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SPECIAL REPORT

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INTRODUCTION

Welcome to this special supplement on energy storage, which it is my pleasure to introduce. We are looking at a global market which has already come a long way and shows no sign of looking back. From residential to grid-scale, to microgrids and vehicle-to-grid, from safety to finance, we've condensed some of the biggest topics and themes into a handy collection which we hope will help illuminate and inform you all. Energy storage is growing into a cornerstone of the grid (and is arguably even more important off-grid); a vital component of decentralised, decarbonised and even digitalised future energy systems. Yet so many misconceptions and concerns remain and there is still so much work to be done in helping stakeholders gain a better understanding of what batteries – and other forms of energy storage – can do.

We've focused primarily on electricity storage here, and we've been fortunate to speak with the likes of Nancy Pfund at DBL Partners, one of Tesla's earliest backers, who has hardly been resting on her laurels since then and now counts the likes of Advanced Microgrid Solutions and Primus Power in her portfolio. Nancy offers a Q&A 'masterclass' on what it is to be a pioneering investor in energy storage and to make positive social contributions in the process. Elsewhere, experts at Fraunhofer ISE have discussed two of their ongoing projects to ensure the safety of household lithium-ion batteries, developer Camborne Capital talk about deploying Tesla Powerpacks in the UK, S&C Electric talk modern microgrids and Navigant write about the critical importance of energy storage software. There's plenty more to enjoy and digest too and we hope you find it useful.

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SAFETY FIRST:

LITHIUM-ION BATTERIES IN STORAGE SYSTEMS UNDER CLOSE SCRUTINY

The majority of advanced energy storage systems are running on lithium-ion batteries and safety is perhaps the most critical aspect of their deployment, especially when they are to be used in consumers' homes. Adequate testing procedures and standards are yet to be developed for the most part, and with 34,000 systems already in the field in Germany alone, the need to do so seems critical at this stage in the market's growth. Dr Matthias Vetter and Stephan Lux of the Fraunhofer Institute for Solar Energy discuss two current projects they are working on that look at exactly that, both in standalone systems and when paired with solar PV.

In 2016 in Germany 34.2% of electricity was generated by renewable energy sources. A major topic is the fluctuation of photovoltaic systems and wind turbines. Increasing the flexibility of the power system through storage systems is therefore being addressed by science and industry at all levels. Currently Germany with its large-scale dissemination of roof-mounted PV systems is becoming a leading market for so-called home storage systems. These storage systems can increase the self-consumption of the produced PV energy significantly and are becoming more and more economically feasible as storage prices are dropping very fast. As these storage systems are installed in private households, they have to be durable, safe and efficient. A study by RWTH pointed out that in spring 2016 approximately 34,000 systems have been installed in Germany with a storage size between 2 and 10kWh. There are different storage technologies on the market, but the majority of these systems are based on lithium-ion batteries. However, adequate standards and testing procedures do not exist for this technology. The Fraunhofer Institute for Solar Energy Systems ISE is now working on two research projects which address the aspects related to the acceptance and dissemination of the technology. The German Federal Ministry for Economic Affairs and Energy (BMWi) provides funding for both projects.

Fig. 1: Fraunhofer ISE's test rig for PV home storage systems. Before battery storage tests start the set-up as well as all necessary process steps are checked once again. ©Fraunhofer ISE

In principle also other established technologies like lead-acid batteries and new promising technologies like sodium-ion batteries are an alternative for residential applications. However, those new technologies have to compete with lithium-ion batteries, which have a longer calendar and cycle lifetimes, provide higher efficiencies and are able to provide a huge range of services and require less space, e.g. compared to conventional lead-acid batteries. Therefore lithium-ion batteries are gaining popularity for use in stationary applications (grid-coupled and grid-independent), besides their use in electric mobility applications. Synergy effects can be realised here that quickly lead to economies-of-scale effects although the requirements for these two applications differ.

Safety, a central issue for lithium-ion batteries, depends on different factors weighted according to the application. Heat localised over a small area at defects will dissipate slowly and can lead to material failure or fire in the worst case, as lithium-ion batteries are containing flammable electrolyte and might produce their own oxygen in case of a so called thermal runaway. One burning cell might ignite the adjacent cell (propagation effect), leading to a hazardous event. Functional safety of the battery system, comprising of battery management, cells, switching units and power electronics, is another issue as overcharging and deep discharge has to be prevented for each single cell in the system.

There exist many different approaches to ensure safety. The basic prerequisites are the selection of cells with high quality and a reliable battery management system as well as an efficient and effective thermal management.

Whereas for example lead-acid batteries have been tested in practice for many years and huge information on field experiences is available, lithium-ion batteries must first prove themselves as stationary storage systems in order to win the trust of consumers. Long-term experience has not yet been available in such applications and therefore cannot be applied.

Standards

One important issue is that fixed standards for home storage do not exist yet. If the current situation is considered, a mixture of rules is used being partially in a draft version up to now.

Currently used standards for Certification (1/2017)

- Transportation : UN38.3
- Safety:
- AR-E 2510 - 50
  AR-E 2510 - 2
  EN 62619
  EN 61000
  EN61010-1
- Safety Guidelines Lithium-ion Home Battery Storage Systems
  (rev. 1, NOV 2014)

The Safety Guidelines for lithium-ion Home Battery Storage Systems have been developed in a voluntary scheme organized by German BSW. Leading research organizations, manufacturers and test institutes worked together, but the safety guidelines are not a legal standard today. The Application Rules AR-E 2510-50 and AR-E 2510-2 are intended for stationary storage and published by German VDE but unfortunately they are in a draft version since years. The EN 62619 is focusing on industrial application like fork lifters and the standards EN 61000 and 61010-1 are not made for systems containing lithium-ion batteries.

Fig. 2.: Storage systems under test at Fraunhofer ISE. ©Fraunhofer ISE

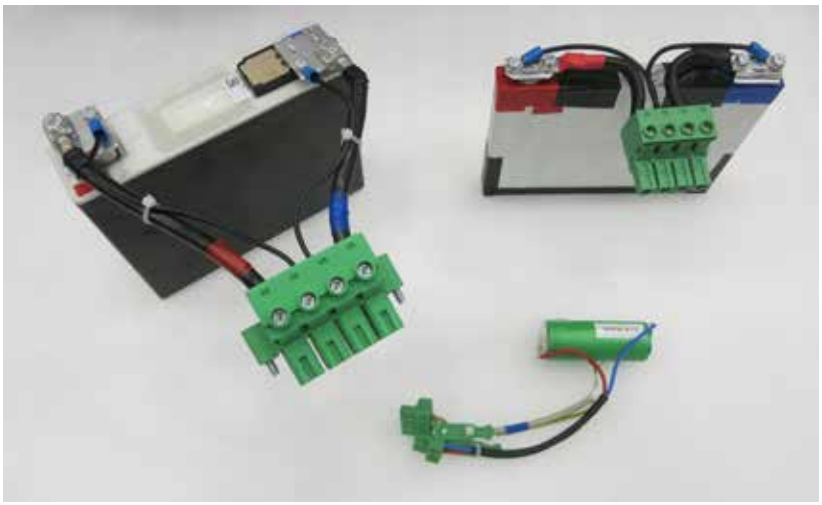

Fig. 3: Lithium-ion cells used in home storage system prepared for test. ©Fraunhofer ISE

So to say UN 38.3 Transport directive is still one of the most trusted standards for those devices.

A final standard should cover aspects of functional safety, propagation and especially the safety behavior of aged systems as life times of more than 10 years are the target in stationary applications.

Project 'Safety First': Safe grid-supportive storage for households

In the joint research project 'Safety First', Fraunhofer ISE partners with the Karlsruhe Institute for Technology (KIT) and the Centre for Solar Energy and Hydrogen Research (ZSW) to investigate the current safety, quality and grid suitability of commercially available residential battery storage systems. In this project, scientists develop recommendations for manufacturers, standardisation bodies and authorities based on their investigations on home storage systems

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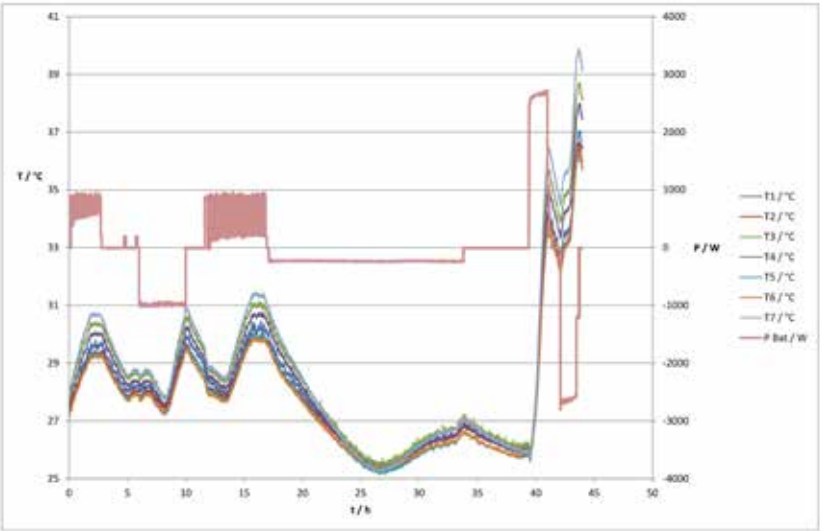

Fig. 4: Power profile with temperature distribution in a typical lithium-ion module of a commercial available home storage system. ©Fraunhofer ISE

for increasing self-consumption. These home storage systems based on lithium-ion batteries are becoming increasingly inexpensive and thus more attractive for the end user. Up to now, however, standardised, verifiable criteria for assessing the efficiency and safety of these systems have been lacking. Therefore the goal of this project is to assess commercially available PV home storage systems in order to prepare future safety standards.

In the project, twenty home storage systems undergo long-term tests, carried out on test rigs that imitate actual operation in private households. Using special load profiles, it is not only possible to analyse the safety of new batteries direct from the factory but also at later ageing stages. Data is collected on the safety properties and the expected lifetime of the storage systems. Also the change of the efficiency over the lifetime will be registered. Complementary to the analyses on the home storage systems, singular lithium-ion battery cells are selected and analysed at Fraunhofer ISE and at ZSW. Fraunhofer ISE analyses and evaluates the ageing properties of various cell types and the entire system in parallel. With this acquired knowledge, information about ageing and safety can be collected in the future by merely performing short investigative tests. Based on the results in the laboratory, the research team compiles recommendations so that the properties of modern lithium-ion batteries are factored into the standards, test specifications and funding.

