Energy Storage NEWS

The Energy Storage Report 2026

Charting the key trends, challenges and successes in the world's most exciting industry

Grid-forming technology
Leading providers discuss the next frontier of BESS applications, p7-10

Fluence Q&A
Director of strategy discusses high-level strategy, plans and challenges, p16-18

Fire safety
The latest on NFPA 855 and LSFTs, p19-20

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Cover image: A render of LEAG's 1GW/4GWh Germany project, to be supplied by Fluence. *Credit: Fluence/LEAG.*

Introduction

Welcome to the 2026 edition of The Energy Storage Report, the supplemental publication for the Energy Storage Summit EU, Australia and USA events put on by Solar Media, part of Informa Markets.

In it, you'll find insights, analysis and fresh reporting from the *Energy-Storage.news* editorial team, giving you the inside track on this rapidly evolving industry.

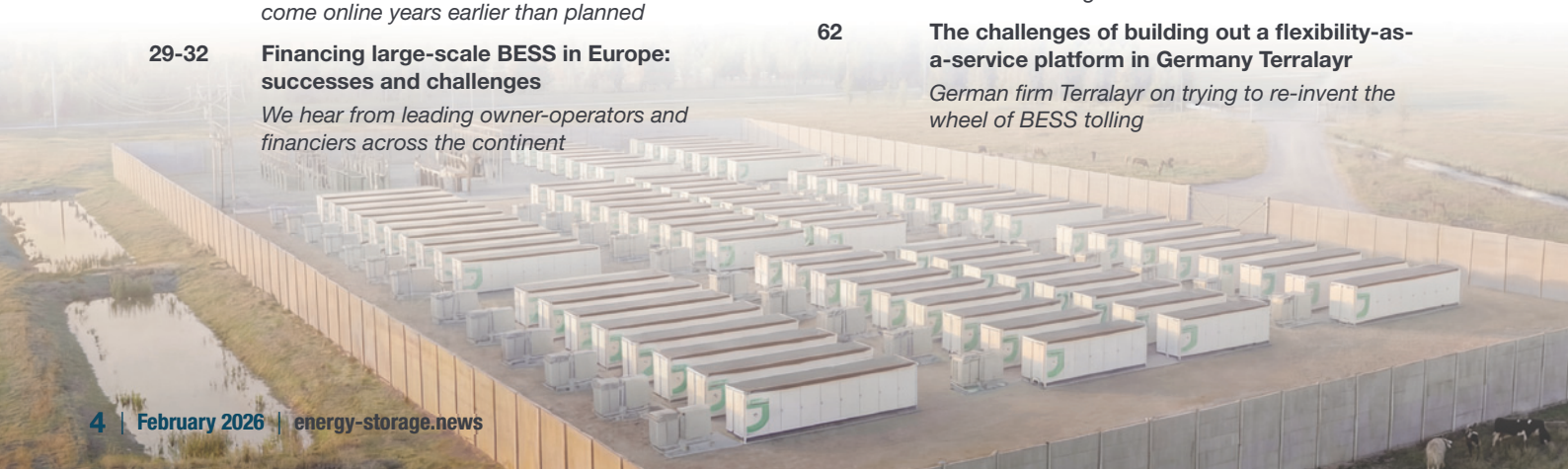
Some of the content is taken from our *Energy-Storage.news Premium* offering, which offers 20-30 exclusive news, analysis and interview articles a month, back issues of our quarterly journal *PV Tech Power* and other exclusive content, including video interviews, as well as event discounts and more.

Read on for deep-dives on the biggest topics in BESS today, including fire safety, grid-forming technology, supply chain, grid, pricing, tolls and PPAs, optimisation, cybersecurity, bankability, warranties, project financing and more. Most content is globally relevant, with some regional deep-dives on Europe and the US, plus a healthy sprinkling of Australia content for our friends down under.

So, from myself and the whole team at Solar Media, thank you for reading our content, attending and supporting our events, and most of all for being part of this exciting, game-changing industry.

Supplement editor:
Cameron Murray

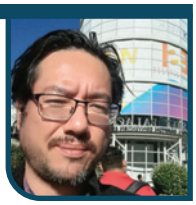
Contents



Meet the team

The Energy-Storage.news team will be walking the show floor at the Energy Storage Summit in London. They'll also be involved in a number of sessions each day. Here's where you can find them.

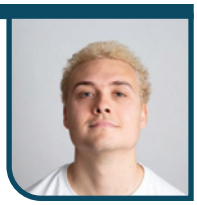
Andy Colthorpe



Editor, Energy-Storage.news

Energy-Storage.news editor, Andy, will be providing the **Welcome Address** on day one. He'll also be moderating the **Smarter Connections for a Storage-Ready Grid** session on the morning of day one. On day two, you can catch Andy moderating the **Cybersecurity and Critical Power Infrastructure** session.

Cameron Murray



Senior reporter, Energy-Storage.news

Cameron is set to moderate day two's **Product Selection, Quality, and Underperformance in Battery Storage Projects** session, followed swiftly by a turn moderating the **Driving LDES Forward: The Perfect Time to Invest?** Session.

Molly Green

Senior reporter, Solar Power Portal

Solar Power Portal and EV Infrastructure News' senior reporter, Molly, will be moderating day two's **The Carbon Benefit of BESS and its Impact on Reducing Emissions** session. Catch her there and roving the show floor during both days.

Jessica Winch

Business Development Manager

Leading our sales team at the event, Jessica will be available at the **Energy-Storage.news** stand (F18). We encourage you to stop by to introduce yourself and discuss how we can assist in delivering your message to a highly engaged energy storage audience. This is an excellent opportunity to explore advertising options in the upcoming edition of this Report or future editions.

Michael Brook

Editor-in-chief

Michael will be on-site for the duration of the show. He can be found on at the **Energy-Storage.news** stand (F18). He'll be happy to talk to you about all things editorial and hear your thoughts on our coverage.

News

Germany: LEAG builds 1GW/4GWh largest BESS project in Europe, Fluence to supply tech

The low-carbon subsidiary of German energy company LEAG is constructing Europe's largest single-site battery storage project, in partnership with Fluence.

LEAG Clean Power will deploy the 1GW/4GWh standalone BESS in Jänschwalde, a municipality in Germany near the country's eastern border with Poland.

Fluence will supply its SmartStack BESS solution to the project, equipped with lithium iron phosphate (LFP) chemistry battery cells.

'Catastrophic failure' of transformer at Waratah Super Battery, Australia's 'giant shock-absorber' for the grid

The 850MW Waratah Super Battery in New South Wales, Australia, has experienced a temporary reduction in operational capacity due to transformer issues identified during testing as it transitions to full output, according to project developer Akaysha Energy.

This comes amid reports in various news outlets, such as the Australian Financial Times (AFR), regarding a "catastrophic failure" of transformer equipment at the site of the project.

A spokesperson from Akaysha Energy told Energy-Storage.news that the company "notified the energy market of a temporary loss of capacity at the battery due to a transformer outage."

The BESS for the project was provided by system integrator Powin, which filed for bankruptcy, with most of its assets acquired by competitor FlexGen, in 2025.

Tesla reports record energy storage deployments and profit ahead of vote on Musk's monster pay proposal

Tesla reported record energy storage deployments and business segment profits in Q3 2025, just ahead of a shareholder vote on CEO Elon Musk's historic remuneration package.

The US electric vehicle (EV), energy storage, software and robotics company reported its third-quarter results last week (22 October), in which it also reported record vehicle deliveries.

Tesla made 12.5GWh of energy storage deployments in the quarter across the residential, commercial & utility (C&I) and utility-scale market segments, an 81% increase from the same period last year, when it delivered 6.9GWh.

Chile to reach 2050 energy storage target within next two years, says energy minister

During the opening address of Energy Storage Summit Latin America 2025, in Santiago, Chile, the Chilean Minister of Energy Diego Pardow Lorenzo said the country was most likely set to surpass its 2050 targets in 2027.

Pardow added that by January, Chile will have installed 2GW of BESS, which represents the country's 2030 target. Moreover, the energy minister added that there are 8GW under construction, 2GW more than the 2050 target set by the government.

Italy's 'exceptionally competitive' first MACSE energy storage auction concludes, procuring 10GWh

The TSO of Italy has completed its first MACSE auctions for energy storage, procuring 10GWh of capacity at what the NHOA CEO called 'exceptionally competitive prices'.

TSO Terna announced the results of Italy's long-awaited energy storage-focused capacity auction scheme, full name Meccanismo di Approvvigionamento di Capacità di Stoccaggio Elettrico, on 1 October.

All 10GWh of capacity targeted was procured, covering four different zones in Southern Italy and the islands, with bids exceeding the available capacity by a factor of four.

The weighted average clearing prices were €12,959/MWh-year (US$15,230) across all four, with the individual zones.

BYD launches 14.5MWh BESS as energy density race continues

BYD has presented its latest grid-scale BESS product, Haohan, pushing energy density even further to its limits.

Haohan "redefines possibilities in utility-scale energy storage", the company said on LinkedIn, outlining several differentiating features, including the use of its 2,710Ah Blade Battery, which is four-to-eight times larger than the industry standard.

It packs 14.5MWh of energy storage capacity into one unit, equivalent to 10MWh in a 20-foot area. That is far higher than the 6-7MWh products that have been announced over the past year, and double the 5MWh, which has become the industry minimum standard over the last several years.

Samsung SDI ramps up ESS battery manufacturing in US to 30GWh, Tesla deal talks reported

Samsung SDI is ramping up its manufacturing of energy storage batteries in the US to 30GWh by the end of 2026, while electric vehicle (EV) battery demand remains sluggish.

The news came as The Korea Herald and news agency Reuters both reported that the company is in talks over a multi-year, multi-gigawatt-hour stationary energy storage battery supply deal with Tesla.

Grid-forming: a technical adjustment with a big impact

Grid-forming battery storage assets make stable electricity grids based on majority shares of variable renewable energy a technological and economic reality, writes Andy Colthorpe.

The first century and a half of humanity's reliance on electricity was, of course, under a paradigm of centralised thermal generation. The rising adoption of low-carbon renewable energy technologies worldwide brings many benefits, including reduced air pollution and greenhouse gas (GHG) emissions, lower generation costs, and less reliance on a limited number of points of failure.

The need to supplant thermal generation extends beyond replacing generation capacity. Of course, batteries and other forms of energy storage add flexibility as well as help cover those times when the sun doesn't shine, and the wind doesn't blow.

However, another legacy of thermal generation that is gradually being overturned is the stability that the rotating mass provides to electricity grids—the world's biggest machines.

Electric grids operate at the same frequency as the gas, coal, nuclear or even hydroelectric turbines connected to them, whether 50Hz or 60Hz, depending on grid design and geography. In a relatively low renewables environment, that stability is not threatened.

Post-fault corrections to frequency can be made with battery energy storage systems (BESS) providing ancillary services, but a drawback of inverter-based variable renewable energy (VRE) generation, if we can call it a drawback since it's a well-known feature, is that, of course, solar PV and wind plants do not run 24/7 with a consistent generation profile.

This is where BESS assets equipped with grid-forming inverters come in. As opposed to grid-following inverters, which respond to the operating signals of the existing grid infrastructure, 'grid-forming' enables VRE and BESS resources to actively maintain the grid's stability.

Grid-forming resources do this primarily by providing the inertia that rotating mass currently supplies, along with other supporting system stability services such as voltage regulation, short-circuit ratio, and enabling black start of the grid from zero.

"The topic of grid-forming battery power plants is an existential issue to the electric grid itself," says Luke Witmer, VP of software engineering at Wärtsilä Energy Storage.

"Without sufficient grid-forming sources, you have no electric grid. You cannot run 100% renewables without that."

Credit: Zenobē Energy.

Zenobē's second grid-forming BESS in Scotland, Kilmarnock South, went into commercial operation shortly before this publication went to press.

Witmer gives the example of the California Independent Electric System Operator (CAISO) grid. Each year, CAISO presents "beautiful charts" showing it runs 100% on solar power in the middle of the day for several hours at a time.

"How are they doing that? They're doing it because they're connected to the Pacific Northwest, in the western interconnection, where there is a lot of hydro. That is the grid-forming entity for that [CAISO] electric grid. That's the only reason they can do it. They don't have sufficient battery capacity to create the grid with the grid-forming technologies in existence there."

As explained in a recent position paper from trade association SolarPower Europe, the ability of batteries with grid-forming inverters to mimic those behavioural characteristics of traditional synchronous generators is enabled by advanced control algorithms.

Called droop control algorithms, these regulate inverter output to generate stable voltage waveforms and respond dynamically to disturbances, providing the necessary millisecond-level response.

The benefits of grid-forming

Grid-forming is not new. Island grids the world over, often powered predominantly by renewable generation and energy storage, typically with thermal generation as backup, have needed to create their own frequency and voltage.

"From Wärtsilä's perspective, we've been running utility-scale battery power plants in grid-forming mode since 2018 in our islanded projects. Across the Caribbean nations, or in mining contexts, we have hundreds of megawatts of battery assets that run 24/7 in grid-forming mode. This isn't new to us. We're ready for it," Witmer says.

What is new, however, is the recognition that grid-forming from inverter-based resources will become increasingly necessary for grid-connected environments to integrate higher penetrations of VRE.

This has been demonstrated at Blackhillock, Scotland, where the first 200MW/400MWh phase of a 300MW, 2-hour-duration grid-forming system has been in operation for about a year, equipped with SMA grid-forming inverters. Owner-operator Zenobē was awarded a contract for system stability services, including inertia, by the UK's National Electricity System Operator (NESO) through a tender for innovative options to manage the network called Stability Pathfinder.

It aims to mitigate grid congestion and wind curtailment, and Zenobē has said it could equate to around £170 million (US$228.5 million) in consumer savings over 15 years. Perhaps just as importantly, it helps provide a solid technical foundation for the UK's Clean Power 2030 net-zero emissions policy.

Although inverters provide inertia and enable other system stability services, such as short-circuit ratio and black start capability, the hardware adjustments required to convert a BESS power conversion system (PCS) from grid-following to grid-forming are relatively minimal.

What is more complex is the system studies to understand the need for those services, then ensuring that power electronics and the power plant controller (PPC) interact in such a way that the BESS can continue providing stackable applications like ancillary services and intraday trading as it ordinarily would, responding in milliseconds to each command.

There is not much difference between a grid-forming and a grid-following inverter in the hardware or the data sheet, in short. The control, the software, the firmware, and the control behaviour, however, are different. 'Orchestration' with the power plant controller, interconnection to the transmission level and tuning performance in milliseconds, are among the details that can present a challenge.

That means expertise in interconnection procedures, simulation, modelling, engineering design, and the engineering of the interconnection are the real points of differentiation, rather than anything inherent to the inverter itself.

Hitachi Energy has also provided grid-forming capabilities to off-grid or grid-edge power plants for many years, developing its control algorithms and onboarding them at projects such as the Energy Storage for Commercial Renewable Integration (ESCRI) 30MW/8MWh BESS project in Dalrymple, South Australia.

That project, commissioned in 2018, aimed to demonstrate grid-forming at the far end of South Australia's dispersed, relatively weak transmission network, helping stabilise the grid as more large-scale wind and rooftop solar resources were added, supported by funding from the Australian Renewable Energy Agency (ARENA).

Hitachi Energy, which also supplied and integrated the BESS at Dalrymple, further added inverter, PCS and PPC know-how to its portfolio with the recent acquisition of Spanish power electronics manufacturer eks Energy, itself a pioneer in off-grid and grid-edge renewables.

Alberto Prieto, head of power conversion solutions, grid automation at Hitachi Energy, says that while in theory, any power electronics provider could do grid-forming, there is no substitute for developing, testing and proving the reliability of the solution through real-world deployments, which through Hitachi Energy and eks, has been done everywhere from the Faroe Islands in northern Europe to Hawaii and now most recently a project in Finland.

"We go through simulations first, and then we go through actual testing of the algorithms, and then we have pilot installations with customers. We had our first pilots many years ago; that technological barrier was over for us many years ago," Prieto says.

Analysis must be conducted in the context of the local grid connection and the required applications and functionalities, including grid-forming stability services. Dynamic simulations using tools like PowerFactory are performed to optimise the overall system concept.

According to Hitachi Energy, the goal is to balance the need for grid strength with short-circuit currents, ensure a stable grid reference provided by grid-forming assets, and address any specific energy and active power support required for the analysed applications.

"For a new player, someone who has been doing the PV inverters for many years, but has zero experience with grid-forming, there is a long way, a long path to this point," Prieto says.

Credit: Hitachi Energy

Hitachi Energy PCS unit at a customer site.

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"It takes time. If you have done that in the past and your simulation and models are already tested and validated through experience, then you can improve or develop on what you have. If you haven't done that all before, it doesn't matter how many gigawatts of PV inverters you have done in the past; if you haven't really approached the problem, there is a barrier."

Where in the world?

So, in other words, somewhat challenging but eminently feasible. Not a huge expense either, but the need for grid-forming does need to be recognised, either made mandatory or incentivised, or it doesn't stack up.

"What we really need is more places in the world that are experiencing these high and riskier levels of renewable penetration and are experiencing weak grid conditions to create avenues for financial compensation to battery owners who provide that service to the grid," Wärtsilä's Luke Witmer says.

