ENERGY STORAGE SPECIAL REPORT 2019

This special report is taken from PV Tech Power 20, the downstream solar industry journal from our publisher Solar Media.

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Introduction

The stationary energy storage industry, with batteries as the prime mover, has enjoyed a series of record years of deployment across North America, Europe and Asia in particular, but what comes next after that first wave? What are the challenges still posed for the 'mainstream' adoption of cost-effective energy storage technologies in a modern, low-carbon grid?

Energy Storage Special Report 2019, from the editorial teams behind Energy-Storage.news and PV Tech, brings you no less than seven feature articles and technical papers looking at everything from the policy and regulatory initiatives that still need to happen, to bankability and profitability of ESS, system technologies and architecture, all the way to recycling and end-of-life care for batteries.

We've collected together these articles from Volume 20 of PV Tech Power, the downstream solar industry journal from our publisher Solar Media, which celebrates its fifth birthday this quarter.

Additionally, we've also thrown in Energy-Storage.news' contributed section of the journal, Storage & Smart Power, to this edition of the report: with three further feature articles on the UK's recent blackouts and how batteries can help maintain system stability, the role of flexibility in smarter energy networks and finally a fascinating technical paper on the role batteries can play in delivering a 'synchronous grid takeover'.

Thanks to all our contributors and advertisers and of course, most of all, to our loyal readers.

Andy Colthorpe
Solar Media

Open season: the next steps for energy storage

Storage | Despite the huge strides energy storage has made, significant hurdles remain before the technology in its many guises can be claimed to have fulfilled its massive potential. Introducing a PV Tech Power energy storage special report, Andy Colthorpe assesses the key successes and ongoing challenges for this indispensable part of the future power system

Credit: Anesco

Large-scale battery sites have been built in regions including the UK (pictured). But are they doing enough and should there be commercial impetus to build more?

The world has watched on as some of its leading regional markets, China, South Korea, Australia, Japan, parts of the US, the UK, and many parts of Europe have raced ahead in deploying energy storage in the last five years, mostly, but not only, lithium-ion batteries. IHS Markit says that the US in 2019 will deploy around 712MW, becoming the world's largest market for grid-connected batteries this year, while another research firm, Wood Mackenzie Power & Renewables, has predicted that 4.3GW could be installed worldwide during 2019.

Record-breaking figures have been reported in the US and other territories such as the UK, year-on-year. Yet from other territories reports come in of interminable delays, of hotly contested jurisdictional rights, the difficulty in overhauling not only the technical design of the grid but the ways in which we think about energy markets too. Everyone seems certain energy storage is a key part of the decarbonised energy system, but no one seems certain when we will be able to breathe a sigh of relief that that place is assured. And of course, there's the question of whether success in these leading markets can be replicated all over the world.

In those leading regions, the rapid rise is happening both in front of and behind the meter, with economic cases that are finally starting to make sense and often – but not always – with specific policy support. And while solar industry investor and commentator Jigar Shah predicted confidently that utilities would try to take ownership of energy storage as much as they could themselves at the beginning of 2018, it seems as though 2019 was the year that this really took shape.

A quick case study of a utility in one of those 'leading regions' is municipal power provider LADWP in California, which over the next few years will deploy enough batteries to cover more storage output and capacity than its existing 1.5GW pumped hydro plant (see box, p.23). We also asked Janice Lin and Jack Chang at consultancy Strategen, itself based in California, to write about the 'challenges in the sun' California faces and some of the initiatives, both private and public, that are seeking to overcome them (see p.32).

Meanwhile in Australia, major utility AGL is now offering rebates of up to AU$7,000 off the cost of residential ESS purchases, as well as a virtual power plant programme which benefits homeowners in some states to the tune of AU$280 credit for a year for enrolling.

They and others are pushing ahead in areas where there may be high electricity prices and high grid congestion, falling feed-in tariffs and favourable tax regimes. Whatever the reason, circumstances have come together to reduce the risk and improve the return of procuring, owning and operating energy storage in some territories.

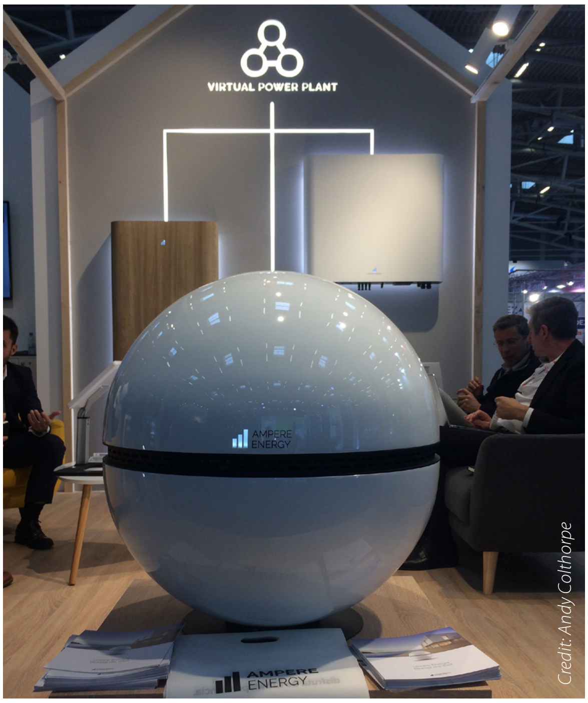
Fear of missing out

Other utilities in other territories face totally different circumstances, such as Xcel Energy, which operates as a near-monopoly in Colorado, USA. Holding an all-resource, all-technology bid for new capacity a couple of years ago, in addition to picking out wind power projects, the utility also selected three solar-plus-storage projects, Alex Eller, analyst with Navigant Research says.

The utility hasn't done much in the way of standalone storage, because Xcel hasn't yet found "other use cases where storage was economical for distribution upgrade deferral and things like that", Eller says, and so in Colorado, where land is fairly cheap and so is electricity, it's the competitive economics of solar – now dispatchable with the addition of storage – that appeals, rather than storage in its own right. Being a vertically integrated utility, Xcel could later use the batteries at its solar-storage plants, each of which will have in the region of 50MW of batteries, for frequency regulation and other balancing services, but the main impetus is the deployment of renewables to replace fossil fuels.

It is an interesting snapshot of the wider picture across much of the US, Eller says. Many utilities now procure storage alongside solar as a low-cost generation source. Backed with PPAs, they offer the most certainty of use cases for energy storage on the US grid so far. Elsewhere, some standalone storage is deployed increasingly by municipal utilities, which have a certain degree of autonomy – in other US regions such as New England, where the regional Independent System Operator (New England ISO) has also opened up some of its markets to energy storage.

So, even with this seemingly positive picture, where in some areas electric system stakeholders of various kinds and local and even national governments are getting behind energy storage in a big way and in other regions solar-plus-storage makes sense, will it be enough? And if, as we suspect, it might not be, what are the challenges and barriers in the road ahead?



Despite futuristic concepts and design, battery energy storage is about functionality for both grid and end customers.

More to cost reduction than batteries themselves

A lot of emphasis has been placed on the cost of the batteries, which as we all know continue to enjoy a decline. Navigant's Eller has previously predicted a fall to around US$76 per kWh by 2030, rival analyst Logan Goldie-Scott at BloombergNEF conversely says that an "average" lithium-ion battery pack could cost as low as US$62 per kWh by that year.

Beyond the cost of the battery as well, power electronics components could still enjoy improvements in design and lowering of costs, Eller says, with much of that to centre around the standardisation of battery inverters, which the analyst says were "pretty customised" in the past.

One area Eller highlights is the growing interest in DC-coupled storage, explored in more detail in Sara Verbruggen's piece on storage system architecture later in this special report (see p.29). "[That] reduces the cost…because the DC converters are much cheaper than full grid-tied inverters are. So I think that certainly helps bring prices down," Eller says.

On the system side, there's also the reduction in cost of software, but much of this has already been squeezed out, Eller says. Still, software is key in another vital way – the role it plays in complete system integration.

This year, product launches on the global market have included a 2.5MWh containerised solution from Saft and later a 3MWh 'Megapack' from Tesla. Offering more fully integrated, modular, all-in-one units that include the battery management system (BMS) and safety and protection features delivered in a single container from a single vendor can lower costs significantly, Eller says, noting that NEC's Energy Solutions division and Fluence are also now marketing "specific, defined products" to the market. Standardisation within individual vendor's offerings is certainly encouraging, the Navigant analyst says.

In the long term, Eller says storage companies should aim to offer more "plug-and-play" products to utilities, that will be "faster and easier to deploy" than more specialised equipment.

The edge of profitability

Stationary energy storage systems are on the "edge of profitability in many market segments today", we hear in this special edition of the journal from Dr. Kai-Philipp Kairies, Jan Figgener and David Haberschusz of RWTH Aachen University (see p.24).

Yet markets that reward the benefits of energy storage are drastically underdeveloped. Many in the US are looking to the bipartisan ruling FERC Order 841 from the Federal Energy Regulatory Commission, which instructs regional grid operators to open up wholesale markets to the participation of energy storage and is intended to be a game changer for the industry.

Many of the regional ISOs of the US have already responded by drafting their initial plans to comply with the Order. However, says Jennifer L. Key, a FERC lawyer with law firm Steptoe & Johnson LLP, there have been "somewhat surprising legal challenges…from both the state and public power and even parts of the utility industry dealing with jurisdictional fights over storage, between FERC and the states".

A "uniquely American problem", Key says, of dual state and federal regulation, is holding up FERC Order 841 before the details are even put on the table for discussion. A lot of the disagreement essentially stems from "whether FERC or the state should have control over all things wholesale going on on the distribution system because a lot of storage is being connected to the distribution system – as opposed to the transmission system", Key says. "A large swathe" of distribution system companies and state commissions have "filed for an appeal of Order 841 on jurisdictional grounds".

"What's interesting is that you have some states that are fully supportive of storage, that don't mind at all that FERC is taking a lead and you have utilities and distribution system owners who don't care who has jurisdiction; the storage that's coming in, they're dealing with it, they're doing the right thing to get the storage interconnected.

"[Then] you have this whole entire pushback and it's unclear if that's because the states want to control the entry and use of storage," Key says. Whether that is because individual state commissioners believe they could do it better than FERC perhaps, or believe that distributed storage could interfere with operations of their electric system somehow is also unclear, Key adds.

Credit: Wasatch Group/ Sonnen/Rocky Mountain Power

Soleil Lofts, a 600 apartment development in Utah where Sonnen will deploy 12.6MWh of batteries in new homes

Regulation, regulation, regulations

Jennifer Key and others argue that when FERC Order 841 does come to pass, it really will be a game changer partly because "it is compelling the organised markets in the US to develop and make sure that their systems whether it's their software, or their market systems, have a place for energy storage which compensates".

"One of the issues [Order 481] is raising is: can storage obtain enough compensation in the market, especially in markets where it's hard for storage unless paired with something else (such as solar PV) to provide a capacity product?

"But it's opening up, setting the rules of the organised market so that they can make accommodations as needed for storage and also the clarity of permitting storage devices to charge at wholesale [prices]."

On the subject of clarity, while the FERC Order 841 saga and in particular the recent pushback continue, in Europe, in both the UK and mainland Europe, a more basic regulatory issue continues to play out. As we hear from the continental European Association for the Storage of Energy (EASE) in this special report, so-called 'double-charging' remains a huge, huge stumbling block for grid-connected energy storage (see p.38).

In the UK, too, a regulatory definition for energy storage has only just been proposed by the regulator, Ofgem. At present, energy storage is quite often still categorised as generation, Kirsti Massie, a UK-based lawyer with White & Case, says. Not having a dedicated definition or even a licence for energy storage, has "implications across a number of pieces."

"If you have a generation licence it means in the UK certainly, as a transmission system operator or distribution network operator, you're not also going to be able to own and operate storage facilities because they can't become part of the grid because the way their licensing is structured," Massie says.

"As a generator you're often looking to smooth out intermittency to renewables. That's fine but storage can do a lot more than that and it can provide grid services – it's not just an add-on to generation. Grid services are hugely important and become increasingly important as more renewables come on the wires," Massie says, while, as with mainland Europe, double-charging still exists.

"Also as a generator you will pay system charges when you're charging up your battery but you'll also pay when you're actually discharging the power from the battery. You're getting hit both times."

Grid service markets are not often enough structured in such a way to take advantage of the fast-responding, low carbon generation-enabling qualities of energy storage. As a lawyer, Massie says she looks closely at developments in the UK, Europe, the Middle East and Africa, but also works closely with colleagues in the US and Australia.

"What I've found very interesting is that the issues that we are talking about and that the industry and the regulator is trying to get their heads around in the UK are the same issues that you see in various markets in the US and in Australia. We've got a commonality of issues, in terms of questions people are trying to answer."

The customer will always come first

Deployed energy storage capacity around the world largely remains pumped hydro while lithium-ion is the current flavour of choice. Coming in all shapes and stackable up to hundreds of megawatts, the advantages of lithium-ion battery systems include how quickly they can be deployed and their rapidly falling cost. One of the challenges from a big picture perspective is going to be figuring out how much energy storage capacity is needed in front of the meter, providing services to the grid and capacity to utilities, and how much of it goes behind the meter, at customer sites.

These behind-the-meter sites are increasingly being aggregated to create energy trading opportunities and virtual power plants (VPPs). In much of the US, however, residential net metering for solar obviates much of the financial case for batteries in the home while in other territories, feed-in tariffs still reward customers well for energy delivered to the grid.

"It (net metering) effectively pays the homeowner the fully delivered cost of power. So I don't think you're going to get this notion of all these distributed residential resources getting together to sell power because they'd have to give up the benefits of net metering," Jennifer Key says, with some 40 US states still running net metering programmes.

So again, there will be some specific parts of the US adopting VPP programmes earlier than others: Energy-Storage.news reported on a 12.6MWh VPP in Utah from Sonnen and utility Rocky Mountain Power across 600 apartments as this edition went to press, for example. In other global markets however such as Japan, Australia, the UK and Europe including Germany, the cutting of feed-in tariff support is inspiring homeowners with solar to 'go battery storage' too.

A recent blackout in the UK which affected one million electricity customers was responded to by frequency response assets including 6MW of aggregated residential storage, acting as a VPP, from independent utility Social Energy. To be able to do this on a grand scale and as the norm, using both large and small ESS assets, will not only require more simplified and readily accessible revenue streams for grid services, it will also require coordination of effort and engagement with the end customer.

"Decentralisation, decarbonisation is the right thing to do, but we can't forget the consumer in all of this because the consumer is fundamental," says Faisal Hussein of UK industry body Flexi ORB (Flexible Energy Oversight Registration Body).

"In our focus on decentralisation and decarbonisation, we've got to be careful that we don't leave the consumer behind."

If the industry is ok, is that enough?

Despite some significant challenges, the adoption of energy storage as both an essential companion for renewables and as a flexibility resource for the grid in its own right appears healthy enough to suggest that in key markets adoption will only increase. Elsewhere, off grid, the economics are even better, and recent interest in microgrid companies active in emerging markets from major energy companies means that energy storage for energy access is also a reality.

At Solar Media and in particular through Energy-Storage.news, we'll be looking at some of these challenges in the coming months, as well as others we have barely mentioned, including the supply chain and end of life management (although you can read about the efforts of one company, Li-Cycle in Canada, to create an effective system for battery recycling on p.45). There's also the integration of data and fire safety, the choice of technologies, whether batteries, lithium batteries, or otherwise.

We're certainly encouraged to see so much proactive discussion of how many of these problems can be solved, and for many of our readers coming from a renewable energy background, a difficult challenge is nothing new. In regulation and many other areas however, "we've got away with a sticking plaster approach so far", Kirsti Massie of White & Case says, but the existing frameworks in the UK and many other regions still need to catch up to the progress – and promise – of energy storage technology.

"Trying to shove it in an existing framework, I think, limits the value [of energy storage]," Massie says. "You're not going to be able to take full advantage of the flexibility that storage can offer, if you're constraining it within a regulatory framework that dates way back before some of these technologies were even thought of."

As Massie says, there's been a huge amount of progress and it's certainly not a negative picture out there today for the energy storage industry. If we are to meet policy goals in reducing carbon emissions and transitioning to renewable energy, however, "energy storage inevitably is going to have to play a bigger role", Massie says.

"In order to play a bigger role, you need people who are willing to invest and to invest and develop at scale. One of the key things that then will arise, is, how are you going to finance this? If you're not able to really leverage off all of the benefits that storage can bring, the full flexibility of the storage offering, you're kind of limiting your revenue stream and that makes it more tricky and difficult to attract financing and I think will get in the way of the real, scale deployment of storage that is going to be key." ■

LA's big ambitions

By Janice Lin & Jack Chang, Strategen Consulting

Even in progressive California, Los Angeles stands out with its bold plans to decarbonise its power sector. The city's municipal utility, Los Angeles Department of Water and Power (LADWP), is the United States' largest publicly owned utility. LADWP is fully embracing energy storage as a critical tool for achieving the city's clean and affordable energy goals.

LADWP is already very familiar with the benefits of energy storage. It operates a 20MW lithium-ion battery storage system at its Beacon Solar Plant as well as a 1,500MW pumped hydro facility at Lake Castaic. In February 2019, LADWP announced it will not be replacing three gas-fired power plants scheduled to close by 2029. Instead, the utility will employ clean-energy alternatives such as solar and energy storage to make up for their 1,660MW of generation capacity. In July, LADWP proposed building the largest capacity utility-scale solar battery project in the country to date. The plan, submitted by developer 8minute Solar Energy, would build as much as 400MW of solar capacity and 300MW of energy storage at the historically low price of US$19.97 per MWh. As of early August, approval is pending at the LADWP board.

These moves are aligned with the city's Green New Deal, which lays out ambitious sustainability targets and devotes billions of dollars for new infrastructure. The plan calls for increasing cumulative energy storage to as much 4,000MW by 2050 – far larger than the current target for the entire state of California (1,500MW). Driving all that energy storage demand is the city's goal to supply 55% of its electricity needs with renewable energy within six years and 100% by 2045. Much work remains but given the leadership of the city and state, Los Angeles is well poised to succeed in achieving its clean energy goals with storage.

Year	Cumulative energy storage (MW)
2021	1,524
2025	1,750
2035	3,000
2050	4,000

LA's energy storage goals to 2050

Market and technology development of stationary battery storage systems

Economics | The business models and technologies underpinning the development of stationary energy storage markets are evolving rapidly. Dr. Kai-Philipp Kairies, Jan Figgener and David Haberschusz look at some of the key trends driving the sector forward

Credit: SPP

Battery systems sitting alongside solar projects, such as the UK's Clayhill, will become more common as storage plays an increasingly important role in grid balancing

The international market for stationary battery storage systems (BSS) is growing rapidly. Within less than a decade, grid-connected BSS have evolved from a niche product to a mass market in which today international energy and automotive companies are competing for market shares. According to a recent study by BloombergNEF, almost 4GW of new battery storage systems went online in 2018 worldwide – and the market researchers expect this number to double by 2020 [1]. Accordingly, the International Renewable Energy Agency (IRENA) predicts that a total storage capacity of up to 420GWh will be installed by 2030 (see Figure 1).