Beyond those, internal parameters like temperature distribution, single cell voltage and current distribution in modules that are switched in parallel are collected to capture inhomogeneity in the storage systems. This inhomogeneity tends to increase over the lifetime of the system and might lead to failures and safety issues.

In the example in figure 4 the power of a commercially available battery module is depicted along with the temperature of seven temperature sensors that are mounted in the battery module. The measurement was done at an ambient temperature of 25° C and the battery module is passive cooled by natural convection. It is obvious that at very low power levels the temperature distribution is very equal, but if the battery is operated at maximum power, the maximum temperature is 14 K above ambient temperature and the temperature spread inside the module reaches 4° K between cells. In case of operating these systems in a Mediterranean or tropical climate, fast degradation and inhomogeneous ageing effects are expected.

Project 'SpeiSi': Safety of stationary storage systems for solar electricity

Fraunhofer ISE is additionally working on a research project, headed by TÜV Rheinland, on the topic of safety and reliability of PV systems with storage. Project 'SpeiSi' investigates the safety of such systems, which are installed mainly with the aim of increasing self-consumption. In cooperation with TÜV-Rheinland, the German Section of the International Solar Energy Society and the Centre for Solar Energy and Hydrogen Research (ZSW), weak points in handling, installation and operation are analysed within the project. Existing regulations for stationary battery systems consider separate battery rooms for systems with emergency or back-up power or for systems with an uninterruptable power supply (UPS). The regulations must be adapted to accommodate a broader use of stationary energy storage with higher energy content like lithium-ion batteries in private homes. Beyond, criteria for determining the performance of PV storage systems, among other things, shall be developed, allowing further information about the quality of the energy management to be gained.

At Fraunhofer ISE three aspects affecting the safety of stationary PV storage systems are considered. For one, a study was carried out on suitable storage technologies and their respective potential hazards. Secondly the probability of light arcs developing in the system and their detection – or better yet the avoidance thereof – was investigated. Thirdly the behavior of switching and safety devices undergoing pronounced cyclical stress was analysed. In particular, the researchers would like to find out if the electrical connections become weaker in the course of time, which would lead to a higher fire risk.

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A NEW ERA FOR BATTERY ENERGY STORAGE

While energy storage has been around since the advent of hydro, the last several years have seen the emergence of battery energy storage as the preferred choice, particularly lithium-ion due to its energy density. Cost, portability, sizing and scalability all play a role in lithium's favored position. Yet, despite the efforts of large brand named lithium battery manufacturers with impressive balance sheets getting into the energy storage market, the amount and volume of MW deployments in the field is small compared to the need.

There is no secret about the safety issues that some consumer level lithium-ion batteries have had recently. The fact is, the same technology, with the same flammable electrolyte is used in all lithium-ion batteries in commercial energy storage products on the market. The risk of fire and explosion exists in all brands (except what is described below), and that safety risk is heightened the closer energy storage gets to load centers and more populated areas.

The second technological barrier to mass deployment of lithium battery energy storage is performance. Lithium batteries have had challenges following load signals, reaching nameplate cycle durations, meeting power demands, and in maintaining uptime. Had these market needs been met, in combination with a regulatory environment that appropriately values the benefit of energy storage, the proliferation of battery energy storage in the market would be much higher today.

Alevo delivers its first GridBank to the Snook Substation in Hagerstown, MD. The 2MW/1MWh GridBank energy storage system is the first of 12 MWs that Alevo will be installing in Hagerstown.

The New Energy Storage Technology – It's All About the Battery

Systems Integration and Project Development each play an important role in a successful energy storage project, but nothing will determine the long-term success like the choice of battery. The team at Alevo™ has been developing breakthrough electrolyte science for over a decade and has produced a new electrolyte for lithium-ion batteries that is non-flammable, there is nothing in its composition that can catch fire so the risk of fire is eliminated. This same property reduces internal resistance to a level where the power output remains constant throughout the lifetime of the battery, which is over 50,000 full depth of discharge cycles, extreme long life compared to any other lithium battery.

The GridBank GB35 (35 kWh / 70 kW) can be used for behind the meter commercial and industrial applications.

The Alevo GridBank™ is a 2MW/1MWh workhorse that is best suited for higher use cases on and off the grid. Its mini versions - the GB™35 & 50 kWh are behind the meter products well suited for critical must run situations like hospitals and data centers. They are also perfect for EV charging stations due to their safety and higher charge/discharge speeds. All Alevo products are non-flammable and boast extreme long life, robustness and reliability.

Alevo Stacked Services™ - Multiple Incomes Streams from One Energy Storage System

Alevo GridBanks are capable and well suited for high power applications from twenty milliseconds to less than one hour in duration, they also work in more energy centric multi-hour applications. This opens up the list of applications Alevo is suitable for - Regulation and other Ancillary Services, Peak Shaving, T&D Deferral as well as Renewables Integration can all be performed singly, sequentially or simultaneously by a single GridBank, making them the Swiss army knife like tool for the grid – multi-application flexibility means multiple revenue streams for its operator.

Alevo also has its own analytics division which combines consulting services with high performance computing (HPC) and proprietary intelligence software to identify the best possible use of energy storage, whether it be GridBanks or other energy storage products. Alevo Analytics determines the highest revenue applications and energy storage size requirements as well as the best suited energy storage systems for grids worldwide.

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RESPONDING TO DEMAND

The potential for storage to help stabilise the grid has finally been recognised in the UK, where battery projects took all of the 200MW on offer in a recent frequency response tender. David Pickup looks at the evolving role of storage in the future grid and how further policy support can help it flourish.

Energy storage is big news and, thanks in part to some high-profile companies such as Tesla, has got people in many different industries very excited. And rightly so; as the costs have fallen, for lithium-ion in particular, large-scale storage systems are becoming viable across the world and have the ability to revolutionise power networks.

The combination of political and technological drivers means decentralised renewables are set to dominate the world's energy supply; renewables' global capacity has already overtaken coal and new installations in 2015 outstripped all fossil fuel sources. Supporting variable renewables through greater system flexibility is increasingly important for the development of an efficient, low-carbon and secure energy system.

The mutual benefits between solar and storage are obvious. For end users it allows solar to be available around the clock; in 2015 41% of new solar PV systems in Germany were tied to storage, showing remarkably quick adoption. However energy storage systems are not commercially economical for all customers yet, and more work needs to be done to support continuing cost reduction. The STA's immediate focus will be on laying the foundations for a strong, sustainable, solar + storage market. Globally the solar + storage market alone is predicted to be worth US$8 billion by 2026, with the storage sector as a whole worth even more, according to Lux Research.

The UK's position as an island, with relatively old grid infrastructure, increases the potential value that flexible and smart grid infrastructure such as storage can deliver. In December 2015 the UK's Department for Energy & Climate Change (DECC) published a policy paper covering the challenges that the energy system faces of the coming years and focussing on how to deliver affordable, clean and secure energy through a smarter system. DECC states that the benefits of a smart grid include: less investment, reduced balancing costs and a reduced need for curtailing generation. Each unit of energy generated can be used more effectively, leading to a cheaper, greener, more resilient energy system.

Ofgem, the UK's energy regulator, is working with the new Department of Business, Energy & Industrial Strategy (BEIS) in this area, specifically leading on enabling new business models and in facilitating the transition to new roles for distribution network operators and industrial or commercial users. However Ofgem's position paper admits there needs to be clarification of the legal and commercial status of storage.

In October 2015 the Treasury set up the National Infrastructure Commission (NIC) to advise on long-term strategic infrastructure. The NIC's first report in March 2016, 'Smart Power', found that £8 billion could be saved annually by 2030 through increased flexibility from a combination of additional interconnectors, energy storage and demand-side flexibility. The report specifically said the UK should become a world leader in storage through reforming the regulatory and legal status of storage, and removing barriers.

However there has also been some uncertainty, such as the merger between DECC and the Department for Business, Innovation and Skills into BEIS, as well as the vote to leave the European Union. These may have an impact on the timelines, but neither changes the fundamental reasons why energy storage is so important.

While storage can offer a host of services for the grid, it is with intermittent renewables such as solar where it can make the biggest difference. In a world with high battery penetration into the grid the intermittency of renewables moves from a cost on the grid into savings, as the extra flexibility helps smooth peaks and troughs of production.

The STA recently commissioned a report into the costs associated with intermittency from independent researchers Aurora Energy Research. The report found

that current intermittency costs equate to around £1.30/MWh, and rise to £6.80/MWh with the central forecast of 40GW of solar by 2030. However in that same future scenario but with high battery penetration the costs drop to £-3.70/MWh, delivering actual savings. This means that within this system solar production is actually more beneficial than a baseload equivalent output profile.

Domestically there are already a number of companies launching products; there is a lot of excitement around new products from high profile brands such as Tesla, Nissan and E.On, for example. The drivers are obvious: solar energy is largely produced during the day while people are at work and demand remains after the sun has gone down; storage allows you to use solar power at night.

The system can be that simple, however there is no reason why the business model for solar + storage need be the same as solar-only models. Peer-to-peer trading at a local level could provide value for a domestic customer. An aggregator-owned approach would allow an aggregator to provide balancing services to the grid through a large number of small domestic batteries. Another model could be a large-scale battery installed as a "bank," allowing people to deposit excess generation and other consumers to withdraw on the same basis.

At a large scale, solar farms and energy storage seem intuitively a perfect match. Grid connections are typically underutilised due to the variable nature of solar generation and lack of sun at night. Space is typically available and planning permission either already granted or relatively simple to obtain. They can also offer further services than just energy generation, including frequency response.

Storage and frequency response

Last summer the UK government announced the outcome of its Enhanced Frequency Response (EFR) tender, with eight contracts between £7-12/MW/hr. EFR can react to frequency changes in under one second, helping maintain the grid at the requisite 50Hz. Battery sites featured heavily in the bidding process and all eight of the successful contracts were to storage systems.

EFR is important because of the potential for savings it offers – National Grid predicts approximately £200 million in reduced costs – so other nations will be watching with interest. The price for the successful bids was also unexpectedly low, below even Fast Frequency Response (FFR) that has a timescale of 10 seconds. This demonstrates the ability for battery systems to compete in the marketplace.