"There's just not enough of that yet. There's a wear-and-tear element to actually operating a battery in grid-forming [mode] all the time. It is additional battery throughput. It is responding to micro fluctuations in frequency and voltage; those inverters are providing both real and reactive power consistently. It's significantly less than one cycle per day throughput—it varies in the context and the quality of the grid—but, if you were to try to get a pulse check, depending on the grid, you're talking anywhere from a quarter of a cycle per day, up to maybe half a cycle per day. So, there is some energy throughput that's happening, and there are aux loads to run the battery. You cannot put these plants into standby mode. They are creating the voltage for the grid 24/7, and that costs money. It's not just reactive power that's free; there's real power consumption to do this."

NESO's Stability Pathfinder innovation scheme in the UK has led to the first auctions for stability services, Australia's ARENA-funded work at ESCRI led to a major financial support scheme to add grid-forming at new-build and existing assets, and it seems like the vast majority of the country's BESS fleet will, sooner or later, be grid-forming.

In the US, ERCOT in Texas is an example of a region that will implement it more quickly than most due to its islanded profile and limited interconnection with other transmission regions, while at the national level, the North American Electric Reliability Corporation (NERC) has long supported and provided technical guidance on grid-forming.

Elsewhere in Europe, Markus Ovaskainen, sales & marketing director at Finland-headquartered energy storage and power electronics solutions provider Merus Power notes that the Nordic country's TSO FinGrid was likely the first in Europe to offer guidance on grid-forming.

Merus Power has delivered its first grid-forming projects in Finland. Ovaskainen says the simulation models and studies that FinGrid requires for grid-forming projects are perhaps "three or four times more intensive than grid-following projects, with more data and simulations needed."

"In grid-forming operation, the reaction speed needed is much, much faster than grid-following or any other technical requirements from the capacity market (CM), frequency response (FR), etc."

Ovaskainen notes that there is not really one unified standard on what grid-forming really means. This is made a little more complicated by the fact that different grids have different needs.

So, for example, in Germany, at the end of January, as instructed by the federal network regulator, the Bundesnetzagentur (BNetzA), the country's four TSOs began paying for inertia services through a new market, Momentanreserve ('Instantaneous Reserve').

Germany is only seeking inertia services to regulate frequency, whereas the Blackhillock project, and Zenobe's newest 300MW/600MWh Kilmarnock South project, also in Scotland, provide Short-Circuit Level (SCL) to regulate voltage.

Germany, being in the centre of the continental power system and interconnected to neighbouring countries, does not have that same "short-circuit problem" that the UK's NESO recognised in Scotland, or indeed, as might be found at the grid edge in Australia, or anywhere else.

ERCOT in Texas, meanwhile, has long distances of wire connecting wind assets over thousands of kilometres and therefore needs a voltage source.

It really depends on the kind of physical structure of the grid, and, of course, the size of the country and the location. Spain, for example, had a major blackout which was caused by voltage oscillations, because they are on the edge of the grid.

Ultimately, while grid-forming is a relatively minor adjustment, it is a highly impactful change in how grid operators view and manage energy storage and renewables. Even where those services are not yet being actively procured and paid for, it makes sense to be ready for it.

Germany's much-talked-about energy storage-as-transmission NetzBoosters ('GridBoosters'), which add redundancy to transmission lines, are being designed with grid-forming capabilities, although they are not delivering inertia or those other services from Day One of operation.

"Even the strongest systems, such as in the US, where you have a strong grid, or in many countries in Europe, end up not being entirely strong when you have a huge amount of renewables," Hitachi Energy's Alberto Prieto says.

"Generally, they [renewables] are concentrated in one area. We do have customers in the US who, even if the grid is strong, will experience a concentration of renewables in specific areas of the grid. It's necessary because the more renewables we have on the grid, the more need there will be for grid-forming." ■

ESS supplier landscape in 2025: strong growth and profitability increases, but for how long?

Solar Media Market Research analyst Charlotte Gisbourne rounds up the latest industry trends and highlights from the *Battery StorageTech Bankability Ratings Report.*

Energy storage cemented its place as the fastest-growing segment within the clean energy sphere in 2025 and saw robust growth despite the turbulent US policy environment.

To really understand the market, you need to examine the companies behind the final products and their performance amid increased competition.

This article examines the 50 energy storage system (ESS) suppliers featured in the *Battery StorageTech Bankability Ratings Report,* covering trends in manufacturing capacity, ESS shipments, technology diversification and financial performance.

Production

Figure 1 displays battery manufacturing cell capacity for both EV and ESS for the ESS suppliers which are also cell manufacturers featured in the Report (27 in total).

China retains the majority share; however, in 2025, this share fell slightly, and 2026 is predicted to see a further decline of nearly five percentage points.

If purely looking at energy storage cells, however, manufacturing in China has an even higher proportion, given that the majority of cell manufacturing in Europe at the moment appears to be for electric vehicles.

Even with new facilities built for energy storage in the region, such as Bulgaria's first ESS factory owned by IPS opened in 2025, these remain mainly without cell production.

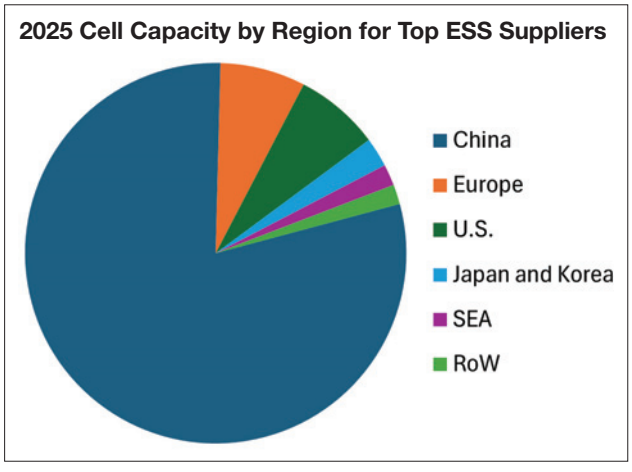


Figure 1: The increase in manufacturing in countries outside China primarily excludes cells, for which supply is still heavily reliant on China.

Uncertain trade relations paired with a sluggish EV demand in the US have led some companies to retool initially purely EV battery factories in North America to also produce ESS batteries. A key example is Envision AESC's plant in Tennessee, as well as LG Energy Solution (LGES), which is now producing cells in its new Michigan facility. LGES had previously manufactured its ESS batteries mainly in its Chinese factories but is now also producing batteries at its Poland plant and has announced plans for domestic manufacturing in Ochang, South Korea, with production scheduled to begin in 2027.

On the back of the growing market capacity, cell capacity has increased by 31% year-over-year for these top manufacturers. There has been a manufacturing uptick to meet demand, with new factories opening for module assembly, such as Fluence's 35GWh facility in Vietnam and Hithium's 10GWh Texas facility. Production capabilities in India have been increasing, mostly by domestic companies, with over 10GWh of battery manufacturing capacity completed in 2025.

Companies are continuing to explore new markets, and this capacity buildout is set to increase with key sites breaking ground, such as CATL's Indonesia facility, which is part of a larger scheme to localise production. Work has also begun on facilities for CALB in Portugal and Gotion High-Tech in Slovakia.

Despite expanding into other countries to derisk the supply chain, key materials remain heavily concentrated in China, namely, lithium. Not only are there large deposits in the country, but the majority of global lithium processing currently occurs there.

Shipments

Shipments for the 50 ESS suppliers in the bankability report this year increased 51% year-over-year. While impressive, the growth is a bit lower than in 2024.

China still remains the most significant end market for ESS shipments, as shown in Figure 2. The regions that experienced the highest growth in shipments were Latin America and the Middle East and Africa, increasing 168% and 126% respectively.

While smaller companies were able to capitalise on the industry's growth, the strongest shipment growth came from estab-

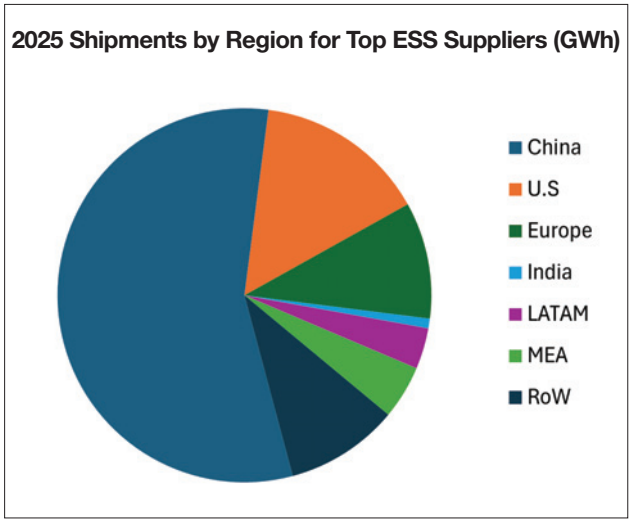


Figure 2: Despite the mandate for renewable energy to be co-located with energy storage ending in China, growth remained strong and is likely to continue to lead the energy storage market for the foreseeable future. Estimates have been made for those companies that do not report figures publicly.

lished companies, albeit outside of the top three. These were slightly newer in the battery storage space and hence still battling to gain market share, such as Jinko Solar and Ganfeng Lithium.

There has been an increase in diversification of shipments, particularly for Chinese companies. They have been expanding their global footprint in the highly competitive domestic battery market and have successfully captured emerging markets.

Some companies whose primary market was the US experienced a decline in orders due to changing regulations in the country and the industry headwinds that accompanied them. Wärtsilä, for example, saw an 84% fall in orders in terms of capacity in the first nine months of the year.

Technology

Companies have begun to diversify away from traditional 20-foot containers, with scalability being a significant trend. Adopting a modular design could ease potential difficulties with international shipping restrictions and increase energy density. New products were regularly launched in 2025, with nearly half of the companies featured in the reports announcing new containerised utility-scale battery storage solutions.

The past few years have seen rampant innovation in the industry, with companies announcing increasingly higher-capacity cells with higher battery density, which would aid in cost reduction. These are shown in Figure 3.

The average R&D intensity for the top energy storage companies is approximately 6% as of 2025, with cell manufacturers generally incurring higher expenditures.

In addition to the traditional lithium-ion cells, manufacturers are looking to expand into other technologies; both BYD and Hithium announced new sodium-ion products for energy storage late 2024, and in 2025, Gotion started its solid-state pilot line.

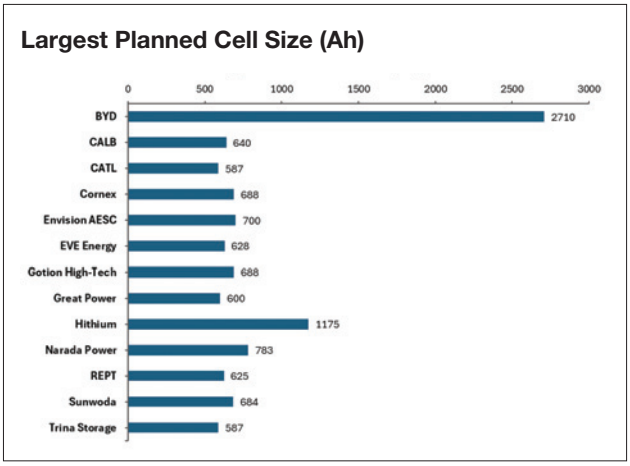


Figure 3: Prismatic LFP cells are the most common; however, new advancements such as BYD's Long Blade Battery Cell are pushing capacity even further.

Financials

When examining the top ESS suppliers that are mostly also cell suppliers, sales from EV batteries have historically accounted for the majority share.

ESS revenue, however, is on the rise; when considering the top cell manufacturers combined into a single company, ESS revenue increased by 24% in 2025 and gained one percentage point in overall share. Operating profit for these cell manufacturers rose 4% year-over-year in the first three quarters, with profit margins increasing by an average of 1 percentage point. The capacity scale-up and increased utilisation could have aided in cost-cutting, which counterbalanced the falling price of batteries.

The financial health of the industry as a whole is still doing well, with valuation making up the vast majority of the Altman-Z from positive investor sentiment; this is especially so in the wake of increased electricity demand in the US and the need for data centres. Stock prices for battery storage suppliers in general

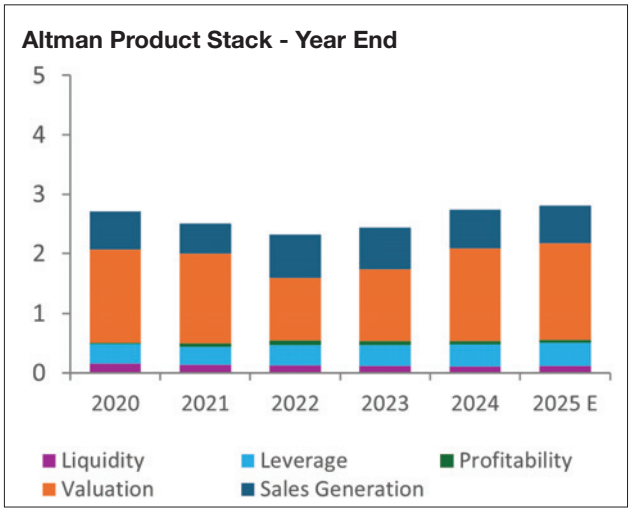


Figure 4: The amalgamated Altman stack of all the featured companies. The increase in AI and data centre demand could be a strong influence on positive investor sentiment for energy storage companies.

began to rise around September, possibly spurred by the Chinese government's announcement of its intention to install 180GW of battery storage by 2027.

One key setback for revenue growth is the decline in battery prices and increasingly low bids resulting from intense competition and oversupply. In 2025, a bid of CNY 0.37/Wh (US$53/kWh) was made for a 4-hour package from the China Energy Engineering Corporation (CEEC). Gangfeng Lithium also won a bid for Petro-China Jichai Power with a unit price of CNY 0.345/Wh. Looking at the industry as a whole, investment seems to be slowing down slightly, with the average quarterly capex in 2025 falling 10% compared to the previous year.

The turbulent regulatory landscape in the US has caused some financial difficulties with ESS players in the region, especially those without a diversified revenue stream. FREYR and KORE Power cancelled previously planned manufacturing facilities, and Powin filed for bankruptcy in June. This is in contrast to suppliers in the report based in China, who were estimated to see an average revenue growth of 12%.

2026 Outlook

The energy storage market is still showing signs of expansion, and the bankability report suppliers are predicted to see over 30% growth in 2026. As markets mature, a slowdown in growth is to be expected; however, utility-scale ESS adoption is still in its early stages in many countries, which are instrumental in driving the overall uptick. The wide range of use cases for ESS helps mitigate the saturation risk in end-use applications.

In general, expect more attempts at manufacturing diversification, particularly in Southeast Asia, from Chinese companies. Indonesia is set to see over 20GWh of capacity by 2028 and has become a hotspot for manufacturing, with CLOU's energy storage factory set to be completed in 2026. Malaysia is also experiencing significant traction.

ESS cell production capacity is expected to reach over 40GWh in the US as domestic manufacturing continues to expand, although this growth primarily originates from companies based overseas, particularly from South Korea. The trend of adopting ESS production in factories previously planned for EVs is predicted to continue, especially as the EV tax subsidy concluded at the end of September 2025 and could potentially slow the already sluggish demand.

The potential of the energy storage market will likely see established companies dip their toes into the market, although this is more likely to be companies in the PV sector; automakers could also make a move, with one already extant example being Ford, which recently established its battery energy storage business with first deliveries planned for 2027.

Overall, in 2026, the energy storage market is expected to continue on its current trajectory. However, one would think it will reach a point where keeping this high growth level while simultaneously maintaining or increasing profitability cannot be sustained. ■

BESS deployments set to soar in 2026 in Europe, US and Australia

This year, large-scale BESS installations could triple across 10 key markets, based on project pipelines, writes Cameron Murray.

There could be three times more BESS brought online this year than last year across the UK, Spain, Italy, Germany, France, Poland, Spain, Netherlands, Belgium, the US and Australia, according to pipeline data from market intelligence firm Rho Motion, part of Benchmark Mineral Intelligence.

Obviously, not all of what is forecast is certain to come online, with EPC and balance of plant (BOP) contractors proving a major bottleneck alongside challenges in supply chain, financing and execution. Policy chaos in the US is certain to mean some projects get delayed beyond 2026.

UK and Continental Europe

The UK had a strong year, with around 1.85GW/4GWh coming online, up by around one-third. Our Solar Media Market Research colleagues' *Battery Storage: UK Pipeline & Completed Assets Database* shows similar data (go to page 52 for a full article from them on UK grid reform and deployments).

Rho Motion says there is a pipeline of 10.3GW/22.3GWh due to enter commercial operations in the UK during 2026.

Although not all of this will definitely come online, 2026 is still likely to eclipse 2025's numbers. The emergence of large infrastructure and institutional capital and structured revenue contracts have enabled the next phase of growth.

Continental Europe is fast catching up. Last year, the seven non-UK European countries in the table added a combined 3,596MWh of capacity, around 10% less than the UK. This year, they look set to add 23,958MWh, nearly 10% more. We suspect that gap will grow in 2027 and beyond.