Grid-connected storage systems today are used for a multitude of purposes, ranging from small-scale applications, such as residential home storage systems, to multi-megawatt batteries that provide balancing services and mitigate grid congestion problems on all voltage levels.

In this article, we will cover the three main market segments of stationary storage systems in Europe – private households, commercial buildings and storage for balancing services – and shed some light on the business models and profitability of these systems.

Home storage systems

Over the last five years, more and more households have adopted battery storage in combination with photovoltaic systems. These so-called home storage systems (HSS) store excess solar energy during the day and make it available for self-consumption in the evening and at night. They provide a twofold benefit for the battery operator and the distribution grid: on the one hand, the operator of a HSS decreases the amount of electricity bought from the grid, thereby reducing his electricity bill. On the other hand, HSS can stabilise power grids with high amounts of renewable energy generation. By storing PV power during peak generation periods, local problems with voltage stability or thermal overloading of electric equipment can be mitigated. Several studies have shown that the use of HSS can reliably limit the maximum feed-in of PV installations to just 40% of their rated power without curtailing undue amounts of renewable energy [3]. This means that HSS can increase the maximum PV penetration of a given distribution grid by a factor of up to 2.5 without having to upgrade the electrical equipment. In some cases, HSS can also benefit from time-of-use schemes by offsetting higher tariffs at night and thus generate additional revenues.

The market for HSS has seen a massive growth in areas such as California, Australia, Italy and Germany. Japan could also emerge as a new, important market for HSS as rooftop PV installations become increasingly popular while electricity rates are comparably high. The German market for HSS is unique, and a research team of Aachen University, one of Europe's largest technical universities, has closely monitored its development from the very beginning. In the scope of a scientific monitoring programme, datasets of more than 23,000 individual HSS were collected that allow a deep insight into the mechanics of this emerging market. Some of the key findings of this ongoing evaluation are presented below.

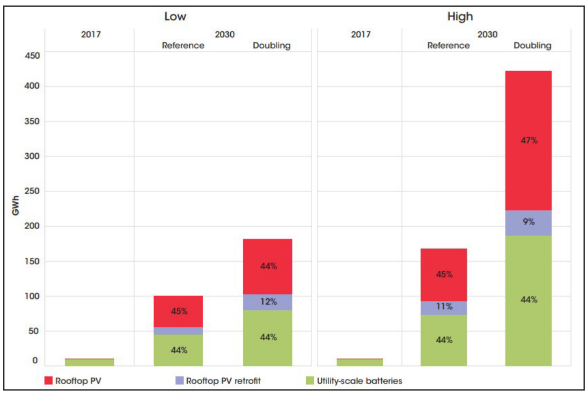


Figure 1. Development of stationary battery storage systems according to IRENA [2]

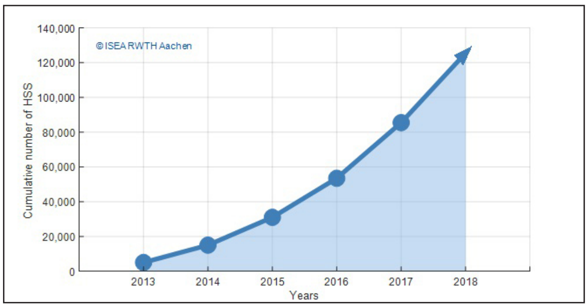


Figure 2. Development of HSS installations in Germany

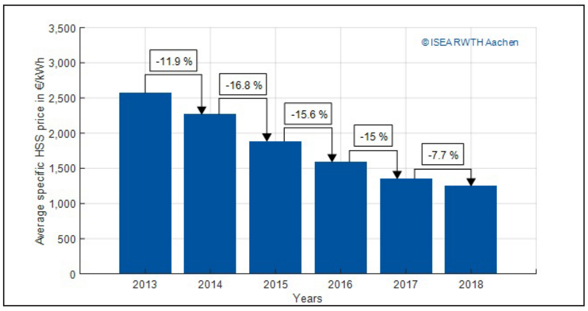


Figure 3. Development of retail prices (incl. VAT) for home storage systems in Germany

Since 2017, every second new residential PV installation in Germany has been accompanied with a battery pack. In some federal states, it is more than two out of three. In total, about 150,000 HSS with an estimated capacity of about 1GWh and a nominal power of 400MW are installed in Germany today (see Figure 2). These impressive growth rates also make HSS increasingly relevant to German utility companies and grid operators. Accordingly, a vast number of research projects focusing on the grid effects and the potential use of decentralised batteries in virtual power plants was initiated over the last years, making it one of the hottest topics in energy research.

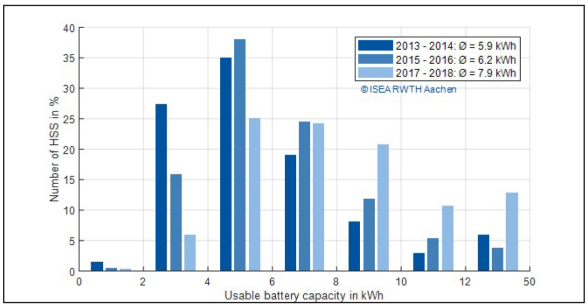


Figure 4. Development of the average usable battery capacities of German HSS

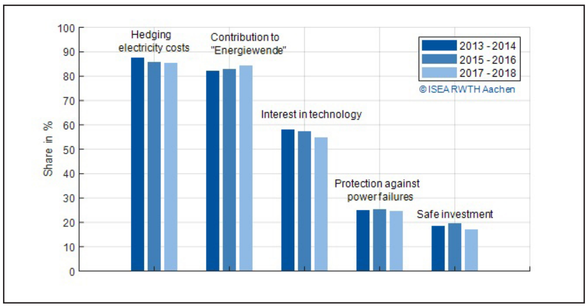


Figure 5. Purchase motivation of home storage systems in Germany.

Much has changed since the commercial success of HSS began in 2013. One major technical development was the battery of choice. While in the early days of the market, more than six out of 10 HSS were using traditional lead-acid batteries as their storage technology, lithium-ion batteries quickly gained market share. Since 2017, they account for more than 99% of all newly installed HSS. The reasons for this remarkable success of lithium-ion over lead-acid batteries are diverse: technically, lithium-ion batteries offer a maintenance-free operation, promise longer lifetimes and feature better roundtrip efficiencies. However, from a customer's point of view, two main advantages seem to outweigh all other aspects. Firstly, due to their very high energy densities, lithium-ion HSS are much more compact and can be mounted to walls, which allows a more efficient use of space and is sometimes perceived to be visually more appealing. The second reason is pricing. Between 2013 and 2018, the average retail price for HSS with lithium-ion batteries fell by more than 50%, whereas prices for lead-acid batteries decreased only slightly [4]. The plummeting costs of lithium-ion batteries not only bolstered their market share, but also helped to push the whole HSS market segment into the mainstream.

Interestingly, while system prices per kWh have been cut in half since the start of the scientific evaluation, the average system expenses of HSS remained virtually unchanged at roughly €10,000 (incl. VAT) over the entire period. The reason for this can be found in a constant increase in battery capacity since 2014. Simply put, customers seem to have invested every euro saved due to cheaper batteries into larger storage capacities. The increase in capacities of lithium-ion batteries from around 6kWh in 2015 to over 8kWh in 2018 are depicted in Figure 4.

A recurring question is the reason for the ongoing HSS boom and one natural answer seems to be their economic benefit. By increasing self-sufficiency and thereby reducing the monthly electricity bills, the investment into a solar battery should pay off within a few years. However, while HSS are often promoted to be a financially attractive investment, the reality is more complex. With average investment costs exceeding €1,000/kWh and typical annual usages of fewer than 250 cycles, payback times for HSS today are in the range of 20 years for most households – a timespan that exceeds the expected lifetime of typical lithium-ion batteries by about one third. Even taking public financial incentives into account, most solar batteries today fall short of a break-even.

Whey, then, are consumers still so excited about it? To get a better understanding of the market mechanisms behind the HSS boom, participants in the scientific monitoring programme were asked a couple of yes-no questions regarding their purchase motivation (see Figure 5). More than 80% of the respondents in Germany stated that the main reasons for investing into a home storage system are to hedge against future increases in electricity prices and the desire to proactively participate in the transitions towards renewable energies ("Energiewende"). In addition, a "general interest" in the technology was a major purchase argument for more than 55% of the home storage operators. By contrast, only 20-25% stated that the wish to make a safe financial investment or securing against power outages was decisive for their purchase. The data suggests that the largest proportion of HSS operators today fall into the category of "innovators" or "early adopters". These population groups tend to be well educated, wealthy and interested in new technologies, paying less attention to the profitability of an investment and showing a high interest in the details of the technology. An additional factor for the rapid growth of the HSS market can be attributed to the sluggish PV market over the past years. A solar technician can double his sales by selling a battery in conjunction with solar panels, so many installers have pushed batteries to make up for the drop in solar PV orders. For many, storage has become essential for survival in this extremely regulation-driven market.

Battery storage for commercial buildings

While HSS can be seen as a typical "emotional" B2C product, where profitability often is not a priority, business leaders need to make economically sensible decisions when investing into BSS. However, the diversity of possible applications and the complexity of the individual business models make it difficult to make general statements about the profitability of BSS in commercial and industrial environments. To allow a first understanding of the potentials and challenges of this

Figure 6. PV installation on a commercial building

market segment, two examples are briefly outlined in the following.

Increasing solar self-consumption The combination of PV and battery storage is also an option for commercial buildings with suitable roof surface areas. Depending on the system sizing and the individual load profile, up to 50% of the electricity consumption can be provided through decentralised clean generation. However, complete self-sufficiency from the grid is usually not feasible due to the low irradiation values in the autumn and winter months. In addition, the payback periods of these systems usually greatly exceed the expected service life of the battery storage systems. Nevertheless, many large international corporations are working intensively on this use-case as part of their efforts to increase the use of sustainable energies and reach their self-set CO2 reduction goals. Furthermore, large solar batteries can also be used as a means to mitigate blackouts or reduction in supply quality (so-called "brownouts"). Especially for manufacturing companies even a temporary drop in grid voltage can lead to considerable follow-up costs. In paper mills, for example, a brownout can lead to multi-day production stoppages, as the machines need to be cleaned after an unscheduled interruption. Compared to the potential financial damage of such an event, the investment in a battery storage system is often the more cost-effective option.

Reduction of peak loads Due to their extremely fast response times and good scalability, BSS are ideal for reducing peak electricity demand. This use case can be particularly interesting if the company's electricity price has a significant power component or if new loads are added that cannot be covered by the existing grid connection. As an example, Figure 7 shows the load profile of a small data centre located in the German state of North Rhine-Westphalia. The data centre is connected to the medium-voltage grid and has an annual peak load of 122kW and an annual electricity consumption of 581MWh. According to the grid operator's cost tables, annual savings of more than €1,000 can be achieved by reducing the company's peak load by 12kW (blue line in Figure 7). Using a holistic simulation of different energy storage systems it can be shown that a lithium-ion battery of only 8-12kWh would be sufficient to realise these savings, allowing an amortisation period of about six years. Because the battery is only used a few hours of the year, additional revenue streams, such as providing balancing power to the grid, can be tapped (so-called multi-use or value-stacking). By operating flexibly in different business models, BSS can optimise their revenue streams and further reduce their amortisation time.

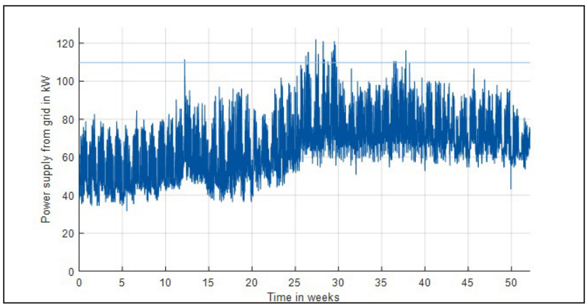


Figure 7. Load profile of a data centre in Germany. Annual savings of more than €1,000 can be realised if the peak demand is reduced by 12kW (blue line)

Battery storage for balancing services

For a stable operation of our power grids, the generation and consumption of electricity must be in balance at all times. Yet, this balance is regularly upset: failures of power plants and transmission lines or forecasting errors of renewable power generation can lead to a sudden over- or undersupply of electricity. In such cases, balancing services such as frequency control or reactive power management come into play to keep the grid frequency and voltage within a given range until the regular operation is restored. Traditionally, large generators such as coal-fired power plants performed these services. However, decreasing numbers of fossil-fueled power plants in our grids spark the demand for new suppliers. BSS are promising assets for providing balancing services due to their extremely fast response, good scalability and quick deployment time. Although often considered a new and upcoming application, utility-scale BSS for grid services are nothing new. In 1986, a 17MW lead-acid battery plant was installed in Steglitz, Germany, to supply frequency control to the then isolated (and notoriously unstable) electricity grid of West Berlin. What is new are the scales and timelines of such BSS projects. In 2017, Tesla built a 100MW/130 MWh containerised lithium-ion storage system in Australia within just three months. Compared to the long planning horizons of transmission grids, this is almost unimaginably fast.

The most important markets for utility-scale BSS in Europe today are Germany and the UK. In Germany, more than 450MW of large-scale BSS went online over the last five years. Most of these projects are in the range of 5-15MW with storage durations of about 1.5 hours and operate in the market for primary control power ("Primärregelleistung"). Primary control power is the fastest balancing service in the UCTE grid and similar to the (dynamic) firm frequency response in the UK. Together with a handful of other countries, Germany is responsible for supplying about 750MW of primary control power to the grid. The service is auctioned in daily tenders of 1MW increments at the energy exchange (EEX) in Leipzig. In order to participate, market players need to be able to ramp up to their nominal power in less than 30s and sustain a constant power output for

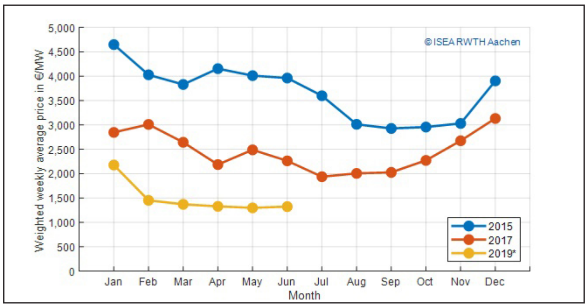


Figure 8. Development of prices for providing primary control power in Germany [5]

15 minutes, requirements easily met by modern lithium-ion batteries.

Still, BSS might have been just too successful too quickly. The entry of large numbers of BSS into the market for primary control power since 2013 turned the energy sector upside down and eventually diminished their own business case. The rapid increase in new market participants flooded the market with cheap biddings. Between 2013 and 2017, the number of weekly bids for supplying primary control power increased by 1,400%. At the same time, prices were cut in half, making the business case successively less attractive. In the first half of 2019, weekly volume-weighted prices fell to an all-time low of €1,300/MW per week. As other potential revenue sources for utility-scale BSS with short discharge times, such as providing black start capability or reactive power to the grid, are not established in the market yet, many new projects for this market segment of BSS have been shelved. One major obstacle to the development of new business cases for utility-scale BSS is regulation. Today, battery storage systems are considered electricity consumers when in charging mode, and generators when discharging, forcing them to pay some levies twice. While the government has promised to rectify this issue soon, many legal and operational questions remain open.

As an island grid, the UK's energy system has a higher demand for balancing services than other countries. While Germany is well connected to its neighbours, with roughly 40GW of cross-border trade capacity at 80GW peak demand, the energy exchange between the UK and its neighbours is limited. With higher shares of renewable power generation, new flexibility options are needed to compensate the lack of transport capacities. The system operator of the UK, National Grid, calculated that, in order to reach the UK's carbon reduction targets, more than 6GW of electricity storage are required until 2026 to support the grid integration of renewable energies [6]. But even today system stability can already become an issue: due to a sudden shutdown of a gas-fired power plant and a large wind park in Wales, lights went out for almost 1 million households in early August (see p.114). Increasing amounts of utility-scale BSS can prevent, or at least mitigate, the effects of such events by bridging the power gap until new generation units go online. Accordingly, the UK already introduced a new ultra-fast balancing service in 2016. The so-called Enhanced Frequency Response (EFR) requires service providers to ramp up to their nominal power in less than one second, the most demanding conditions for a balancing service, worldwide. The national grid operator accepted eight tenders totaling 201MW of capacity at a committed cost of £66 million over four years with batteries winning contracts hands down. National Grid expects to return an economic benefit of £244 million in avoided costs over the duration of the contracts [7].

In addition to providing balancing services, plummeting costs of lithium-ion batteries open up new use cases for stationary storage system. One particularly interesting market segment lies in BSS with a duration of about four hours. Combinations of such storage systems with renewable energies, especially PV, are increasingly used to replace gas-fired power plants to meet the peak demand. Another potential use case for multi-megawatt battery storage systems might be evaluated in Germany soon. In just a few years, massive BSSs with nominal powers of up to 500MW could be installed in Germany to support the transmission grids and enable the faster expansion of renewable energies while at the same time phasing out coal and nuclear power generation. Three of the four German transmission grid operators have submitted applications to the German grid regulator to test so-called grid boosters, battery storage systems with a total capacity of 1.3GW. These battery systems – shortly speaking – add an extra layer of security to the transmission grids and allow a higher utilisation of existing power lines. Thereby, transmission capacities can be increased by more than 30% in some cases. In the event of a failing substation, for instance, BSS can take over until the grid operator completes a redispatch. At the same time, however, the use of grid boosters presents grid operators with new challenges, as it requires a more complex network automation. In the event of a component failure, numerous switching operations must be coordinated in the shortest possible time.

Summary

Stationary BSSs are at the edge of profitability in many market segments today and will play a crucial role in enabling the next phase of the international transition towards renewable energies. The practical insights into the operation of grid-connected battery systems gained today will also help us to manage growing quantities of electric vehicles in our grids. We can be curious to see which innovative applications BSS will open up in the coming years. ■

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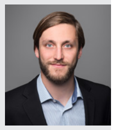

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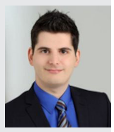

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Go big, go DC

Storage system architecture | New technologies and designs aimed at driving down the cost of energy storage facilities are currently the focus of intense industry R&D. Sara Verbruggen reports on DC coupling, an emerging system architecture that many believe will soon become the industry standard

As the costs of solar PV modules continue to reduce, and those of batteries follow a similar downward trajectory, solar-plus-storage is in growing demand among utilities and solar developers.