One of the reasons that the price for EFR could fall so far was the contract length. At four years the contracts on offer were much longer than traditional FFR ones; this enabled lower financing costs as investors had greater security. For renewable technologies looking to go subsidy-free this provides useful information on how changes to the business landscape can affect the viability of projects.

Credit: Red-T

EFR contracts were awarded at between £7-12/MW/hr

There is clearly a bright future for storage technologies. The grid of the future will have large amounts of renewables on it, with storage helping to even out the peaks and troughs. However, government needs to act to provide the right environment to help the industry flourish: currently there is no clear regulatory framework for storage; the industry will remain limited until that issue is solved. This is especially important for multi-use sites such as solar + storage.

Currently storage is treated as generation, and subject to network charges on that basis. Any electricity stored is therefore charged twice: firstly for importing and storing the energy and secondly for discharging and using that energy. If charges were levied on final consumption and not all consumption this double-charging problem would be solved and level the playing field for storage.

To fulfil storage's potential new marketplaces for services must be made. Distribution Network Operators (DNOs) are network operators, not distribution system operators. As a result they are unable to procure and tender for services to ensure the stability of the grid in the way that National Grid can: we couldn't have an EFR tender at the local level, for example. This means that a significant amount is spent on passive grid reinforcement even if by spending a lesser amount DNOs could procure storage services that would mean upgrades are not required.

Storage, along with solar, has a major role to play in the transformation of the UK's energy system into a truly smart grid fit for the 21st Century. The UK is making progress in this area, but more can be done; the potential benefits from such a system are too big to pass up.

The International Bromine Council

BROMINE FLOW BATTERIES: A PROMISING ENERGY STORAGE SOLUTION

Bromine-based technologies, such as flow batteries, are innovative storage solutions for renewable energy sources like wind and solar.

The world's population is expected to grow by two billion people by 2050 and global energy demand is expected to roughly double during the same period. At the same time, the power generation sector is undergoing a major transformation as economies and consumers move away from fossil-energy-based centralized power systems towards low-carbon, renewable-energy-based systems.

Energy storage will play a key role in enabling economies globally to accelerate this transition. It can supply more flexibility and balancing to the grid, providing back-up to intermittent renewable energy. Locally it can improve the management of distribution networks, reducing costs and improving efficiency. It can also give customers freedom to manage their own power needs.

ENERGY STORAGE SOLUTIONS

Currently there is limited storage of electricity in global electricity systems relative to increasing demand. Globally, pumped hydro storage (PHS) accounts for more than 99% of bulk storage capacity worldwide or around 127,000 MW across 200 large sites . In the EU it accounts for 5% of installed capacity – 100% of it as hydropower. For a variety of factors (water availability, geography, engineering constraints and costs), further growth of PHS will not be sufficient to meet the projected energy storage requirements now being forecast – especially in the US, China, Japan and the EU.

BROMINE-BASED ENERGY STORAGE TECNOLOGIES

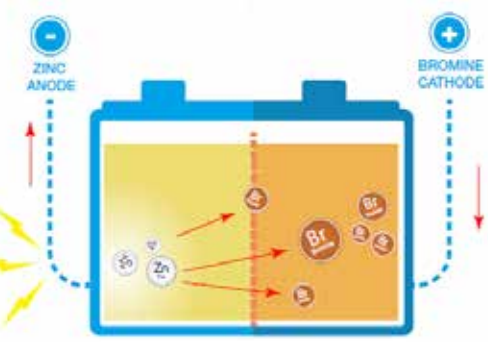
Bromine-based energy storage technologies are centered around bromine flow batteries. Flow batteries are battery systems that can release energy continuously at a high rate of discharge for up to 10 hours or more. They also have no self-discharge as there is no reaction outside of the reaction chamber.

Unlike with fuel cells where only the electro-active chemicals (e.g. hydrogen, methanol, and oxygen) flow through the reactor and the electrolyte remains at all times within the reactor, flow batteries drive (both) the electrolyte flows through the reactor.

As the chemical reaction in flow batteries is reversible, just like conventional electrochemical batteries they can be recharged without replacing the electro-active material. Typical bromine-based flow batteries include, hydrogen bromide (HBr) and zinc-bromine (Zn-Br). Other variants in flow battery technology using bromine are also under development or being demonstrated at pilot scale.

HOW DO BROMINE FLOW BATTERIES WORK

In a Zn-Br battery, two different electrolytes flow past carbon–plastic composite electrodes in two compartments separated by a micro-porous polyolefin membrane. During discharge, Zn and Br combine into zinc bromide, generating 1.8V across each cell. During charge, metallic zinc will be deposited (plated) as a thin film on one side of the carbon–plastic composite electrode. The net efficiency of this battery is about 75%.



Zn-Br batteries offer the high cell voltages of flow batteries and two electrons are released per atom of Zinc. This gives them the highest energy density among currently available flow batteries. It is estimated that at the end of 2009 there was around 4 MW / 8 MWh of installed Zn-Br flow batteries in the world, with the 'ZBB energy corporation' and 'Premium Power Corporation' the two major developers. Other developers include Redflow of Australia who are installing projects comprising 5-kW/2-hour as an alternative to installing new power lines.

AUTHOR

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Secretary General

BSEF - The International Bromine Council
www.bsef.org

MONEY **TALKS**

There is undoubted potential for a significant amount of battery storage capacity to be co-located with utility-scale solar farms in the UK, but are the owners of these assets – predominantly listed funds and other major investors – satisfied with the technology's immediate potential? Liam Stoker analyses why this might not be the case.

Listed funds in the UK which own a significant portion of the country's utility-scale solar PV assets are not currently convinced by battery storage's feasibility, but remain primed to deploy the technology at scale when the time is right.

Four of the UK's largest listed funds with solar interests suggested as such during this year's Solar Finance & Investment Europe conference – held in London - while providing an update on their activities. While interest in the booming secondary solar market took centre stage, attention quickly turned to the future and the potential role for battery storage within their operations.

Retrofitting utility-scale storage applications on the UK's solar assets – which now top 12GW in capacity, roughly 7.5GW of which is utility-scale – has long been considered as an ideal way to both ease grid frequency fluctuations and help smooth generation peaks caused by solar's variable load profile.

Owners of generation assets could theoretically shift their load profile to peak demand times for more significant profits, while frequency response tenders organised by National Grid, which operates the country's national infrastructure, such as EFR and FFR, as well as various capacity market auctions, offer the potential for projects to 'stack' revenues to make them more viable financially.

There is also considerable interest from the market, and recent research compiled by Solar Media' in-house research team found that the country's battery storage pipeline stands at circa 2.3GW, with a large portion of these installations being lined-up to be retrofitted onto existing generation assets.

But those present at the event took a dim view of the storage market's current prospects and insisted that the technology was not currently right for listed funds to adopt.

Matt Black, investment director at Foresight, said it would be some time before listed funds adopted storage en masse and his view was echoed by James Armstrong, founding partner at Bluefield, who said: "We've got the generation capacity. We don't have to take the risk [of deploying storage]."

Michael Bonte-Friedheim, chief executive of NextEnergy Capital, remarked that investors are currently not satisfied with the technological risks associated with storage against what is still regarded as an uncertain set of returns, and even went as far as to suggest that early investors in battery storage stood to lose money.

While the T-4 capacity market auction offered contracts for battery storage assets lasting 15-years, other tenders have been limited in length to one or four years. The support mechanisms are most definitely valued and have been pointed to as a major enabler for the nascent industry to gain valuable pricing insight, but it's widely considered that until longer-term incentives are offered investors will remain sceptical of the technology's financial viability as long as prices remain high.

"The only way storage will work for us is if we can use existing grid connections and stack revenues…load shifting is not worthwhile," Bonte-Friedheim said.

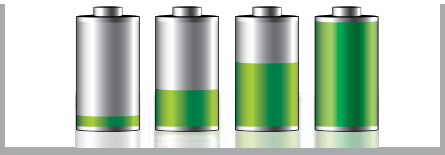
But while their immediate potential was questioned, all listed funds present insisted that battery storage would remain on their radar and that they would be primed to roll it out to their sites whenever the investment made sense.

Both Armstrong and Bonte-Friedheim said they considered battery storage to be a "free hit", meaning that they would not miss out by refraining from being an early adopter and would still be able to reap the benefits as soon as the cost reductions made investments economical.

Armstrong said discussions surrounding battery storage were likely to be held at the start of every year. "When it becomes viable, then we'll move," he said. Bonte-Friedheim implied the same would happen at NextEnergy Capital, adding that his firm could install battery storage at all of its operational solar farms in a relatively short space of time as soon as it was viable.

THE CO-LOCATION OPPORTUNITY

With a number of trials currently underway testing the feasibility of co-locating grid-scale storage facilities with solar generators, it's unsurprising that so much is spoken of the sector's potential. The panel at Solar Finance & Investment Europe included representatives from four of the largest asset owners in the UK market, with others also in the room, and storage was a hot topic of discussion. Indeed, as Solar Media's head of market research Finlay Colville pointed out on the day, the six largest owners by capacity currently hold more than a quarter of the UK's estimated 7.6GW+ of utility-scale solar. Should the economics stack up and the technology becomes financially bankable, it's those asset owners that will hold the keys to a hugely significant pipeline of battery storage development.



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PRODUCT BRIEFINGS

COMMERCIAL & INDUSTRIAL AND UTILITY-SCALE

DYNAPOWER, SAMSUNG SDI LAUNCH BEHIND-THE-METER INTEGRATED STORAGE SOLUTION

US energy storage inverter manufacturer Dynapower partnered with South Korea's Samsung SDI to launch an integrated behind-the-meter energy storage system, featuring Dynapower's Generation 2 MPS inverters and Samsung SDI's E2 batteries. The integrated solution seeks to reduce the costs for end users across commercial and industrial (C&I) segments for energy storage. "We have worked alongside Samsung SDI for a number of years and are excited to take that collaborative effort to the next level with the introduction of an integrated energy storage solution," said Adam Knudsen, president of Dynapower. "As the energy storage industry has rapidly evolved we have seen a clear demand from the market for engineered solutions that are flexible and proven. This is a solution customers can rely upon." The initial launch will be a 250kW system to be followed with a 100kW system. The first deployment will be for the University of Minnesota, with plans in the pipeline for deployment across the US in 2017.