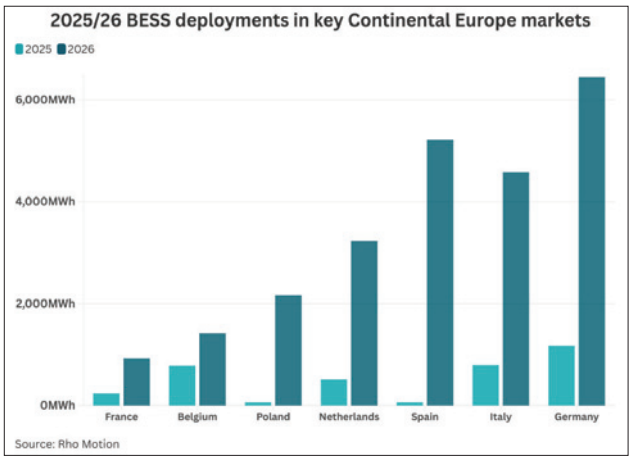
Europe as a whole added just over 10GWh in 2025, up 28%.

The Italian market can finally kick off now that the first MACSE auction has concluded (see articles about that on pages 48-49 and pages 54-55). Whether developers won contracts or not, they can now make investment decisions using MACSE as a reference point.

Spain has also moved fast in the past six months to set up a busy 2026 of completions (2GW/5.2GWh forecast), with Iberdrola, Naturgy, Zelestra and Galp all starting construction on major projects last year. Projects in Spain are generally

Country	2025 MW Deployed	2026 MW Pipeline	2025 MWh Deployed	2026 MWh pipeline	MWh % growth	Average duration 2026
UK	1,849	10,311	3,989	22,347	460	2.2
Spain	29	1,998	56	5,216	9214	2.6
Italy	369	1,639	788	4,579	481	2.8
Germany	704	2,814	1,172	6,444	449	2.3
Poland	32	567	56	2,158	3753	3.8
France	115	460	234	920	293	2
Netherlands	193	887	515	3,231	527	3.6
Belgium	201	400	775	1,410	81	3.5
US	15,735	30,523	46,285	100,405	116	3.3
Australia	4,244	15,202	9,803	39,372	301	2.6
Total	**23,471**	**64,801**	**63,673**	**186,082**	**192**	**2.9**

2025 and 2026 large-scale BESS deployments, data from Rho Motion



using either private toll deals or EU Recovery and Resilience funding as the bedrock of their business case.

Germany goes from strength to strength with an increasingly BESS-familiar lending and financing community, more widely available tolling structures, and huge arbitrage opportunities in what is Europe's largest energy market. Most activity is geared towards getting projects online before August 2029, when a grid fee exemption expires (a permanent solution is in the works).

However, Rho Motion said it expects much of both countries' 2026 pipelines to be delayed.

Poland also looks set to become a hotbed of activity, and project wins in the capacity market (CM) have now translated into final investment decisions (FIDs). Some 13GW of BESS projects have won contracts in the CM in the past three years, all of which must be delivered.

US

It's been a tumultuous 12 months for the clean energy industry in the US, with tariffs and policy chaos under Trump 2.0.

That mainly impacts projects further out, so 2025 was still a very strong year: 15.8G/46.3GWh came online, up 19% year-on-year. For 2026, some 30.5GW/100.4GWh has commercial operation dates, though, again, some of that will get delayed.

Turn to pages 37-38 to read an article about the latest US-China trade, tariff and FEOC challenges.

Australia

2025 laid much of the groundwork for what is expected to be a transformational few years for the Australian market. Grid-forming BESS are becoming the new norm, and the country hosts several high-profile operational projects including Akaysha Energy's 850MW Waratah Super Battery and Origin Energy's 460MW/1,770MWh Eraring BESS. ■

‘Expectations will continue to rise’: Fluence director Q&A

Fluence’s senior director of commercial strategy Andrew Gilligan talks to Cameron Murray about the firm’s successes and challenges, staying competitive, domestic manufacturing and more.

System integrator Fluence needs little introduction. From being founded by industry giants AES and Siemens in 2018, to a huge IPO, to working on some of the most high-profile BESS projects in the world, with its fair share of challenges along the way. Andrew Gilligan talks us through these and more in this exclusive Q&A.

Energy-Storage.news: How would you assess Fluence’s success in adapting to its headline challenges over the past two to three years, and what are your strategic priorities for the coming two to three years?

Andrew Gilligan: Over the past few years, Fluence has operated with the belief that energy storage is on a fast track to becoming essential infrastructure, and we planned accordingly. The industry was maturing in real-time, and we leaned into quality and scale as strategic advantages. This included tightening execution discipline, making deliberate supply chain and manufacturing choices, and sharpening our focus on real-world performance once systems are deployed on the grid, drawing on all of the available experience we were starting with. That foresight positioned us to help customers meet rising expectations as storage plays essential roles in providing resiliency, peak supply, and balancing support for some of the largest power markets in the world.

Looking ahead, our priorities build on that same forward-looking approach. As storage becomes even more integral to grid reliability, expectations around safety, delivery speed, availability, and long-term performance will continue to rise. We are focused on scaling responsibly, advancing the intelligence and controls needed for increasingly complex grid functions, aligning our platform to regional policy and market needs, and ensuring our solutions deliver predictable performance over decades.

How would you assess the evolution of BESS applications globally, as we move from load shifting and ancillary service to grid-forming and balancing (and beyond)?

The evolution of battery energy storage applications globally reflects a clear progression in both maturity and necessity. Early deployments were largely focused on relatively shallow markets and on providing ancillary services to support renewable integration into the grid or to replace inefficient peaker plants.

Today, energy storage is increasingly deployed as a primary resource to deliver energy during the most critical hours of a market on a daily basis, while simultaneously performing advanced functions such as grid-forming and enabling higher utilisation of existing grid capacity. This shift is being driven by higher renewable energy penetration and rising electricity demand, including from AI data centres, which are fundamentally reshaping how power systems are planned and operated.

As a result, storage assets are now expected to deliver value across multiple use cases, at longer durations, and over extended operating lifetimes, often under more dynamic and demanding conditions. This evolution places greater emphasis on advanced controls, high availability, predictable degradation, and overall system intelligence. Value is no longer defined by a single service delivered, but by a system’s ability to perform reliably, efficiently, and dynamically, depending on what is most demanded by a utility or the power market.

How do you stay competitive on performance?

Performance, for us, starts with listening. We engage closely with customers through structured feedback mechanisms, including customer advisory forums, to understand how their needs are evolving and how systems are performing in real-world operating conditions.

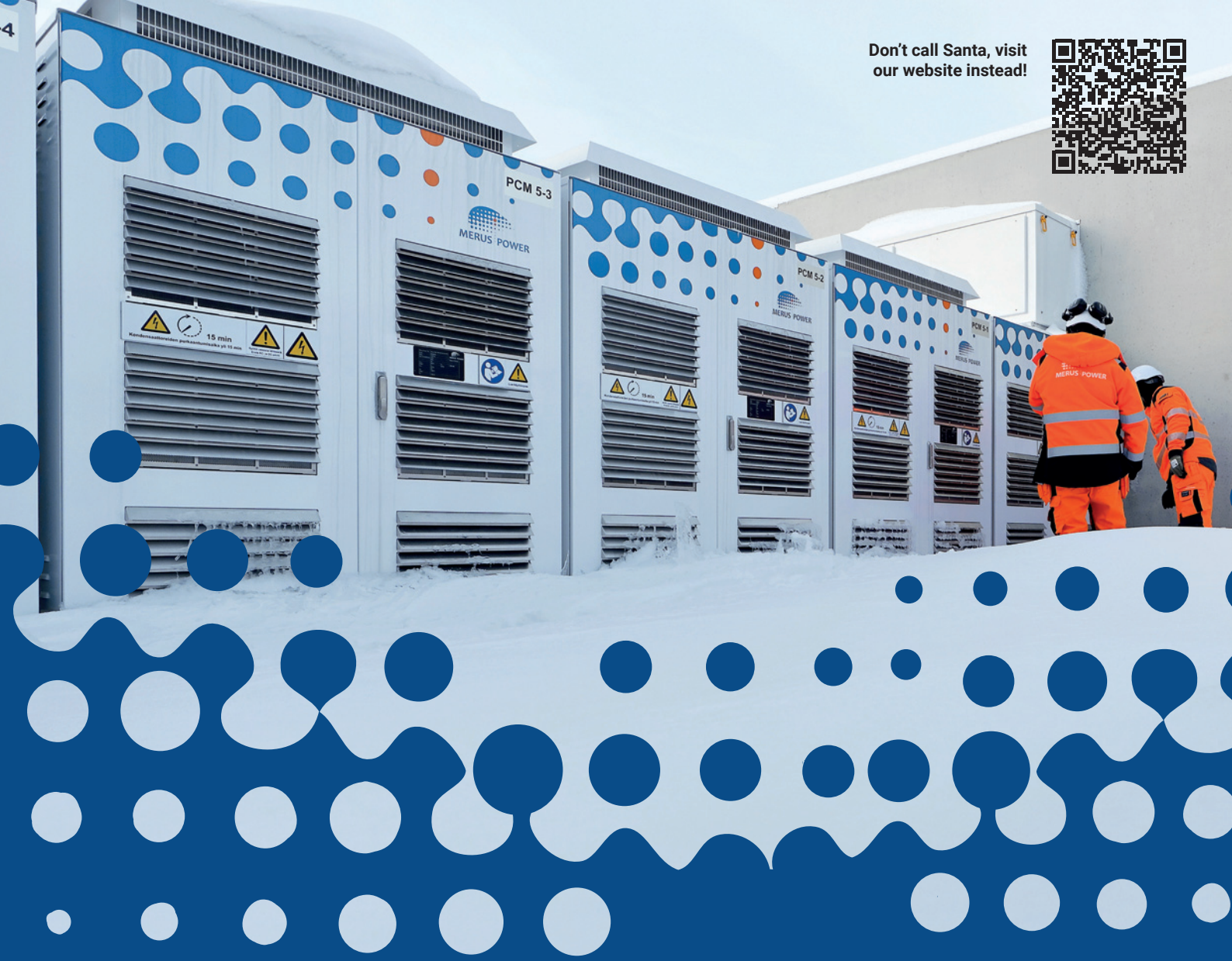
We also constantly evaluate our data, drawing on years of operating experience from one of the largest BESS portfolios in the world. This depth of data, combined with ongoing customer conversations, has enabled us to identify key opportunities to innovate and improve system performance. These insights have directly informed how we serve the market today and have been incorporated into our newest products, most notably Smartstack.

In parallel, we maintain very close relationships with our suppliers. This allows us to deeply understand the underlying chemistry and physics of the batteries we integrate. We also invest heavily in validation and testing to understand how batteries behave under real-world operating conditions, including degradation over time and performance under stress.

That combination of customer insight, operating data, supplier collaboration, and rigorous testing enables us to design systems that deliver consistent performance across a wide range of markets and applications.

Same question, but for price: Chinese BESS providers appear to be able to reduce costs further and further. What is the balance of competing with them versus

Article continues on page 18



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Our strategy to deliver value is multifaceted. Our global manufacturing footprint gives us scale, helps secure favourable terms, and allows us to meet local content requirements, which is especially important in markets like the United States. Our innovative system design drives high performance, lowers installation costs, and reduces operating costs over a 25-year-plus asset life. From our 15 years of team experience delivering battery energy storage systems, we believe it is rare that the lowest upfront price delivers the best long-term value and security.

Your US domestic manufacturing appears to only be for the Gridstack Pro, not yet the Smartstack: is that decision related to costs of manufacturing or differing market demand?

Smartstack's rollout was intentionally phased. At launch, we focused on international markets where higher-density requirements were immediate, while Gridstack Pro continued to meet US market needs. That sequencing has now evolved. Smartstack is currently being sold in the US with domestic content, leveraging the same supplier base across our portfolio.

Where does Fluence position itself on the BESS value chain and why? Would you say you are a BESS OEM, system integrator, EPC and O&M/software provider all-in-one, or have you chosen to focus only on some of these roles?

Fluence is a solutions provider. We support customers across the project lifecycle, from project development and system design through deployment, revenue optimisation, and long-term service. We are active in the design, manufacturing, and integration of all BESS components, hardware, and software to ensure customers' successful integration of battery energy storage systems. We are also long-term service providers and serve as the EPC provider when desired by a customer.

This integrated approach allows us to align hardware, software, and services in a way that optimises how storage assets are actually used and monetised over time. We focus on delivering outcomes, including safe operation, reliable performance, and sustained value for customers as market conditions evolve.

When it comes to performance warranties, how do you balance the need to enable flexibility for project owners/optimisers while also guaranteeing your product?

At Fluence, we do not approach these commitments as traditional warranties. Instead, we use performance guarantees, which are designed to be measurable, financially backed, and aligned with how grid-scale energy storage assets are actually operated in the real world.

Grid-scale storage assets are used very differently depending on the market, the revenue stack, and how owners and optimisers choose to operate them over time. Rather than applying a one-size-fits-all approach, we intentionally build flexibility into our commercial structures while still standing firmly behind the performance of the system.

In practice, this means offering multiple service packages with different levels of guarantees, allowing customers to align risk, cost, and operational freedom in a way that fits their specific project.

There is also flexibility built into the performance guarantees. Energy capacity guarantees, for example, can be structured around a defined use case or offered as a flexible performance guarantee, which creates a curve that varies with the asset's use. We also uniquely support in-use life extension, which allows energy capacity guarantees to be reassessed and, where possible, upgraded even after a contract is signed. Availability guarantees can vary by season, reflecting how the value of the asset's dispatch oscillates throughout the year. For efficiency, round-trip efficiency guarantees can be defined to include or exclude auxiliary loads, allowing for different site designs.

Ultimately, the flexibility comes from grounding performance guarantees in Fluence's proprietary lab data, operating data experience, and distinct levels of service engagement. By combining system intelligence, real-time monitoring, and configurable service structures, we are able to stand behind product performance while limiting the amount of constraints on how owners and optimisers operate their assets over the long term.

Battery cell form factors have now gone beyond 300/314Ah to 600-1000Ah, enabling higher energy density. Based on announcements, you have stuck with the former. If that's the case, why (and if not, please outline the change)?

Our approach to cell selection is driven by system-level outcomes, not cell size alone. While larger-format cells can increase nominal energy density, they also introduce additional thermal, safety, and integration considerations that become more pronounced at scale. Managing those risks often requires added insulation, cooling, and protection, which can offset some of the apparent benefits and add complexity over the life of the asset, especially for customers who must secure permits for their BESS projects and face additional scrutiny when proposing less-proven battery cells.

For example, in Gridstack Pro, the use of 5XX-class cells reflects a deliberate balance between capacity, thermal performance, and reliability. With Smartstack, we achieved a step change in energy density through system design and architecture rather than relying solely on larger cells. This allows us to deliver higher-density solutions while maintaining the safety margins, flexibility, and lifecycle performance our customers expect, and it sets them up for a higher likelihood of success in their BESS development efforts. ■

NFPA 855: 2026 edition key updates and what they mean for energy storage projects

Saleel Anthrathodiyil, fire protection engineer at Telgian Engineering & Consulting, discusses changes in the 2026 edition of the US National Fire Protection Association standard NFPA 855.

First published in 2020, NFPA 855: Standard for the Installation of Stationary Energy Storage Systems, has quickly become a key reference for the safe deployment of batteries across residential, commercial, and utility-scale projects.

This article highlights five of the most significant changes from the 2023 edition, why they matter, and how the updates may affect project planning and approvals. It is a shortened version of an article originally published on *Energy-Storage.news* , which contains a table listing all the technologies covered and more details on the 2026 updates.

Scope and applicability: more technologies listed

The first step in applying NFPA 855 is confirming whether it applies to the system. Applicability is influenced by battery chemistry and system energy capacity (kWh).

Hazard Mitigation Analysis: now the default, with more influence

One of the most significant changes in NFPA 855 (2026) is the expanded scope of the Hazard Mitigation Analysis (HMA). In the 2023 edition, an HMA was only required under certain conditions.

In the 2026 edition, that approach has changed. HMA is now the default expectation for most ESS installations, unless later chapters provide exceptions. For example, specific well-established chemistries, such as lead-acid and aqueous nickel-based systems, that have been around for a long time may not require an HMA, in particular cases.

Emergency response planning and training: more structure and review

The 2023 edition required emergency planning and training, but the 2026 edition provides more direction on when and how these plans must be created and maintained.

A new section 4.3.3 adds more specific minimum requirements for an Emergency Response Plan (ERP) and training programme. The ERP must address key phases, such as mitigation, preparedness, response, and recovery. It also requires an annual review of the emergency operations plan and a yearly refresher training with the AHJ to be notified of this training.

Stricter fire testing requirements: UL9540A & Large-Scale Fire Testing

A significant headline change in the 2026 edition is the more stringent fire and explosion testing expectations. UL 9540A remains a foundational test method, evaluating thermal runaway at multiple levels (cell, module, unit, and installation). The 2026 edition now explicitly requires large-scale fire testing (LSFT) alongside UL 9540A testing, demonstrating systems can withstand and contain severe thermal runaway events.