The US is leading the trend, where these types of clean energy power stations are starting to produce electricity competitively with gas peaking plants, especially when other revenue streams from grid services are factored in.

To further push down the levelised cost of energy (LCoE) of solar-plus-storage and maximise the amount of megawatt hours (MWh) of solar-generated electricity that can be fed into the grid, energy suppliers and developers are turning to direct current (DC) coupling these installations.

Compared with alternating current (AC) coupling, DC coupling the PV array and the battery storage system in front-of-meter installations, such as utility-scale plants, is a much newer, less standardised approach. This had led some US utilities to begin piloting these configurations to see how the technology performs. On the supply chain side, balance of plant (BoP) equipment manufacturers are delivering more standardised and simpler to use power electronics equipment for enabling DC-coupled plants.

DC- versus AC-coupled solar-plus-storage

In AC-coupled solar-plus-storage installations there are two inverters, one for the PV array and another for the battery energy storage system.

With this system configuration, both the battery and solar array can be discharged at maximum power and they can be dispatched independently or together, providing the operator with more flexibility in terms of how they operate and dispatch the asset. Located at the same site the solar array and energy storage facility can either share a single point of interconnection to the grid or have two separate interconnections.

Credit: Dynapower

A DC-coupled battery at Duke Energy's Mount Holly test site. Expectations are high that DC coupling will help drive down solar-plus-storage costs

In DC coupling, the co-located solar and energy storage assets share the same interconnection, are connected on the same DC bus and use the same inverter. They are dispatched together as a single facility. DC coupling reduces efficiency losses, which occur when electricity current is converted, such as from DC to AC (Figure 1).

According to Wood Mackenzie analyst Mitalee Gupta: "Hybrid approaches emerged in the past where you would see both PV and batteries connected to the grid via one multiport inverter, a configuration more common in behind-the-meter DC-coupled systems. But one of the disadvantages for the front-of-meter market has been the cost of multiport inverters."

The newer variation of DC architecture that has emerged for front-of-meter solar-storage, which Gupta is referring to, is a DC-DC converter. This piece of hardware is tied to the batteries and connects to the PV inverter along with the PV array, allowing for a single interconnection only.

Reduced capex

Since interconnection can make up anywhere between one fifth to over a third of BoP costs, DC coupling can help reduce these costs. Co-locating different assets, be it solar and storage, solar and wind or solar, wind and storage, will always reduce BoP costs, compared with a standalone installa-

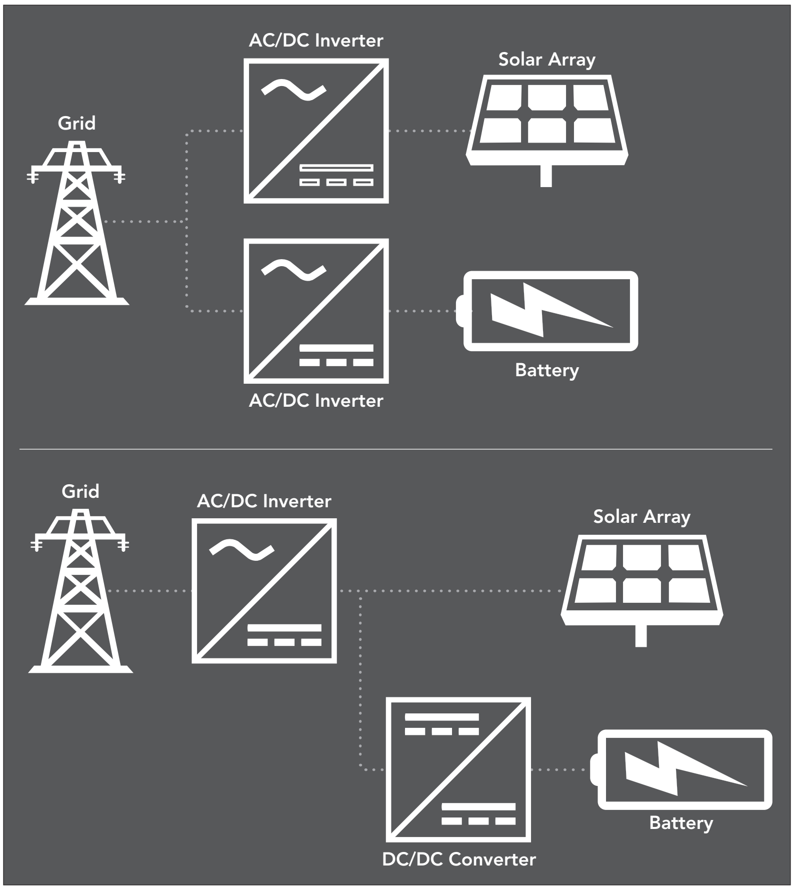


Figure 1. Co-located solar and storage systems, in AC-coupled (left) and DC-coupled (right) configurations

tion of a solar or wind plant, simply through sharing costs associated with land acquisition or leasing, labour, project management and permitting.

The US National Renewable Energy Laboratory (NREL) estimates that by 2020, BoP costs for co-located DC-coupled solar-plus-storage will be 40% lower and those for AC-coupled solar-plus-storage will be 30% lower.

Business case for clipping recapture

According to analysts IHS Markit, return to stronger global solar growth in 2019 is occurring, driven by declining PV module prices, which have fallen by 32% on average in the past two years, while average PV inverter prices have also been falling, by 18% over the same period. As the cost of modules continue to come down, DC coupling becomes increasingly advantageous when designing a solar-plus-storage plant, in order to outsize the plant's solar capacity.

Eos Energy Storage business development manager Philippe Bouchard says: "As well as capturing more cheap solar energy for sending to the grid, you also have a dispatchable power plant and are able to maximise its output too. Power is being fed into the grid in the morning, in the day and in the evening."

One company that has done modelling around clipping recapture is US power electronics company Dynapower. Through its activity in the energy storage business during the past 10 years, the company saw the advantage of DC coupling, before developing conversion hardware to enable these types of installations. Dynapower launched the first DC-DC converter aimed at the utility-scale solar-plus-storage market in 2018.

In AC-coupled solar-plus-storage configurations optimal PV inverter loading ratios are around 1.30 for the PV array (DC rating) to 1.0 for the inverter (AC rating). Using the example of a 100MW AC inverter connected to a 130MW DC solar array, the plant's output is 100MW, resulting in many megawatt hours of clipped energy annually.

Connecting energy storage to the PV array by DC coupling allows for the PV-to-inverter ratio to be significantly increased, and output otherwise clipped and lost in the more conventional AC-coupling approach is used to charge the battery.

According to financial and technical analysis undertaken by Dynapower for DC-coupled solar-storage under the Solar Massachusetts Renewable Target (SMART) programme, an owner of a solar-plus-storage system comprising a 3MW PV array, a 2MW (AC) PV inverter, which is DC coupled to a 1MW/2MWh energy storage system, will be able to capture 265,388kWh of clipped solar energy annually, resulting in US$1.5 million of additional annual revenue, compared with an AC-coupled solar-storage system. The return on investment is estimated to be 5.6 years.

Pilots

Dynapower has worked on several pilots with utilities that are first movers in doing DC-coupled solar-plus-storage installations. These include NextEra and Duke Energy, which have deployed the company's DC-DC converter technology.

In the Citrus project in DeSoto in Florida, NextEra subsidiary Florida Power & Light has installed a 4MW/16MWh lithium-ion battery system DC-connected to a PV array, which has been in operation since late 2018. The utility is comparing the benefits of the Citrus facility against a 10MW/40MWh AC coupled solar-storage plant, Babcock Ranch, in Charlotte County, also in Florida.

In these pilots NextEra is interested in how storage paired with a PV facility can capture a portion of the solar megawatt-hours that are clipped during peak solar output hours for delivery to customers later in the day.

The utility sees the advantage of DC-coupled solar-plus-storage compared with AC coupling as an ability to capture a greater amount of clipped solar energy, combined with a higher round-trip efficiency (charging to discharging). However, it acknowledges that AC coupling approaches are better known and understood. As both projects continue, NextEra says it will adapt its assumptions.

Dynapower has also supplied its DC-DC converters to pilots undertaken by Duke Energy. They include an installation at Duke's premises in Mount Holly, North Carolina, as part of a microgrid, which includes a 150kW solar array coupled to a 240kW/122kWh Total (Saft) battery system with Dynapower's 250kW DC-DC converter.

This August, Duke Energy will commission another DC-coupled solar-storage installation using alternative battery chemistry at its McAlpine facility, also in North Carolina. Eos Energy Storage has supplied a 30kW/120kWh energy storage system, based on its aqueous, zinc battery technology, which is integrated with Dynapower's DC-DC converter technology.

Dynapower marketing manager Richard Morin says: "These projects are exciting because, until now, what's slowed the floodgates for DC-coupled solar-plus-storage is that it presents a new technological approach to doing these types of projects, but with these pilots utilities are putting the benefits of DC-coupled architecture to the test, ahead of wider adoption."

To expedite the rollout of DC-coupled solar- plus-storage projects in the future, Dynapower is partnering with large, global manufacturers of central inverters. "We are kind of behind the scenes with our converter. We have designed it to be compatible with different PV inverter makes and pave the way for more plug-and-play type offerings, so we are in the process now of partnering with global suppliers of utility-scale PV inverters, including SMA," says Morin.

One often-cited disadvantage of doing DC-coupled projects is that the batteries have to be installed in a distributed way throughout the solar array, compared with an AC coupled installation where one central container of batteries is installed.

While it is technically possible to do a DC-coupled central battery storage system, it would entail a high number of long cable runs, making it more practical to co-locate the batteries with the central inverters distributed throughout the installation.

Gupta says: "If a site is space constrained, it may be better to do AC coupled. With DC coupling, blocks of energy storage are

DC microgrids

Growth in solar and other distributed generation as well as energy storage has helped fuel demand for microgrids, which can offer buildings and communities power resiliency.

According to Eaton's distributed energy segment leader EMEA, Louis Shaffer, by adding a smart operating system over the top of integrated distributed generation and loads, to create a microgrid, minimises overall peak demand, so the main grid becomes a source of back-up only.

Losses can be significantly reduced in DC microgrids, compared with AC. Clean distributed generation sources, including solar, batteries and also wind turbines, generate DC power, while loads, such as certain types of machinery, appliances, LED lighting and computing devices, run off DC power. The growing availability of critical components, like DC-DC converters, is simplifying design and development of DC microgrids.

Shaffer sees decarbonisation of cars and transport as a key driver for DC microgrids. Since electric car chargers run on DC power, EV charging could become a significant load for a building complex or campus that dedicates a percentage of its car parking area to charging. "So, the rationale increases then for designing a microgrid based on DC architecture," he says.

Dynapower's marketing director Richard Morin says the company is seeing growing interest for its DC-DC converters for different types of microgrid applications. "DC coupling loads and generation eliminate efficiency losses. We are having early stage conversations with companies in various industries, from manufacturing to mining."

distributed over the site and are connected to blocks of storage."

Other perceived disadvantages of DC coupling, compared with AC-coupling, include increased connection costs. Operations and maintenance costs could also be impacted, if technicians spend time getting to and checking or working on various battery containers spread over a solar field.

However, Morin says: "We have found that in speaking with our customers they prefer containerised distributed batteries for safety and risk mitigation. By distributing the batteries, if there was a thermal event, it would be contained to the singular battery container, reducing the scale of the event and loss of battery assets."

He adds: "Additionally, the types of large-scale solar installations that we are discussing typically do not require a lot of maintenance. The economic advantages of the DC-coupled approach, such as improved roundtrip efficiency, reduced installation cost and clipping recapture capability, far outweigh any additional costs for maintaining multiple battery structures."

Demand drivers for DC coupling

According to Fluence Energy's managing director Daniel Wishnick, the US is the only market where DC-coupled solar-storage is in demand at present. "These types of installations are tax-advantageous," he says, referring to the federal investment tax credit (ITC).

Gupta says that even with the ITC stepdown in 2021, DC coupling demand will continue as the industry becomes more comfortable with these types of projects and look to optimise revenues from clipping recapture and other streams.

"The number of integrators and working on DC-coupled projects is growing, including Fluence, GE and Greensmith, while more vendors are launching DC-DC converters and DC-integrated solar-storage solutions in the past 18 months. That said, at this stage the market has not achieved the same level of standardised, or 'plug-and-play' systems that AC-coupled projects benefit from," Gupta says.

Regarding integration, Bouchard points out that the real development work being done with these first projects is establishing the code and control interface to allow a system of components to interoperate seamlessly.

"In a typical DC-coupled solar-plus-storage project, you have the AC inverter, DC-DC converter, energy management system (EMS), battery management system (BMS) and DC solar array operating together to deliver maximum, dispatchable energy when called upon.

In most cases, all these components, including Eos' own BMS, use the same communication platform and what is known as SunSpec communication protocols, which have been developed by an alliance of solar and storage distributed energy industry companies, including SMA, NexTracker, Engie, Fronius and NEC participants, to support system interoperability.

While there is ongoing development work required in the EMS space to optimise dispatch according to contract or market requirements, Bouchard says that getting these systems to 'talk' to each other is not difficult.

"Once you've done it the first time, you can leverage the interface development and register mapping to replicate and scale for much larger projects," he says.

According to Wishnick, specifics of individual projects are influencing decisions on whether to DC- couple or not. "Site layout, interconnection costs and considerations can all have an impact on whether DC coupling or AC coupling is the best approach to take," he says.

Fluence is working with several customers, mainly developers of front-of-meter, ground-mounted solar-plus-storage projects, on DC-coupled designs. Most clients of Fluence are at the stage where this is their first DC-coupled solar storage project, indicating the market is still at an early phase.

Bouchard says: "As the US is by far the biggest market for solar-storage, naturally it is where DC coupling is happening first." In five years' time, he thinks it will be more widely deployed in US and also in other markets.

"We are seeing interest in India, Australia and especially Middle East, where you need a large solar-storage plant able to cover the evening load. In domestic terms interest is growing in south-west US and also California, as well as North Carolina, which is one of the fastest growing solar states in the US."

Bouchard says the company is supplying a DC-coupled solar-storage project in a market outside the US, though won't provide further details at this stage.

Morin says Dynapower is seeing global interest for its DC-DC converter for DC coupling solar and storage, noting Australia in particular, where electricity market changes are facilitating demand for DC-coupled solar-storage plants.

He is bullish about the prospects for DC coupling. "In the next five years it will be mainstream. If you look at the market research up to 2025, that is the trend. ■

SolarEdge readies for rise in demand for DC coupling in residential solar-plus-storage

Another market where DC coupling is seeing more demand is in the residential PV market, where adding batteries increases self-consumption of solar-generated electricity.

According to SolarEdge founder Lior Handelsman, DC coupling behind-the-meter solar and batteries for residential markets results in more energy production and increased return on investment, because there is only the one conversion to AC after energy is discharged from the battery. AC coupling requires three conversions. "The reduced number means increased efficiency and energy loss is minimised," he says.

Depending on upfront costs, AC coupling can make more sense when retrofitting an existing PV system to include energy storage. But, Handelsman says: "DC coupling is becoming increasingly popular as more new PV systems are initially being installed with a battery. This is due to decreasing PV and battery costs, increasing electricity prices and evolving incentive structures."


Credit: SolarEdge

DC coupling residential solar and batteries results in more energy production and increased return on investment, according to SolarEdge

DC coupling also provides a number of other benefits. "A DC-coupled system requires only one inverter, which means simpler installation and reduced costs. Additionally, one inverter to manage the system means functionality benefits, such as simpler synchronisation and coordination of advanced features," he adds.

In addition, a DC-coupled solar and battery installation allows the system owner to use PV power above the inverter rating and the inverter does not limit power, in other words act as a bottleneck for the power flow due to energy conversion.

Initiatives for California to overcome its challenges in the sun

Technology | California's success in embracing renewable energy technologies, particularly solar, has brought with it challenges around reliability of supply to consumers. Janice Lin and Jack Chang of Strategen explore how the Golden State is pioneering the deployment of energy storage as it pursues its goal of complete energy decarbonisation by 2045

Credit: Doosan GridTech.

A planned 20MW battery energy storage system project for LA Department of Water and Power with Doosan GridTech

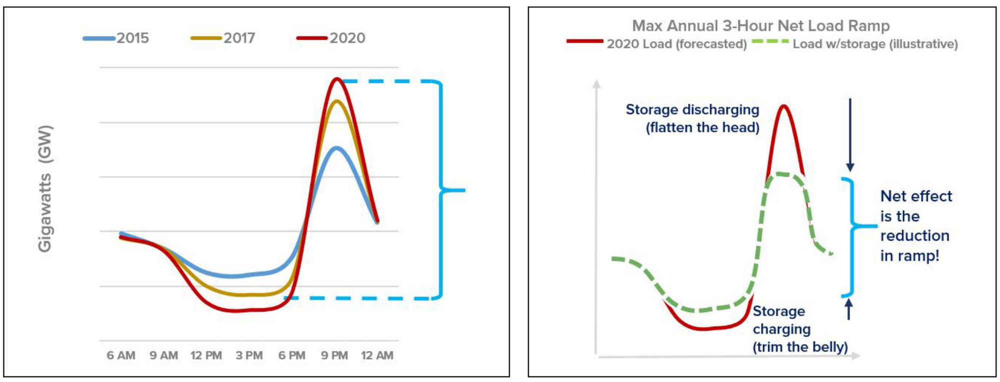
California is embracing energy storage as a reliability solution for an electrical grid that's adopting more renewable, intermittent generation. Public agencies such as the Los Angeles Department of Water and Power have set ambitious energy storage targets while companies across the state are developing cutting-edge storage technologies such as zinc-air batteries and renewable hydrogen. The goal is to ensure a dependable energy supply for the state as it races toward its target of 100% carbon-free energy by 2045.

For more than two decades, California has overcome a series of unforeseen challenges that have threatened to derail the state's transformation to clean, reliable energy. Whether it was cheap natural gas challenging the economics of renewables or California's push to implement the country's toughest auto emissions standards, state policymakers have untangled regulatory and economic clean energy knots years before other states or countries were even aware of them. In doing so, California reduced carbon dioxide emissions by 13% from 2004 to 2016 while its economy grew by 63%.

With the ramp-up of renewable energy generation, one of the trickiest challenges bedevilling state policymakers has been how to supply reliable energy to consumers despite the intermittent nature of solar, wind and other forms of renewable generation.