SONNEN PARTNERS WITH IDEAL POWER ON COMMERCIAL ENERGY STORAGE PRODUCT

German energy storage hardware and services provider sonnen launched a new product for the commercial energy storage market using power conversion systems from Ideal Power. The sonnenBatterie pro is a smart energy management solution, which uses self-learning software to reduce electricity costs by shaving peak demand and responding to time-of-use electricity rates. Aimed at small businesses using solar power, the pro product also helps optimize self-consumption of solar energy as well as enabling participation in utility demand response programmes. The sonnenBatterie pro system includes an inverter from Ideal Power, battery modules with a 10,000 cycle lifetime, and the smart energy management platform. It also includes Ideal Power's 30kW power conversion system. The modular system scales from 18kW/24kWh up to 90kW/240kWh.

NEC ENERGY LAUNCHES DISTRIBUTED ENERGY STORAGE PLATFORM FOR C&I SEGMENT

NEC Energy Solutions, a subsidiary of IT and network integration firm NEC Corporation, launched a new distributed energy storage product for commercial and industrial (C&I) customers. The technology comes with lithium-ion battery storage and power conversion along with controls software, all available in a range of scales for both in-front-of or behind-the-meter applications. Roger Lin, marketing director at NEC Energy Solutions, said the product for sub-1MWh applications will help companies expand their portfolio through energy storage at the edge of grid, but removing the technology risk by providing guarantees and 10-year warranties backed by a global Fortune 500 company. The solution also aims to simplify the deployment of energy storage-based services. The firm is already working with customers in North America, with plans to have the product commercially available in the region by April 2017. A global roll out will follow by the end of 2017 with certifications already in the works for the Asia Pacific region.

DEMAND ENERGY

Italian utility company Enel bought US-based energy storage project developer and software company Demand Energy at the beginning of this year. Demand Energy has executed some 24 projects behind-the-meter, around 3MW/9MWh of installed capacity to date. The company is known for DEN.OSTM ('Distributed Energy Network Optimisation System'), a software platform for intelligently controlling energy management resources. Demand Energy recently completed a 500kW/1MWh battery storage system on a microgrid at a medical manufacturing facility in Costa Rica. The microgrid provides multiple services, which include assisting the grid. Behind-the-meter it reduces peak demand and 'smoothes' out variable solar energy output for effective onsite self-consumption as well as being a source of backup power in the case of outages. The system will also allow the facility to cut power costs through peak power reduction while maintaining stability of supply as well as reducing its dependence on diesel.

TESLA UNVEILS DOUBLE-DENSITY, 'COST-COMPETITIVE' POWERPACK 2 STORAGE SYSTEM

Energy company Tesla started shipping an updated version of its commercial battery storage solution in September 2016, featuring doubled energy density. The upgraded version – dubbed Powerpack 2 – contains a new energy module and power electronics system which provides twice the energy density as its previous version. The system also comes with a new inverter designed and manufactured by Tesla itself, rather than the previous system which relied upon inverters supplied by Dynapower. Tesla has claimed this "significantly simplifies" the installation of Powerpack systems by integrating a number of components into the inverter while also making the system more cost competitive. "The Tesla inverter paired with the Powerpack 2 allows storage to be available to the utility industry at price points and with functionality previously unknown. "Furthermore, the Powerpack system interface and software controls give utilities and grid operators high fidelity control, allowing for better energy management and dispatch, which improves grid performance, efficiency and reliability at a low cost," Tesla revealed in a blog post.

SIEMENS - SIESTORAGE

German utility SWW Wunsiedel has ordered a large-scale battery storage system from engineering and technology giant Siemens, which will participate in weekly tenders to help balance the local grid. The distribution grid-connected system will be based on Siemens' Siestorage modular electrical energy storage system (ESS), which consists of grid connection, converter, controls and battery components. It will use 6MW+ of lithium-ion batteries. The system will utilise three containers of batteries, a container with inverters, a concrete station hosting transformers and control system. The system will participate in the primary control reserve market which allows German transmission system operators (TSO) to maintain the balance between electricity consumption and generation on their networks. To enter into the weekly bidding process, the Siestorage system will need to be able to offer the full amount of power required within 30 seconds so that the frequency of the transmission grid stays at the required 50Hz.

AES TAKES ADVANCION UTILITY-SCALE ENERGY STORAGE TO EUROPE, ASIA AND AFRICA

US-based Storage provider AES Energy Storage has made significant expansions away from established markets into relatively untapped regions across the globe. The company recently teamed up with power electronics and engineering group Eaton to supply AES's Advancion battery-based energy storage systems to utilities, industrial and commercial customers and IPPs in Central and Eastern Europe, Nordic countries, the UK, South Africa and Morocco. AES's Advancion 4 includes racks of lithium-ion batteries that can be scaled for standard configurations from sub-100 kW to over 1GW, and from 15 minutes of duration to over four hours without any reengineering. Brian Perusse, vice president of international market development for AES energy storage, said that by partnering with Eaton as well as Japanese firm Mitsubishi Corporation, the Advancion product is now available globally adding that the European markets holding the most promise at present include the UK, much of Eastern Europe, as well as Italy and Germany.

RESIDENTIAL

SUNRUN - BRIGHTBOX

US residential solar company Sunrun's BrightBox solar energy generation and home battery storage service is now available to homeowners across California. With BrightBox, homeowners can utilise a customised and innovative solution with little to no money down, while Sunrun will maintain, monitor and insure the system for 20 years. Systems are available through a monthly or prepaid lease. As California adopts a Time-of-Use (TOU) rate structure, Sunrun BrightBox will provide consumers new ways to manage their energy consumption, allowing homeowners the opportunity to time shift when they use solar energy to minimise paying peak rate energy prices. "Importantly, with innovations such as BrightBox, we hope to forge new relationships with utilities as we work with them to maximize the value of solar energy in modernizing America's energy infrastructure," Sunrun CEO Lynn Jurich said.

Sunrun will maintain, monitor and ensure its BrightBox systems for **20 years**

SMA AND LG CHEM

German inverter manufacturer SMA and Korean battery maker LG Chem have teamed up to offer a residential solar storage solution in Europe and Australia. Using SMA's Sunny Boy Storage 2.5 battery inverters and LG's new RESU10 (100V, 10kWh) or 7 (48V, 7kWh) batteries, the residential storage solution can be retrofitted to existing PV systems, and is set to achieve significant savings for customers. "By using the new SMA/LG Chem package, private households can reduce their electricity bill by more than 80% and decouple from the trend of rising electricity prices," SMA chief executive Pierre-Pascal Urbon said. Users of the storage solution also have access to SMA's online portal SunnyPlaces, and can monitor energy flows and savings opportunities. In addition, the system can be integrated with the Sunny Home Manager into a comprehensive energy management system if required. The two market leaders are also planning to extend the partnership to include utility-scale storage solutions.

MERCEDES-BENZ ENERGY

The energy storage business of German auto manufacturer Mercedes-Benz, Daimler AG Energy Storage, was officially launched last summer. Focusing initially on a range of 2.5kWh lithium-ion battery systems with distribution beginning in Germany, the products were rolled out to the US at the end of 2016. Manufacturing of both automotive and stationary storage systems has been entrusted to subsidiary Accumotive, which according to Daimler is spending around half a billion Euros on a factory. The systems carry the Mercedes Benz brand and Mercedes will install, develop and distribute them. The residential product is a 2.5kWh device that is modular and can be "stacked" for up to 20kWh of storage. From an initial 50 employees, Mercedes Benz Energy plans to recruit a further 50 by the end of this year and then double that figure to 200 workers by the end of 2017. The company confirmed it will continue working with SMA and others to distribute products in Germany.

SUNVERGE AC-COUPLED STORAGE

California-based energy storage system maker Sunverge has launched an AC-coupled version of its Solar Integration System (SIS) energy storage devices. Available to utilities and renewable energy installers, the new model of SIS can be installed as a retrofit to existing PV systems or added to new ones at the point of installation. DC-coupled systems are more closely tied to the PV system, charging only from the PV rather than also being able to charge from the grid and retrofitting can often require additional hardware. Sunverge has made a name for itself through its behind the meter systems being used for several 'virtual power plant' (VPP) projects in territories including Australia, the US and Canada, where the capabilities of several systems are aggregated to form a larger grid asset. The AC-coupled SIS includes that proprietary VPP software. The product is available in four sizes from 7.7kWh to 19.4kWh. It provides 7kW of peak power, or 6kW continuous, can be installed indoors or outdoors and comes with a 10-year warranty.

SOMETHING DIFFERENT

EOS AURORA BATTERY

EOS has its own patented aqueous battery technology, dubbed Znyth. The company's standard 1MW DC battery, Aurora 1000|4000, uses Znyth's aqueous electrolyte and zinc-hybrid cathode. The containerised Aurora battery is sold at US$160 per kWh, with EOS claiming the battery is safe as well as cost-competitive with gas peaking generation and with distribution infrastructure operated by utilities. Aurora systems can discharge a duration of four hours of stored electricity and last 5,000 cycles for a 15-year calendar life. The company raised US$23 million in Round C equality financing in May 2015 which it said was to be used to help its commercial launch of the grid-scale battery technology in January 2016. At the time it had racked up some 3000MWh of pre-orders and was tested by Con Edison and GDF Suez in New York and Pacific Gas & Electric in California.

US$23 million
Raised by EOS in Round C equality financing to commercialise its technology

JLM ENERGY – MICROSTORAGE PHAZR

California-based system provider JLM Energy has developed a suite of energy storage products – dubbed MicroStorage – that connects battery storage directly to solar panels. Microstorage couples a battery directly to a corresponding solar panel, meaning power from the solar PV can charge the batteries or be fed into the grid. It can also do both simultaneously, JLM Energy claims. Additionally, as solar generation tails off in the late afternoon or evening, the battery discharges, while the system supplies power directly to the building it is connected to. JLM Energy claims that Phazr, the first product launched in the range which nestles behind a solar panel, can be used in everything from residential to utility-scale applications. The company says it makes for "virtually cost free" installation. The briefcase-sized product weighs about 7kg, uses lithium iron phosphate (LiFePO4) batteries, operates at a voltage of 20-40V and comes with a 20-year warranty.

ICE ENERGY – ICE BEAR

Ice Energy's ice batteries use copper coils to pump cold refrigerant through regular tap water, making ice, with the idea being that this can be done during off-peak hours. The residential model, branded Ice Bear 20, can cool a home continuously for four hours, with the company claiming it can save 95% of associated electricity costs. The larger Ice Bear 30 model is available to commercial users. Ice Energy claims Ice Bear is smart-grid enabled, including bi-directional communications technology and can completely replace existing home air conditioning units. The four hours' continuous cooling they offer allow the utility to load shed for that time. In February 2017 The Southern California Public Power Authority (SCPPA) ordered up to 1MW of ice battery storage systems from Ice Energy, considering that the systems would allow member utilities to reduce their peak demand, in effect saving energy, increasing efficiency and lowering emissions.