The UL 9540A test method forces thermal runaway at the cell, then module, unit, and installation levels, collecting data at each stage. Because UL 9540A allows testing to end early if fire propagation is contained at the module level, many battery systems are never physically tested as a complete unit. This creates a data gap for large-scale installations, which must then rely on mathematical interpolation and engineering analysis to predict fire behaviour rather than a test-based validation. The 2026 edition addresses this gap.

Involvement of a registered fire protection engineer

Chapter 3 definitions in the 2026 edition go in-depth to ensure common terms used later in the code are defined with less room for interpretation, including “fire risk assessment” and “registered design professional.” The “qualified person” definition is reworded to list knowledge and training related to specific energy storage systems.

In the 2026 edition, Annex G states that a registered design professional (fire protection engineer) experienced in fire protection engineering and in energy storage risk assessment and plant operation of the type of, or similar to, the plant under consideration should direct the risk assessment design process.

NFPA 855 continues to evolve quickly as energy storage adoption grows and real-world experience increases. The 2026 edition places greater emphasis on hazard evaluation by a qualified fire protection engineer, emergency planning, and fire testing evidence. For project teams, these updates reinforce the importance of early design coordination, documentation planning, and ongoing engagement with the AHJ. ■

Large-Scale Fire Testing: from best practice to mandatory requirement

Cameron Murray and Andrew Colthorpe look at BESS Large-Scale Fire Testing (LSFT) which has been adopted as part of best practice thinking on safety validation, with at least a dozen companies announcing tests and results and many more expected going forward. It becomes mandatory in the 2026 edition of NFPA 855 (see previous article).

What is LSFT and why is it being done?

An LSFT involves setting a BESS unit completely alight, with all suppression and detection systems turned off, mimicking a worst-case scenario fire. The aim is to see if the fire spreads to neighbouring units.

LSFT, conducted under a technical specification protocol (CSA TS-800:24) developed by CSA Group, is a companion to the cell-level thermal runaway test UL9540A. UL9540A itself continues to evolve, but its limitations became evident over time.

NFPA 855, including LSFT from this year, is required by many Authorities Having Jurisdiction (AHJs) in the US. It is also a widely used reference for projects elsewhere and is increasingly asked for by insurers and financiers.

No fire, or no propagation?

LSFT's emergence reflects an acceptance that in the unlikely event a BESS fire does happen, the spread is contained to a single unit at the system level, in much the same way that UL9540A assesses the propagation risk of thermal runaway from a single cell.

In an ideal world, BESS temperature management and fire detection and suppression systems should prevent fires from happening or going beyond a single module. Fire suppression technologies like Etica's immersion cooling, StatX's aerosol-based tech or Honeywell's Li-Ion Tamer off-gas detection systems aim to contribute to reducing fire incidents to near zero.

With LSFTs, technology providers aim to demonstrate that if systems do fail, there will be no repeat of fires at the Moss Landing or Gateway projects in California, where entire BESS arrays caught fire and burned for days.

LSFTs aim to ensure that any future fire events are more like the incident at the Thurrock BESS project in the UK, where a single unit caught fire during construction. With close monitoring and a carefully controlled response, the fire was contained, with no risk to the wider community. The site was declared safe by fire teams and handed back to owner Statera within 24 hours. Thurrock BESS went into commercial operation in the second half of 2025.

"That is the story of BESS fires and the types of loss events that we expect to see for the BESS market going forward," an insurer said at the time, referencing Thurrock.

So, who has done them?

The table below shows notable LSFTs conducted by leading BESS manufacturers and system integrators, using what has been publicly announced and reported on by Energy-Storage.news.

The list is not comprehensive and as LSFTs become minimum requirements expect more in 2026, possibly between the time of writing and printing. ■

Company	Product	Date
BYD	MC Cube	June 2025
Canadian Solar	SolBank 3.0 BESS	June 2025
Clou ESS	Aqua C2.5	May 2025
Envision	Envision Smart Energy Storage	July 2025
Fluence	Gridstack Pro 5000	June 2025
Hithium	Block 5MWh BESS	June 2025
Huawei	LUNA2000-4472 Series	February 2025
Prevalon	HD5	April 2025
Rept Battero	Grid-scale BESS product	July 2025
Sungrow	PowerTitan 1.0, PowerTitan 2.0	June 2024, April 2025
Trina Storage	Elementa 2, Elementa 2 Pro	September 2024, December 2025
Wärtsilä	GridSolv High Energy, Quantum 2 and Quantum 3	2023/2024

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Immersion Cooling: Redefining Battery Energy Storage Safety and Performance

As lithium-ion energy storage projects scale, thermal management has become a defining factor for safety, performance, and long-term asset value. The shift from air-cooled systems to liquid plate cooling improved performance but rising utilisation is exposing the limits of indirect thermal control and reactive safety measures.

The industry is evolving toward approaches that maintain consistent cell temperatures and prevent failure events before they start.

Indirect Cooling and Reactive Safety Aren't Enough

Liquid plate cooling removes heat through contact interfaces and coolant channels. Variability in plate contact and flow distribution creates temperature gradients across cells. Under high C-rate operation, these gradients produce hot spots that accelerate ageing.

Over time, uneven operating temperatures cause cells to age at different rates, reducing usable capacity and shortening battery life. The impact compounds across thousands of cycles, increasing augmentation requirements and compressing replacement timelines.

From a safety standpoint, when a thermal runaway event occurs, legacy lithium-ion BESS rely on reactive suppression systems such as aerosol agents to attempt extinguishment. If suppression is unsuccessful, the strategy shifts to containment: isolate the system, manage exposure, and allow it to burn out.

While containment can limit escalation beyond the enclosure, it offers limited control over event duration or system downtime and can expose first responders and nearby communities to toxic gases.

Immersion Cooling for Fire Prevention and Degradation Control

Immersion cooling changes the role of thermal management. By fully submerging cells in a non-toxic, dielectric synthetic ester with a high fire point, heat is removed directly from all cell surfaces. This eliminates interface losses, suppresses hot spot formation, and tightens temperature consistency.

EticaAG's immersion systems can maintain cells near 25 °C, with temperature variation typically limited to ±1.5 °C. This thermal uniformity reduces stress, slows degradation, and supports consistent performance across extreme climates, from desert heat approaching 60 °C to Arctic conditions below –45 °C.

Immersion cooling also changes how failure events behave. By surrounding each cell with a high fire point liquid, immersion cooling passively removes heat and displaces oxygen. This reduces ignition risk and interrupts pathways that enable cell-to-cell propagation. In the event of a thermal runaway, heat is absorbed rapidly, confining the event to the originating cell and preventing escalation into a large-scale fire.

Why the Immersion Fluid Matters

At the centre of immersion cooling is the liquid itself. Synthetic ester immersion fluids from Shell featuring MIVOLT ester technology are engineered for energy storage environments. They combine strong dielectric performance with high fire point characteristics, long-term thermal durability, and excellent oxidation stability. Their non-toxic and biodegradable formulation also aligns with evolving environmental and ESG expectations for safety-critical infrastructure.

Designed for long service life in continuous immersion, the fluid helps maintain consistent thermal and electrical properties over time, reducing maintenance uncertainty.

In operation, the fluid maintains stable thermal and electrical properties across steady-state and transient conditions, supporting consistent performance over thousands of cycles. This stability simplifies O&M planning and strengthens confidence in long-term asset value.

A New Standard for Energy Storage Safety

Moratoriums, bans, permitting delays, and heightened scrutiny signal a broader industry shift toward higher safety expectations. As the focus moves toward proactive safety rather than post-failure response, immersion cooling is poised to redefine energy storage safety across the industry.

Immersion cooling's combined impact of thermal consistency and fire prevention enables deployment in critical areas with more predictable lifetime performance.

A render of EticaAG's immersion cooling module for battery storage in action.

BESS energy density race creates questions of site logistics and product standardisation

BESS products have become ever more energy-dense over the past few years, a trend which both reached its peak and shifted in nature in 2025, with logistics limitations forcing a cap on 20-foot products and prompting a partial shift to modular units. Andy Colthorpe hears views from system integrators Wärtsilä and Saft on how the industry needs to think about the topic going forward.

The battery storage industry's race for higher energy density should be put into a site-level perspective, rather than focusing solely on larger cells.

That was a view shared by representatives of two manufacturers and system integrators of battery energy storage system (BESS) technologies, given in separate interviews with ESN Premium.

Much of recent industry conversation and many headlines have been dominated by the seemingly competitive approach to energy density increases that the BESS business divisions of lithium-ion (Li-ion) battery manufacturers, predominantly those based in China, have adopted.

Most recently, in September, BYD unveiled Haohan, a 14.5MWh BESS unit, which the company claimed achieves an equivalent of 10MWh capacity in a 20-foot area. As Energy-Storage.news wrote at the time, that doubled the common industry standard of around 5MWh per 20-foot standard ISO container.

Haohan also uses a BYD Blade Battery of 2,710Ah and while some sources have commented that the Blade Battery is as much module as cell, for an individual component, the sizing is significant.

Other examples abound, with CATL launching its 9MWh Tener Stack product and Sunwoda and Eve Energy progressing the commercialisation of 600Ah+ cells. At this year's SNEC trade show in Shanghai, a whole host of other companies presented cells in excess of the 314Ah capacity that again had become something of an industry standard.

At the US trade show RE+ in September 2025, energy density was arguably the most frequently discussed topic after domestic content.

'Everything big'

"Yes, [energy] density is becoming one of the key elements for energy storage. Basically, the solar farms are bigger and bigger, and the shifting needs are bigger and bigger," Vincent Le Quintrec, energy storage sales and marketing director at Saft, told ESN Premium.

"We're now talking about 4-hour duration projects more commonly; 4-hour is kind of the norm in Australia, California and a couple of other areas, and we know that it will move to 6-hour and so on. We know that sites of more than one gigawatt-hours will become kind of normal in a lot of markets."

Saft is the battery manufacturer and BESS integrator owned by France's TotalEnergies. Le Quintrec said the company had even been in negotiations for projects that might host more than 10GWh at a single site in some regions.

The race toward "big things, everything big" in the industry includes cells, but Le Quintrec said that when speaking with customers about energy density, the focus should be on energy available at the point of connection to the grid.

"Not at DC level, not at AC level, but at the point of connection per metre squared. That's the first criteria [for considering energy density]."

The second is considering the logistics of the equipment, including ease of transport and then installation. That means controlling the weight and limiting the amount of site work that needs to be done, according to the Saft representative.

The company's newest iteration to its grid-scale Intensium BESS solution range is Intensium Flex (i-Flex). It's a liquid-cooled AC block with 3.4MWh to 5.1MWh capacity, aimed at being a compact building block for energy storage projects at gigawatt-hour scale.

Using lithium iron phosphate (LFP) cells, it will be available by the end of 2026 or beginning of 2027 in both AC and DC configurations. Similar to Tesla's recently launched Megablock product, it enables users to connect multiple units in parallel. Its thermal insulation design will allow containers to be deployed back-to-back and side-by-side, thereby reducing their footprint.

"We believe with our solution, having an AC block—and we designed a 20MWh AC block with a [weight] limit of 43 tonnes. Easy to transport, easy to install, is the right answer. We will be able to reach 1.5kWh per square metre with i-Flex," Le Quintrec said.

Luke Witmer, VP of software engineering at Wärtsilä Energy

Credit: Wärtsilä Corporation

Employees at the Giga Buffalo BESS in the Netherlands, which Wärtsilä deployed.

Storage, agreed that ease of installation and logistics are major factors to consider.

"From a physical perspective, the costs of building and owning and operating a battery plant, sure, the land is expensive, and you want it to be energy dense, and that's really important, but in the end, there's a lot of other costs as well, [many relating to] transportation costs," Witmer told *ESN Premium.*

In terms of construction and integration, certain technologies may take longer to install, which would add cost. Witmer added that choosing "a 20-foot BESS enclosure with the most battery capacity [possible] shoved into it" may not equate to easy commissioning.

High-density containers might have outsized auxiliary power loads, for example, among a wide range of factors to consider, over the whole lifecycle of the project and directly related to the business case.

That said, from his own specific area of expertise in data and software, Witmer said that energy management system (EMS) controls and plant optimisation are only marginally impacted by energy density.

"It changes the models a bit. So, if you have a denser one and the thermal profile is different, that impacts it. However, for us, we simply train a different model and fit the thresholds differently to capture those anomalies. The algorithms will still work regardless of whether it's more or less energy," Witmer said.

Le Quintrec said, meanwhile, that higher energy density is unlikely to be a significant cause of project development bottlenecks in terms of permitting or discussions with planners, as long as key certifications are in place and products are bankable.

No standard cell size anymore

Beyond the physical and technical considerations outlined above, Le Quintrec said it could prove problematic that different BESS cells are being produced which have wildly varying capacities and form factors.

"That's the problem. Everybody is talking about big cells, but there is no one standard. Today, there is one standard, which is the 314Ah [cell]. Therefore, we understand that this is a standard, and we recognise that another solution can replace one with the same formula."

The market is "not yet mature" in dealing with the bigger cells or the divergence of capacities, he said.

However, the market is undoubtedly excited about the rapid progress of battery technology and Saft is no different in that respect.

The company will bring out a new solution, SuperFlex, in 2027 which will use 600Ah+ cells, Le Quintrec said. Though Saft does manufacture some of its own cells, SuperFlex cells will be sourced from an outside supplier and currently the company's R&D team is "ageing big cells, trying to figure out what will be the standard for tomorrow," he said.

While he was not yet able to divulge details of the new product, its key concept and a principle held by Saft—which Le Quintrec points out was the first to commercialise the 20-foot container form factor—is to keep design consistent with what the industry is used to.

"Saft invented the 20-foot container concept, and 13 years later, we keep using the same concept but increasing the energy density ten times. Our first container was 500kWh [capacity], now it's 5MWh."

"We will keep [this], because we strongly believe that's the way; including big cells, but we must make sure that we control the supply to the customer, and we have this ability. Everybody needs to keep the agility and ability to control the supply. That's a really key element in my mind because if you decide on one technology and there is a unique provider of this technology, you know what can happen." ■

Western Australia's 500MWh vanadium flow battery initiative 'is a pivotal moment'

A Western Australian government initiative to deploy the largest vanadium redox flow battery (VRFB) project outside China is a "pivotal moment," one technology provider told Andy Colthorpe.

In late November 2025, the state government launched the first stage of an expression of interest (EOI) for a 50MW/500MWh (10-hour duration) VRFB energy storage project, to be built in Kalgoorlie, around 600km northeast of Perth, Western Australia (WA).

The project, backed by AU$150 million (US$97 million) of government funding and administered by the Department of Energy and Economic Diversification (DEED), requires the use of flow battery technology manufactured within WA, using locally sourced and processed vanadium.

The project is designed in part to replace the role of the 57MW West Kalgoorlie Power Station gas power plant, due for decommissioning in 2026.

"This is a pivotal moment for Australia's vanadium industry, battery manufacturing industry, and diverse energy consumers," a spokesperson for Perth-headquartered VRFB company AVESS Energy told ESN Premium.

The "breakthrough" project will be the largest VRFB to date outside of China, as well as the first large-scale VRFB project in Australia to connect to either the country's biggest electricity markets (the NEM and the WEM).

The spokesperson said AVESS Energy expects the Kalgoorlie project to "unlock the expansion of VRFB deployments in Australia and across the region."

The company is making a Stage One EOI submission in a consortium with other companies based in WA. These are vanadium producer Atlantic Vanadium and design and project delivery engineer Lycopodium.

Kalgoorlie project necessitates fast-tracked manufacturing and supply chain development

AVESS bought a majority stake in KORID Energy, a South Korean AVESS acquired South Korea-based VRFB firm KORID in 2023 and has deployed commercial-scale VRFBs in Australia, based around a 50kW module, of 4- to 5-hour durations. It is now launching a utility-scale configuration leveraging the same IP for Kalgoorlie and future opportunities.

"The biggest technical challenge lies in the fact that a plant-style VFB system of this scale has never been attempted before in Australia. While there is a plethora of engineering and construction capabilities, there is also limited exposure to plant-style VFB," the AVESS spokesperson said.

"Commercially, the challenges will be in the scale of cell-stack manufacturing and battery pack assembly. To supply the required components for the Kalgoorlie VBESS with local content, manufacturing facility expansion would have to be fast-tracked. The same can be said for vanadium electrolyte supply, with more than 30 million litres required to support energy storage to 500MWh."

Technology ready for 'multi-decade storage asset life'

Australian Vanadium, an ASX-listed vanadium exploration and processing company, built a vanadium electrolyte factory in WA with government funding support and is establishing a vertically integrated VRFB business, VSUN Energy. 2024 saw VSUN commission a 78kW/220kWh trial project for WA utility Horizon Power.

The country's largest flow battery installation to-date meanwhile is a 2MW/8MWh deployed in South Australia by UK-based Invinity Energy Systems.

The Kalgoorlie project's expected commercial operation date of 2029 means that a participant could yet set up operations in WA.

The VRFB was first invented in Australia in the early 1980s, but the space has been dominated since then by China, driven by supportive policies. This leadership by China has come at the expense of "supply chain resilience and domestic manufacturing capabilities," for providers in other countries, AVESS said.

VRFBs are an "ideal technology for Australia's bushfire-prone and drying climate," the spokesperson said, due to the lack of fire risk associated with the aqueous electrolyte liquid that cannot experience thermal runaway.

