled to obtain the long-term nonrecourse debt financing that is common in the utility-scale PV market. Debt financing will require securing long-term cash flows through contracts similar to power purchase agreements. The market uncertainty surrounding battery storage has made these types of contracts challenging, but we believe that commercial financing will become more commonplace over time, unlocking significant market growth.

Understanding the Changing Market for PV and Storage

Significantly higher penetration rates for battery storage will transform PV markets, and companies with the best batteries will dominate. At the same time, growth in the use of smart-home technologies, electric vehicles, and geothermal heat pumps will provide additional value for companies that can integrate these products with

PV and battery storage, rather than with just the PV panels. This will help avoid the commoditization of PV systems. While specialists like Sonnen and Senec serve much of the behind-the-meter storage market, we expect that companies such as SolarCity and Tesla Energy in the US, which are in the process of merging, will integrate their PV and battery offerings.

Companies that can position themselves for the turning point in the battery storage market in individual countries will be able to meet rising demand with tailored products and sales channels. Once the market is established, we expect a consolidation phase to follow, shaking out the less successful players.

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Behind the Meter. In the behind-the-meter market, original equipment manufacturers, integrators, and system providers should identify the countries that best fit their capabilities and products. Key success factors across all regions include the following:

- A mature battery product at a price that is better than breakeven and that is easy to install and compatible with most PV systems
- A strong marketing campaign combined with a well-timed market entry that benefits from growing public awareness, such as that arising from the launch of Tesla's Powerwall in 2015
- A market strategy that takes regional characteristics into account in the choice of sales channels and partners

Methods for reaching potential customers range from classic PV sales channels, such as installers and wholesalers, to innovative offers that bundle PV and storage with energy management systems and smart-home interfaces. In the latter case, batteries could be sold through furniture stores, telecommunication service providers, and white-goods companies either directly or online.

The most important strategic decision, especially for small companies entering new markets, is the choice of a sales and distribution partner. Partnering with energy utilities that wish to offer new products in order to retain customers will bring immediate access to millions of residential and small-commercial customers. This can be beneficial for small equipment manufacturers that lack their own sales networks in new markets. But such partnerships also risk isolating companies from direct contact with customers and limiting their ability to expand their product offerings.

In Front of the Meter. In the utility-scale business, market entrants from adjacent industries with diverse capabilities and experience levels are presenting traditional utilities with rapidly growing competition. Software, integration, and EPC have the highest margins, but these will shrink as competition increases. Standardization and modular solutions will require a greater reliance on software, warranty and performance guarantees, and dependable performance. Companies that can leverage expertise in renewable-energy projects and that already have close relationships with utilities and IPPs as grid storage customers will have a competitive advantage.

BATTERY STORAGE CONTINUES to evolve, enabling the transition to a renewable energy future in dramatically different ways in different parts of the world. In Europe and Australia, it is changing how consumers buy and use electricity. In the US, it is providing stability to a grid that is struggling to accommodate the intermittent nature of renewables. Meanwhile, grid storage is becoming more widespread in Europe and Australia. And behind-the-meter storage is growing in the US, a market that could develop further as net metering, which makes grid operators solely responsible for accommodating fluctuations in renewable generation, becomes increasingly difficult for utilities to maintain. Already there are signs of change. California, for example, has proposed time-of-use tariffs that would charge residential and small-commercial customers different rates depending on the time of day. All of these changes are creating opportunities for companies and investors that understand how markets are developing. As storage technology improves and battery costs decline, the disruptive force of these developments will continue to grow, transforming the world's energy markets.

NOTE

1. This subsidy will be reduced by 3 percentage points every six months.
2. With net metering, the more energy is fed into the grid, the higher the savings on electricity bills. It offers no price difference between consumed and produced electricity and creates no economic incentive to use behind-the-meter batteries, inhibiting the development of the small-scale storage market.
3. These are the costs of an installed system. They do not include the costs associated with project development, such as siting and interconnection. Front-of-the-meter systems currently cost about $1,010 per kWh.

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