NEXTRACKER NX FUSION PLUS INTEGRATED STORAGE SOLUTION

Solar tracking manufacturer NEXTracker has unveiled a storage solution paired with its PV tracking infrastructure. The NX Fusion Plus includes a tracker, inverter, battery and software. While the hardware synergies may not be obvious, the company claims that with the objectives of its tracker and storage aligned, it is well-placed to offer both together. The system will use the predictive software of Brightbox, a company NEXTracker acquired in August 2016. Upon the product's launch Alex Au, CTO at NEXTracker, said the product enabled solar arrays to deliver high returns on investment because it enabled them to utilise more energy and offset potential demand chargers for end users.

DRIVING **CHANGE**

With electric vehicle uptake set to surge, vehicle-to-grid networks that utilise onboard battery capacities have been highlighted as a key technology for the future. Liam Stoker looks at some of the work already taking place.

Electric vehicle uptake is expected to soar in the UK, with National Grid forecasting that 700,000 EVs could be on UK roads by 2020. That could prove to be a conservative estimate.

Even if it rings true, such a rapid deployment of electrified transport would prove to be a considerable drain on electricity resource; some 500MW of electricity according to National Grid. But it also points to a hugely interesting opportunity for the grid to embrace.

By possessing an onboard battery, EVs can be viewed essentially as portable power stations capable of ferrying charge between a driver's home, workplace and even to the shops. It's why vehicle-to-grid (V2G) technologies have emerged in recent months and garnered particular interest, both commercially and from industries tasked with managing national infrastructure.

Nissan is perhaps the biggest early adopter of the technology, highlighting it as a crucial enabler within its 'Nissan Futures' vision of a much wider, interconnected smart grid network that could be deployed across entire cities. In the middle of last year it partnered with energy giant Enel to launch its maiden UK trial of a V2G network that would comprise 100 connected charging stations at locations where private and fleet owners of Nissan EVs are used.

The concept is simple. Once plugged into the charging units – developed by Enel – any stored electricity in the vehicle can be sold back to the national grid for profit. The grid benefits from the system's inherent flexibility, and owners can profit from their car's capabilities. Paul Wilcox, chairman at Nissan Europe, said it helped solve "one of the biggest challenge any nation faces for the future".

"We see Nissan electric vehicles as being the mobile energy hubs of the future, pioneering a self-sustaining energy infrastructure that will help solve the capacity issues of the future," he added.

It received explicit backing from ex-National Grid chief executive and now non-executive director Steven Holliday, who said the entity would always support innovative and "pioneering projects" such as this one due to its potential to "make a real difference to the way we manage energy supply and demand".

In November last year Nissan put its money where its mouth was. It installed eight of the charging units at its R&D facility in Cranfield and made them available for all employees to use. David Moss, vice president of vehicle design and development at Nissan Technical Centre Europe, added: "Integrating it into our own facilities demonstrates the confidence we have in the technology and our steadfast belief that our electric vehicles can play a pivotal role in developing an ecosystem of technologies that work seamlessly together to create sustainable and efficient solutions for the future."

While Nissan has yet to disclose the results of the trial – an update is expected later this year – Nissan Europe's director of energy services Francisco Carranza lauded the system's ability to "change the rules of the game and make energy cheaper for everyone".

But Nissan is not alone in realising the potential for V2G chargers. BMW broke cover in late November to reveal that it was close to launching a new 'Digital Charging Service' for its BMWi fleet of EVs which, where available, will utilise battery capacities to offer grid services. The car giant has already partnered with Dutch utilities Eneco and Jedlix for the service when it launches in The Netherlands later this year, and it has expressed interest in finding similar partners in other launch markets, one of which is the UK.

UK storage and technology company Powerstar has also looked to enter the fray with its connected Virtue EV rapid charging system which it combines with 80kWh of NMC batteries itself to help accommodate for increased load and demand of rapid charging, which it hopes to offer to businesses across multiple sectors. With the major retailers embracing EV charging bays to boost their CSR status and accommodate for green-thinking consumers, it can only be so long until they wake up to the benefits of utilising the storage capacity sitting in its car park.

With so many tangible benefits, commercialisation of V2G systems like that Nissan is attempting to achieve through its trial will only be warmly received. Nissan Futures' 'fuel stations of the future' concept might not be too distant after all.

THE BIG FUTURE OF MICROGRIDS

Microgrids are about more than novel off-grid systems. They could be the building blocks of the future, flexible, intelligent electricity network. S&C Electric discusses how one early project is helping prove the point.

The terminology might seem diminutive, but there is no doubt that the future for microgrids is anything but small.

In fact, in future, microgrids themselves won't necessarily be that small physically in their own right either. Misconceptions about the isolation of microgrids also abound.

They don't have to work in full isolation, they may in fact be made up of several small grids and via the legacy grid, they may well be connected in the future to series of similar microgrids. It's not easy to find a catch-all term that encompasses all of these characteristics. So with the objective of scaling up the benefits of microgrids to larger and larger systems, is the name misleading?

"Possibly, yes," says Troy Miller, director of grid solutions at S&C Electric. "We've got some exciting projects in the pipeline that are much larger. People have used the term microgrid generically to mean a system, whatever the size, that can be separated from, islanded from. The overall larger grid is measured in gigawatts and terawatts, microgrids can be tens or hundreds of megawatts. I haven't heard a name for them as they get bigger but people have coined new terms for them as they got smaller, nano- grids and pico-grids."

Credit: S&C Electric

S&C played a key role in the development of an ambitious micro-grid project completed in 2015 for the Texas public utility firm Oncor. The site is part of a large Oncor testing facility that had been operating with diesel back-up. The motivation for the project was two-fold, one financial and one strategic.

"They originally wanted to build a microgrid from the ground up, greenfield, with all new sources of generation. To save on some of the capex they decided to integrate the existing generation assets. So they hired S&C to create a dynamic microgrid to combine the sources they had on-site with some newer assets, a microturbine, some battery storage as well as PV," explains Miller. "It was a fairly complex problem. They were looking to reduce the amount of energy they used and use the most energy efficient sources first, the PV, followed by the energy storage, followed by the microturbine and lastly the diesel, to reduce their need for additional generation. Then they were trying to match the critical loads with the available and existing generation."

The initial plan was to incorporate all of these components into one, singular microgrid. As is often the case, the plan needed to change as the work began.

"Because of the different ages of the diesel generation on site, what we ended up doing was creating four separate zones within the microgrid," explains Miller. "One zone with two existing gens, another with two further existing diesel generators, a zone with a community energy storage battery and the last with the gas turbine, some PV and a slightly larger battery.

"The main reason was that if you tried to bring all these online at the same time, specifically the two different sources of diesel generation they would resonate, they were operating at different frequencies, and this would create very strong power quality issues. So we had to come up with a very creative

way to eliminate that, which was to have these four microgrid zones within the larger microgrid."

The technical challenges did not end there. S&C designed and built a custom grounding transformer to ensure the system had a different ground-reference depending on whether it was connected to the main grid or was operating in islanded mode.

"This custom transformer allowed all those newer sources of generation to operate, even in an islanded mode. What we're basically saying is that you have to come up with some creative solutions to overcome the limitations of existing sources of generation," says Miller.

Show and tell

The second motivation for Oncor, S&C and project partner Schneider Electric was to have an operational demonstration of what battery storage, some sophisticated controls and clever design can achieve. Storage suffers from the same inertia in reputation that still plagues solar PV. There is a misconception that because the technology has not bottomed out its cost reductions that it must be in some way unaffordable, that significant gains are required before it is worthy of mainstream attention. Energy storage is of course a technology for the here and now and is already solving a variety of problems on the grid – without handouts.

Oncor went one step further than building a microgrid as a demonstration of this fact. With lobbying, and selling, in mind, the site in Lancaster, Texas, also includes a visitor suite.

"The interesting thing about the Oncor facility is that they have built a fully interactive customer centre where people can experience the microgrid. The idea is to bring in legislators, regulators, other customers and their end customers to be able to show them this new form of generation. Part of the idea was to get regulators in Texas comfortable with the fact that utilities could own energy storage and microgrids. Encor is what is called a wires company, they are forbidden from owning any type of generation and because of an antiquated regulation, energy storage is classified as generation when really it is neither load or generation, it's kind of in the middle."

So the facility is in a way, helping to re-write the rulebook at a time when regulations are a significant obstruction to energy storage projects.

"Yes and we are. It is helping to demonstrate that and we are working very hard on regulatory approval both in ERCOT as well as PJM, CalSO, the MidWest ISO and the rest," says Miller adding that walking the talk is also crucial.

"I think that is helping but energy storage is solving real problems. We installed a system at the village of Minster, a municipality in Ohio. They had an existing 4.5MW PV plant and S&C and half Moon ventures put in a 7MW/3MWh energy storage system that does three simultaneous things," he says.

Credit: S&C Electric

The system participates in the frequency response market, helps the village avoid peak load contribution charges and corrected the town's power factor using the battery, negating the need to purchase power factor correction capacitors.

Miller also points to the contribution storage is making to California's response to the Aliso Canyon gas leak.

"It can get sited a lot quicker, it can get built a lot quicker and it is taking care of a problem, basically supplementing production on the peak days next summer, that would have taken three to four years [to solve by] building traditional generation. There's other specific examples too of energy storage solving problems that can't be done with traditional forms of upgrades or traditional upgrades of distribution," says Miller.

The glue

Microgrids can serve several purposes, just like energy storage can in its own right. With more than 200MWh of storage deployed and proven microgrid pedigree, S&C is well-placed to comment on where they can fit into the existing infrastructure.

"We're very bullish on microgrids and we think they are going to be a big part of the utility of the future, combining alternate sources of generation, intelligent switching and protection, a microgrid controller and energy storage to form the backbone of an islanded microgrid. We believe utilities will see more and more of these being installed and the utility will serve as the coordinator of the microgrid, or the grid of microgrids," says Miller.