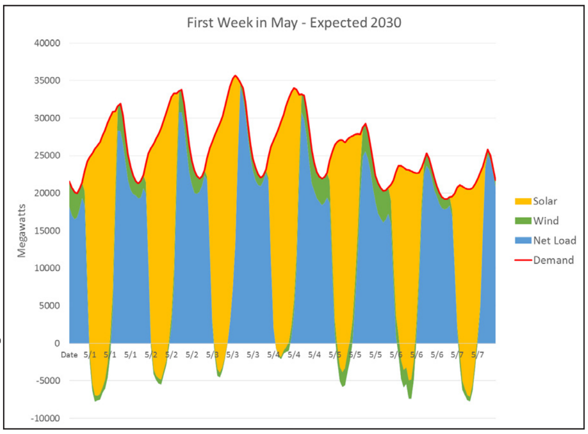
The California Independent System Operator, CAISO, christened this pattern the "the Duck Curve" to describe the net electricity demand they must serve after netting out daily solar and wind energy generation. The resulting net load has a regularly recurring daily dip and rise that looks like a duck. The addition of 20,000 megawatts of new renewable generation over the past nine years in the state has exacerbated that curve by steepening its slope over the course of the day as ever more solar energy floods into the market and then retreats.

Visually, instead of the smooth, almost lazy "U" of diminishing and rising demand, the state now rides a daily roller coaster as millions of solar cells begin to generate power in the morning and then taper off production in the late afternoon – just as households turn on their TVs, washing machines and other appliances.



Source: Strategen

Modelling of daily net energy demand in California sees what CAISO christened the 'duck curve' become even more steep



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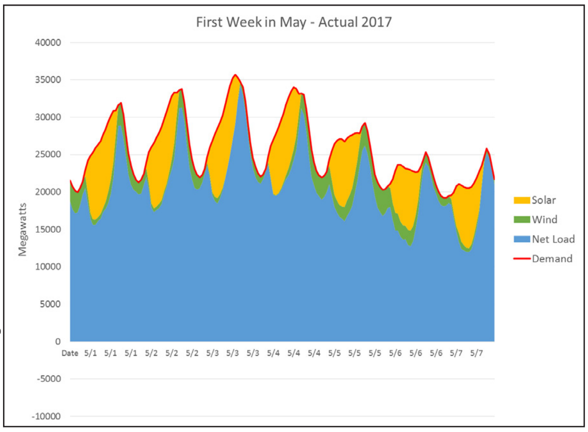


Source: Strategen

The Duck Curve over the course of a week in May 2017 (actual) and May 2030 (predicted) shows 'icicles of opportunity' on the grid.

Viewed on a weekly or monthly scale, the dramatic peaks and valleys of this peaking power profile appear something like multiple stalagmites rising from a cavern floor.

At the leading edge – of a complex energy problem

The addition of thousands of megawatts of solar energy has not only made the grid harder to manage, it has increased reliability on expensive, inefficient and polluting natural gas peaker plants to meet the ramp, which has hampered greenhouse gas reduction efforts.

So California once again finds itself at the leading edge of a complex energy problem, and its success or failure is likely to impact the renewable energy efforts of other states and regions around the world. That transition to a smoother energy profile requires storage because of its core ability to take energy from one period and dispatch it when needed in another period, freeing the grid from the constraints of renewables ramping up or down.

Leaders in both the state's public and private sectors have recognised that promise and have already created promising new storage technologies as well as a successful regulatory framework for enabling energy storage in all its diverse forms. Storage is transforming California's power sector while helping the state achieve its ambitious clean energy policy goals.

We at Strategen present here a shortlist of public and private energy storage initiatives in California that we believe have a good shot at bringing more reliability to the grid. Taken as a whole, efforts of both state agencies and companies are working with lots of creativity and daring to make widespread energy storage a reality:

Public initiatives

In 2018, Sacramento lawmakers went all-in on clean energy by passing Senate Bill 100, which requires 100% of the state's energy to come from carbon-free sources by the end of 2045. That legislation has spurred cities across the state to incorporate storage in their energy plans, the most notable example coming from the Los Angeles Department of Water and Power's Green New Deal. L.A.'s ambitious initiative calls for increasing cumulative energy storage by 18% to as much as 1,524MW. It also identifies and prioritises solar and microgrid backup power projects at municipal facilities, streamlines permitting and interconnection processes for energy storage projects and launches pilot technology for dispatchable and customer-side storage.

Additionally, the state has launched a variety of incentive and pilot projects supporting energy storage.

SGIP

By the end of 2017, the California Public Utilities Commission's Self-Generation Incentive Program had funded 1,768 projects representing over 568MW of rebated capacity and supporting technologies such as advanced energy storage and fuel cells. Known as SGIP and introduced to primarily support solar generation equipment purchases, the programme paid more than US$845 million in incentives for completed projects.

EPIC

The California Energy Commission has already spent more than US$5 million and earmarked an additional US$30 million to support commercialisation of the next generation of energy storage technologies. Focusing on diverse battery chemistries, innovative energy management software, as well as thermal and mechanical storage technologies, the CEC aims to deploy storage that will meet a variety of use cases. Additionally, this past April, the commission awarded US$11 million to four energy storage technology research projects in its latest round of its BRIDGE, or Bringing Rapid Innovation Development to Green Energy, project. The commission funding supported an electric vehicle charging and energy storage programme from Natron Energy, a zinc battery storage project from Eos Energy Storage, a large-scale sulphur thermal battery demonstration project from Element 16 Technologies and a redox flow battery from UniEnergy Technologies.

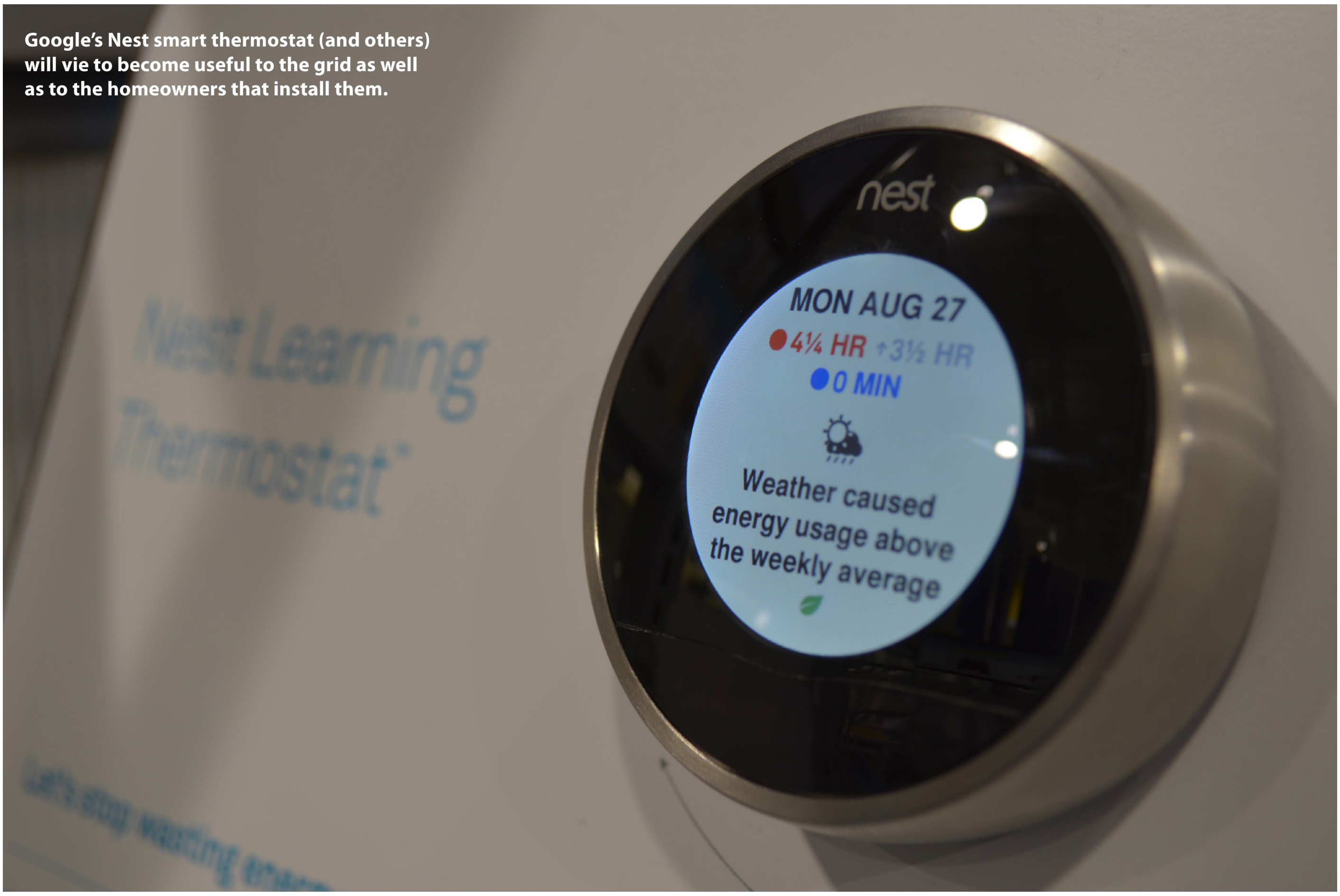
Private sector

Companies across California are tackling the storage challenge with the same type of scrappy start-up spirit that has reshaped the technology sector, and by extension, the world. The research and development action is happening at more established companies as well such as the Malta molten salt energy storage project launched at Google X, the tech giant's "Moonshot" factory. Paired with forward-thinking policy coming out of Sacramento, the conditions are right for real storage breakthroughs.

Hydrogen

Hydrogen fuel cells are already powering thousands of buses and cars all over California, so much so that the technology is often linked principally to transportation. That's changing, however, as hydrogen is increasingly considered a potential long-duration, multi-day and multi-energy storage solution that can help flatten daily load. Companies are experimenting with new ways to produce hydrogen such as through the thermal conversion of garbage. Another big opportunity is to convert water to hydrogen gas and oxygen through electrolysis by harnessing solar and wind energy.

As prices for solar and wind continue to plummet, this cheap, abundant and clean electricity could produce climate neutral (non-GHG) hydrogen gas at scales large enough to eventually displace natural gas in some cases and



Google's Nest smart thermostat (and others) will vie to become useful to the grid as well as to the homeowners that install them.

Credit: Raysonho @Open Grid Scheduler/Grid Engine

even serve as a peaker resource. Renewable hydrogen could also come from Mitsubishi-manufactured turbines that run on a blend of gas and hydrogen, with the goal of running on 100% hydrogen within a few years. Such technology used at scale could repurpose for renewable hydrogen existing infrastructure such as gas pipelines and interconnections.

If the falling price trajectory of solar and wind energy is any indication, renewable hydrogen has the potential to become economically competitive with natural gas-derived hydrogen.

That means renewable hydrogen could displace gas use in industrial, electric generation, agriculture, long-haul transportation fuels and other applications. To push the hydrogen ball along, the state's Public Utilities Commission is considering a new docket that will analyse the feasibility of hydrogen injection in the natural gas pipeline and further define renewable hydrogen and its potential use as a storage as well as a natural gas substitute. The California Fuel Cell Partnership, a public-private group, argues that the state can leverage its 60-plus hydrogen fuel stations in operation or in development to help transform the fuel source as a high volume and seasonal storage medium. The state already requires that at least a third of the hydrogen sold at California stations be renewable. Building out that infrastructure at the needed scale, however, is seen as a potential challenge to hydrogen playing a viable role in any state-wide storage solution.

Long-duration storage

More renewable energy coming online will mean a growing need for long-duration storage that can even out the intermittency of solar and wind generation and bring reliability to a renewables-dominated grid. For grid operators, long-duration storage offers more flexibility in integrating wind and solar energy generated during different times of the day. That's especially important as gas-fired generation makes up a smaller portion of state-wide generation and capacity.

Zinc-air batteries have received attention as a long-duration storage alternative with the high-profile growth of El Segundo-based NantEnergy and its leadership under chairman Patrick Soon-Shiong, the billionaire owner of the *Los Angeles Times*. NantEnergy touts rechargeable zinc-air battery storage systems as cheaper than lithium-ion systems – about US$100 per kilowatt hour versus as much as US$500 per kilowatt hour for lithium-ion batteries. NantEnergy is already installing its battery systems in dozens of rural communities in Africa and Latin America as a proof of concept. The company has already raised more than US$200 million in funding.

The systems are often installed along with solar panel-powered microgrids run by advanced monitoring systems that help users analyse and adjust generation and load profiles in real time to better meet demand. The batteries use solar-generated electricity to separate zinc oxide into zinc and oxygen, with the zinc later combining with air when needed to produce energy. For zinc-air boosters, the best argument in their favour is that companies are already producing the units, the technology has been deployed around the world and it has shown itself to be a viable long-duration storage option.

Google X spinoff Malta Inc is exploring another long-duration storage pathway with its pioneering use of heat-trapping molten salt. The Malta process uses renewable electricity to power heat pumps that store heat in molten salt and cold in chilled liquid. When needed, a heat engine converts the temperature difference between the stored heat and cold back into electricity. The company says the technology can store energy for more than six hours and be charged thousands of time before its performance degrades. The simplicity of its materials – salt, steel, anti-freeze and air – gives the system an estimated 20-year product lifetime. Malta CEO Ramya Swaminathan and principal engineer Raj Apte are scheduled to deliver keynote addresses at ESNA on the future of long-duration energy storage.

Other forms of long-duration storage such as pumped hydro and compressed air require millions of dollars in infrastructure investment to operationalise, but that hasn't stopped California utilities from jumping in. Pacific Gas & Electric (PG&E), the state's biggest utility, is studying building a compressed-air storage facility in the agricultural San Joaquin Valley that would use energy during low demand periods to inject air into sand deposits or other porous rock formations. That air is then tapped to spin turbines and generate electricity when demand is highest.

Further south, the Los Angeles Department of Water and Power is already operating a pumped hydro system in the Los Padres National Forest above the L.A. basin that pumps water from Castaic Lake 7.5 miles uphill to Pyramid Lake during low demand times. When the electricity is needed, the system releases the water back into Castaic Lake where turbines await. The department is looking at implementing a similar storage system at the Hoover Dam.

Electric vehicles

With more auto manufacturers shifting to the electric vehicle market, successfully integrating all those Teslas, Bolts and Leafs into a dispatchable grid promises enormous benefits. As usual, California is leading the way, having already set a goal of putting five million zero-emission vehicles on the road by 2030 and installing 250,000 electric vehicle charging stations by 2025. The state's utilities have also been mandated to develop targeted EV plans establishing clear guidelines for charging by residential, commercial and industrial vehicles. As a result, the state's three main investor-owned utilities – Pacific Gas & Electric, Southern California Edison and San Diego Gas & Electric – have taken the lead nationwide in developing rate structures specifically to help electric vehicles charge when electricity is cheapest as well as to help pay for electrical upgrades at residential homes installing electric vehicle charging infrastructure.

Beyond charging, state planners are studying electric vehicles as load-management and energy storage resources especially as the state's EV fleet balloons. For example, smartly charging EVs system-wide during low energy-use periods alone could save the state US$1.45 billion to US$1.75 billion in stationary storage investments that would otherwise be needed to meet California's clean energy goals. The next step will be to encourage V2G, or Vehicle-to-Grid, policies and infrastructure that can help EVs send power back into the grid. System-wide V2G balancing capabilities would help the state avoid an estimated US$12.8 billion to US$15.4 billion in stationary storage investments.

San Diego-based Nuuve is already selling its patented V2G bidirectional AC and DC charging stations that ensure vehicles have enough charge to complete trips and also let them sell energy back to the grid if the price is right. Nuuve is collaborating with auto giant Honda to demonstrate the viability of such vehicle grid integration.

Household appliances

Taken individually, a water heater or a home thermostat doesn't make a big impact on total energy load. Together, however, millions of residential devices switching on or off in unison could be a real game changer. That's the idea behind moves both in the public and private sectors across California to get thermostats, heaters and other appliances into the storage and demand response game.

For example, California lawmakers are trying to transform millions of electric water heaters across the state into both mini-energy storage devices and replacements for natural gas-generated heat. Last year, the state Legislature passed State Bill 1477, which dedicated US$200 million over four years to help advance low-carbon space and water heating technologies. The big-picture goal is to decarbonise residences across the state by weaning them off natural gas and have them use electric appliances instead. Electric water and space heaters tapping an increasingly clean grid are seen as the linchpin to creating carbon-free households. On top of that, heat pump technology, when fitted with software that matches heating times with dips in energy prices, also make for excellent energy storage devices that can store hot water for later use.

In July of this year, Google-owned Nest announced it was pairing up with Leap, a San Francisco-based firm that runs a universal distributed energy exchange. Nest's smart thermostats will deploy energy to meet demand response capacity on Leap's exchange. Already, some 2,500 thermostats across the state are turning on and off in response to energy price signals sent from the Leap exchange. Multiply those thermostats' numbers many times over and those stalagmites of energy demand will really start shrinking.

Forward movement with clean energy

With these initiatives, California is tackling the challenges of building a more integrated, reliable electrical grid that makes full use of renewable generation and energy storage. Public agencies are creating the incentives and regulatory framework that can inspire private companies to invest in and develop the latest solutions to long-duration storage, demand management and other pieces of the reliability puzzle.