Vanadium flow battery stacks are also degradation-free over many cycles, versus lithium-ion BESS installations, where increased power and cycling demand could result in voided warranties and rapid degradation of battery health, the representative said.

"All components, including electrolyte, are serviceable. This means that the Kalgoorlie vanadium battery energy storage system (VBESS) will exhibit a 10-hour duration from commissioning to a multi-decade storage asset life. This provides a robustness and economic benefit that means that the cost of every kilowatt-hour provided over the life of the VBESS may be cheaper than the limited kilowatt-hours of a similar Li-ion BESS."

Turning data centres from a 'potential liability to a grid asset': Calibrant on its first-of-a-kind BESS with Aligned

Calibrant's BESS for a new data centre in Oregon, US, was hailed as the first of its kind, but what are the details beyond the headline? Cameron Murray caught up with Calibrant's CCO to discuss the practical, commercial and technical specifics of the project.

Calibrant Energy will deploy a 31MW/62MWh battery energy storage system (BESS) at Aligned Data Centers' campus in the Hillsboro, Oregon, US, it announced in October 2025. Aligned said it will be the first BESS that is purpose-built to accelerate interconnection and bring a large-scale data centre online.

A peak power constraint

Unpacking this in conversation with ESN Premium, Calibrant CCO Matt Barnes explained that in this case, the constraint that the BESS will alleviate is less about physical wires and transmission lines and more about the 72MW-demand data centre's possible impact on the overall grid.

"The data centre is already built but was waiting on utility power that was potentially years out. The BESS enables [utility] PGE to serve the customer in a more accelerated time frame, because the delays were about the data centres' load during peak hours. The BESS will essentially make the data centre a more flexible form of load," Barnes said.

"The site got its initial power earlier this year, and now the BESS will be built and enable it to ramp up to full power. That ramp-up period is fairly normal for data centres anyway."

PGE to dispatch it, with 'no additional costs for ratepayers'

The specific mechanism by which it will do this for utility PGE (Portland General Electric) is through the PGE's Dispatchable Standby Generation (DSG) programme, whereby PGE can call upon resources during critical grid periods.

In those instances, PGE effectively becomes the dispatcher, Barnes said, utilising DSG assets' controllable flexibility to maintain reliable service without causing additional stress on the grid.

In a case study paper, Calibrant said it was helping Aligned turn its data centre 'from a potential grid liability into a dynamic grid asset'.

Barnes said that it's also important to emphasise that ratepayers are not paying anything for the project, as the cost is entirely being borne by Aligned and Calibrant together. Calibrant is building and operating it while Aligned will fund it.

"It will actually reduce net overall cost by spreading the fixed costs of the grid over more hours in the year, it's one of the first projects done in this way," Barnes said.

He added that the use cases will evolve over time, indicating that the BESS will do more than just peak demand management for PGE.

Technology and configuration

The BESS is going to be located on the same site as the data centre but actually ended up front-of-meter (FTM), rather than behind-the-meter (BTM) as might be assumed to be the case when a BESS is deployed alongside a large industrial load centre.

"Whether it would be BTM or FTM flipped a few times during the planned. We prioritised speed over perfection, and in this case FTM made more sense. The difference between the two is only 6-10 feet of distance," Barnes said.

"In many cases it is faster to interconnect BTM, because of the longer utility studies required for FTM. A BTM project is not exporting to the grid, so the only scenarios to be modelled are 'load' and 'not load'. But in this case, PGE said it could complete the studies for an FTM project just as fast, and an FTM project enabled a slightly simpler set of engineering to be done, too."

In terms of the technology itself, the BESS will be provided by Tesla alongside locally made Tier-1 transformers, ensuring compliance with domestic content aspects of the investment tax credits (ITC) for energy storage.

"The critical piece for this project was to move quickly, so

Aligned hailed the project as being the 'first-of-its-kind', because it "will be the first time in the US that a battery system is purpose-built to accelerate interconnection and bring a large-scale data centre online".

Credit: Calibrant and Aligned.

it was important for it to be domestic and to have that supply chain certainty baked in," Barnes said.

Barnes also pointed to the maturation of BESS as a reason why this is happening now. "Five years ago, data centres wouldn't have let you put large-scale BESS on their facilities; it's now accepted as a mature enough technology."

New solutions needed for era of 'incredible load growth'

In 'A path to faster data center deployment,' a recent webinar hosted by Aligned, Barnes and executives from Aligned and PGE discussed at length how the key to the project was close collaboration between the three organisations and an openness to trying new solutions.

"Nothing like this had been done before, so the way we worked through that was by having partners that were willing to work together through uncertainty, with a shared goal, and together making phased commitments that didn't require 100% signed documents. That was critical," Barnes told us.

"As we see this moment of incredible load growth, it necessitates solutions that are a bit different from what's been done before, there is not enough time to do it without new solutions that stretch the bounds."

Barnes also pointed to a letter from Secretary of Energy Chris Wright directed to the Federal Energy Regulatory Commission (FERC) just a few days after the project announcement, instructing the regulator to take steps to "rapidly accelerate the interconnection of large loads, including data centres".

The seventh point in Wright's letter stated that "…the interconnection study of large loads that agree to be curtailable and hybrid facilities that agree to be curtailable and dispatchable should be expedited."

"Not all agree with this principle," Barnes said. "But it is a great one to put out into the public discourse. Pair that with our project, and you see clear tailwinds for a solution like this project."

The explosive growth in data centre demand driven by artificial intelligence and cloud computing is a huge challenge for grid operators and utilities, but it represents opportunities for clean energy and BESS firms.

This surge in demand they created has contributed to interconnection bottlenecks, with utilities struggling to accommodate new large loads while maintaining grid reliability. Some regions have had to say no to data centres entirely.

And where they are allowed, the provision of utility power can potentially only be available years later than a project's completion schedule, as in the case of Aligned's Oregon project.

Meanwhile, leading data centre operators, known as hyperscalers, are racing to deploy AI computing capacity.

Giovanni Damato, redox flow battery developer CMBlu's North American President told Energy-Storage.news recently: "All the hyperscalers that we talk to are disappointed with themselves for not deploying fast enough, and they are even more disappointed with the whole interconnection queue and utilities."

Many data centres are in turn deploying power generation (not always clean) and energy storage on-site, or procuring clean power via offtake deals with IPPs and renewable generators.

The integration of BESS with data centres offers another solution to these challenges, by actually changing the demand profile of the data centre, while also creating a possible additional revenue stream for the site.

Some BESS manufacturers and system integrators have started to announce data centre-specific tailored BESS solutions, including Hithium, Energy Vault, Prevalon. ■

Financing large-scale BESS in Europe: successes and challenges

Cameron Murray hears from leading BESS owner-operators across the continent on the key trends around the financing of large-scale projects, now and going forward.

Image: RWE.

A render of a 400MW/700MWh BESS project in Germany that RWE started building in 2025, among the largest in Continental Europe to reach that stage.

As you might have read in our article on pages 14-15, Europe deployed over 10GWh of large-scale storage last year, up 28%, and installations could as much as triple in 2026 based on stated commercial operation dates. The UK is still the largest national market within these figures, for now, but no longer comprises the majority as in previous years.

This is a far cry from three or four years ago, when the conversation was around what Continental European markets needed to do to get even close to the kinds of volumes being deployed in the UK.

What has enabled this, and what challenges remain?

Market has reached 'pivotal stage of maturity'

"The European energy storage market is at a pivotal stage of maturity, having transitioned from a niche technology to an increasingly mainstream infrastructure asset," says Ariane Brunel, investment director at financing firm Triple Point.

Growing lender and investor confidence, improved technology performance and more sophisticated revenue-stacking strategies have driven this, she added.

Chris Elder, CEO of Fidra Energy, adds that longer warranties from BESS providers are allowing banks to give longer debt terms, reducing the cost of capital for the industry. Fidra is building the 1.4GW/3.1GWh Thorpe Marsh project in the UK, one of the continent's largest.

Brunel says that the UK financing space has evolved from being dominated by a relatively small group of specialist lenders to a marked increase in participants. But the trend is similar elsewhere.

"Larger pan-European lenders have established dedicated renewables and BESS teams," adds Ben Brooks, managing director of Bluestar Energy Capital's European BESS platform Noveria Energy.

"BESS is now well-known and understood by most institutional investors' investment committees and is readily financeable through both debt and equity."

Evolving business case across the continent

In a nutshell, the business case for large-scale BESS across Europe can be segmented into a few 'buckets'. In the UK, Northern Europe, Nordics and Baltics, merchant trading and ancillary service opportunities form the bedrock of the business case. Tolling is becoming widely available, but fully merchant projects

Article continues on page 31.

For five-nine data-centre uptime, four letters matter: GEMS.

Interconnection queues stretching five to seven years are making grid capacity tight—fast. Add AI's skyrocketing power demand and it's no surprise data centre developers are scrambling for on-site power. Islanded grids offer a pragmatic path forward: start in islanded mode, stay resilient through disturbances, and later connect to the grid without re-architecting the power system. But building an islanded grid that can withstand AI-driven volatility while targeting five-nine (99.999%) availability— roughly five minutes of downtime a year—is where software determines outcomes.

As grid codes grow more complex and projects scale to multi-GWh storage, the stakes for stability are too high for slow, piecemeal controls. For years, Wärtsilä's control and optimisation software, GEMS, has been the choice of first-to-market movers because it delivers the speed, specificity, and site-wide coordination complex markets demand. These capabilities are no longer optional; they are the foundation of AI-era data centres that require uncompromising reliability and uptime.

Intelligent off-grid control

At the heart of an AI data centre islanded grid is software that moves seamlessly between grid-forming and grid-following modes. In practice, this means enabling blackstart capabilities to bring critical loads online during a blackout, maintaining strict frequency and voltage control to protect asset health, and orchestrating engines, batteries, renewables, UPSs, and balance-of-plant under one unified system. At millisecond timescales, every extra connection adds latency and risk. That's why complex or multi-GWh-scale sites depend on a single control platform capable of deterministic, site-wide response.

A need for speed

AI training workloads are uniquely volatile, making rapid, large step changes in their load profiles that do not

align with thermal generator operating patterns. Pairing engines, battery storage, and intelligent controls solves this mismatch: energy storage absorbs load spikes in milliseconds, stabilising the engine-side load and maintaining site power quality. Meeting these fast-response requirements depends on seamless end-to-end control: coordinated assets, precise measurements at the point of interconnection, and reserve management in the BESS enabled by accurate state-of-charge measurement.

Intelligent full-site command software doesn't just keep engines and UPSs from tripping or overheating; it optimises the islanded grid for efficiency, cost, and sustainability. GEMS Dispatch balances renewables, thermal, and BESS to reduce fuel utilisation and maximise renewable output, all while preserving headroom for contingencies. Crucially, it keeps the site grid-friendly. With the right controls, data centre loads can maintain low-voltage ride through, provide fast frequency response, and participate in ancillary-services markets—without sacrificing on-site power quality.

Always on, always ready

When speed-to-power and near-100% availability are the end game, islanded-grid control is the answer. Data centres need power that is stable, predictable, and immediately available. GEMS-enabled islanded grids deliver exactly that: absorbing AI volatility, protecting critical assets, and orchestrating every asset to provide flexible, always-on power with confidence.

By Ruchira Shah, general manager software product management for Wärtsilä Energy Storage.

are also being built, with primarily equity financing.

In Southern and Eastern Europe, the business case is more around load-shifting solar, combined with grant funding from EU-wide schemes like Recovery and Resilience, to kick-start the market. It is much more common to see BESS added to solar projects here.

Projects in Belgium, Poland and Italy are taking advantage of capacity market (CM) auctions to provide long-term minimum revenue guarantees on top of which they can stack other revenue streams.

And in Italy, there is the relatively unique MACSE auction, effectively a BESS-specific CM. Read a Q&A interview with IPP Greenvolt about that on pages 48-49.

Many UK players have expanded abroad, says Andy Willis, founder and CEO of developer Kona Energy: "Many developers have shifted their focus toward European markets such as Italy and Germany, attracted by greater contractual revenue certainty and materially higher returns than are currently available in the UK."

Last year saw c.700MWh projects start construction in Germany, by RWE and Eco Stor, representing a new scale for the market.

The rise of tolls and other revenue-firming arrangements

It gets talked about a lot, but the rise of private sector tolling arrangements in BESS has enabled it to get to the investment volumes comparable to solar, particularly in light of the saturation of ancillary service markets in early-movers UK and Germany.

"Tolling has emerged as a significant trend across the European energy storage market, particularly as stakeholders seek ways to maximise asset value, secure predictable cash flows and manage risk," says Leandra Boes, director of asset management at German owner-operator Green Flexibility.

Wider revenue-guaranteeing products are available beyond conventional tolls too, adds Rimshah Javed, principal originator at Danske Commodities, one of Europe's largest power and gas trading companies.

"Merchant and floor deals are fairly understood at this point, and increasingly we see tolling, swaps and virtual products with newer entrants such as corporates. In general, the sector is good at collaborating on customised and unique offtake structures," she says.

The trend is now a few years old, and in that time, there has also been an evolution in how much lenders rely on these structures. Brunel says, speaking primarily about the UK:

"For debt-financed projects, lenders initially required a minimum level of contracted revenues—often around 50% of projected cash flows, typically supported by floor mechanisms. As confidence in the asset class grew, this requirement softened, with many financings accepting significantly higher merchant exposure and, in some cases, little or no long-term contracted revenue beyond what might be provided under a capacity market or optimisation agreement, if at all."

However, 50% is still around the sweet spot for large-scale financing, at least for Fidra Energy in the UK, Elder says.

In countries where less has been deployed, there are still opportunities to be innovative using conventional tolling agreements. 2025 saw numerous long-term rolling and BESS PPA agreements hailed as the first-of-their-kind, including in Germany, Italy and Spain. We heard from IPP Zelestra about its deals in the latter two; read that Q&A on pages 54-55.

As Boes says: "For forward-thinking BESS owners, there is now an opportunity to establish market standards by being among the first to successfully implement tolling agreements in this emerging sector while still benefiting from a merchant upside."

Saturation of tolling market?

Most sources agree that the actual supply of tolling products is much smaller than might initially seem, given how frequently they're discussed.

"While numerous market participants are actively exploring fixed revenue structures, only a limited number proceed to execution, largely because tolling offtakers apply steep risk discounts," Boes says.

"The market is still relatively thin for people who are able to deliver reasonable volumes of tolls and floors. It is definitely a risk for the sector," adds Fidra's Elder.

However, some see the number and variety of companies offering tolling increasing.

"Aer Soléir's 1GWh BESS toll in Italy with Shell's Ego Energy was significant. It's a positive sign that companies like Shell are finding potential future revenue in these projects and are happy to take the revenue risk on themselves," an advisor says.

Although not necessarily an industry-wide trend, the launch of German startup Terralayr's BESS tolling platform (covered on page 63) is notable as it provides another avenue to secure long-term revenues for projects simply (in theory at least) via software integration.

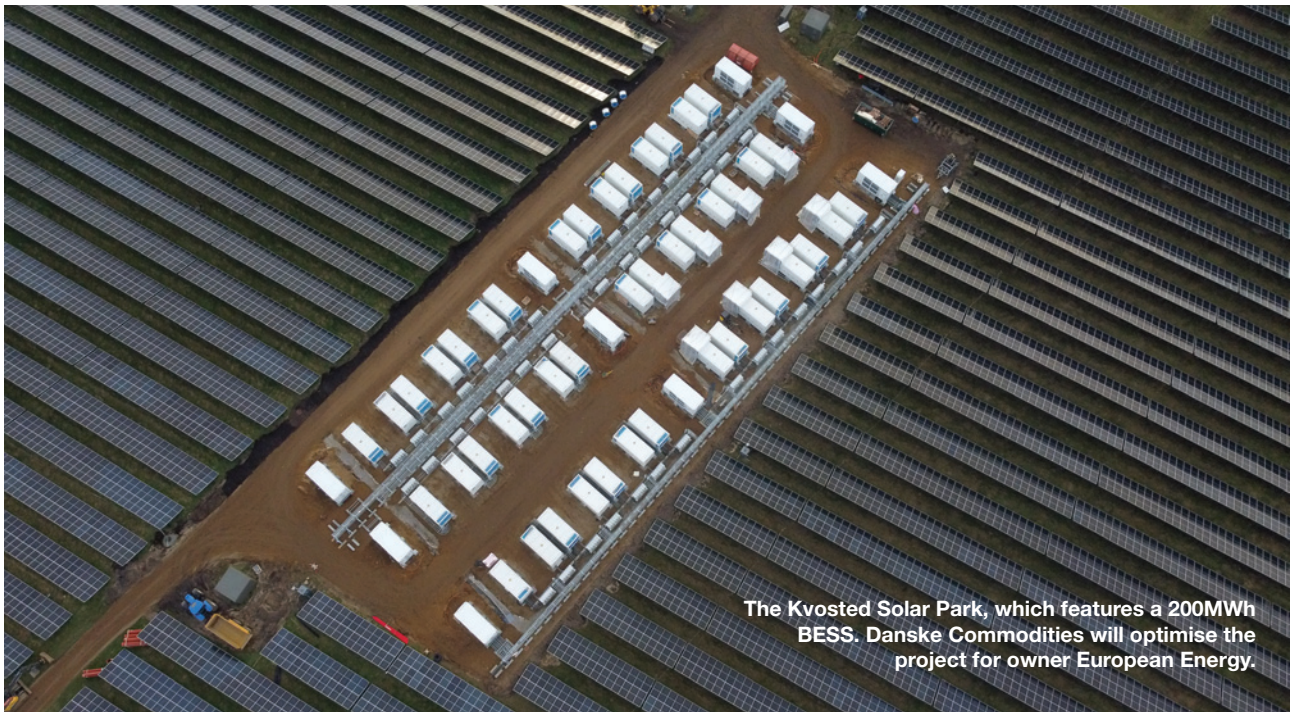
Whether most projects are getting to final investment decision (FID) with or without tolls or fixed revenue arrangements depends on where you are.