If microgrids are themselves a patchwork, and the architecture of the future grid is likely to include a number of microgrids, a lot of challenges will lie around interoperability, frequency matching and finding a common tongue for all these disparate assets to communicate in. At the heart of this future is energy storage, the great enabler. ●

ASTRA VENTURES

Investment opportunities in the energy paradigm shift

Astra Ventures is a low carbon and renewable energy infrastructure developer with headquarters in London, developing project portfolios in new markets such as battery storage and renewables plus storage, in the UK and internationally. Amongst several other initiatives, Astra Ventures is currently working on a strategically diversified portfolio of UK based grid connected Energy Storage projects.

A paradigm shift

The axiom of the electrical system as a structure for following and supplying the national loads has been under attack in recent years: the rising cost of fossil fuels, climate concerns, and the cost of renewable generation and flexibility resources continuing to fall, have led to a deeply modified landscape for energy investments.

The initial golden era for highly subsidised renewables is over. This has left developed countries a more sustainable but challenging market based on the competition against traditional generation, whilst leaving as a legacy a tenfold drop in investment cost, that translates to the lowest ever PPA prices.

The new class of energy storage systems has shown batteries as an early winner. Whilst showing a similar cost reduction pattern to other renewables, battery storage perfectly complements the surge of distributed generation making them a baseload resource in the developing countries and providing balancing services in more developed markets.

This paradigm shift is creating the environment for a set of new investment opportunities that Astra Ventures is studying and developing.

Battery Storage in the UK

One of the most intriguing investment opportunities in the UK as today is the battery storage market. The addition of the Enhanced Frequency Response scheme to the already present stack of diverse revenues sources for the new low cost and multi-purpose battery systems kicked off the ESS market in 2016. The 550 MW of projects winning EFR and CM auctions in the face of over 2GW of proposed projects justifies the hype for these projects, which ensures a series of profitable business models.

Astra is strategically developing a diversified portfolio of battery projects and is currently looking for partners and investors to bring these projects to the bidding and construction phase.

Solar plus storage in developing countries

In the foreseeable future, the majority of investments into low carbon generation will be executed in developing countries. Often the grid infrastructure is weak, which means they are usually not able to receive high inputs from renewables, frequently the most economic generational option. This sets the ideal environment for renewables coupling with storage systems.

The complexity of business development in those areas and the identification of the right opportunities and sites is often limiting investment.

Thanks to their network of connections and partners, Astra Ventures is developing a series of innovative solar plus storage utility scale projects in several African Countries through direct participation and collaboration with investment partners and local entities.

Behind the meter applications

The falling cost of components and the development of new customer centered services opens a whole new set of opportunities "behind the meter". Especially for Commercial and Industrial customers, where a combination of low carbon on-site generation, energy storage systems and demand side management services offers savings that widely surpass the necessary investment without the need of subsidies.

Astra have recognised the potential of the behind the meter market in UK and is creating a network of partnerships to enable a turnkey solution for Commercial and Industrial customers, with the goal to condense a series of projects in a portfolio to maximise revenues and minimise the investment risk.

About Astra Ventures

Astra Ventures was born from a group of experienced PV developers with decades of combined experience and hundreds of MW deployed. Astra Ventures was founded to originate investments, advise and develop projects within the global energy and infrastructure sector. In the last two years Astra Ventures invested to embrace the new arising opportunities adding resources to the team, studying the markets and investigating innovative business models in UK and abroad.

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FINANCING COMMERCIAL **STORAGE**

Camborne Energy Storage discusses how it financed and connected Europe's first C&I Tesla Powerpack installation.

In December 2016, the energy minister at the time and her Smart Energy Team from BEIS, officially opened Camborne Energy Storage's 500kWh Tesla Powerpack installation. This energy storage facility is the first grid-connected Tesla Powerpack in Europe and is co-located with an existing solar PV plant.

The minister welcomed the 'exciting project' from Tesla and Camborne as an example of the sort of innovation in storage that will 'help manage our electricity grid more efficiently, support greater energy security and, crucially drive down consumer bills'.

The facility is generating revenue through grid and ancillary services as well as generating revenue through time of use discharging.

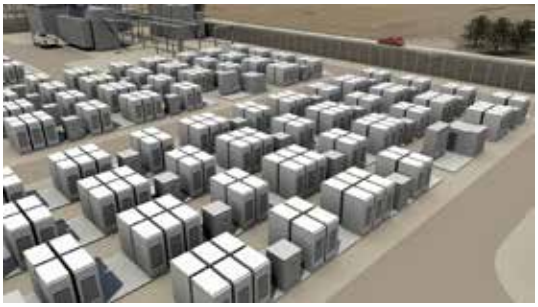
Camborne Energy Storage (CES) worked with a number of partners in delivering this privately funded project, including Poweri Services, who carried out the EPC work and connected it to the local 11kV network, and the ancillary services are being managed by Open Energi.

CES decided to partner with Open Energi on the basis of their innovative approach and proven track record working with customers to deliver Firm Frequency Response (FFR).

David Hill, Strategy Director at Open Energi, commented: "The UK urgently needs greater grid flexibility, and lithium-ion batteries offer a powerful substitute for thermal generation, cutting costs and carbon. But there's more to unlocking value from energy storage than putting a battery in a field. We have worked closely with Camborne Energy Storage to seamlessly integrate our Dynamic Demand software and provide access to the UK's Firm Frequency Response market. It's a great revenue opportunity - already worth £200 million a year, the market is expected to grow significantly as more renewable generation comes on-line."

By co-locating with an existing solar PV plant, CES was able to share the benefit of the export capacity as this was already in place. Additional grid import was needed so that the energy storage facility could still partake in FFR at those times when the solar PV plant was not generating.

Dan Taylor, Managing Director at CES said of the project, "Camborne is pleased to have developed Europe's first Tesla grid scale installation by co-locating with a solar farm in Somerset, England. This project is



already commercially operational providing low carbon power during times of high demand.

Our first co-located site is an early step in the right direction, both for Camborne and for the industry and we look forward to continuing to deliver further low carbon power to the UK."

Looking ahead to 2017, Dan stated: "Having developed our first project last year, we are excited to start 2017 with a range of consented sites ready for construction and a healthy pipeline in planning or planning preparation."

The year has kicked off with the submission of responses to Ofgem's Call for Evidence on 'A Smart, Flexible Energy System', and CES were delighted to respond with a focus on the definition of energy storage and the challenge double charging.

Drawing upon their experience, CES's response presented evidence of the issues associated with the lack of a clear definition. CES stressed that the means of defining energy storage should be detailed and allow scope for the rapid rate of technology advancement that is sweeping through this sector. In the months ahead, Ofgem and BEIS have a real opportunity to provide clarity to all stakeholders, from councils and commercial entities to developers, investors and technology providers, by providing an effective scheme for defining energy storage in its different forms and applications.

Looking at double charging and connections, CES gave the example of double charging having increased the cost of energy showing how this has hampered the development of some assets that could provide necessary services to the energy system of the UK.

CES believe that an end-to-end review of the current arrangements for connections is key to allow for stronger competition in delivering low carbon projects sooner and for the best value for the consumer.

AUTHOR
Harry Vickers is business development manager at Camborne Energy Storage

INSTALLING COMMERCIAL **STORAGE**

Like many companies active in the solar industry, life has become challenging, but with the advent of cost-effective large-scale battery storage we at Poweri see a means to provide a compelling proposition for our clients, which can address many needs whilst being less reliant on government subsidy.

It was because of this reputation that we were asked to become involved with Tesla's first installation in Europe of its commercial-scale Powerpack system.

The system is located in Somerset alongside a 500kW ground-mount solar system. This was not, in this instance, so that the battery could be used for time-shifting of the solar output as is often presumed. The Powerpack was simply sharing the connection that had already been created (and paid for) for the solar system and so kept connection costs to a minimum.

This Powerpack installed consisted of a 250kVA inverter, five no. 100kWh battery units, a DC combiner box, and Tesla's master control unit (which as the name suggests, controls the whole operation) and various remote data communications equipment.

The Powerpack system is available in various configurations where the inverter power can be multiples of 50kVA units (so 50kVA being the smallest) and 1.7, 2 and 4.2hr storage capacity.

What batteries can do

The reasons for installing batteries of this scale vary, and it's a versatile proposition, but an overview of possible options are:-

- Firm frequency response – the battery system monitors local grid frequency, injecting energy when frequency drops, and charging when frequency rises. This is a service that National Grid will pay for. The Somerset system is being used for this purpose.

- DUoS / TNUoS charge reduction – the battery is charged during the Green DUoS period, and discharged during the red DUoS period and the presumed TRIAD hours, so reducing energy bills significantly.
- Load shifting – This is charging the battery during hours when electricity is cheap, and then using that energy on site when electricity is expensive, saving money.
- Price arbitrage – involves charging the battery during cheap periods, and then exporting that energy to the grid during expensive periods if possible.
- UPS – The battery system can act as an uninterruptible power supply for a whole building, or part of a building if needed.
- Load smoothing – if a building needs a bigger supply, a battery system can be used to expand peak onsite energy supply by charging when the site connection is not being fully used, and then discharged at peak times to expand the peak amount of power a building can draw.

Interesting insights

Being a first for everyone involved, the project presented some new challenges and Poweri learnt a lot during the design and build. Things that differ from a typical solar installs would be:

- Grid connection needs to be for equal import/export rather than predominantly export. DNO's are also not familiar with systems like this as they are with solar, so the protection engineers were paying closer attention than you may be accustomed to. Needing to be both G59 and G100 compliance here was a little fiddly to arrange.

- Ease of access – The battery systems themselves are very heavy, needing plant to move around, so access was an issue, and given the value of the equipment involved, we were being very careful indeed on the days that the main equipment was being lifted into place.

- Large switch-gear – this system had a 400A connection into a 630A board, which is the scale of switchgear that would usually be business critical. This is on the smaller end of Powerpack system sizes. You need to be very confident of your designs and installation processes in dealing with switchgear of this size and bigger. In working on it you're risking large-scale failure of other equipment if you get it wrong, and most organisations won't let you touch it unless you have a very thorough risk assessment and contingency planning in place.

It's likely that systems bigger than this one would need an HV connection instead on an LV one, making the project that much more complex. Overall conclusions were that the Powepack system itself is well designed and not too complex, however integrating it into existing systems is complex and needs great care.

