

SOLAR PV PLUS BATTERY STORAGE

POISED FOR TAKEOFF

By Cornelius Pieper, Hartwig Ostermeyer, Philipp Konecny, Gunar Hering, and Holger Rubel

INTERMITTENT RENEWABLE-ENERGY SOURCES, LED by wind and solar photovoltaics (PV), figure prominently in many countries' energy plans and are expected to account for an increasingly significant share of the world's energy output in coming years. For that to happen, a key part of the puzzle has to fall into place: energy storage. Storage is a must-have for the large-scale deployment of these technologies. It can mitigate the considerable challenges that the on-again, off-again nature of intermittent renewables create for an integrated energy system. It can also enhance grid stability, especially in the distribution grid, where most renewable assets are deployed and where the potential for regional balancing is limited. Given its indispensable role, we expect global demand for energy storage to soar over the next two decades, as intermittent renewables become increasingly prevalent and core technologies increasingly cost competitive.

Energy storage today is very much a work in progress, however. Many storage

technologies are still developing. Others have not proven themselves on a large scale, do not have a positive business case, and are not yet ready for commercialization. Further, regulatory uncertainty and lack of transparency into the industry's operating economics and core investment parameters have weakened the appeal of storage to potential buyers and investors.

There is, however, an emerging exception to the rule: solar PV paired with battery storage. Driven largely by its increasingly favorable economics in some locations, this technology is now on the cusp of viability.

An Evolving Landscape

Intermittent renewables offer widely recognized advantages over conventional fossil-fuel-based power generation, including reduced carbon emissions and increased energy independence and security. But large-scale reliance on these technologies brings a host of challenges, especially

those associated with intermittent generation. Wind and solar PV can generate no electricity in the absence of wind and sunshine, and when wind and sunshine are plentiful, they often produce far more power than the system needs or is even able to absorb.

Energy storage can smooth out the resulting peaks and valleys by storing surplus energy generated from these sources when the system's supply is high and releasing it back into the system when supply is low. Storage, in both centralized and decentralized applications, will therefore be integral to facilitating the world's growing reliance on intermittent renewables, giving it the potential for dynamic growth over the next several decades. BCG expects annual global sales of storage technologies of €6 billion by 2015 (compared with less than €3 billion in 2012), €15 billion by 2020, and €26 billion by 2030. By region, growth stands to be particularly robust in North America, China and Japan, and Europe, where we expect annual sales of €7.7 billion, €7.6 billion, and €7.2 billion, respectively, by 2030. (See Exhibit 1.)

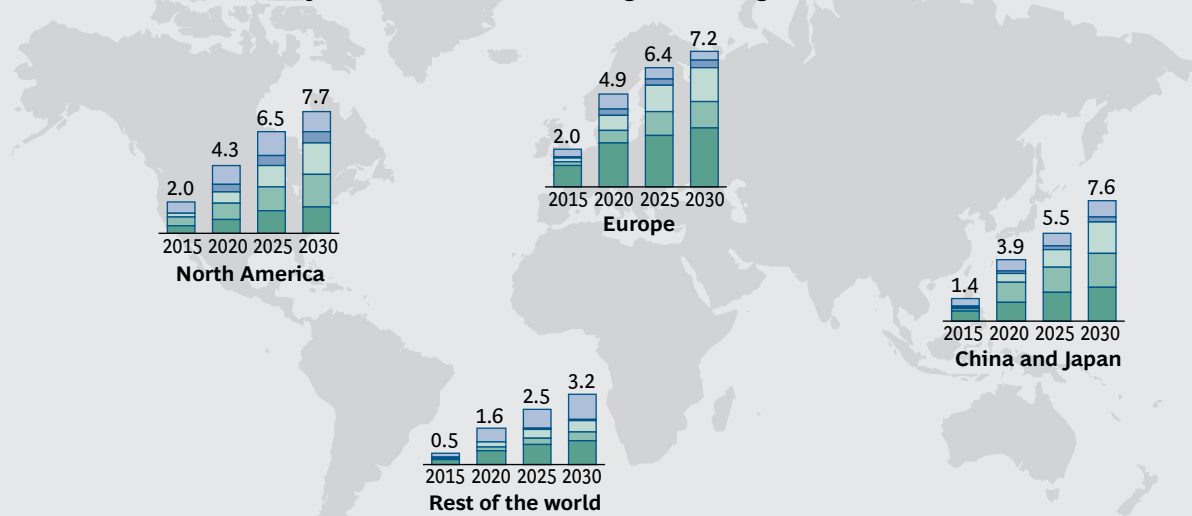
But the storage industry today is far from technologically mature. A single technology—pumped hydroelectric storage, which accounts for the vast majority of the world's existing storage capacity—represents nearly half the money currently invested in storage projects under development. But storage technologies are evolving. Stationary batteries, in particular, are maturing and will have an increasing presence in the next two to four years. Hydrogen storage, similarly, continues to advance and will take on a much larger share of the market toward the end of the decade. Hydrogen storage also could see significantly accelerated growth beyond 2020 as its main differentiating feature versus other technologies—the ability to store very large amounts of energy—becomes increasingly important. Large-scale compressed-air storage, in contrast to stationary batteries and hydrogen, is likely to remain marginal through at least 2020.