Many of these programmes and technologies will be on display at Energy Storage North America Conference & Expo (ESNA) in San Diego on November 5 to 7, 2019. In its 7th year, the event is celebrating innovation in energy storage alongside government leaders of California and Germany, two of the world's most clean energy-forward places, as it hosts the California-Germany Bilateral Energy Conference. ■

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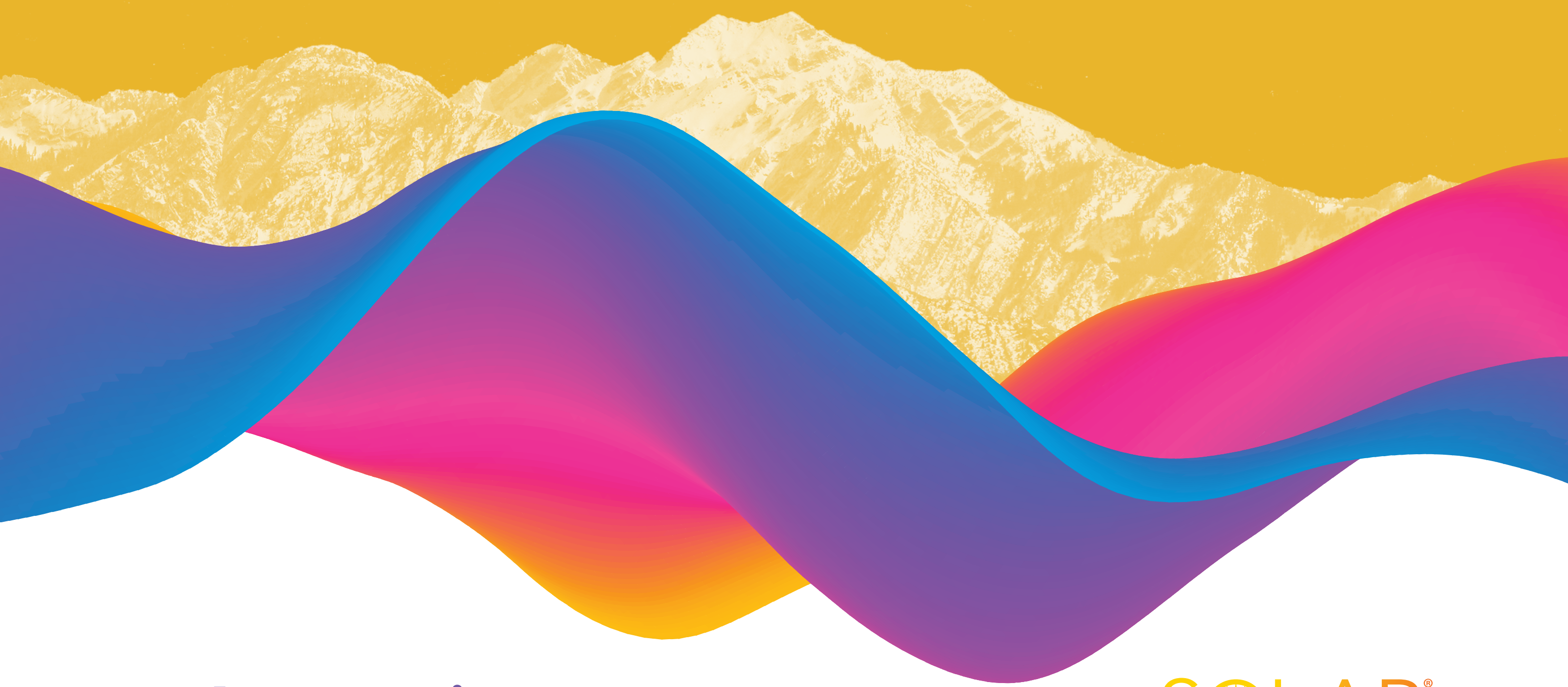

The Clean Energy Package is here – now what?

EU policy | The EU's clean energy policy framework for the first time recognises energy storage as a key part of the future energy system. It is far from perfect, but lays the foundation for storage to become an integral part of efforts to decarbonise the energy system, writes Brittney Elzarei

Only 10 years ago, the value of energy storage for the energy system was not at all recognised by European Union policymakers. In the Third Energy Package, the 2009 package of EU energy legislation, there was no mention of energy storage. In an energy system and regulatory framework built around the traditional assets of generation, transmission/distribution and consumption, energy storage was seen as a rather unimportant niche technology.

Just as the energy storage market has grown in leaps and bounds, the thinking of policymakers across the EU has evolved since then. The European Commission now recognises that "Energy storage has a key role to play in the transition towards a carbon-neutral economy, and it addresses several of the central principles in the Clean Energy for All Europeans package" [1].

This package of legislative and non-legislative proposals, commonly referred to as the CEP, ushers in a new era for the energy storage industry. The CEP for the first time in EU law formally recognises energy storage as one of the key players in the energy system and seeks to address the main barriers that have hampered storage deployment.

Clean Energy Package: game changer for storage?

The CEP is undoubtedly positive for the storage sector. By establishing a binding renewables target of 32% by 2030 – along with targets for renewables in transport, heating and cooling – the package sets a high level of ambition that can only be achieved with the widespread deployment of flexibility solutions such as storage.

Within the CEP, the recast Electricity Directive and Regulation tackle some of the most pressing challenges for storage technologies. First of all, they establish a definition for energy storage that covers all of the different technologies: pumped hydro storage, power-to-gas, power-to-heat, liquid air, batteries, supercapacitors, flywheels and others. This technology-neutral definition ensures that both current technologies and those that may be developed in the future are covered by the legislative framework.

Second, the Clean Energy Package clarifies the important issue of regulated entities owning and operating storage facilities. As a general rule, transmission and distribution system operations (TSOs and DSOs) should not own and operate storage, unless they are considered "fully integrated network components". However, in situations where there is no market party willing to build a storage device, the National Regulatory Authority (NRA) may introduce a derogation. Prior to the CEP, the lack of clarity on ownership of storage held back the development of storage devices; addressing this point therefore represents an important step forward.

The CEP also focuses on the evolving role of TSOs and DSOs more broadly: TSOs and DSOs must consider energy storage in their network planning and are encouraged to move towards market-based tendering of flexibility services as an alternative to grid expansion. This will allow energy storage to access more revenue streams, building a more robust business case and creating a level playing field between the different flexibility options.

In addition, the CEP emphasises the changing role of consumers in the energy system. Instead of being passive players in the energy system, consumers can choose to play an active role, deploying renewables and storage and participating in different electricity markets. The package formally recognises the right of "active customers" and "citizens energy communities" to own and operate energy storage devices. These customers and communities should be able to offer the flexibility of their storage devices to the grid, including via aggregators.

Credit: Belectric

The role of energy storage facilities in providing grid services is more clearly defined in the Clean Energy Package

Although the CEP is a significant step forward for the industry, it does not address all of the issues that are holding back storage deployment. For instance, energy storage will require at least some investment certainty in the form of long-term contracts for storage services. Yet the CEP limits the duration of balancing services, which could reduce investment certainty. This means that there are ever fewer longer-term revenue streams on which storage operators – and investors – can rely.

Another key issue is that grid fees, taxes and tariffs applied to energy storage may be higher than on other devices, as storage is sometimes taxed when 'consuming' electricity and then again when 'generating' electricity. This point is not adequately addressed in the CEP, since taxation remains an EU member state competence.

Beyond the CEP: new policy initiatives and challenges for storage

Although the CEP addresses some of the key high-level principles that are needed to formalise the role of energy storage and ensure access to new revenue streams, there are many more topics that are still up for discussion.

One key challenge is that the implementation of the CEP provisions may not be uniform across all member states. Some markets that are now closed to energy storage technologies (for example, the Czech Republic, which does not allow stand-alone grid-scale storage facilities to be built), may still lag behind in terms of implementing the package. Urging governments to implement the CEP as quickly as possible is therefore a key priority in order to have a harmonised EU market.

While CEP implementation is important, there are also many new EU policy initiatives that can benefit storage. Next year, the Commission is expected to propose changes to the EU's gas legislation. The 'Gas Package' will cover a range of gas market design issues, notably the role of power-to-gas. Definition of renewable and low-carbon gases, guarantees of origin and certification schemes will have an important impact on the storage sector [2].

Over the past two years, there has also been a flurry of Commission activity focused on supporting the batteries sector in Europe. Commissioner Maroš Šefčovič, vice-president of the European Commission in charge of the energy union, has repeatedly emphasised the strategic importance of a strong EU value chain for batteries. At his initiative, a European Battery Alliance was established to enhance collaboration between industry and policymakers. This has led to a number of other activities including a proposal for sustainability criteria for batteries, a battery working group in the European Parliament, and additional funding for battery R&D projects.

This year the European institutions have also been debating the EU's 2050 strategy for greenhouse gas emissions reductions. The Commission's proposal, issued in November 2018, envisaged that power generation be fully decarbonised by 2050, with a share of variable renewables in gross electricity generation of 81-85% [3].

The Commission's analysis of the different options to reach this target underlined the vital role of energy storage: stationary storage use is expected to increase from about 30TWh today to 70TWh in 2030 and 170-270TWh in 2050 to achieve 80% greenhouse gas reductions compared to 1990 levels. This is a massive increase in energy storage deployments, which will require significant investments in the sector. However, this analysis only considers some storage technologies and does not quantify the flexibility that can be provided by behind-the-meter storage or – potentially – smart charging and vehicle-to-grid solutions.

The discussion about this strategy is still ongoing, as the growing number of EU Member States that support a target of net-zero emissions by 2050 have been blocked by a minority. There is also a debate about potentially revising the 2030 greenhouse gas emissions reduction targets to reflect a higher level of ambition.

For behind-the-meter storage, there are ongoing discussions in various member states about the grid fees and tariffs that customers should pay, and several countries and regions are considering incentive schemes for storage behind-the-meter. Another interesting development is the Smart Readiness Indicator [4], one of the proposals contained in the Energy Performance of Buildings Directive (part of the CEP). European policymakers are currently defining the methodology to assess the smart readiness of buildings, which will include measuring the ability of buildings to provide flexibility to the grid and support electric vehicle charging. Deployed alongside energy performance certificates, the smart readiness indicator of buildings could be a valuable way to communicate the added value of smart energy technologies – including energy storage – to consumers.

Finally, there are also developments related to DSO-TSO cooperation, for example to define new services such as congestion management that could be provided by services, and around the EU electricity network codes. The revision of the grid connection codes to include battery storage and other storage technologies (of which currently only pumped hydro storage is included in the codes) is an important step that could help create a more harmonised regulatory framework for storage across the EU.

What's next for storage?

While the CEP is a big success for the storage industry, now is not the time to rest on one's laurels. As the energy storage industry matures, and as the energy transition accelerates, engagement with policymakers will be essential to ensure that the right policies are put in place to support storage deployments. A few key risks are worth mentioning, which could derail some of the advancements made in recent years.

One risk, as highlighted above, is the tendency of EU policymakers to discourage longer-term contracts for flexibility services, which could reduce certainty for energy storage investors. Another risk is that policymakers tend to pick winners and losers among the technologies. For instance, significant attention is paid to li-ion batteries and hydrogen, potentially shutting out some of the other promising energy storage technologies that will be needed for the energy transition.

Not only is the diversity of energy storage technologies not considered, but also the diversity of services storage can offer is difficult for policymakers to take into account. This is noticeable, for instance, when looking at the modelling used by EU policymakers to support the 2050 targets, or the discussions around the Smart Readiness Indicator for buildings.

Since the European elections in May, new members of the European Parliament have come to Brussels, and a new College of Commissioners is being formed to take up its activities in November 2019. There is no guarantee that these policymakers will continue the positive efforts of the current Commission – and, to a lesser extent, the European Parliament – when it comes to energy storage.

Continued engagement with policymakers at the local, regional, national and EU level is therefore essential to ensure that they understand the complexity of the energy storage business case and the many different services that energy storage can provide – and should, ideally, be remunerated for. Industry and policymakers must work together to design smart and effective policies to ensure that energy storage can reach the levels needed to achieve the 2030 and 2050 decarbonisation targets. ■

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Bankable and insurable energy storage: a necessary next step for renewable energy

Finance | The rapid acceleration in energy storage deployment expected over the coming years will require innovation in the quality and safety standards underpinning new battery and associated technologies. VDE's Jan Geder looks at the technical work underway to ensure the coming storage boom has firm bankability and insurability foundations


Credit: VDE

Stringent testing of storage technologies will be critical to the sector's future bankability

Renewable energy is taking up an increasing share in the global energy mix. Utilities, distributors and users are facing the increased need to supplement renewables with energy storage systems to tackle the intermittency of these sources and ensure stable supply. Bankability and insurability of renewables, particularly photovoltaic systems, is nowadays a common concept with clearly defined criteria and processes. As the viability and availability of energy storage becomes the crucial factor in further growth of renewable energy generation, it is necessary to ensure bankable and insurable solutions for deployment of energy storage systems. This article explores the status and outlook for bankability and insurability of battery energy storage systems.

Recent years have seen a stellar rise in the generation of electricity from renewable sources. In the first half of 2019, 47.3% of net electricity generation in Germany came from renewables [1], an increase of 9.1 percentage points (23.8%) since 2017 [2]. According to Eurostat, the share of renewables in European Union's energy mix of 2017 amounted to 17.5%, an increase by two thirds since 2007 [3]. At the same time, the share of renewable energy has been increasing in developing markets as well. This is particularly the case for PV systems, which are set to break the 100GW milestone of newly installed capacity in 2019 [4]. This is driven mainly by rapid growth in the developing markets of Latin America, Middle East and Africa.

Increasing solar capacity and its share in the overall electricity mix requires an increase in energy storage capacity. This is due to the intermittent nature of solar irradiation, which rarely corresponds to required grid demand in real time. A 2015 report by the Rocky Mountain Institute lists 13 different services that battery energy storage system can provide to the grid [5]. These services can be provided to system operators and utilities, as well as to end-customers. There is a clear distinction between centralised and distributed systems as battery systems can be placed at three different levels: at distribution level, at transmission level and behind the meter. The latter, customer-sited and most decentralised systems, are also capable of providing the largest variety of services to grid.

The case for bankable battery energy storage systems

Projections for Germany [6] predict that 110-190GWh of energy storage systems would need to be installed by 2050 in order to meet energy transformation goals. Based on nine different scenarios, this is divided into 70GWh of pumped storage and 40-120GWh of battery energy storage systems, and excludes heat storage and power-to-fuel systems. These storage systems would be integrated in a grid with an installed capacity of renewables between 193 and 536GW, of which 122-290GW would belong to PV systems, according to the same projections.

Battery energy storage systems play a significant role in future rural electrification in developing countries. They are namely expected to enable deployment of renewable energy-based microgrids where photovoltaic system would play the major role in power generation. Reliable battery systems would therefore eliminate the need for costly infrastructure investments aimed at connecting remote and insular areas to the grid. Furthermore, efficient and sustainable microgrids would reduce the current dependency on diesel generators and their sensitivity to the logistics of the fossil fuel supply chain and its price volatility.

Both cases mentioned above face the challenge of acquiring financing for the construction, commissioning and operation of battery systems. At the utility scale, one expects to deal with large systems on which

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the reliability and stability of the grid shall depend. In the case of microgrids, the global majority of potential implementation sites are located in developing countries, where the low purchasing power of consumers may hinder the initial investment. For both cases, it is therefore equally important to ensure high-quality technical foundations that help ensure the profitable operation of battery systems, which is crucial for enabling the financial sector to provide financing products at reasonable conditions for these systems.

What makes batteries different from solar panels?

In the timeline of renewable energy development, batteries are commonly seen as the next big thing after the success of PV at the beginning of 21st century. Cheap and reliable storage is believed to deliver a much-needed boost to the solar-powered renewables boom which is happening globally. To follow the successful path of PV deployment, battery storage also needs to become bankable, insurable and investable. Although adding battery storage to the equation does not require us to completely reinvent the ideas of bankability and insurability, it is worth noting several important technical aspects of batteries that affect and influence the financing decision-making process for energy storage.

The most obvious distinction between batteries and PV systems or wind turbines is that batteries only store energy for later consumption and do not generate power themselves. The reality of bi-directional energy flows to and from battery systems requires careful dimensioning with regards to expected load profiles on both the charge and discharge sides. Energy storage systems therefore need to be planned to operate with regards to generation and consumption characteristics of the grid. This includes accounting for future upgrades based on the grid's needs.

On the costs side, there are further differences between battery systems and PV systems. "Lithium is not silicon" is an oft-invoked saying when the long-term price prospects of lithium-ion battery systems are discussed and compared to the last two decades of price development for PV modules. In fact, the lithium-ion cell price per kilowatt-hour dropped 85% between 2010 and 2018, with an average annual decline of 20%. This happened mainly due to technical improvements on the product side (higher energy density electrodes) and the process side (larger, more efficient manufacturing lines). However, the rate of price decline may slow down in the future due to several factors:

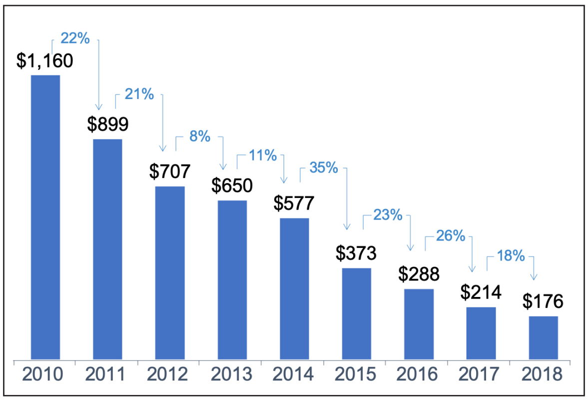


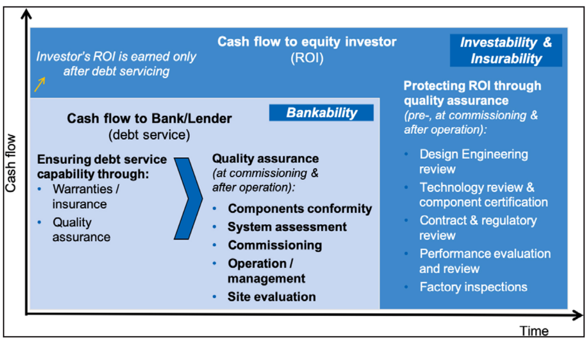
Figure 1. Price per kWh of lithium-ion storage capacity adjusted to 2018 US dollars [7]

- Increasing price of relatively scarce resources such as lithium and cobalt;
- Increasing demand for batteries from the electric vehicle industry;
- Consolidation of the industry with a few globally dominant manufacturers.

Parallel to improvements in energy density and price declines, there has also been a shift towards safer lithium-ion technologies. Safety of lithium-ion cells has marginally improved since their first commercialisation in the 1990s, though there is currently still no such thing as a "safe" lithium-ion battery. A state-of-the art lithium-ion battery is a thermodynamically meta-stable system whose failure modes may lead to grave consequences in the forms of explosions and fires. Recently, more than 20 battery storage system fires made headlines in South Korea [8]. These incidents caused hundreds of energy storage systems country-wide to be suspended from operation and inflicted millions of dollars' worth of damage to adjacent facilities. Investigations conducted by local authorities suggest that the fires were caused by poor site management [9].

Such prospects raise the issue of insurability of battery energy storage systems to a much higher degree than in the case of PV systems – the tendency of lithium-ion batteries to catch fire in an uncontrollable manner may lead to much higher total damages. It is therefore critical to devise rigorous processes of safety and quality assurance in order to gain the confidence of insurance companies, banks and investors. As the track record of such processes is yet to be established, it is critical that all stakeholders get on board and enforce the best practices in design and operation of battery systems.

Figure 2. Bankability and insurability of a project in terms of cash flow projection



Development of technical criteria to support bankability and insurability

The basic idea of bankability and insurability is presented in Figure 2. Quality assurance is understood as a wide range of measures aimed at securing the technical foundations for insurability and bankability of a project. Furthermore, it is important to recognise that the quality assurance requirements of an investor or an insurer can go beyond the requirements of a lender. There are two main objectives of quality assurance with regards to project economics and financing:

1. Understanding, mitigation and control of risks in order to make the residual risks of the project acceptable for insurers and investors;
2. Performance and efficiency analysis, reviews and tracking to ensure profitability of the project.

The origins of technical risks in a battery system can be divided into four major sources: components, system design, installation site and management/operation. They affect three crucially interconnected system characteristics: safety, performance/efficiency and lifetime.