Boes, primarily discussing Germany, says a majority reach FID without them. Javed, primarily discussing the UK, says that "there are some merchant projects in the market through equity financing but the share of players requiring revenue guarantees is certainly larger."

Portfolio deals and the future of BESS financing

Boes adds there is "a shift away from single-project financing, with an increasing emphasis on utilising both equity and debt facility structures that aggregate multiple projects into a single portfolio."

The same trend has been seen in European solar, although some would argue portfolio financings are just a series of single project-financings rolled into one agreement.



The Kvosted Solar Park, which features a 200MWh BESS. Danske Commodities will optimise the project for owner European Energy.

Image: European Energy.

Discussing the topic of financing, Hassen Bali, co-founder and director of developer Ion Ventures, says that the future will see financing go beyond simple revenue forecasts and towards the wider value that BESS can generate.

"It's a constant evolution, like any commercially pre-emptive response to cause and effect. We live in a more technologically complex world, with different cashflows than before, and a bidirectional power system with greater variability of generation," he says.

"The financing view needs to shift to value rather than revenue from MWs. What else can the company do to create value in its assets which isn't as black and white as returns from trading and ancillary services? Our answer lies in derisking our supply chain and with that, a host of other responsibility-linked actions which safeguard operations and bring value in other ways."

Flower, an optimiser and BESS owner-operator mainly active in Sweden, has argued that the most value for the technology lies in its ability to hedge long-term risk for renewable operators. But, CEO John Diklev told us last year, the market is not yet mature enough to price this under long-term agreements.

Expansion of the range of services that BESS can provide, displacing other tech

The range of services that BESS can provide and the roles it is playing on the grid are evolving too. While the particulars of this evolution might not be front of mind for BESS financiers when doing deals, it's worth noting what's coming down the line.

One obvious one is grid-forming services, covered earlier on in a deep-dive with leading BESS and PCS providers on pages 7-10. These include synthetic inertia, voltage support, black start capabilities and more.

Bali says he expects inertia to emerge at scale as a new application for BESS. Unpacking this a bit in the context of the UK, Willis says that these kinds of services will start to be valued accurately by the market over time.

"Kona continues to believe that operability revenues remain materially undervalued by both the market and many optimisers. We expect a significant increase in the utilisation of BESS assets for non-energy services from 2027 onwards, as system needs evolve and the value of stability, voltage and other operability products becomes more clearly recognised," he says.

Javed adds: "BESS is also displacing more expensive technologies. In Sweden, [TSO] Svenska kraftnät publishes data that shows BESS is often becoming the price-setting technology and displacing other forms of flex, like hydro."

Grid

Challenges around grid interconnection are more relevant to financing development portfolios, rather than reaching FID, but they are significant.

At the time of writing (January 2026), the UK's grid interconnection reform has been lamented by developers and owner-operators. Beyond 2027, no one is certain of their grid connection date, making financing for them impossible, a source says.

In Germany meanwhile, the challenge is more around the emergence of Flexible Connection Agreements (FCAs) and how to navigate these, Boes says.

Conclusion

Huge progress has clearly been made in the past few years in getting large-scale BESS to FID in Europe, driven by developments within technology, finance and business models. That's set the continent up to be on its way to 2030 goals. Whether it gets to those now appears to depend on how the industry navigates the next set of challenges around grid and market policy. ■

Lessons learned from a year of US battery storage project local engagement after Moss Landing

The Moss Landing fire in January 2025 sent shockwaves through the industry. BESS already suffered fire safety concern-based opposition before it, but the fire at what was once the world's largest BESS sent those concerns into overdrive. Cameron Murray looks at key events in US project local engagement, drawing on a year of ESN Premium reporting from our freelancer Matthew Biss since the event.

Swathe of moratoriums in counties across the US, local opposition increases

The Moss Landing fire incident led to heightened scrutiny of fire safety protocols for BESS projects and, in some cases, outright bans on the technology.

Temporary halts on all permitting activity for BESS projects, so-called 'moratoriums', were enacted in counties, towns and cities across California, Oregon, Kansas, Michigan, New York and Massachusetts. And those are just the ones we reported on.

Officials signing off on these said that the temporary restrictions were needed while they drafted or re-wrote zoning, ordinance and permitting frameworks to accommodate BESS, so some may be rescinded earlier, and may have been already.

They ranged in length from 120 days to 2.5 years, although some had no planned expiry date at all. Generally, decisions were put down to public safety concerns around the risk of fire, environmental pollution, loss of farmland, and a lack of existing zoning regulations for the technology.

BESS moratoriums had been enacted in the US before Moss Landing, but 2025 saw a proliferation of them.

Legislation

Perhaps most important of all was California's Senate Bill 283 (SB 283), which became law in January 2026 and mandates adherence to National Fire Protection Association (NFPA) standards and requires local fire authority involvement in planning and inspections for BESS. California is by far the largest BESS market in the US.

The passage of the bill also affected developments at the local level. For example, in November the Santa Cruz County's Board of Supervisors (BoS) delayed voting on a draft BESS zoning ordinance, and with it a decision on specific BESS projects, in light of SB 283 making its way through the legislative houses.

Local engagement

Developers always stress the importance of early and open community engagement when it comes to getting locals on side for your BESS project. Over the year, we reported examples of developers offering practical solutions and approaches which helped them get projects over the line.

Spearmint Energy got approval for its 300MW/600MWh Red Egret BESS in Texas City, Texas, in August. It changed the site for its project following community feedback, and the company "answered every tough question thrown at them at community meetings", one local was quoted as saying at a Texas City board meeting.

Dominion Energy, meanwhile, had officials from Fauquier County, Virginia, visit its operational Dry Bridge Energy Storage project in Chesterfield to better understand fire mitigation measures, helping it get project approval in September. The firm also agreed to exceed the NFPA 855 standard requirements and reimburse fire personnel expenses in case of incidents.

In mid-2025, another company, Eolian, actually proposed a detailed zoning law text amendment to enable officials in Lancaster County, Nebraska, to permit privately-owned BESS projects.

Eolian suggested pathways for approval and scrutiny on projects via public hearings with local residents and explained the difference in design between current BESS projects and Moss Landing during discussions. The Planning Commission unanimously approved it, sending it to the Board of Commissioners for final approval. A document published by the Board of Commissioners on 2 September appears to show the amendment being approved.

Reassuring local stakeholders about the safety of BESS is arguably easier if you are a big utility or power firm with a strong track record, like Italy-headquartered Engie, which reached 1.8GW of operational US BESS by late 2024. It highlighted its strong safety record and showcased third-party fire testing of Tesla's Megapack 2XL units when proposing its Compass project in California (though the project's fate is still to be determined at the time of writing).

Article continues on page 36.

HyperStrong: Driving Energy Storage from Price Competition to Long-Term Value Creation

The energy storage industry is shifting its focus from short-term cost to long-term performance.

Dr Jianhui Zhang, Founder, Chairman, and CEO of HyperStrong, says the future of energy lies in the deep integration of renewable generation and advanced energy storage.

"Green power, combined with energy storage, represents one of the most promising long-term solutions for global energy transformation," Dr Zhang says. The transition from fossil fuels to low-carbon development is no longer a question of if, but how fast.

The major renewable energy resources, wind and solar, are inherently variable, and this volatility remains a fundamental constraint on their integration into power systems. Energy storage addresses this challenge: stabilising output, smoothing fluctuations, and enabling renewables to meet the reliability and resilience requirements of modern grids.

Energy storage is now an indispensable stabiliser for grid integration.

From Price Competition to Long-Term Value Creation

Between 2021 and 2025, lithium-ion battery energy storage systems (BESS) experienced rapid technological advancement. Energy density increased by up to eight times, enabling higher capacity within smaller footprints while driving down system-level costs.

However, Dr Zhang has observed a fundamental shift in industry priorities, "…moving beyond price-driven competition," he explains.

Today, project developers and investors evaluate long-term performance, rather than upfront equipment prices. Key considerations include system efficiency and operational consistency, safety and reliability, operational lifespan, and degradation controls.

Success requires more than strong products. Companies must build end-to-end capabilities across sales, localisation, operations, asset management, and power market participation to unlock long-term value beyond equipment sales in global markets as varied as Europe, Southeast Asia and the Americas.

Technology Needs to Deliver Far Beyond Hype

"There is no so-called 'overnight breakthrough' in energy storage," Dr Zhang asserts. "Real progress comes from continuous engineering improvement and validation in real operating environments."

Credit: HyperStrong

HyperStrong's HyperBlock M, the company's newest utility-scale BESS solution.

Dr. Jianhui Zhang, Chairman & CEO of HyperStrong

HyperStrong was among the early pioneers in applying AI and data intelligence across the full system lifecycle. The company continuously optimises system design and capacity planning, product R&D, manufacturing automation and intelligent upgrading, charging and discharging strategies, power trading and pricing bid optimisation.

A Practical Path to Next-Generation Batteries

In the evolution of next-generation batteries, Dr Zhang advocates a pragmatic, step-by-step pathway. Semi-solid-state lithium batteries are a critical transitional technology toward fully solid-state systems. "The semi-solid-state energy storage products we have jointly developed with our partner are now being deployed at scale, and we have significantly enhanced the safety profile of energy storage stations," Dr Zhang remarks.

At the same time, researchers and manufacturers are systematically transferring safety technologies developed in liquid electrolyte lithium batteries into solid-state materials and manufacturing processes. These advances lay a robust foundation for the commercialisation of fully solid-state batteries.

Toward an Energy-Autonomous Future

Energy storage will fundamentally reshape how electricity is generated, stored, and consumed. Dr Zhang envisions a future in which solid-state batteries enable buildings and communities to function as large-scale energy buffers, capable of meeting daily power demands with greater autonomy and resilience.

Today, a modular 10-foot BESS can hold up to 4MWh of storage capacity. In the future, systems of the same physical size may be capable of storing 10MWh or more—enough to provide stable power for entire buildings over extended periods.

With deep technical expertise, global execution capability, and a long-term innovation mindset, HyperStrong continues to build the energy infrastructure of the future—reliably, intelligently, and at scale.

Bio of Dr Jianhui Zhang

Dr Jianhui Zhang is the founder, chairman, and CEO of Beijing HyperStrong Technology Co., Ltd. He holds a PhD in Electrical Engineering from the University of California, Berkeley, as well as M.S. and B.S. degrees in Electrical Engineering from Tsinghua University.

For more information, please visit: **www.hyperstrong.com**

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Making Energy Storage Simple

Spearmint Energy's Red Egret BESS project, which got the go-ahead in 2025.

Credit: Spearmint Energy.

Strategies for success

These cases showed the benefits of engaging early with communities and authorities in the planning process, communicating transparently, and addressing concerns upfront.

Close collaboration with fire departments and planning decision-makers has proved key. Emphasising adherence to fire safety standards like NFPA 855 and UL 9540A is a big part of that.

But the wider economic benefits to communities of hosting BESS projects locally, including via increased tax revenues, job creation or community funds, have also been shown to help get locals on-side.

BESS technology's contribution to states' wider decarbonisation efforts has appeared to help in some cases, though local factors tend to be at the forefront of discussions. BESS as an emergency backup for the local grid was cited as a positive for the tech when discussing Spearmint's Red Egret project, for example.

Project setbacks

Sometimes, no matter what developers do, projects will still be refused. Over 2025 we reported on several high-profile projects from major developers and IPPs that were either shut down entirely, withdrawn by the company or had their futures severely thrown into question.

These included projects we reported on from some of the US' most prominent players in BESS, notably East Point Energy, Aypa Power, Engie, Northland Power and New Leaf Energy. But unsuccessful projects are part of the game for any developer, and are baked into their business models, and in some cases the projects could be resubmitted.

The reasons given by decision-makers for refusals were typically the same as those given for moratoriums: concerns over fire safety risk, potential harm to the local environment, and a general lack of applicable regulations for the technology.

Location-specific reasons were given for some projects. Northland Power had a 1GWh BESS at its existing Ball Hill Wind Farm in New York state rejected because of close proximity to a school and to Lake Erie.

This location challenge harks back to comments from RWE's chief development officer Hanson Wood in an interview with *Energy-Storage.news* in mid-2024. Wood said one major challenge for BESS developers going forward would be that projects need to be near demand centres, often in urban or populated areas, whereas wind and solar have typically been deployed in more rural areas. "The difference in approach for development and construction cannot be underestimated," Wood said at the time.

Going to the state

In some cases, developers have chosen to bypass county and town-level decision-makers and gone to state-level energy commission opt-in schemes. This does risk antagonising local stakeholders, who may see it as a way developers sidestep or ignore local concerns.

NextEra Energy Resources faced intense local criticism from Solano County officials when it sought approval through the California Energy Commission (CEC) for its Corby BESS project in the county.

Engie had the same experience when doing the same for its Compass project, after the City of San Juan Capistrano denied a rezoning request for the development. At the time of writing (December 2025), both projects are still undergoing review. Engie told the CEC on 22 December that it was considering alternative sites for Compass.

Conclusion

The more time passes from the Moss Landing incident, the easier it should become to demonstrate modern BESS technology's strong safety record and assuage local fire safety concerns. But we suspect the key challenges of developing projects will remain and perhaps even increase as projects need to be built ever closer to where people live. ■

EV slowdown creates potential lifeline for US energy storage amid FEOC, tariffs

Foreign entity of concern (FEOC) restrictions and the scheduled Section 301 tariff increase to 25% on Chinese-origin battery energy storage systems (BESS) went into effect on 1 January 2026. April Bonner hears from IPP Arevon about life under the new rules.

What's changed

The 'One Big, Beautiful Bill Act' (H.R. 1) maintained investment and production tax credits for battery storage until 2033. However, it introduced new restrictions that disqualify projects from these tax benefits if they receive significant aid from restricted foreign entities like China, beyond set limits.

These restrictions cover materials, finished products, and investment and service agreements, creating notable challenges for an industry where about 75% of US lithium-ion battery imports come from China. The FEOC thresholds start at 55% for projects beginning construction this year and rise to 75% after 2029.

Meanwhile, the Section 301 of the Trade Act of 1974 is used to "remedy a foreign trade practice," according to the US Congress. In 2024, the Biden Administration announced it would increase the tariff rate on non-electric vehicle (EV) and EV lithium-ion batteries, from China, to 25% in 2026.

Overall, it means that on 1 January, 2026, tariffs on Chinese batteries and BESS went from around 37.5% to around 55%.

Era of uncertainty

While the industry has been aware of these coming changes, the unpredictability of the Trump administration's additional announced tariffs over the past year has caused uncertainty and a need for careful planning.

Speaking with *Energy-Storage.news*, Justin Johnson, COO of renewable energy developer-operator Arevon Energy, explains of the BESS industry, "The combination of the Inflation Reduction Act (IRA) and then all these tariffs and FEOC restrictions have just been another impetus to continue to bring more domestic supply online. The slower uptake of EVs is freeing up battery cell capacity for BESS to use. They're now retooling those production lines and creating cells specifically for the energy storage space."

He continues, "The short answer is it's creating even more impetus to use domestic production as much as possible. We saw the same movie with modules over the last three years when the Uyghur Forced Labour Prevention Act (UFLPA) went into effect – there was a big impetus to try to source domestic or US-compliant modules."

This view is consistent with a consultant's statement to ESN in December, suggesting that changing trends in the US BESS industry might eliminate the need for Chinese batteries in the near future.

"EV demand is going to decrease because of the removal of the EV consumer tax credit. The battery manufacturing capacity from those is now being repurposed to BESS. It's not cheap to repurpose, but there's a lot of sunk cost with a gigafactory, so it's happening," they said.

"The South Korean battery manufacturers' announcements could even be enough to meet domestic demand for BESS. You might not even need Chinese batteries online at all, once those are all online."

Repurposing EV battery facilities

LG Energy Solution, Samsung SDI, and SK On have all increased local manufacturing and announced domestic supply agreements with BESS integrators. Similarly, US-based system integrators like Fluence and non-lithium battery companies such as Eos are also expanding their local supply chains.

Johnson says, "Maybe it's bad for climate change, but the slower uptake of EVs is kind of saving our asses a bit. We did have a domestic BESS supply coming online, but it wasn't going to be enough. But the fact that LG, Samsung, SK On, and a bunch of others are retooling factories and sending that capacity into the stationary storage market, most of the forecasts I've looked at show us in an oversupply scenario by late 2026, so through 2027, 2028, throughout the foreseeable future. There will be excess cell capacity to meet our needs.