Solar PV and Storage: A Growth Market

In order for individual energy-storage technologies to gain widespread adoption,

EXHIBIT 1 | North America, China and Japan, and Europe Will See Particularly Strong Demand for Energy Storage

Projected annual sales of storage technologies (€billions)



- Pumped hydroelectric
- Compressed air
- Hydrogen
- Large battery (>500 kW)
- Small battery (<500 kW)

Source: BCG analysis.

their underlying economics will have to be compelling. Solar PV with battery storage has already reached, or will soon reach, that threshold in a number of countries and regions. For many consumers, it is now less expensive to consume self-generated electricity from solar PV with battery storage than it is to use electricity from the grid supplemented by self-generated electricity from solar PV without storage. The economics are particularly strong for decentralized, standalone residential applications, where the feasibility and economic transparency are greatest and where electricity prices make the financial logic particularly compelling.

Falling system costs are the primary reason for the improving economics. But there are other drivers, which vary by location. These include high retail energy prices, low compensation for surplus electricity fed into the grid, and, in at least one instance, direct government support for solar PV with battery storage. These factors have improved both the near-term economics and the system lifetime economics.

In Europe, countries that stand to be particularly strong markets for solar PV with battery storage in the near to medium term include Germany and Italy—and potentially Spain, depending, to a degree, on the outcome of pending net metering legislation. Germany has high retail electricity prices—27.5 eurocents per kilowatt hour (¢ct/kWh) in 2013—owing to high grid fees and taxes and the markup resulting from subsidies on renewable power. The German government also recently introduced a 30 percent investment subsidy for small-scale solar PV storage systems. Both of these factors encourage adoption of solar PV with battery storage. However, Germany has only moderate solar radiation, and therefore moderately high implied costs of solar electricity, and we assume that compensation for power sold back to the grid will stay reasonably high through 2020. All things considered—particularly the effects of the government’s recent

subsidy—we estimate that German residents who invest in solar PV plus battery storage could see breakeven as early as 2014. (See Exhibit 2.)