Various risk sources require different approaches to quality assurance. On the component level (e.g. battery module, power conversion system), one can rely on a large number of applicable international and national norms and standards, for example IEC 62619 for battery modules, IEC 62909 for bi-directional converters and VDE-AR-E 2510-2 for battery systems intended for low-voltage grid connection. Component conformity is the cornerstone of quality assurance and the very foundation of risk management. Basic components, such as cells, modules and auxiliary systems (e.g. cooling systems, monitoring systems) shall be tested and certified to the above mentioned standards. However, with increasing levels of component complexity, design reviews are gaining importance as a supplement to pass-or-fail tests. This is particularly true for components such as the battery management system or energy

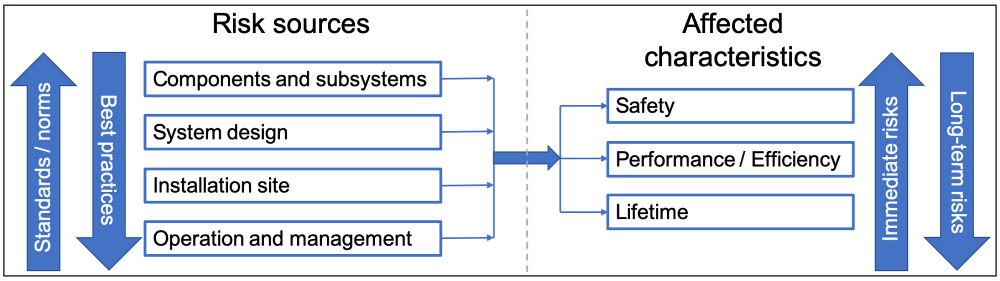


Figure 3. Visualisation of risk sources and affected system characteristics

management system, which are critical for functional safety.

Going beyond components, the complexity of quality issues surpasses the pass/fail dichotomy of the standards and related tests and reviews. As the publication of relevant international standards, such as those from the International Electrotechnical Commission (IEC), lags behind the need for quality assurance on the ground, one needs to increasingly rely on empirical "best practices" and other tailored criteria. With these, overall system design and the battery system installation site can be evaluated.

Finally, it is important to look at how the battery systems are managed on a day-to-day basis. This includes keeping the system and its environment consistently in proper condition, conducting regular maintenance, adhering to plausible risk management principles, and implementing strict control of documentation and record-keeping for the system. With proper practices, system risks are kept under control even as the system ages with time and inevitably decreases in performance.

There are several best practice documents and norms dealing with various individual segments of the above described processes. However, taking into account the lessons learned from bankability in the solar industry, it is important to take a holistic view of quality assurance for the entire system and project. A stakeholder that is looking to secure technical bankability and insurability through quality assurance would be best advised to implement the following practices into their processes:

- A guideline of compliance requirements and best practices for designing, installing and managing battery energy storage systems;
- A criteria catalogue or checklist based on the guideline that enables evaluation of each system considered;
- A procedure of inspections of system sites, preferably conducted by independent engineers, to regularly evaluate risks arising from the above-mentioned risk sources.

The described process of defining the criteria is visualised by the "VDE Quality Pyramid" as seen in Figure 4. The fundamentals (first level) are the standard market entry criteria in the form of national or international standards. These make sure that core components are compliant with basic regulations, but do not always follow the state-of-the-art developments in the market. Therefore, the test/evaluation criteria are expanded to address requirements of the highly competitive market and industry, rather than only those from the legislator/regulator point of view (second level). At the top level, tailored criteria are introduced to address the specific requirements and purpose of the project/system.

A look into the future of financially sound battery energy storage

As the demand for safe and reliable energy storage steadily follows the increase in renewable power generation, the involvement of financial institutions will become indispensable to provide the necessary financing and insurance for storage systems. Testing, inspection and certification institutions and technical consultants are developing processes and criteria to secure technical foundations for bankability and insurability of battery systems. In this case, the experience and progress with PV bankability and insurability can serve as a basis and reference point.

As was the case with PV systems in the past, many challenges lie ahead on the way to establishing a track record for reliable quality assurance for energy storage systems. Well-known safety issues of lithium-ion systems and the related pricing development are perhaps the most pertinent. On the other hand, there are many opportunities to capitalise on the lessons learned. Furthermore, battery energy storage may become even more economically attractive with the concept of repurposing used batteries from electric vehicles for stationary storage (i.e. second-life applications). Needless to say, this concept will again require stringent quality assurance and risk management tailored to the application. ■

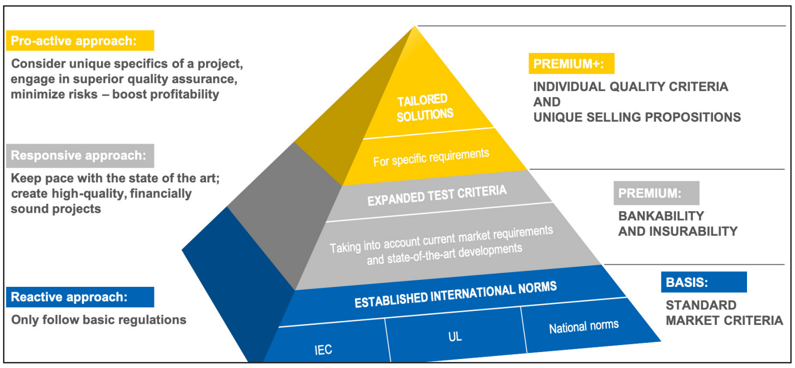


Figure 4. The VDE Quality Pyramid concept

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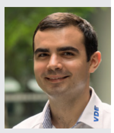

Jan Geder is a chemical engineer with extensive experience in energy storage and lithium-ion batteries. His main focus is consulting and managing industrial R&D projects for various clients. In 2016, he and his team successfully spun off their academic research lab to become a commercial R&D and testing facility. Since 2017, Jan has served as head of energy storage systems at VDE Renewables Asia, and leads the VDE's Energy Storage PrimeLab in Singapore.

Batteries need to be 'renewable' too: why recycling matters now

Recycling | The huge upsurge in lithium-ion battery deployment expected over the next two decades poses a problem: what to do with cells that have reached the end of their useful life. Stefan Hogg investigates the importance of lithium recyling in the transition to a low carbon energy system

Credit: Li-Cycle

Output shred product from the first stage of Li-Cycle's resource recovery process

In 30 years since commercialisation, lithium-ion (li-ion) batteries have been used in an increasingly diverse range of products, starting from early generation handheld electronics to powering cars and buses. Additionally, these batteries are increasingly sought after for utilisation in energy storage applications, often paired with renewable energy generation. The continued decline in battery prices combined with the global trend toward energy grids being powered by renewable energy sources is predicted to increase the world's cumulative energy storage capacity to 2,857GWh by 2040 [1], a substantial increase from the current capacity of ~545MWh [2], according to recent estimates by Bloomberg New Energy Finance.

These staggering projections paint an encouraging picture for how prominent li-ion-driven energy storage applications will become in the future as the world increases its usage of renewable, clean energy sources to power energy grids worldwide. Driven increasingly by electro-mobility as well as grid-scale energy storage applications, the volume of li-ion battery cells being sold is set to surge. The graph in Figure 2 contextualises the relative volume (in tonnes) of new li-ion battery cells forecasted to be sold through to 2025.

The growing quantities of li-ion batteries being placed on the market accelerates the urgency with which the world must find an economically viable, commercial-scale recycling solution for end-of-lifecycle li-ion batteries to be recycled at a 'mega' scale. This article will take a closer look at some of the challenges that exist today within the li-ion recycling sector and where opportunities exist to overcome the current roadblocks.

Li-ion recycling industry challenges

Feed sourcing

Secondary resource recovery (i.e. recycling) has a set of unique operational challenges that need to be addressed concurrent to the development of an economic, advanced technology. For the purpose of recycling, feed materials are typically inherently distributed, making it difficult to collect a high volume of feed for a processing plant. Although the collection supply chains for some analogous industries such as lead-acid battery recycling are well established and mature by comparison, the li-ion battery recycling supply chain continues to be fluid.

Spent li-ion battery sources can be broadly segmented into portable/'small format' and 'large format', which corresponds to the relative voltage of li-ion batteries (i.e. low voltage and intermediate to high voltage, respectively). Each of these types of batteries has a diverse group of stakeholders – from manufacturers, to the dealer network, recycling programmes, electronics and vehicle recyclers. In the context of the energy storage sector, its own diverse group of stakeholders exists – battery technology provider, energy storage integrator, project developer and asset owner. Managing the inherently heterogenous nature of li-ion batteries from a wide range of stakeholders remains a central challenge for companies in the li-ion resource recovery industry.

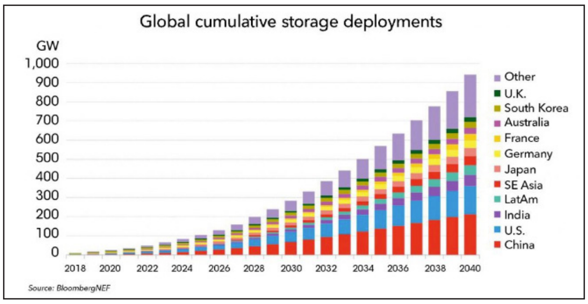

Figure 1. Global cumulative li-ion battery storage deployments. Source: BloombergNEF

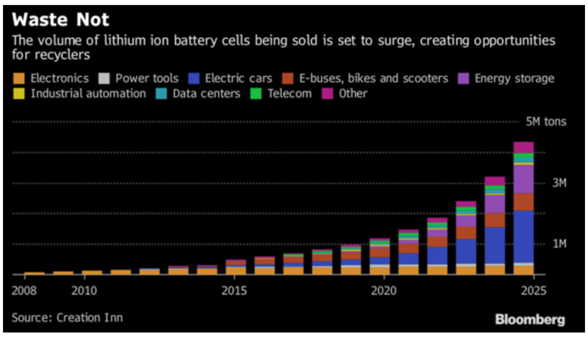

Figure 2. Global lithium-ion battery cell sales, 2008 to 2025. Source: Bloomberg and Circular Energy Storage, 2018

Logistics and regulations

Li-ion batteries are currently classified as Class 9 Dangerous Goods due their dual chemical and electrical hazard. Li-ion batteries can possibly undergo thermal runaway, typically resulting from internal shorting, leading to fire or explosion. There are numerous factors that can cause thermal runaway, including but not limited to overcharging, environmental conditions (e.g. extreme external temperatures) and manufacturing defects. At the onset of thermal runaway, the battery heats in seconds from room temperature to above 700°C. As part of this complex set of chemical reactions, the electrolyte solvent in lithium-ion batteries – typically alkyl carbonate-based – acts as a 'fuel' source for combustion.

Added care must also be taken when handling critical or damaged/defective batteries as there is an increased risk of thermal runaway. Specialised systems (e.g.

Genius Technology's LionGuard container for intermediate to high voltage lithium-ion batteries [3]) are typically used in tandem with non-flammable packing material to safely transport these batteries. As the overall volume of li-ion batteries increases, the quantity of critical or damaged/defective batteries is expected to increase across a broad swath of applications.

As the li-ion battery resource recovery industry is still maturing, regulations vary significantly around the world. These regulations can also change significantly from year to year, as new industry and research reports are released. As a result, it is important to keep close track of regulatory (including logistics) considerations concurrent to process development.

Safety and storage

The challenges of logistics and changing regulations typically revolve around one key factor – safety. Safety is paramount for those who handle, transport, store and process li-ion batteries, as there is a risk of thermal runaway. This raises another unique challenge for processors and consolidators, relative to the primary production of commodities and specialties.

Specifically, the safest approach is to have the lowest amount of spent li-ion batteries on site as possible, in order to mitigate the risk of a thermal runaway event occurring. However, this is contradictory to the requirement to secure significant amounts of feed for processing purposes. The development of safe storage is further complicated by the currently prominent format factor of spent li-ion batteries, i.e. portable/small format batteries (e.g. from mobile phones, laptops and other consumer products). Portable li-ion batteries are typically consolidated in drums and could be mixed with other battery types.

Upon an initial inspection, the state of all collected batteries within a single drum is not always clear (i.e. whether undamaged or damaged) and often only becomes apparent when the drums are tipped for sorting or processing. As a result, strict protocols must be implemented regarding the pallet/container spacing, total storage density and application of appropriate fire suppression systems within any li-ion battery storage space in order to mitigate the risk associated with thermal runaway and fire

Secondary resource processing challenge

From a process development standpoint, the recovery of constituents from li-ion

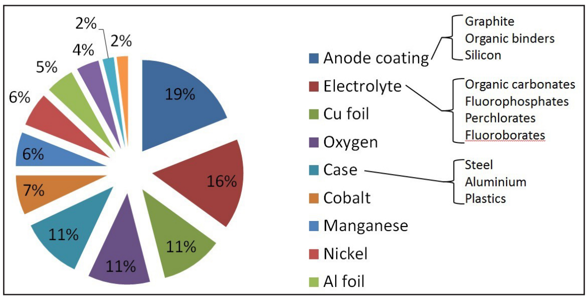

Figure 3. An example li-ion battery composition. Source: Diekmann et al

batteries presents a unique challenge compared to traditional primary metal resources due to the highly heterogeneous nature of the feed material. Currently, there are at least 14 different types of li-ion battery cathode chemistries currently existing in the market [4], each of which has even further permutations when considering specific constituents. With traditional metal resources the primary concentrate stream might have one to four elements to be recovered (e.g. copper, gold, silver and platinum). Li-ion batteries may however contain over 20 elements that demand consideration for recycling as illustrated by the example composition in Figure 3 [5].

In addition, the metal values are typically contaminated with inorganic materials, organic materials and plastics, further complicating the recycling process. To be able to separate out the valuable constituents typically requires complex process flowsheets with many individual unit operations. Under this scenario, it is critical that the physical test-work required to develop the process flowsheet is well focused and driven by techno-economic analysis.

Li-Cycle is one company with a strong focus on technology for resource recovery of end-of-lifecycle li-ion batteries. Since incorporation in 2016, Li-Cycle has developed and validated a unique process to recover 80-100% of all li-ion battery constituent materials using a two-step mechanical and hydrometallurgical system. This advanced resource recovery process, alongside concentrated efforts focused on battery sourcing from various supply chain players and a continuous prioritisation of safety, are fundamental elements supporting Li-Cycle's goal of global commercialisation of Li-Cycle Technology.

Opportunities and future outlook

It is evident that the global volume of li-ion batteries deployed in energy storage and other applications is set to increase steadily over the next two decades, underscoring the necessity for a sustainable end-of-life pathway for these batteries both now and into the future. Li-Cycle is on a mission to leverage its innovative solution to address an emerging and urgent global challenge. Li-ion batteries are increasingly powering our world and there is a need for improved technology and supply chain innovations to better recycle these batteries, and to meet the rapidly growing demand for critical and scarce battery-grade materials. Scalability, low-cost, safety and environmental sustainability are core tenets of commercialising Li-Cycle Technology. In turn, Li-Cycle seeks to enable the global transition to electromobility and reduce greenhouse gas emissions worldwide.

Lithium-ion batteries will continue to electrify our world, now and into the foreseeable future. As a key driver of the transition away from a carbon-based economy, li-ion batteries are integral to the opportunity to drastically reduce greenhouse gas emissions worldwide. However, to ensure a truly positive impact over their lifecycle, we must ensure a closed-loop system is in place to safely handle and recycle spent li-ion batteries at scale. This will enable the reintegration of critical battery materials into the li-ion battery supply chain and the broader economy, while preventing negative environmental and safety impacts. ■

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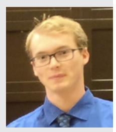


Vanadium redox flow system joins UK's frequency response market

'Flow batteries' could provide frequency response in the UK for the first time ever, as a modestly sized solar-plus-storage system has been pre-qualified into National Grid's dynamic firm frequency response (dFFR) market since late July.

Energy storage technology provider and system integrator RedT - which prefers the description 'flow machines' for its vanadium redox flow, long duration devices - and aggregator / energy data and technology specialist Open Energi achieved pre-qualification status for a 300kWh flow machine installed at an industrial site in Dorset, southern England. The device is coupled with a solar installation with a peak generation capacity of 250kW.

In related news, redT has proposed a 'reverse takeover' with Avalon Battery, in effect a merger, to create a scaled-up global flow energy storage player. You can read in-depth interviews with both parties at Energy-Storage.news.

Credit: redT.

redT's vanadium redox flow in action at a recent project in Australia.

Huge battery system to export cheap solar from South Australia

South Australia's Planning Council has approved a 500MW (AC) solar farm project, co-located with 250MW / 1,000MWh of battery energy storage from renewables developer EPS Energy.

The proposed large utility-scale solar PV plant, Robertstown Solar, will use the batteries to participate in the National Electricity Market, which despite the name spans most, not all, of Australia's national network of grids.

Robertstown Solar alone will constitute 1% of the Federal Government of Australia's target to add 33GW of renewable energy to its networks by next year under its own Renewable Energy Target. It is also expected to create 275 jobs during construction and 15 full-time roles over the operational lifetime of the project. EPS Energy, acting as development manager, said it expects the plant to be operational for 30 years.

Lithium batteries 'more widely recycled' than people think

Lithium-ion batteries are far more widely recycled than many people think, while China and South Korea are already leaders of the emerging circular economy of lithium, a report commissioned by the Swedish Energy Agency has found.

The report's author, consultant Hans Eric Melin, told Energy-Storage.news that many misconceptions and poor observations are made and repeated around lithium recycling. Melin said that more than 70% of lithium-ion batteries recycled today are processed in China and South Korea, with "high" recovery rates of materials.

More than 300 studies of primary research have been conducted worldwide in separating materials in used batteries and re-producing cathode materials or their precursors, 70% of those studies in the two aforementioned Asian battery powerhouses, and finding that "all active materials including lithium can be recycled with high efficiency".

SoftBank puts US$110m bet on Energy Vault

SoftBank's Vision Fund has made its first investment in an energy storage company, betting US$110 million on Swiss start-up Energy Vault.

Energy Vault has developed a form of energy storage inspired by pumped hydropower stations, which rely on the movement of water to store and discharge electricity. In its solution, concrete blocks weighing 35 metric tons are lowered up and down an energy storage tower, storing and releasing energy.

Energy Vault's proprietary cloud-based software autonomously controls the cranes lowering and lifting the blocks. The software relies on a combination of predictive intelligence and algorithms that account for a variety of factors, including supply and demand, grid stability, and weather.

The company was started at California's technology incubator and accelerator program Idealab Studio and launched officially in 2018.

India's 1.2GW tender for dispatchable renewables

The state enterprise Solar Energy Corporation of India (SECI) issued at the beginning of August a tender for 1,200MW of renewable power that can be used to alleviate peak demand issued on the grid, in effect mandating the use of energy storage systems (ESS).