This also comes with uncertainties, though. In September, US Immigration and Customs Enforcement (ICE), along with multiple other law enforcement organisations, raided Hyundai Motor and LG Energy Solution's EV battery cell plant in Ellabell, Georgia.

Although that specific factory was not converting EV manufacturing lines, the work involved in EV and BESS cells is similar because workers from outside the US possess skills that US workers lack in large numbers. These foreign workers are expected to train US workers.

Several aspects of that incident are still unresolved, but Donald Trump has adopted a firmer position against the raid, emphasising the significance of the South Korean worker's skills.

Johnson notes, "[Trump's sentiments] give me some hope that you won't see that sort of activity in the future. I went to LG's cell factory in Holland, Michigan. It is a massive factory; I think they have a couple of billion dollars invested there. It's a sprawling campus that covers acres and acres. There are thousands of people who work there."

He continues, "The vast majority of people I saw working there are just Americans, people born and raised in Michigan, everyone you'd see in the town. I did see some Korean folks, and they were spooling up the factory for training. But everyone I talked to who was leading their individual areas was young, 30-ish college graduates from America pursuing a manufacturing career."

Speaking to immigration raids or other potential delays in building out manufacturing, Johnson says, "I hope we don't see that sort of stuff recur, because that runs contrary to something that's popular on both sides of the aisle, which is bringing manufacturing jobs back into the US."

BESS cost considerations

Johnson says that Chinese-manufactured BESS are still the cheapest option in the industry, but "not by much". And further, that customers are willing to pay more to avoid the possibility of tariff changes.

He explains, "Most of the people you would sign power contracts with, whether you're Arevon or one of our competitors, our customers appreciate and are typically willing to pay a little bit more if they have certainty that you're not going to need to come back and renegotiate with them on the delivery date or the price if you end up being impacted by tariffs or some other thing associated with a really long, extended supply chain. So, they're often willing just to pay a little bit more for the certainty that domestic provides."

Johnson adds, "You have extended timelines on logistics that end up being way more expensive. The combination of those two things – shorter logistics tails and domestic supply – really reduces a lot of the uncertainty. People are usually willing to pay for that. You can't pay twice as much for it, but if it costs 10% more, maybe you're willing to pay for that because of the certainty it provides." ■

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Rethinking Speed to Power: Why BYOG Requires More than just Batteries

As the AI boom accelerates, access to reliable power has become the industry's defining constraint. According to the International Energy Agency (IEA), data centers consumed an estimated 415 terawatt-hours (TWh) of electricity in 2024 which is about 1.5% of global demand.1 That's more than the energy required to power the United Kingdom, the world's 6th largest economy, for one year. The IEA projects data-center demand will nearly double to ~945 TWh by 2030, while BloombergNEF forecasts U.S. data-center load could quadruple from ~25 GW today to over 106 GW by 2035, making it one of the fastest-growing challenges for today's power systems. 2

Not All Data Centers Are Created Equal

That said, not all data center energy profiles are created equal. AI-driven facilities are far more energy-intensive, driven by power-hungry GPUs and specialised accelerators that can exceed 100 kW per rack, with total power requirements 10–30× higher than traditional data centers. Their workloads, including large-language model training, can drive significant and rapid swings in power demand, leading to frequency excursions that increase the risk of data center outages and operational disruption.

Separately, AI data centers can introduce significant local power-quality issues, including voltage flicker, harmonics, that affect nearby homes and businesses. These localised power-quality impacts often result in interconnection delays or requirements for new substation and transmission upgrades.

The Rise of Hybrid Energy Systems

To address these concerns, the industry is increasingly deploying on-site generation to support growing power needs, known as Bring Your Own Generation (BYOG)

A common approach is a hybrid architecture in which gas turbines provide scalable, dispatchable power, while batteries act as a buffer—absorbing load swings and supplying bridge power as generators ramp. Grid-connected data centers that deploy on site battery energy storage can also reduce exposure to utility demand charges and minimise overall energy costs.

Beyond grid and cost benefits, batteries also play a critical role in protecting generation assets. Gas turbines serving AI-driven data centers can experience increased torsional stress as ultra-fast, non-linear load swings create torque fluctuations on the turbine-generator shaft, increasing fatigue and reliability risk. By absorbing these rapid power swings, a battery storage system has the potential to smooth the load profile seen by the turbine, improving mechanical stability and extending equipment life.

Why Batteries Alone Aren't Enough

Batteries alone cannot fully address the challenges created by highly volatile AI data center loads. While energy storage can absorb rapid power swings, without advanced power conversion systems (PCS) and tightly integrated controls, those transients can still propagate to the gas turbine, exposing it to vibration and fatigue risks. Mitigating these risks requires coordinated control architectures that actively manage interactions between data center loads, battery inverters, and gas turbines.

Looking Beyond the Battery

Addressing the challenges of AI-driven data centers requires more than simply adding batteries; it requires system-level integration across generation assets, energy storage systems, and plant controls. Batteries are critical, but inverters and advanced controls are the key to unlocking their full potential. In environments where power demand can change rapidly and unpredictably, grid-forming inverter capabili-

ties can stabilise voltage and frequency during sudden load swings allowing slower generation assets adjust.

To fully realise this capability, inverter performance must be coordinated through advanced BESS controls and feed-forward loops that can anticipate load changes, dispatch batteries in sub-second timescales, and limit the rate of change seen by the turbine. By bringing advanced power conversion and energy storage systems together with gas turbine technology, GE Vernova's Power Conversion & Storage business enables tighter integration between inverters, batteries, and generation. This end-to-end portfolio allows controls to be designed and coordinated across the entire hybrid system—improving dynamic response, protecting generation assets, and delivering the level of reliability required for AI-driven facilities.

Rethinking Speed to Power

As AI-driven data centers reshape electricity demand, speed to power is no longer just a question of how much energy can be delivered, but how reliably and intelligently that power is integrated into the grid.

Bring Your Own Generation strategies anchored by gas turbines and batteries are a necessary step forward, but they are not a complete solution on their own. The extreme power density and volatility of AI workloads demand a system-level approach that goes beyond standalone assets.

Rethinking speed to power means recognising that success is not defined by adding megawatts alone, but by delivering high-quality, reliable power that supports both data center operations and the surrounding grid.

Private sector backers needed for next phase of Middle East energy storage market

Saudi Arabia and the UAE have emerged as two of the world's most prominent energy storage markets, with mega-scale projects announced and moved forward at a staggering pace over the last two years. But what does the next phase look like? Cameron Murray investigates.

At the time of writing, projects totalling around 37GWh of BESS capacity in Saudi Arabia and around 28GWh in the UAE have been announced in operation, construction or procurement.

The two countries are transitioning to diversification from fossil fuel dependence, both as drivers of their economies and in their energy mix. As more solar comes online to replace that, they need large amounts of energy storage, and they need it fast.

Government the driver

Government bodies in the region can move very fast in response, both because of the nature of their political structures and the plentiful oil money to pour into projects.

The projects announced so far have been driven or financed by a handful of state-owned bodies, and supplied exclusively (so far) by Chinese companies, spelt out in the table below.

In Saudi Arabia, it has been the Saudi Electricity Company (SEC) and the Saudi Power Procurement Company (SPPC), responsible for procuring power from IPPs.

In the UAE, two utilities – Emirates Water and Electricity Company (EWEC) and Dubai Electricity and Water Authority (DEWA) – have been driving projects alongside investment firm Masdar.

The projects are generally either directly-owned by these companies or are being procured under build-own-operate (BOO) whereby the state-owned company will procure the energy from the owner (via an SPV).

However, it is the directly-owned projects which have progressed the furthest, with the big tenders in both countries still ongoing. The exception is projects in Saudi by power generation firm ACWA Power, for the NEOM and AMAALA mega-infrastructure projects, but ACWA is still state-controlled.

"The government does want private sector projects to come in for the next phase of the market," says Hammad Rabbani, managing partner at investment and financial services firm Burj Capital.

Saudi Arabia's projects would get it well on its way to its 48GWh large-scale BESS target for 2030, while the UAE has not announced a specific number.

Government-financing the first phase, independent international players the next

There are two main challenges for international independent power companies and developers wishing to launch projects in the region, explains Rabbani.

"One is on the EPC side. The market is changing so quickly in terms of technology and pricing that quotations are very short-lived. By the time due diligence is done things have changed drastically. That is one element that has to be managed," Rabbani told Energy-Storage.news.

"It can take 3-4 months to get to financial close and project lenders want to see a full turnkey proposal, which makes things hard."

The other challenge, he explains, is around policy frameworks.

"The projects have been sovereign wealth fund or local bank-financed, and they have not been electricity market-based but more financed on availability-based payments. Arrangements have been bespoke, as there's been no such framework built in the region," Rabbani says.

"There are a lot of things that need to be managed for lenders, around ESG, but also degradation as BESS technology has not really been tested yet at scale in the region. There are a lot of balls being juggled."

Progress in solar could kickstart progress in BESS

Rabbani says the next phase of BESS projects in the region will be those big established private companies that are already advanced in building and operating solar projects in the region, possibly by adding BESS to those projects. He doesn't see it as likely that a company will come in and do BESS on its own.

"But it's very important for those international developers

Project	Commercial model / owner	BESS Supplier	BESS Capacity	Commercial operation date / target
Saudi Arabia				
Five projects across the country	SEC	BYD	12.5GWh	Not clear
Najran, Madaya, Khamis Mushait BESS projects	SEC	Sungrow	7.8GWh	2025/26
First large-scale tender	Build-own-operate for SPPC	Procurement ongoing – shortlist in January 2025	2GW/8GWh	2026
Tabuk and Hail BESS Projects	SEC	Hithium	1GW/4GWh	2026
Bisha BESS	SEC	BYD	2GWh	2025
AMAALA BESS	EDF, Masdar	Sungrow	760MWh	2027
NEOM BESS	ACWA Power-owned	Sungrow	600MWh	Not clear
Red Sea BESS	ACWA Power-owned	Huawei	1.3GWh	2024
			Total: c.37GWh	
United Arab Emirates				
World's Largest Solar and Battery Storage Project	Masdar and EWEC	CATL	19GWh	2027
EWEC 400MW BESS Project	Build-own-operate for EWEC	Procurement ongoing	800MWh	2026
MBR Solar Park Phase 7	Build-own-operate for DEWA	Procurement ongoing	8.4GWh	2027
			Total: c.28GWh	

and IPPs to start taking a view on having storage," he says.

That phased market development whereby generation comes first followed by storage is fairly typical elsewhere in the world. And announcements in late 2024/25 show that international power firms making strong progress on the solar side.

In November 2025, France-based EDF Renewables secured financing for two Saudi solar projects totalling 1.4GW in partnership with SPIC Huanghe Hydropower Development (SPIC HHDC) and Saudi Aramco Power Company (SAPCO). The 400MW Al Henakiyah-2 and 1GW Al Masa'a solar PV projects have 25-year PPAs with SPPC and will come online in 2027.

So far, EDF had been the only outside company we are aware of to have finalised solar projects in the region, also securing financing for late 2020 and 2024. EDF was said at the time to hold 20% stakes in those projects. Its stake for the recent one wasn't revealed, but it could be more, even a majority.

> "There are a lot of things that need to be managed for lenders, around ESG, but also degradation as BESS technology has not really been tested yet at scale in the region. There are a lot of balls being juggled."

Then in January 2026, Masdar and another French firm, Engie, reached financial close on the 1.5GW Khazna solar project in Abu Dhabi, UAE. The project has a 30-year PPA with EWEC, and is scheduled for operation in 2028.

Both companies manage to secure financing from consortiums of local, East Asian and Western banks and financing institutions.

BESS technology and local climate

The local region has a very particular hot, dry climate, and Sungrow explains to Energy-Storage.news what this meant for its BESS technology provision.

"The frequent sandstorms and extreme climate conditions present significant challenges to the site project, necessitating that the product be equipped with the highest level of protection. Our product is designed with a C5 anti-corrosion rating, an IP55 protection level, and has successfully passed over 770 field tests. It is the industry's first to achieve full-chain safety certification for both AC and DC sides," a spokesperson says.

Rabbani points out that you obviously need very good cooling technology for BESS. But, the harsh climate means non-lithium technologies are being considered too, he says. One possibility is supercapacitors which have better temperature and charging time performance than lithium-ion. ■

Identifying the top LDES vendors

Lukas Karapin-Springorum, research associate at Sightline Climate, looks at the long duration energy storage (LDES) technology companies in the market today.

Dozens of technologies can provide LDES to integrate intermittent renewables, defer transmission upgrades, and make power systems more resilient.

These technologies span electrochemical, mechanical, and thermal storage approaches. Each subtype, like vanadium flow batteries or adiabatic compressed air, has a unique combination of theoretical benefits like the ability to scale energy storage and power output independently, abundant raw material inputs, maturity, manufacturing scale, or fire safety.

This technology diversity maintains competition and gives grid operators options that meet their specific needs.

But the dizzying array of options can make it difficult for utilities, independent power producers, and investors to make tactical decisions: which tech to pilot, which vendor to bid into a tender with, or which company to back.

Vendor rankings can be a starting point. Sightline Climate's LDES leaderboard ranks 23 vendors on technology (% RTE), finance (US$m raised & mobilised), deployment (MW post-FID), and economics ($/kW-yr capex). It shows which companies are competing for and winning LDES tenders, and forms a bridge between crowded market maps and detailed bankability assessments.

The results show that long-duration lithium-ion's low capex and large-scale deployments give it an early lead, with Tesla and Chint Power taking the top two slots. But among non-lithium technologies, there is an unexpected trend.

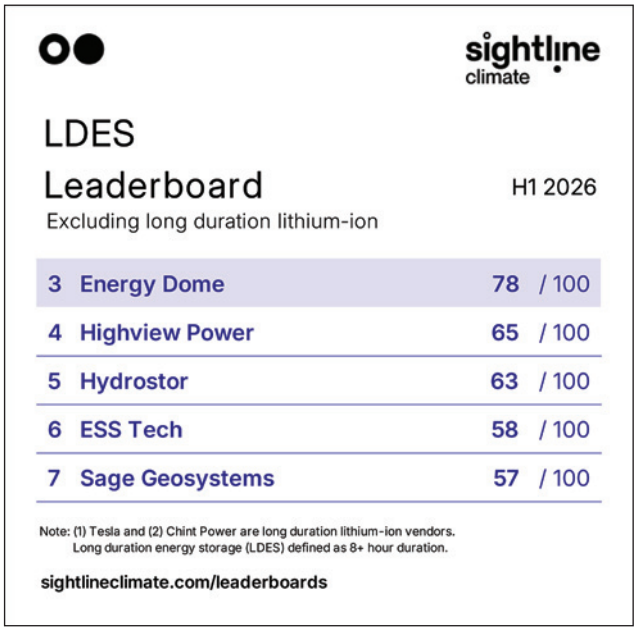
Mechanical storage tops the non-lithium leaderboard

Mechanical storage vendors are in the best position to compete with long duration lithium-ion batteries, thanks to large scale deployments and long lifetimes that lower normalised capex.

Four of the top five non-lithium techs are mechanical:

3. Energy Dome (liquid CO2) has a comfortable thirteen point lead on the next vendor. Two commercial projects post-FID, higher round-trip efficiency than other mechanical storage, and best-in-class capex, in part from low regional costs at its second-of-a-kind project in India, set it apart.

4. Highview Power (liquid air) has an industry-record deployment total, driven by the 50MW Carrington project in the UK and a 5MW project developed by Sumitomo Heavy Industries and Hiroshima Gas in Japan, and a strong financing total buoyed by project finance that makes up for its relatively higher capex.



5. Hydrostor (adiabatic compressed air) has strong financial backing and competitive economics, although its deployment total is held back by delayed FIDs at its 200MW Silver City project in Australia and the 500MW Willow Rock project in California.

6. ESS Tech (iron flow battery) scores well on historical finance and has a moderate deployment score from utility pilots that used its legacy modular products prior to a strategic pivot to large format electrolyte tanks in November 2025.

7. Sage Geosystems (pumped geomechanical) benefits from solid round trip efficiency, a post-FID demonstration project with San Miquel Electric Cooperative in Texas, and mid-range capex despite splitting its focus across energy storage and geothermal generation.

Mechanical storage is scaling early by sidestepping manufacturing barriers

Mechanical storage vendors are outperforming their peers despite some perceived disadvantages. They've raised only a quarter of the VC/growth money of other LDES techs and have four times fewer projects in the announced pipeline, with early mechanical storage leader Energy Vault (gravity-based) pivoting to long duration lithium-ion batteries instead.

But this asset-light period of the energy transition is well timed for mechanical storage, which sidesteps capital-intensive manufacturing. Instead, mechanical storage projects

use off-the-shelf components from mature supply chains and assemble systems on-site to achieve capex that is competitive with 8-hour long duration lithium-ion batteries. This is particularly impressive for first-of-a-kind projects that haven't realised economies of fleet or learnings from deployment.

Conversely, many electrochemical and thermal storage vendors need to finance factories, get them up and running, and find high-volume offtakers before they can offer competitive pricing. This has been difficult for battery manufacturers like Enervenue, Form Energy, and Invinity that placed outside of the top seven based on limited front-of-meter deployments and relatively high capex.