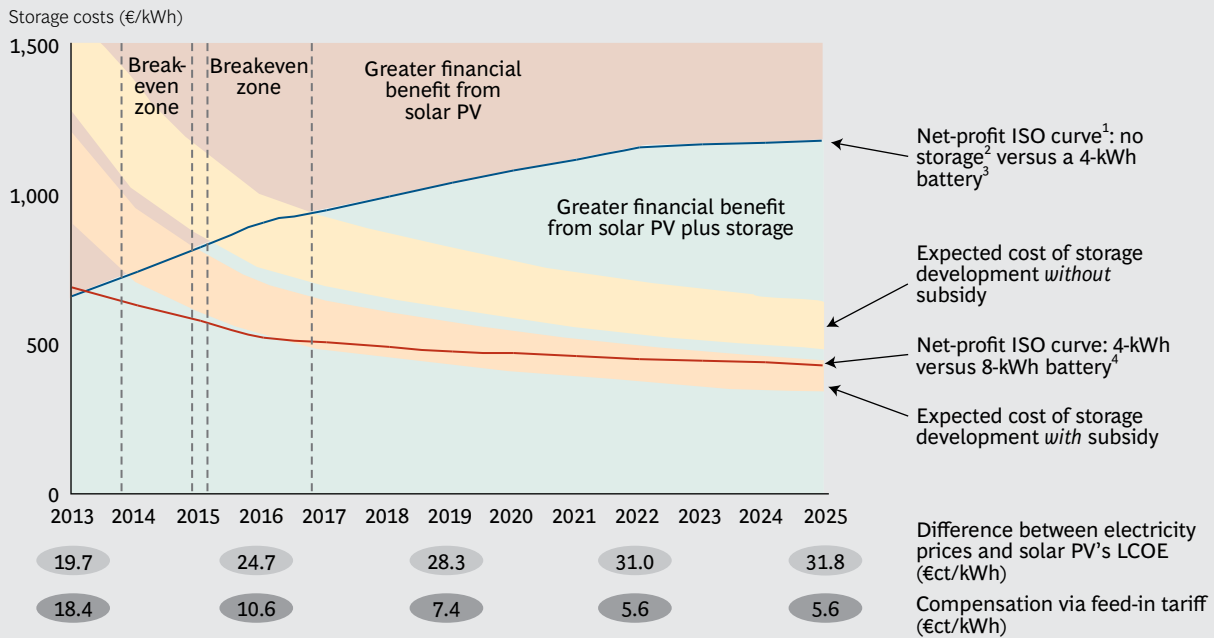
Italy represents perhaps the strongest European market for solar PV plus battery storage. The country’s retail electricity prices are very high (27.3 ¢ct/kWh in 2013), its solar radiation is nearly as high as Spain’s, and compensation via wholesale prices for power sold back to the grid is generally low (and will remain so, assuming there is no extension of the country’s current renewable-energy legislation). Based on its pure economics, solar PV with battery storage is already a superior investment to a standard solar PV installation (one without storage) for many residents of Italy.

Spain combines relatively high retail electricity prices (19.9 ¢ct/kWh in 2013—though the government could push those prices higher as a means of reducing the country’s budget deficit) with the highest solar radiation in Europe and low compensation (following the government’s abolition of the feed-in tariff in January 2012) for power sold back to the grid. For residents of Spain, an investment in solar PV plus battery storage could be financially attractive by 2015.

The economic argument for solar PV with battery storage varies considerably by location, and abundant sunshine is often not the most important factor. Consider California. Its solar radiation is quite high, and compensation (via wholesale prices) for power sold back to the grid is very low. But very low retail electricity prices (9.1 ¢ct/kWh in 2013), due to low taxes and low costs for conventional energy and distribution, greatly reduce the value of solar PV with storage from a cost perspective. For a California resident who invests in solar PV with battery storage today, breakeven would only occur after 2022. (Mitigating factors, such as pricing and tariff schemes designed to moderate power consumption, could strengthen the appeal of solar PV with storage for Californians under certain circumstances.)

EXHIBIT 2 | In Germany, Storage Coupled with Solar PV Will Become an Increasingly Attractive Investment for Households

Due to the recently approved subsidy, homeowners could see breakeven as early as 2014



Source: BCG analysis.

Note: kWh = kilowatt hours; LCOE = levelized cost of energy.

¹Smaller increases in electricity prices from 2020 on will reduce the curve's slope.