An invitation has been issued for bids to build, own and operate renewable generating facilities and enter into 25-year power purchase agreements (PPAs).

Solar and wind (or combined or hybrid systems) must be capable of dispatching power to the grid for at least six hours each day. Off-peak energy will be provided a flat tariff payment of Rs. 2.70/kWh (US$0.038), while a separate peak tariff will be determined through 'e-Reverse Auction', the SECI invitation document said.

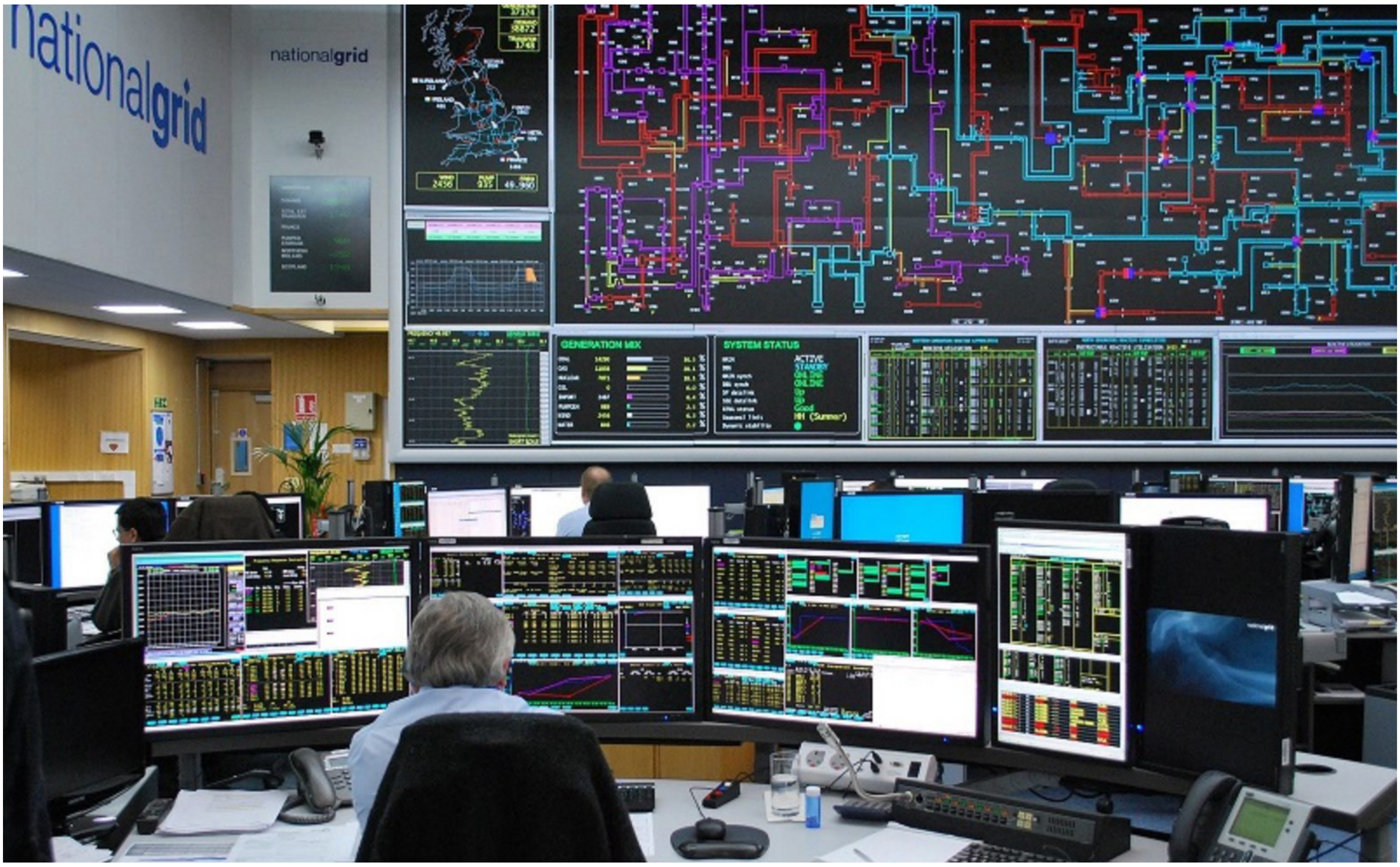
Korea's ESS fires: Batteries not to blame

After fires were started at a reported 23 battery energy storage installations in South Korea during 2018, the country's Ministry of Trade, Industry and Energy, and the national Standards Committee held a press briefing in June, revealing that in nearly every case the issue appears to have been poor management of batteries, rather than anything inherently unsafe in the batteries themselves.

According to local press, defective battery cells were not found to be the cause but instead electric shocks caused by faulty battery management, system control or battery protection systems and faulty installation practises.

Blackouts and batteries: how storage saved the UK grid

Grid | At 4:52pm on Friday 9 August 2019, the UK suffered its first wide-scale blackout in over a decade. More than 1.1 million consumers were plunged into the dark as rail lines screeched to a halt, traffic lights failed and even airports reported problems. Liam Stoker looks at the root causes, and how battery storage came to the rescue



Credit: National Grid

16:52:33.490. Those nine consecutive digits won't mean much outside of the UK's energy sector, but they're likely to be etched into folklore. It's the precise timestamp for when, on 9 August 2019, a single lightning strike sparked a cascade of events that caused the UK's first major blackout in over a decade.

More than one million people experienced power outages and widespread disruption, with not insignificant swathes of the country's rail network taken out of action, albeit temporarily. The incident made national headlines for days after, as theory and rumour abounded.

A cyber attack? No, the UK's transmission system operator National Grid quickly dismissed. Were renewables to blame? Earlier that day wind had provided more than half of the country's power, a feat which had the renewables lobby celebrating. That just hours later the lights had gone out was a fact not lost on a number of climate change sceptics.

But those theories were also dismissed by National Grid in the days after the event. While there was indeed marginally less inertia on the grid that day, courtesy of less synchronous generation, this was not something that ultimately contributed to the blackout.

The true cause, according to National Grid's preliminary investigation, released on 19 August, was perhaps both simpler and more complicated at the same time.

The UK's power blackout on 9 August highlighted the importance of batteries to the grid's stability

Thunderbolts and lightning

National Grid's timeline puts together a sequence of events that while individually manageable, together caused a drop in frequency sizeable enough to cause the blackout. Lightning struck a transmission circuit near Eaton Socon, a town in Cambridgeshire.

That lightning strike, as tens of others that hit grid infrastructure that day, was said by National Grid to have been dealt with by its protections systems normally. It did, however, trigger a Loss of Mains protocol that took around 500MW of embedded generation – domestic solar panels, batteries and the like – off the system. That loss of generation would prove pivotal.

The blackout timeline

16:52:33.490 National Grid Electricity Transmission (NGET) reports a phase to earth fault at the Eaton Socon - Wymondley circuit, caused by a lightning strike.

16:52:33.728 Orsted's Hornsea offshore wind farm starts to deload its generating capacity, having generated 799MW milliseconds before.

16:52:34 A steam turbine trips at Little Barford, taking 244MW off the system.

16:52:34 National Grid Electricity System Operator (ESO) initiates its frequency response in a bid to stabilise the grid frequency having seen it drop to 49.1Hz.

16:53:18 The ESO reports that frequency response recovers to 49.2Hz, stemming the downward curve.

16:53:31 Further units at Little Barford trip, meanwhile all of National Grid's frequency response units are being delivered in an attempt to restore the frequency.

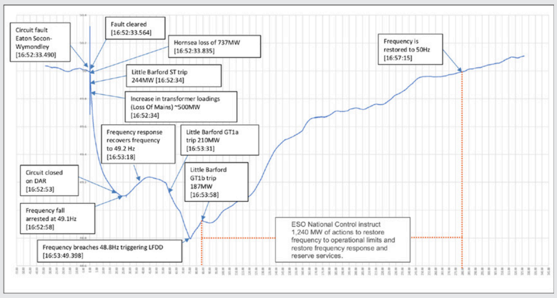
16:53:49.398 Grid frequency dips again, breaching the operationally safe 48.8Hz limit. Distribution network operators trigger LFDD protocols and disconnect 931MW of demand from the system.

16:53:58 A further unit at Little Barford trips, complicating matters further. At this point, the cumulative infeed loss caps out at 1,878MW, totalling 1,378MW of transmission system-connected generation and ~500MW of embedded generation.

16:57:15 Frequency returns to 50Hz after 1GW of DNO response and 1,240MW of control room actions taken by the ESO.

17:06 DNOs are told they can begin to restore demand to consumers.

17:37 All DNOs confirm that demand restoration is complete.



How the grid's frequency dropped and was restored on 9 August

Seconds later, within a few miles of the lightning strike, a CCGT power station, named Little Barford and owned by European power giant RWE, came offline, taking around 700MW of generation with it. Within seconds of that occurring, Orsted's Hornsea offshore wind farm also came offline, contributing to an event National Grid described as "rare and unusual".

The reasons for two sizeable generators coming offline at once are the subject of continuing investigations. National Grid said it wanted to collaborate with both RWE and Orsted to better understand the respective power stations' failure mechanisms, and both operators have remained fairly tight-lipped to date. What the system operator was almost immediately prepared to dismiss however was a previously held theory that the incidents were somehow connected to each other, or that a failure at one plant triggered a failure at the other.

49.5 - 50.5Hz
The safe operating transmission system frequency National Grid is obliged to maintain.

Altogether, around 1,378MW of generation came off the UK's transmission system within mere seconds, plunging grid frequency to an initial low of 49.1Hz, followed by a secondary dip which took frequency to 48.8Hz, far outside the safe operating limit. Attempts to use reserve capacity to restore the frequency failed, meaning that National Grid was forced to call on the UK's regionalised distribution network operators to begin Low Frequency Demand Disconnection (LFDD); essentially switching customers' power supply off.

Customers were left in the dark, but battery storage operators – 475MW worth, according to National Grid – stormed into action.

Batteries and bounces

Milliseconds after Little Barford came offline, National Grid signalled its reserve capacity to help offset the collapse. Batteries began to discharge and other generators sparked into life and, for a fleeting moment, it looked as if the worst had been averted. Hornsea's fault, however, sent frequency falling again and National Grid's reserve was insufficient.

National Grid has since clarified that its capacity reserves stand at around 1GW – the minimum amount approved under its Security and Quality of Supply Standards. This figure is designed to offset the collapse of its single largest generator of power, currently the 1.2GW Sizewell B nuclear reactor.

Losing closer to 1.4GW in seconds is an event, or rather a collection of separate, individual events, that was evidently something for which National Grid was not prepared. Whether or not the system operator should have a more significant reserve to dip into, especially as greater quantities of non-synchronous, renewable power comes onto the system, is something which is likely to end up a central element of forthcoming debates.

Nevertheless, battery storage operators discharged and other generators continued to chip away at the grid's shortfall. As DNOs began to take up to 1GW of demand off the system – the actual, technical cause of customers experiencing blackouts – grid frequency began to return to normal.

It took just two minutes and 22 seconds for that combination of load shedding and frequency response – a not inconsiderable amount provided by batteries – to restore the frequency to safe levels, four-time faster than the last time such an incident occurred in 2008. Within four minutes – 3:47 to be precise – grid frequency had been restored to its usual operating limits, significantly quicker than the 11 minutes it took a decade ago.

The incident was made all the more interesting from an operational perspective when LFDD protocols kicked in. National Grid had already instructed flexible assets to discharge in a bid to make up for the lost capacity, but the moment DNOs started shedding load, National Grid quickly felt a bounce in the frequency and batteries were just as quickly instructed to respond. "When National Grid cut off the power, the frequency bounced back very quickly, sending the system the other way and meaning our battery sites were then called on to balance the grid by taking power out," Anesco asset management director Mike Ryan said.

Within four minutes, the UK's electricity system – widely regarded as one of the most secure in the world – tripped, recovered and was restored to within safe operational limits. Batteries played a pivotal role, but the fact the system tripped altogether has been an event contentious enough to trigger two separate official investigations.

Could more batteries have been used to greater effect?

What the future holds

Limejump chief executive Erik Nygard has called for a significant increase in firm frequency response (FFR) styled products which can procure the kind of fast-acting response necessary to offset such sharp drops in grid frequency.

National Grid's 200MW-strong portfolio of enhanced frequency response (EFR)

Grid-scale battery storage is experiencing a boom in the UK

Credit: Vattenfall

batteries, which respond to frequency events in 0.5 seconds, did indeed help the system operator's response, but a drop off in the rate of FFR procurement in 2017 has meant that fewer batteries and less DSR – the kind of non-synchronous generation that's vital during periods of low inertia – are being supported.

Nygard says that National Grid could effectively double its FFR-ready fleet, possibly mitigating for circumstances like Friday 9 August, at a cost of around £100 million per year. Given that cost would effectively be passed onto consumers via levies, and how sensitive a subject energy bills have become in the UK, what equates to roughly a few pounds extra per year could be a small price to pay for energy security.

Jonathan Ainley, head of public affairs and UK programme manager at KiWi Power, meanwhile, has said that National Grid must do more to open up the Balancing Mechanism (BM) to more significant quantities of distributed generation, arguing that it is currently "dominated" by large-scale, centralised generators of a dirtier heritage.

Indeed, the UK is experiencing a grid-scale battery boom at present. The aforementioned 200MW of EFR-backed batteries provided the industry a stable base to build upon, and developers and financiers alike are now driving a not insignificant amount of activity. *PV Tech Power* publisher Solar Media's in-house market research team has previously guided that as much as 500MW of utility-scale battery storage could be built this year alone, and that's without even considering the nascent C&I and residential markets.

The areas impacting battery storage and its ability to help the UK's grid security lie elsewhere. While it's true that National Grid's distributed energy resource (DER) desk – set up by the energy system operator last year to help operators of smaller, more flexible assets gain access to new markets – has led to a boon in the DER capacity bidding into such markets, some rather sizeable barriers to entry remain, chiefly the need for an energy supply licence, which is a particularly prohibitive obstacle for smaller companies.

"With the right markets, flexibility providers can rapidly bring forward fast-acting, flexible capacity to help National Grid avoid a repeat of [August's blackout] and create a smarter, cleaner, more resilient energy system for everyone," Ainley said.

Meanwhile, there's also the not-insignificant problem created by inertia, or indeed the lack of it. Friday 9 August witnessed considerable wind generation and, having produced as much as 50% earlier in the day, the UK's wind fleet was providing around 33% at the time of the frequency event. As a result, the amount of inertia on the system is expected to have been low.

Inertia's role on the system and whether or not it had much of an impact on the events of that day have appeared to divide opinion in the energy sector so far, and will inevitably be a line of inquiry in both Ofgem and the BEIS' investigations. Nygard says the UK would do well to create a system which produced more inertia as non-synchronous generation grows, either by adding more batteries and DSR or synthetically by forcing such generators to do so via their inverters.

Tinkering with the energy market itself may also elicit a response. Given the entire incident took just under four minutes from trip to recovery, energy markets – which trade in 30-minute settlement periods – were all but unaware of what was happening and unless they were actively looking, traders would have been none the wiser. Bringing those markets to settle more frequently – a technical challenge, but not an impossibility – may have allowed price signals to act as the first canary down the mine so to speak, and the market could have responded in kind.

The incident itself, while perhaps alarming at the time, has arguably demonstrated the efficacy of National Grid's systems and protocols. If it weren't for the "rare and unusual" event of ~1.4GW of capacity collapsing in seconds, consumers would have been none the wiser. What is evident is that grid security is fragile and the margin at which National Grid operates is perhaps no longer fit for a system changing at rapid pace.

National Grid's interim report has provided a skeleton that will inevitably be fleshed out when the final report is published in mid-September. Alternative investigations, led by both Ofgem and the government's official Energy Emergencies Executive Committee (E3C), will establish if any of the parties involved were at fault and, if they were, fines are likely to be issued. National Grid itself could be fined as much as 10% of its annual turnover if it is found to have breached its licence conditions.

The chapters in the final report crucial to the sector will lie somewhere towards the back. Those will establish not just recommendations to prevent similar events from happening in the future, but a timeline for those to be enacted. Flexibility providers consider it highly likely that National Grid's reserve capacity will simply have to increase in the wake of 9 August 2019, something which could see more batteries land reserve contracts and, thus, become bankable.

Battery storage came to the UK's rescue on 9 August 2019, demonstrating – as if it was needed – the role the asset class has to play in grid stability. In the aftermath of that event, that role only looks like increasing. ■

Flex and flexibility

Grids | Power markets are evolving and beginning to value flexibility ahead of generation. As the UK's networks companies move to embrace flexible generation assets, Liam Stoker spoke to some of the country's leading providers to identify the hurdles and solutions to a more flexible power grid

Credit: Getty Images

The UK's power sector is evolving at such a rate that generators, grid operators and utilities alike can scarcely believe the pace of change. It seems a new renewable energy record tumbles each week, with coal falling off the grid for large parts of the year already.

While this is unquestionably good news, it's left the country's transmission and distribution network operators (DNOs) in something of a quandary. There is now a clear and present – and some might add urgent – need for far greater quantities of flexible generation to both balance the grid and offset the need for more costly reinforcement works. A power market that once valued generation above everything now considers flexibility worth its weight in gold or, indeed, lithium-ion.

The networks have been proactive in this regard, and have taken to sourcing their own flexibility. Localised tenders have been introduced, helping connect with owners and operators of flexible assets to ease distribution-level grid constraints. Having tentatively explored the market for such auctions in 2018, DNOs are now transferring flexibility markets into business-as-usual activities, and using them to future-proof large sections of the grid.

But in some locations, the market appears at an impasse. Flexibility is a resource in demand, but providers are either shying away from tenders or simply do not have the projects required, nor the economic business case to build.

In order to address this shortfall, *PV Tech Power* sister publication *Current±* collaborated with the UK's Energy Networks Association and assembled 16 of the UK's leading flexibility providers, aggregators, asset optimisers and energy technology firms to determine precisely what hurdles the flexibility market still faced and, crucially, how the sector could overcome them.

The UK's power network is beginning to value flexibility over generation

A transparent need

One of the significant hurdles raised by market operators spoken to was a distinct lack of necessary data and transparency on the part of the DNOs. At present, data that is shared with the market pertaining to possible areas of curtailment is limited to where the congested areas are today, and is given in broader times.

That, a number of companies said, simply wasn't good enough for them to be able to build a business case robust enough to stand up a new battery storage project or other generating assets. "Data is absolutely key," said Mark Tarry, chief financial officer at asset developer AMP, adding that network operator's Long Term Development Statements – which formally document areas of works – are limited in their scope to areas of constraint today. "What you can't do is try and estimate where the areas of constraint will be in two, three or five years' time, and that is what is important," Tarry said.