AUTHOR
Chris Roberts is managing director at Poweri Services

More than an energy storage solution, renewable hydrogen is the energy vector of the energy transition

Energy systems across the globe are undergoing a fundamental transformation to increase the quality of air and to decrease their dependency on oil, coal and gas as a primary energy source. Driven mainly by a political vision to decrease the negative impacts of climate change and decarbonize the power sector, wind and solar technologies have emerged as key renewable technologies. While the cost of renewable technology has decreased much faster than expected, integrating these intermittent energy sources into the power grid is highly challenging due to the increasing need for grid flexibility and energy storage solutions. This is where Hydrogenics, a global hydrogen technology company, is leading the way in delivering a clean and everlasting solution to the renewable energy equation.

Glencore Raglan Mine (Canada), hydrogen based energy storage solution for a renewable powered off-grid system: electrolyser (350 kW) and fuel cell (120 kW).

Electrolysers are very fast-reacting devices

Water electrolysers are devices that use electrical power to split water (H_2O) into hydrogen (H_2) and oxygen (O_2). Thanks to Hydrogenics' focus on continuous innovation, electrolysers are now capable of modulating their electrical energy input very rapidly (less than 1 second) over the total power range, making them a very attractive solution for the provision of grid balancing services to the power sector in the MW-scale range. Hydrogenics' electrolysers are 'plug and play' units, safely and reliably producing very pure hydrogen in continuous or dynamic operation modes.

Hydrogen is used in a wide range of applications

Hydrogenics has delivered hundreds of electrolyser systems for every industry, including ammonia production plants (fertilizers), oil refineries, industrial manufacturing plants (steel, float glass, semi-conductors), power plants (generator cooling) and for the hydrogenation of oils in the food industry. In addition, Hydrogenics has supplied electrolysis technology to over 50 hydrogen refuelling stations worldwide where hydrogen is used as a fuel for fuel cell electric vehicles.

Renewable hydrogen as an energy vector

Hydrogenics is leading the industry in renewable hydrogen projects where electrolysers are used to store renewable electricity (wind and solar) into hydrogen. Once the renewable hydrogen is produced, there are several ways to commercialize it in the energy system. Hydrogen can be re-electrified via a fuel cell to deliver power again when needed (power-to-power). Hydrogen can be directly injected in gas grids (power-to-gas) under certain conditions or combined with carbon dioxide (CO_2) to produce synthetic methane (CH_4). Hydrogen can be used in industrial applications (power-to-industry), in fuel production (power-to-fuels) at refineries or in the production of methanol.

When produced from renewable power, hydrogen offers the capability to significantly decarbonize the power, gas, transport and industrial sectors, by substituting oil, coal and natural gas. In this case, hydrogen acts a 100% renewable energy vector, connecting these sectors to renewable power.

A fast growing market with game changing potential

It seems quite clear now that hydrogen technologies will be at the core of our new decarbonized energy system. Whether it's for transportation, fuel production or energy storage, major companies around the world are strategically transitioning to renewable hydrogen to help reduce their carbon footprint.

Hydrogenics: the leading provider of renewable hydrogen solutions

Hydrogenics is the global innovation leader with over 60 years of experience in designing, manufacturing and installing industrial and commercial hydrogen systems around the world.

Hydrogenics electrolysers deliver pure hydrogen solutions for industrial processes, renewable hydrogen projects and hydrogen refuelling stations. The company also designs hydrogen fuel cells for light and heavy fuel cell electric vehicles including urban transit buses, commercial fleets, utility vehicles and trains, as well as for stationary applications such as critical power and hydrogen power plants.

Hydrogenics has production sites in Canada, Belgium and Germany and sales offices in select locations around the world. Hydrogenics is publicly listed on the NASDAQ (HYGS) and TSX (HYG) and is the only global company to produce both state-of-the art water electrolysers (alkaline and PEM) and PEM fuel cells, making it the leading company in clean hydrogen technologies.

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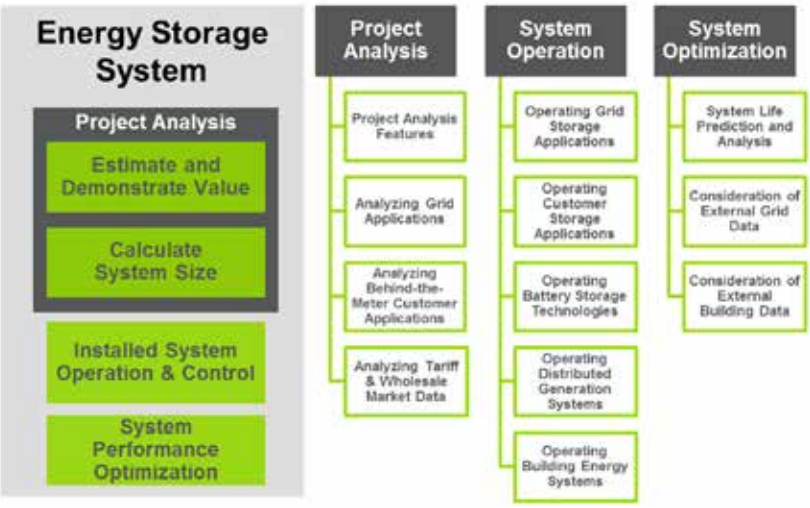
ENERGY STORAGE SOFTWARE **WILL HELP BUILD THE GRID OF THE FUTURE**

Software platforms are emerging as a crucial element in the rapidly expanding energy storage industry. The growing importance of energy storage system (ESS) software is driven by a number of factors as the industry looks to continue recent record-setting growth and overcome several key barriers. Software platforms are primarily responsible for initial project analysis and design, system control and operations, and for optimising system operation over time for maximum value. The following graphic outlines some of the specific functionalities for ESS software. Software and controls will play a central role in the storage industry over the coming years. It is essential for vendors, developers, and other stakeholders to understand the advances being made in software technology and how to capitalise on them.

In addition to these core tasks, ESS software must also ensure safe and reliable operation for as long as possible, a particularly challenging task for battery-based systems where premature degradation is a significant operational and financial risk. Given this range of responsibilities, software is employed throughout the entire lifecycle of a storage project—from design to decommissioning—and has become a critical tool for helping overcome barriers facing the industry. There are two primary barriers to greater energy storage development that software is helping overcome: the high upfront costs for new systems and the lack of customer education and familiarity with the technology.

While these barriers are beginning to come down, the industry remains relatively immature in most of the world. One of the main drivers of future growth will be new software and control platforms that allow ESSs to be virtually aggregated to provide a number of new services for an increasingly diverse range of customers.

ESS Software Core Operating Modules



(Source: Navigant Research)

Barriers to overcome

The most widely cited barrier inhibiting the widespread development of advanced energy storage is the large upfront investment required for these systems. The range of different energy storage technologies and components makes the task of designing an efficient and cost-effective ESS for multiple different customers and use cases challenging and time-consuming. Leading ESS software vendors are offering modeling and design tools that allow their customers to quickly and accurately design a system that meets their needs at the lowest possible cost. This increase in speed and accuracy of system design has a direct impact on a project's bottom line and is becoming a competitive advantage for many vendors and developers.

This complex task also requires accurately predicting any degradation and maintenance requirements for a system to ensure the most suitable technology is chosen based on how the project will operate. Factors such as the required depth of discharge, average number of cycles required per year, time between cycles, and operating environment are all important considerations when designing an ESS. Several early energy storage projects failed due to a poor match between the chosen technology and the required operating parameters. Advanced software platforms can avoid these issues and lower the cost to design and build systems to capture the maximum value over the longest possible time period.

Another major barrier to the industry's growth is the general lack of awareness and familiarity with energy storage and the benefits the technology provides. This lack of education is an issue for numerous stakeholders, including customers, utilities,

investors, and government regulators. The innovative software platforms currently available provide vendors with the ability to visualise the performance of a system over time based on data gathered from already operating projects.

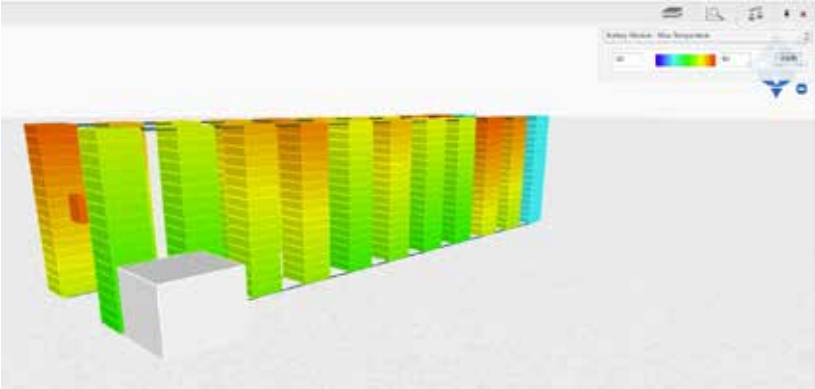
Using these platforms, vendors are able to efficiently educate potential customers and other stakeholders on the performance, lifecycle, and benefits of an ESS, including the expected return on investment. This includes the ability to demonstrate the benefits of storage at various locations on the grid, with the aim of providing utilities with the knowledge they need to include storage systems in their resource plans and rate cases. As the installed base of energy storage continues to grow, the accuracy and functionality of these modeling platforms will also increase. This in turn will lead to better educated customers and a greater level of trust in the technology, resulting in lower costs as financiers become more confident investing in projects.

Software driving a rapidly evolving industry

The global energy storage industry has experienced exponential growth over the past three years. This trend is expected to continue over the coming years as costs fall, while the capabilities and functionality of these systems increase. Some of the most impactful trends expected in this market over the next several years are driven directly by advances made in ESS software.

Perhaps most notably, the aggregation of distributed ESSs through software is a game-changing capability than can have major implications for the future of this industry. The aggregation of ESSs represents one form of virtual power plant (VPP), a platform which greatly enhances overall value by utilising a network of systems, compared to a single system on its own. Software platforms are the key enabling technology for this complex aggregation, which requires both centralised management and coordination, as well as local controls embedded in each system. By aggregating a network of distributed ESSs, a VPP can coordinate charging/discharging patterns to provide valuable services to grid operators such as reduced peak demand in select areas, frequency and voltage regulation, and renewable energy ramp rate management. With the right market structures in place, these services can provide new sources of revenue for distributed ESSs by helping grid operators maintain stability and defer or avoid new infrastructure investments and system upgrades.

Software providing this type of aggregation must balance the differing and often competing interests of customers and the grid while ensuring the maximum possible revenue is generated from each individual system. Although this type of operation requires more advanced and expensive software, the ability to open revenue streams outside of just helping customers save money is expected to lead to lower costs for customers and new deployments. Aggregation is becoming a key focus for software vendors—not only to use for their own ESSs, but also as a service they can provide to utilities and the growing range of energy storage customers.