²Assumes a PV system of 4 kilowatt peak (kWp), total demand of 4,000 kWh per year with a single-house load profile, and PV generation of 1,037 kWh/kWp (based on the U.S. National Renewable Energy Laboratory's PVWatts calculator) with an own-consumption share (OCS, the percentage of total power consumption met by self-generation) of approximately 33 percent.

³Assumes an OCS of approximately 56 percent for the 4-kWh battery (versus 33 percent for no storage).

⁴Assumes an OCS of approximately 63 percent for the 8-kWh battery.

Although residential applications of solar PV with battery storage have the strongest growth prospects in the near term, it is worth noting that such systems are also being deployed increasingly within distribution grids, both for stabilization and as a substitute for low-level grid investments. For equipment makers, the goal is to enhance the benefits of their investment by tapping into revenue streams beyond customer self-supply. While these options bring increased technical and regulatory complexity, the current dynamic developments in energy storage suggest that both established companies and startups are getting ready to develop business models that make such complex applications viable. Off-grid applications of solar PV with battery storage are also emerging. (See the sidebar, "Solar PV Plus Battery Storage: Off-Grid Applications.")

Opportunities and Risks for Stakeholders

The emergence of solar PV with battery storage will present a wide range of potentially lucrative opportunities for commercial stakeholders—including power-generation providers, equipment suppliers, end-product companies; and financial players—including companies that provide financing and leasing services. For battery providers, the choice of technology will be key, and lithium-ion batteries will certainly take a large share of the market. Other battery technologies, including sodium-nickel-chloride batteries (such as those currently offered by GE and Italy's Fiamm), could be viable alternatives if the solution offered to the customer is compelling.

It will be essential for market entrants to differentiate themselves through their business model, and a plethora of new approaches

SOLAR PV PLUS BATTERY STORAGE: OFF-GRID APPLICATIONS

Off-grid use of solar PV with battery storage is still nascent but highly promising. Small off-grid applications (100 kW and below) offer particular promise for the standalone electrification of households and small buildings, such as health centers and schools, in developing rural areas. Large applications (greater than 100 kW) could eventually replace diesel generators in supplying electricity to entire large and midsize communities.

Rural households in South Africa are already benefiting from substituting off-grid solar PV with battery storage for diesel generators. The economics—high

diesel-fuel costs (40.4 €/ct/kWh in 2013) in combination with high solar radiation—make the substitution very compelling. Residential off-grid PV storage should soon be an economically feasible alternative to diesel generators in Australia as well, driven by the country's high solar radiation and large land mass, which mitigate the impact of its inexpensive diesel fuel (25.8 €/ct/kWh in 2013).

will emerge based on the provision, installation, financing, servicing, and optimization of equipment. “Smart home” appliance vendors, battery vendors, IT software and service providers, grid service and connectivity providers, efficiency contractors, and energy traders, among others, all stand to see their businesses surge.

The greatest success in this nascent market will ultimately come to the players, partnerships, and joint ventures that combine the following:

- A proven battery product that is easy to install and use (although it is unlikely that batteries will serve as the main source of differentiation in the next few years)
- A clear, well-marketed value proposition, one that has compelling economics and appeals to end users emotionally (for example, by stressing the product's potential benefits to the environment)
- Most important, a clever go-to-market approach, one that leverages partnership and acquisition opportunities (for example, with system integrators and installers) to fill gaps in key capabilities

This new frontier will bring risks as well as opportunities, especially to those that benefit from the status quo. But today's status quo will become increasingly unstable as it is undermined by the rise of “prosumers,” who both consume and produce power. Revenue from grid usage fees, for example, which pay for grid maintenance and upgrades, stands to fall significantly as consumers increasingly substitute self-generated electricity for conventionally purchased power. What (or who) will make up for the shortfall? Aside from negotiating the political implications of this new landscape, incumbents—especially utilities—must shift their business focus as their traditional competencies and business models become obsolete and their market share shrinks.

SOLAR PV WITH battery storage is on the verge of breaking through. The rules of the game will be defined in the next few years; partnerships among technology providers, installers, and operators are being explored and established now. Is your business ready?

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