Better data is needed to identify network constraints where, for example, battery projects would help ease congestion

This is significant for project lead times, particularly if there is any involvement from a community energy group or other party such as a landowner, as is frequently the case in the UK power sector. Identifying an appropriate site, conducting due diligence, negotiating lease fees, agreeing contract terms, building a bankable business case, pursuing and sealing planning permission, gaining a grid connection agreement, and all the associated procurement, engineering and construction works mean it can be years before a project can get off the ground. Jo-Jo Hubbard, founder at blockchain specialist Electron, concluded that time remained amongst the biggest challenges across the board for small-scale flexibility assets. It's evident that even the most nimble and expedient of project developers cannot move fast enough for the status quo.

Credit: Zenobe Energy

James Basden, founder and director at battery storage developer Zenobe, echoed Tarry's sentiments, commenting that transparency surrounding data, particularly those relating to networks and areas of constraint, needed to be drastically improved.

"If we can see what the potential is to get in and put new flexibility assets on [to the grid], whether there is a rate of return that's acceptable… looking at how different technologies could be a better solution than conventional grid reinforcement, it's something that could be really very interesting… but it's almost impossible get hold of that data," Basden said.

And when that data is forthcoming, it might not even be particularly useful. Tarry spoke of a time when he was shown constraint information – essentially the projected load versus the capacity – of a particular substation in the UK. In order to forecast how that load may develop over time, the DNO in question had applied a generic growth rate of 1%, something it had applied universally across its licensed network.

That substation was already at 80% of its capacity, but what the DNO had failed to factor into its forecasting was that, next door, a new business park was to be built under the premise of creating 15,000 jobs. Not only that, but a considerable factor of that development's sustainability credentials was the addition of electric vehicle chargers, contributing to what would have been a sizeable addition to the load on that substation. That information had been in the public domain, and could have been used intelligently by the DNO to create a more accurate, forward-looking picture of future constraint.

The solution, according to our panel, is for the DNOs to ramp up their efforts when it comes to data and transparency. If the network operator can forecast constraint zones two to five years in the future, then these forecasts should be forthcoming to take into account the inevitable lag in project lead times.

Furthermore, the data provided needs to be far more granular than is currently on the table. If such constraint data was to be made available on a substation-by-substation basis, then project developers would be able to pinpoint precisely the areas of need, and target their services more accurately than is currently the case.

This point becomes all the more salient when network charges are taken into account, and how this level of granularity could be adopted into the densely complicated area which is network charging, and used to great effect.

Charging forward

The UK's network infrastructure is essentially owned by monopolies regulated by the country's regulator Ofgem, meaning that their respective revenues are tightly controlled. This is achieved through network charging, which is essentially a cost levied against generators and suppliers in order to transmit and distribute power via the country's cables and lines. These charges are many and complex, and subject to a significant ongoing review.

The aforementioned Ofgem is facing a quandary; how to evolve those charges alongside a changing energy system, while maintaining their impartiality and equality. It's something the energy sector remains split on, and Ofgem has been on the end of some stern criticism surrounding recent proposals that the flexibility industry has warned could render large numbers of projects uneconomical.

The panel of flexibility providers assembled was unequivocal that uncertainty stemming from Ofgem's charging reviews had hindered flexibility projects coming forward, but were equally certain that, with a few minor tweaks, they could be used as a signal within areas of constraint that flexibility projects, and services, are needed.

These tweaks divided the room, representing the difficult nature of Ofgem's job. Conor Maher-McWilliams, head of flexibility at Kaluza, which is part of the OVO Group, said that price signals could be broadcast through network charging opportunities – essentially making it cheaper to operate a flexible generation asset than it might otherwise have been – pre-empting an overloaded substation and direct procurement.

Network charges could stand to be an ideal way of incentivising flexibility asset development and indeed targeting it, but nothing does the trick quite like a market auction, as the network operators have already established.

Markets and contracts

When it comes to how best to procure flexibility, timing once again rears its head. Melanie Ellis, head of regulatory affairs at aggregator Limejump, said that it was critical that project lead times are taken into account when tendering for services. There's no point tendering for flexibility for six months' time in an area where there's little existing flexible generation, for example.

It's also critical that the contract lengths on offer remain diverse. Long-term contracts are perfect if projects need financing – nothing quite sates a financier like multiple years of predictable revenues – but locking a sizeable battery, for example, into four years of having to be available during peak times, when revenues and values may well shift elsewhere, could dissuade operators from taking the plunge. Claire Addison, head of regulation at Flexitricity, said there was a "spectrum of views" when it came to contract lengths.

Handing out lengthy contracts can also negatively impact market liquidity. Locking in sizeable contracts for years at a time could limit availability in future years and, as a result, prevent new projects from coming forward.

There is also something of a split between what asset owners want and what DNOs need. Owners, as Hubbard says, need to be able to have explicit, concrete guarantees that they can provide flexibility in return for revenues and if there are non-delivery penalties, then a clear idea of what those are precisely. Network operators on the other hand simply need to know that there's enough flexibility on the network in the near future to balance should the need arise.

Given the considerations at hand, the network operators face a Goldilocks-esque dilemma when it comes to procuring flexibility. One such possibility mooted by the panel would require more of the previously highlighted transparency, but would exhibit the direct value flexible generators can provide. If, for instance, a network was considering traditional reinforcement works, said network could publish its cost expectations and the additional capacity to be delivered, and invite flexibility providers to compete against those parameters. Basden was convinced that in doing so, it would be "fairly rare to find a case where the battery doesn't outperform the reinforcement".

If the data were more granular, network charging reformed to send the initial signal and the products designed in the correct way, then all that's left is to properly engage, both with flexibility providers, communities and consumers.

But even that isn't as straight forward as it may first appear.

Prior engagements

There is a stated desire for community energy groups to be brought into the fold when flexibility is procured, given their inherent engagement with the very communities the DNOs serve. These are often made up of likeminded individuals who have a passion for renewable electricity, but not necessarily the expertise to see a project through. As a result, these groups are likely to need a broader spectrum of support, be it financial, legal or technical, when it comes to bidding into flexibility markets.

There needs to be a greater degree of "hand holding" in the early stages of project development, Flexitricity's Claire Addison said, which could take the form of a series of case studies or successful project examples. That way, rather than having to navigate the complicated UK energy market on their own, community groups could assess which project or case study more closely resembles their own and simply follow a (hopefully) well-trodden path.

Then it becomes a case of engaging with perhaps the least engaged party of all: the consumer.

The UK power market isn't exactly famed for its consumer-centric approach. Since it was privatised in the 1990s, the energy retail space in the UK has treated consumers more like assets than valued customers, much to the chagrin of consumer groups and politicians alike. A cap on what energy companies could charge customers on standard tariffs, enacted at the start of 2019, has only served to complicate relations further.

But there are signs of hope on the horizon. A number of trials which involve bringing consumers into demand-side response markets have been successful, and energy companies are now waking up to the inherent value of having hundreds of thousands of informed and engaged customers.

Maher-McWilliams, whose parent company could be about to become the UK's second-largest energy supplier, is vocal in his support of equipping consumers with all they need to enter such markets – both hardware and otherwise – and then ensuring that the benefits are shared with them.

It would appear that while it's the DNOs that ultimately need the flexibility, and indeed should bear some responsibility in consumer engagement and education, the relationship ultimately lies with the provider of energy. The DNOs should therefore be more concerned with ensuring the market framework is correct, enabling their participation in the first place.

"We as aggregators need to work out ways of sharing the benefits with domestic consumers by letting them know up front what those benefits might be," Addison said, adding that it's not just those that are presently engaged that need convincing. "Early adopters aren't going to tip the dial and you need engagement with a broader spectrum of customers, and much more concrete ways of sharing the financial benefit."

Flexibility is a nascent market for the UK power sector, so enamoured as it has been with generation, to consider. But it is nevertheless coming to terms with the new energy paradigm and flexibility markets are opening up across the country, from the Shetland Isles in the north to Cornwall's south coast.

There are undoubtedly lessons to learn and regulations to be tweaked, but this is a sector that's as much as a learning curve for network operators and regulators alike. If these adjustments can be made, flexibility could be on the cusp of a transformative boom. ■

The GenGame example

Over the course of two years, more than 2,000 of Northern Powergrid's customers in the north east of the country shaved an average of 11% off their electricity consumption simply, principally by playing a game developed by gamification firm GenGame.

Downloaded to mobile devices via Facebook, the game communicated with devices installed in homes which monitored consumption. During periods of high demand on the grid, GenGame prompted players to reduce their consumption in return for points, which were used each month in order to increase their chances of winning portions of a £350 cash prize.

Northern Powergrid assessed the responses, and found that while the average customer turned down to the effect of 305W, some consumers managed to switch off as much as 4.9kW by switching off their EV chargers, for example.

The premise behind the game is simple, according to GenGame chief executive Stephane Lee-Favier. A consumer might only save 10p by turning their washing machine on at a less convenient time, but if doing so could help them win as much as £100, then that stands to be far more successful at incentivising behavioural change.

Credit: Northern Power Grid

GenGame is helping customers save money on power bills

Using batteries to reduce the impact of grid maintenance

Storage applications | Batteries are increasingly widely used in grid balancing, but there are many more applications where a battery can play an important role. With electric grids requiring periodic maintenance, batteries can stand in for the grid during downtime in order to reduce the impact on industry and households, writes Dieter Castelein

We consume more and more electricity every day. The utilities and grid distribution operators must ensure industry and households are provided with the necessary connections. In order to do that, the grid must be expanded, and must be maintained periodically. This means that more often the power on the grid will be cut off while the necessary works are undertaken.

How is this currently done?

Today, when the grid is being maintained, the power is cut off at the transformer where the maintenance is done.

Nowadays, it is not possible to do any business or run a household without having power available; that is why during this time of maintainance, a solution has to be found to keeping the lights on.

It's all about efficiency

Traditionally, the energy demand for these periods has been met by diesel-fuelled generators. To absorb the peak demands of the grid and to prevent power loss, an oversized setup of generators is used to guarantee a consistent flow of energy.

Research from multiple festivals, where a lot of diesel generators are used, show that the average load was 12%, while the generators are the most efficient between 60% and 80% of their maximum engine power output. See Figure 1 for the energy data of a four-day festival and the average power output of the diesel generator.

The inefficient use of generators means that a great deal of diesel is being burned unnecessarily. These emissions contribute to climate change and poor air quality in cities.

Moreover, we see that more and more buildings have solar panels on their rooftops. A diesel generator cannot cope with current coming back on its output

Battery systems can play an important role in providing grid continuity during maintenance periods

Credit: Greener power solutions

side. This means that when the load on the grid is smaller than what the solar panels in this area are producing, this energy has to be (quite literally) burnt away in big heaters. Which naturally is, again, a waste of energy and is not helping in our efforts to tackle climate change.

Also, these diesel generators produce quite some noise. This can be irritating to inhabitants when this solution is applied next to their bedroom.

Can batteries be a solutions during these grid take-overs?

Batteries can provide a solution to a couple of the challenges that are faced during these grid take-overs, but also have a challenge of their own. When applying a battery in this situation, you can only use as many kWhs as the batteries you bring to the site. When the battery has 0% charge left, it cannot fill itself anymore. With a generator on the other hand, you could just fill up the diesel again and start it back up.

That is why the best possible combination is a hybrid system. The benefits of the hybrid system are:

1. A significant saving in fuel consumption;
2. Reduction in CO2 emissions by using

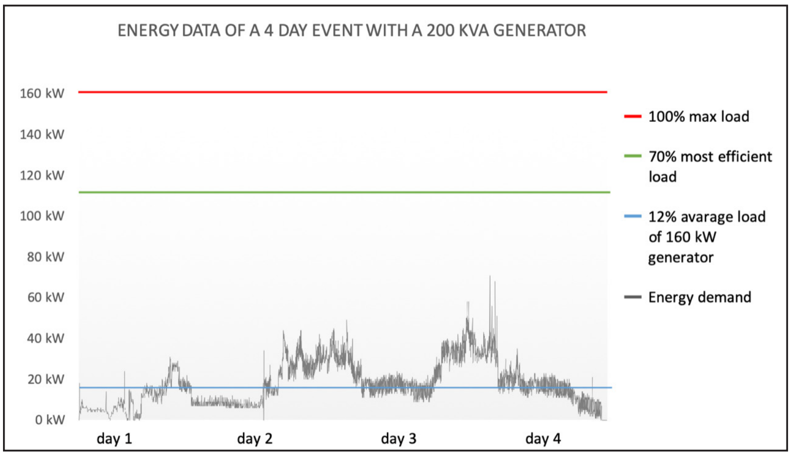


Figure 1. Energy data of a four-day event with a 200kva generator

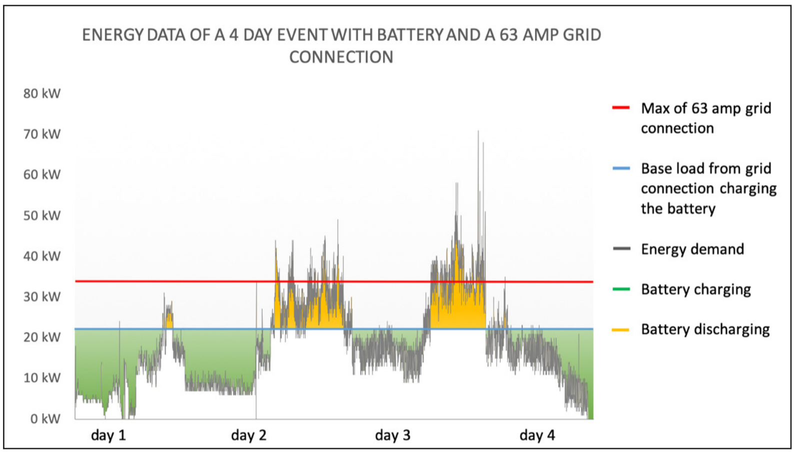
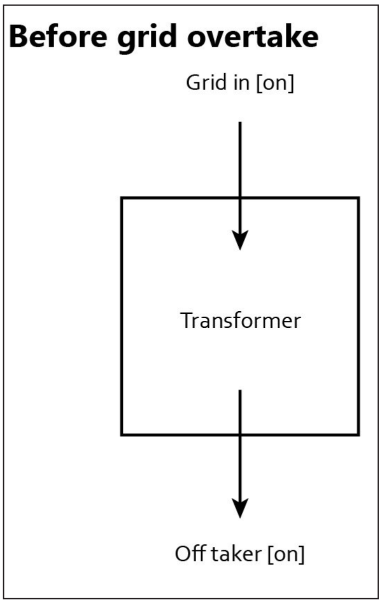
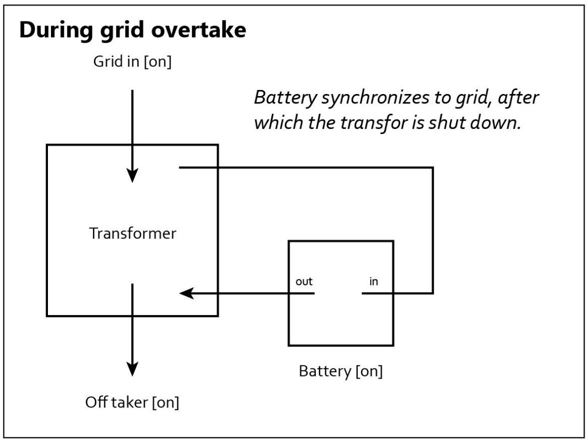


Figure 2. Energy data of a four-day event with a battery and a 63 amp grid connection





▲ **Figure 4. During grid overtake**

◀ **Figure 3. Grid before maintenance**

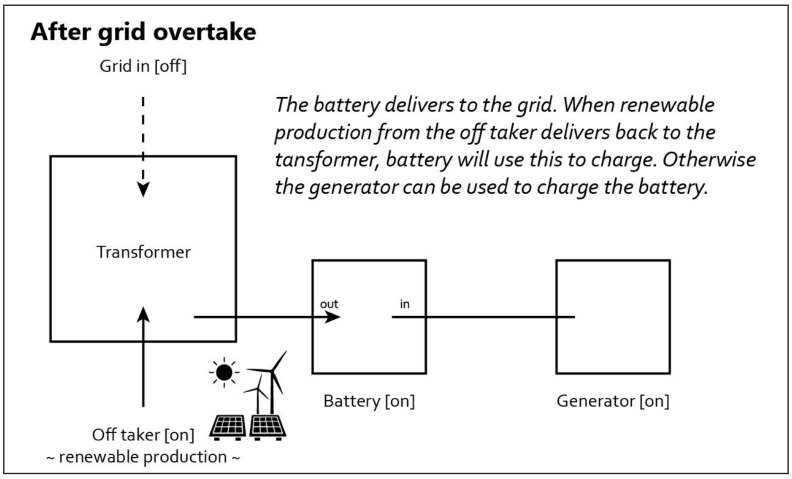


Figure 5. After grid-overtake

the battery as a "peak shaver" (see Figure 2);
3. Low noise: during the night hours the battery can provide the complete supply of power;
4. Energy reduction: energy generated by renewable sources delivered back to the grid during the day is stored in the battery and can power the grid at nighttime;
5. Compact arrangement makes ideal use in urban areas;
6. Reliable and clean power;
7. The grid can be taken-over without the power going out.

How would this new situation work?

Let us first define three situations when a grid take-over happens. These three scenario(s) will be explained in more detail after:

1. Before grid overtake
2. During grid overtake
3. After grid overtake

Before grid overtake

Prior to maintenance, the grid requiring maintenance supplies power to the off-taker via a transformer, as shown in Figure 3.

During grid over-take

When the battery is in place, and the maintenance can start, the battery will synchronise to the grid and start delivering power to the off-takers, alongside the power that is delivered by the transformer. See Figure 4.

The battery can now even take over all the power consumption that is happening on the off-taker's side, so the electricians can safely disconnect the grid at the transformer side.

After grid over-take

When the power is disconnected at the transformer side, the battery is solely providing all the power that is needed on the off-taker side.

Whenever there is an overproduction of solar energy from rooftops, the battery will start charging, or when there is an underproduction, the battery will deliver the power that is required.

In order to guarantee that the power is always there, a diesel generator is attached to the input of the battery, so that it can charge back up on 70% of the diesel generator capacity in the shortest amount of time. The new situation looks as Figure 5.

What is the upside?

Batteries provide the event with energy, and when the state of charge of the battery reaches a certain threshold, the generator will charge the battery at its most efficient load of 70%. This method can reduce emissions by up to 62% and reduce operating hours of generators up to 85%. Next, to the reduction of emissions, this method also reduces the running time significantly, so there is less noise from the generators. ■

Author

Dieter is a wind energy engineer who specialised in sustainability and green energy during his studies. His ideal of a world running solely on renewable energy is realised and spread through Greener power solutions, https://greener.nu

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