Credit: Greensmith

Software is a critical piece of the puzzle, from design, to operation, to decommissioning.

Traditionally, there have been only a select number of potential customers for advanced ESSs. These were primarily utilities with specific needs and off-grid customers that relied on renewables or other forms of distributed generation. However, the falling costs for ESSs, along with the enhanced functionality enabled by software, have resulted in a broadening customer base with diverse needs. Customers including utilities, renewable energy project developers, ESS and project developers, commercial & industrial building owners, and energy management companies are now procuring energy storage to provide a variety of services. This range of customers requires advanced software capable of properly designing systems and tailoring operations to each individual customer for the maximum benefit at the lowest possible cost.

Software is expected to play an increasingly important role in the energy storage industry as power grids around the world transition to a system more reliant on variable generation and distributed energy resources. Energy storage is viewed as a key technological building block for the grid of the future; however, without sophisticated platforms for design and control, these systems have limited value. The ability to optimally and cost-effectively design and control an ESS through advanced software is bringing down many of the barriers that have held back the development of energy storage to date. As the industry continues to mature, software's significance will expand by allowing for communication and coordination between systems distributed throughout the grid, providing the essential links for a clean and resilient power system. ●

Alex Eller is a research analyst and senior consultant at Colorado-headquartered Navigant Research, responsible for Navigant's Grid-Tied Energy Storage research programme.

Q&A

Nancy Pfund, DBL Partners

Nancy Pfund was among Tesla's earliest backers and was previously on the executive board at SolarCity.

Credit: Tesla

Nancy Pfund is managing partner at DBL Partners, a venture capital firm which specialises in investing in companies and start-ups that offer both rewarding financial returns, and positive social impacts. There have been some serious clean tech companies in DBL's portfolio. As well as being one of the earliest backers to Tesla and SolarCity, to utility-scale solar tracker company NEXTracker to Off-Grid Electric, which deploys solar in rural Africa; to others in energy storage like Advanced Microgrid Solutions and Primus Power, Pfund is extremely well-placed to offer a quick Q&A 'masterclass' in energy storage investing.

What were some of your key takeaways from 2016 in energy storage?

It was a seminal year for energy storage. Energy storage really moved from dream to reality. The hard work that lots and lots of companies have been doing for several years to get battery storage into primetime, they flipped the switch and while we don't have widespread energy storage yet, we definitely took the important first steps toward that reality. I think you see it through the very high profile merger of SolarCity and Tesla, which was a statement about energy storage and its role not only in transportation but most importantly in greening the grid and pursuing consumer personalisation and choice, as well as utility use of storage to avoid the need for peaker plants and such.

Similarly other chemistries that will be important made some very significant moves into pilots and flow batteries, different chemistries, nickel-zinc, zinc bromide. I'm not the person to ask for all the different battery types but we've seen uptake on the

part of utilities, corporate customers and in certain locales, residential when paired with PV. For all of those reasons we saw 2016 as a huge inflection point for energy storage.

We've seen significant growth in the various different use cases for energy storage. It's not just households with PV, or just utilities doing more to make grids resilient – would you say it's been an "all of the above" kind of year?

I would but with the underlining emphasis that corporations are becoming significant storage customers. As we see the move towards 100% renewables on the part of massive companies like Apple and Google and Microsoft and Amazon, they are now becoming, as they build that renewable infrastructure for their servers and operations, not surprisingly, some of the earliest storage customers. One of our companies Primus Power that has a zinc bromide flow battery has an installation at Microsoft HQ for example which is very significant in terms of signalling that part of the toolkit for corporations to reduce costs by going renewable and achieve their sustainability goals, a big part of that toolkit is the battery or the storage architecture.

A huge part of DBL's raison d'etre is positive social impact – if corporations are choosing to do this is that a good marriage of business sense with social benefits?

You don't have to sacrifice financial return to deliver a positive social result and I think storage epitomises that because you're seeing significant companies in their early days being built that will bring returns to investors at the same time that you're addressing a critical need. If we electrify everything - which we're moving towards doing - we need to do it in a way that uses green resources and the nature of those resources will require storage. So it's a virtuous circle.

And it's not just the batteries or the storage architecture, it's also the integration. There's some really interesting work being done, like Advanced Microgrid Solutions [is doing] to develop a virtual power plant at a commercial building or office park by integrating storage assets with renewables, with the grid, with software to manage demand and reshape load. Saving the customer money, strengthening the grid reliability by applying locational strategies, putting storage in areas where it's needed - so helping the utility and the end use customer and the overall grid. So that's really where we're heading and using storage both in front of and behind the meter.

Is energy storage in the US still concentrated in leading regions, such as California, where around 100MW was deployed in six months to deal with the shortfall created by the Aliso Canyon gas leak? And have developments in those leading regions sent shockwaves around the rest of the country?

A lot of energy innovations happen in California first because there's a history here of good policy and utility and innovative new entrants pushing the envelope - and there's a consumer will for it. I can tell you that every battery company, every battery integration effort is being affected by what's going on in California. AMS just announced that they've got a Texas utility to do this [take up energy storage]. Hawaii is of course active in PV and storage.

So it's happening and just as with solar where California is head and tails above others in terms of PV installations, you're going to see other states catch up and in some ways storage has less of a headwind because you don't need the elaborate policies that solar needed to get started with. I would signal that Massachusetts has a storage mandate they're working on and it's just a process that we'll see dissemination of across the board. In Hawaii residential PV-plus-storage is cost effective given that they have extremely high utility rates so it's natural they would look at it there too. The numbers will start to work out in California over the next two to three years, so you'll see a steady rise in the customer solution architecture for storage as well, as prices come down.

The fact that California is leading, it's the sixth largest economy in the world - so it's not like it's some tiny state that doesn't have anyone living there. Even today, a huge percentage of US solar is in California, so it's a terrific place to start. It's like this is a really good place to hatch the next generation of the clean grid infrastructure.

It's interesting from a manufacturing point of view as well I guess because Tesla assembles cars in California and they're producing batteries out of the Gigafactory in Nevada. I guess it's another nice social benefit of this technology to foster that manufacturing side of things?

We really care about creating quality jobs here in the US and that was one of our main motivations, for our first investment in Tesla many years ago, is that we thought there'd be an opportunity to revitalise and grow the car manufacturing industry in the US for 21st Century needs. That has turned out to be the case, so with storage in the early days, of course everything came from Asia, that's where the battery market was thriving and continues to thrive. We will increasingly see domestic production because of the ability to do it in a cost effective way, with all kinds of savings relating to transportation and international regulatory obligations so there are a lot of reasons to build the domestic US battery manufacturing business and it has a huge positive impact in terms of employment and migrat-

Nancy Pfund, DBL Partners

ing people from the 20th Century energy job profile to a 21st Century one.

There's going to be so much demand for energy storage between electrification of transport and stationary storage that we're going to need plants in a lot of different places, which is good news. This is going to be a full employment act for battery manufacturing.

When you first invested in Tesla, you knew there was this aim to turn around transportation but could you see them coming this far, both in transport and in energy storage?

With every investment you make you hope it's going to be a gamechanger and make great returns but also change the world. We had that belief going in, we knew it was risky and we went through many years, it was a very difficult evolution for the company but of course now it's legendary. We did believe very firmly from the get-go, not only in the electrification of transportation vision that Tesla had, and we wanted our company to be successful but we also wanted it to change the industry in terms of its social impact. We want Detroit, Germany, Japan and China to make EVs and so that took a little longer than the immediate rise of Tesla but it's happening in a very emphatic way. So that's been a huge win but really the combination of solar and storage was part of the original plan! I know people may find that hard to believe but we invested in SolarCity very soon after investing in Tesla, we'd been in the solar market, we knew that storage was going to be important and the companies started working on this many, many, years ago.

So while it looks like this is a new idea, a new vision on the part of Tesla, it really isn't. It's been part of the plan from pretty much the beginning of the company.

Once you electrify transportation and people have electric cars and are charging them, then it sets up a huge incentive to green grids, to power your car off solar and put in storage to optimise your energy footprint from the roof to the garage.

We've seen a big portion of the success of US solar has been in the Investment Tax Credit (ITC) mechanism, which gives buyers a form of subsidy. Other countries like Germany, the UK and Japan boosted their solar industry with feed-in tariffs (FiTs). There seems less expectation that there will be a subsidy-driven market for energy storage in most territories, but are things like ITCs and FiTs crucial, or just nice to have?

Certainly the ITC has played a critical role in growing the solar industry in the US by creating the ability in the first five to seven years to use tax equity to finance the leases. And it's brought in billions of dollars of private capital to finance the growth, it's a huge success story. Now that the industry is bigger and more mature, we're moving to loans, banks are coming in, there are other ways to finance now but there certainly weren't in the first years. It's not a coincidence that the places that do have supportive policies for storage are going to be the early adopters. California has significant storage mandates, there's the SGIP rebate, Massachusetts is doing similar things, Hawaii has some programmes. So you will see supportive policies driving the industry in those regions.

Now, a lot of people feel it would be great to have something like an ITC for storage and there have been discussions about that. In this political climate it's very unclear if that would be feasible, but the good news is that it's not 100% necessary because you've got huge states like California with supportive policies that create the model and then as you're scaling – and this is assisted by the growth of the EV industry that's driving down battery prices – you'll get costs in line over the next few years so that they become compelling on their own vis a vis alternative approaches. We do need supportive policies that show the true cost of the peaker plant approach, for example, and it's becoming widely known that we're seeing a lot more methane leaks from gas infrastructure than we thought. While it's been viewed as a bridge [to lower emissions], it's not as solid a bridge as we thought. As that becomes known and it becomes harder to build and justify more gas peaker infrastructure, it will help storage as well, because the comparison will be more favourable.

> "You don't have to sacrifice financial return to deliver a positive social result and I think storage epitomises that because you're seeing significant companies in their early days being built that will bring returns to investors at the same time that you're addressing a critical need."

For companies like DBL it's like looking at those innovations from an early stage investor interest but will we see more institutional investors get involved?

Absolutely. We have visitors from all of the big finance firms all the time wanting to know more about these companies and where will they go next. So I think that there's a huge amount of interest in this and you'll see this become – I mean, even now the investment firms are writing reports about it and visiting the companies so it's all going to be good.

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