Competitive pricing is a decisive advantage for mechanical storage. Government tenders use economic viability as a central evaluation metric, which makes low capex crucial for LDES projects that are reliant on policy support to reach FID. Low capex benefits vendors' scores threefold: it is scored directly on a lifetime- and degradation-normalised basis (economics), facilitates FID on projects (deployment), and mobilises project finance (finance).

Tenders will supercharge the winners

In the first half of 2026, 9.3GW of tender awards will be announced, causing a step-change in contracted capacity that will ripple through to FIDs. Tenders in the UK (2.7-7.7GW), New South Wales (1GW), and Ontario (0.6GW) are selecting projects by June 2026 and could more than triple the contracted capacity of all previous tenders combined. The vendors with successful projects will have a clear path to FID in late 2026 or early 2027 and could pull ahead of their competitors in the leaderboard once they start construction.

The results of these tenders will show whether any vendors can compete with 8-hour long duration lithium-ion batteries. The vast majority of the projects benefitting from pre-2026

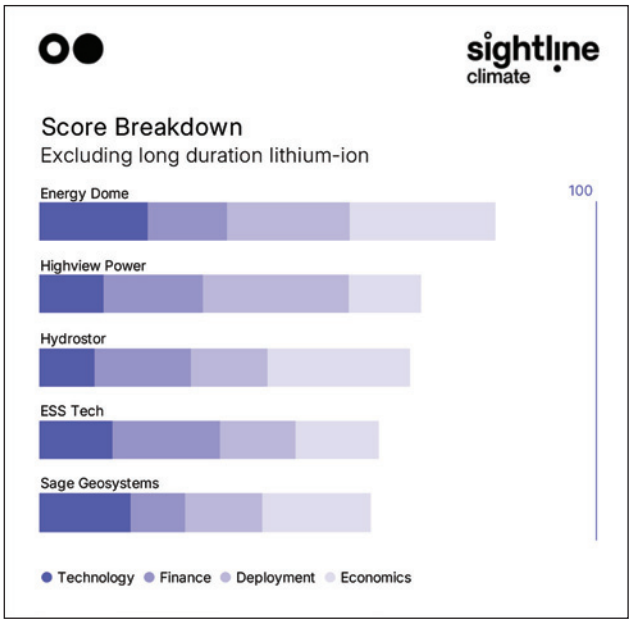


Image: Highview Power.

Mayor of Greater Manchester Andy Burnham breaks ground at Highview long duration energy storage plant in Carrington, Greater Manchester.

LDES policies in New South Wales and California are long duration lithium-ion batteries because of their maturity and low cost, and the technology makes up 77% of the global capacity scheduled to be operational by 2030. If non-lithium technologies don't win sizable contracts in 2026, their best option going forward will be to focus on programmes in California and Ontario that exclude long duration lithium-ion.

Electrochemical techs could make a comeback in 2026, but thermal storage will focus on industrial heat

Non-lithium electrochemical technologies could make a comeback. UK regulator Ofgem is considering 3.1GW of projects using Invinity's vanadium flow batteries for its cap-and-floor scheme, and it could push the vendor from MW- to GW-scale if it selects these projects for long-term contracts. But if Invinity is passed over in the UK, the most successful electrochemical vendors could turn out to be earlier-stage companies with stronger cost fundamentals, like organic flow batteries.

Thermal storage will likely focus on industrial heat, not power-to-power LDES. The technology has high capex and low efficiency in power-to-power configurations, and the top thermal storage company comes in at #15 in the leaderboard. But vendors focused on industrial heat have more traction; several commercial-scale projects reached FID or became operational in the last six months.

The final word

LDES is set for a step-change as the industry moves from grant-funded pilots to commercial-scale steel in the ground. Mechanical storage companies are positioned to lead as the industry scales, but well-funded non-lithium electrochemical techs are nipping at their heels and will have the chance to prove themselves in 2026. ■

Note: Sightline Climate defines long duration energy storage (LDES) as power-to-power energy storage systems that can discharge for at least eight hours, excluding pumped hydro.

Beyond Lithium: The Technology Quietly Defining Long-Duration Energy Storage

A different class of storage is moving from "alternative" to "core infrastructure", and Energy Dome, with its CO2 Battery, sits at the centre of it.

For the last decade, energy storage has been framed as a lithium-ion story, and for good reason. Lithium-ion proved that batteries could move from niche grid experiments to mainstream infrastructure, scaling quickly, responding fast, and accelerating renewable integration in market after market.

But something is changing.

As renewable penetration rises, grid operators and energy buyers are discovering that the "storage problem" is no longer simply about milliseconds and frequency response, or even about shifting solar power into the evening peak. Increasingly, the question is time: how long can stored energy remain dispatchable, dependable, and economic, day after day, year after year?

That is why LDES has moved from a technology category to a procurement priority. The world is entering an era where 8-hour-plus storage is no longer a nice-to-have; it's becoming one of the enabling conditions of the modern grid.

And once you accept that premise, the conversation naturally moves beyond lithium.

When storage goes long, the rules change

Lithium-ion batteries have shaped the modern energy storage market, but the industry's centre of gravity is shifting toward applications that stress different capabilities.

LDES is increasingly expected to support renewable firming, deeper time-shifting, and resilience, not just short bursts of power. The storage asset is no longer judged only on response speed and installed megawatts. It is judged on lifetime economics, on the ability to deliver the same performance profile across many years of cycling, in a wider range of operating conditions, and under scrutiny from utilities, regulators, and financing partners.

That is where the limitations of lithium-ion become harder to ignore.

The more hours you add, the more the business case is exposed to questions about long-term performance certainty, augmentation, and lifecycle cost. In parallel, safety considerations have become central, with communities and authorities applying stricter scrutiny to large stationary systems.

In other words, as storage becomes a core grid asset rather than a supporting tool, it starts to be evaluated like infrastructure.

The CO2 Battery: an LDES system designed like infrastructure

Energy Dome's CO2 Battery is one of the clearest expressions of this shift.

Rather than relying on electrochemical cells, the CO2 Battery is a closed-loop thermo-mechanical system that uses off-the-shelf equipment to store energy by compressing carbon dioxide and releases it to generate electricity through a turbine when required. The underlying promise is straightforward, deliver multi-hour storage (8-24) at utility scale, with a performance profile designed for repeatability and long operating life.

The advantages of this architecture become particularly relevant when storage is expected to perform daily, for decades:

- Duration designed for LDES, targeting the 8–24 hour range where grids need deeper flexibility.
- No electrochemical degradation dynamics, shifting the economics away from capacity fade and towards predictable long-term performance.
- Temperature resilience, a practical advantage as deployment expands into hotter, more variable climates.
- A materially different safety profile, aligned with industrial equipment standards rather than densely packed electrochemical systems.

None of that matters, of course, if it remains theoretical.

So the real test is whether it works in the only place that counts: on the grid.

The operational reality

Energy Dome's full-scale CO2 Battery facility in Ottana, Sardinia, rated at 20MW/200MWh, has become a reference point in the LDES conversation precisely because it moves the discussion from "what could work" to "what is operating."

In the LDES world, scale matters. A 200MWh asset is no longer a lab-sized demonstration or a marketing prototype. It is a grid-scale system that has to be built, connected, commissioned, and operated like any other energy infrastructure, with real-world constraints, dispatch requirements, and operational accountability.

This is why many observers considered the Ottana plant as a threshold moment. And crucially, this was not only a technical milestone: it is also an early proof point for how LDES can be commercialised under bankable contractual structures. In late 2024, Energy Dome signed a long-term offtake agreement

The operational 20MW/200MWh CO2 Battery plant in Ottana, Sardinia, Italy.

with ENGIE for the Ottana facility under an Energy Storage as a Service model, a first-of-its-kind offtake arrangement for long-duration CO2 storage at this scale. Under this structure, Energy Dome retains ownership and operational responsibility for the asset, while ENGIE optimises and dispatches the stored energy into Italy's power markets, bringing a utility-grade commercial framework to a full-scale deployment.

From "technology story" to "market story": partnerships that signal scale

LDES is won in markets, through customers, contracts, and repeatable deployment.

That is why Energy Dome's commercial momentum matters.

In July 2025, Google announced a commercial partnership with Energy Dome, alongside a strategic investment, as part of its strategy to reach 24/7 carbon-free energy by 2030.

For the market, this was a meaningful signal, not just because Google is a sophisticated energy buyer and heavy user (i.e. because of their Data Centre energy needs), but because 24/7 carbon-free ambitions inherently demand solutions that can cover longer renewable gaps, not just short fluctuations.

In India, state-owned utility NTPC selected the CO2 Battery for a 20MW/160MWh (8-hour) project in Karnataka, framing the decision around the characteristics of pumped hydro and the logic of long-duration infrastructure.

In the United States, the Alliant Energy project in Wisconsin, a 20MW/200MWh CO2 Battery, received regulatory approval, another indicator of momentum in one of the world's most active storage markets.

And back in Italy, the tolling and offtaker discussions around long-duration storage have increasingly centred around what utilities care about most: reliable performance, credible economics, and investment-grade counterparties, while the growing role of competitive auctions is helping formalise demand and establish clearer routes to bankable revenue frameworks.

The bigger picture: storage is evolving into "modern energy" infrastructure

Energy Dome's uniqueness is not that it speaks loudly about long-duration energy storage. It has moved swiftly and aggressively from the hypothesis phase into the deployment phase, with grid-connected assets, global partnerships, and a technology architecture designed for the realities of modern power systems.

The lithium era of storage is not ending. But the long-duration era has clearly begun, and Energy Dome has already rewritten the definition of what "standard" looks like.

‘Italy is a natural market for batteries’: Greenvolt Power on its MACSE-winning project

Cameron Murray catches up with developer and IPP Greenvolt Power’s head of storage Antonio Montoto Rojo about the recent MACSE auction in Italy, where it won a contract for a 75MW BESS.

The long-awaited MACSE auction in Italy concluded in September 2025, handing out 17-year contracts to c.10GWh of battery energy storage system (BESS) projects bid in by a handful of companies, one of which was Greenvolt.

The auction’s low price and relatively low number of winning companies sparked debate in the industry. Head to pages 54-55 for a Q&A with another IPP, Zelestra, about why it chose not to proceed in the auction when it saw how low prices were going.

Credit: Terna.

The Capagatti electrical substation in the province of Pescara in Abruzzo. TSO Terna used MACSE to procure 10GWh of BESS capacity.

Energy-Storage.news: Can you talk us through how Greenvolt approached the MACSE auction and the Italian market?

Antonio Montoto Rojo: We were aware that the price was going to be low, and our analysis was close to the final results.

There were a few factors that would condition the results. Some companies have a lot of projects concentrated in it, we expected this would work to reduce the price as people tried to capture the volumes. Greenvolt only presented one project and we obtained a contract for its whole capacity.

Our strategy is to work in a global way in terms of procurement and in auctions, where being competitive is critical. We are working in several European markets, trying to make a good global price for the product and having tools to decide internally what is the best price locally too.

One of our partners asked if the capex for the Italy project is achievable, as some BESS players in the auction with a lot of experience didn’t win contracts. It’s important to emphasise the local team you have, as that gives you an understanding of the local dynamics and companies. Most companies who were from outside didn’t have all those details, which gives you the ability to read between the lines.

Why do you think lots of people were taken by surprise regarding the final prices that came out of the auction?

First thing to say is that the auction conditions are very interesting in that they give you bankable and fully insured projects in terms of the revenues. But the auction wasn’t one that was appropriate for ambitious, high-profitability objectives. It’s more about having an asset that will be reliable in terms of operations in the long-term.

But after MACSE’s 17 years [ends], there are a few years of merchant, so you need an understanding of other revenues, and a good relationship with suppliers, to make some more profits after the contract ends.

It was really important to have one project in Italy. It’s a message that we are betting to be seriously a long-term player in the BESS market.

A lot of people have talked about the strict operational requirements. Can you talk a little about that?

It’s not necessarily strict, but it is very clear. Also, it is one of the first auctions I’ve seen where the parameters are basically in the megawatt-hours (MWh) and not in the megawatts (MW).

Because of the way it’s structured, for 4-hour systems MACSE is in effect in competition with other revenue streams, while for 8-hour ones it’s a very singular opportunity to start a project.

I think Terna and ARERA did a good job in aligning the penalties with what the system can provide. The risk of not aligning with those is low, the operational conditions are reasonable, but we obviously still need to take care.

In our case, we decided to just go all in on MACSE because our project size of 75MW, that relatively limits the ability to stack revenues, based on our analysis.

I think most players also bid all of the projects’ capacity into the auction. Some projects only won part of their capacity bid in, but I’m not aware of projects that specifically planned to do that. There might be some, but I’m not aware of them.

However, you need to manage correctly the project construction and costs. We didn't use any incredible, ambitious numbers in the capex. We never use the lowest potential capex we can achieve, we always have a margin. There could be risks in taxes, logistics, raw materials. You can't go to the lowest scenario.

In our scenario, the revenues are acceptable for us in these conditions and in this context.

What kind of optimisation is needed for a MACSE project, how exactly does it work? Are you just handing over control to Terna?

Terna is creating a unit to manage all these MACSE contracts but they also need aggregators as they don't want to have public direct management of the facilities. They want to cover the needs for the electricity, you need to manage the electricity system world in the best way.

You need to implement a serious asset management strategy according to the commands you get from Terna.

And there is a variable part of MACSE, which is the secondary market, the balancing market. In this part, you need to do your best to capture this variable revenue.

If you have a 2-hour project, there's a variety in the number of cycles you would do. With an 8-hour system, you can do 1-1.2 cycles a day maximum because there just aren't that many hours in the day, so the extra revenues are not so dynamic. It's bulk energy management.

We will need to have strict rules and have traders in the conventional way, as with merchant, but we effectively have a power purchase agreement (PPA) contract, which we need to follow. You have a requirement of one cycle per day in the energy market as part of MACSE. You need to follow this.

It's not really a tolling agreement, but it's the same philosophy, as it caps the maximum revenues you can achieve by making you follow its prescriptions. It's not clear yet how high the revenues could be in the merchant space, but the revenues would not be competitive for an 8-hour solution. You'd really need to justify an 8-hour solution in the merchant market, maybe with lots of agreements with PV projects. In this sense, the MACSE mechanism is a smart way for solving the imbalance.

The project has a 75MW capacity contract. The contract levelises the capacity according to some conditions, it's about 70MW for charging from the grid and 62MW charging to the grid. The project is 600MWh.

What about the IRR you are targeting?

I can't give a number but it is according to our strategic plan, this market entry is not a shift in our policy.

Can you talk me through your choice in supplier and EPCs for the project?

One advantage is that we have a local team that has done projects in mainly PV and wind, but also our main people in Iberia and Warsaw, who have experience in other Italian companies. So, we don't arrive from scratch, we have good knowledge of the local partners we can use, so we can manage numbers with lower risk than companies that come from scratch.

At the end, you need to manage this budget. But in general, the battery price has been reducing a lot in the last 3 years. In fact, from the first moment MACSE started to be published to today, there was a further variation in the price but also increasingly dynamic changes on the integration technologies and performance.

We have solid partners and we will announce them in the next weeks.

For the Italy project, will you take it into operation yourself or sell it at a later stage? In Poland, for the projects you won capacity market (CM) contracts for you've sold some of them but are taking some of them into operation yourself.

Sometimes we sell previous to construction but we still build the project ourselves. We are working to have the Italy project built by Greenvolt, we select all the suppliers for the projects. We're doing that in Poland too, whether we've sold the project or not.

The commercial office decides if, at a particular point in time, it makes sense to sell.

But the default operation and philosophy is to build and operate the project ourselves; this is the best way to make a project profitable for other parties. All the business case is done considering the full lifetime of a project.

So, selling is more of an opportunistic option?

Yep, the company decides based on the asset value, but it's another team, separate from me, that decides. And that set-up is better for my own health!

Can you talk about Italy as a market in terms of developing projects and the grid?

Italy and the UK are two countries where they've made the more serious efforts to include BESS from the beginning. Italy's ultra-fast response auction was also very interesting and now also with this MACSE mechanism. But there is a very interesting merchant market too, especially at the medium-voltage level. Many operators from Europe and UK are moving fast into Italy.

The market is solid. The most important thing is that there is a real need for storage in Italy, because of the electrical topology of asymmetric production and consumption in the South and North, and the diversity of energies Italy wants to achieve in the next 20 years, makes batteries very important. It is not an artificial support, it is a natural market for batteries.

For us, it is a top three or four market in Europe. There is a diversity of opportunities, both public and private in Italy, it makes you more relaxed regarding your strategy. You do not need to strictly depend on the MACSE result to make a project profitable, there are other options.

Terna's grid infrastructure still needs to grow its nodes and capacity, they have an ambitious plan. The routes to market are very defined. ■

Grid-Forming Technology: The Key to Global Energy Storage and Grid Stability

As renewable energy sources like wind and solar become a larger part of our power generation mix, traditional power grids face unprecedented challenges. Historically, grids relied on stable, predictable generation from thermal and hydro plants. Now, with the rise of variable renewables, grids must handle fluctuations that can cause instability and threaten reliability.

This is where grid-forming technology plays a crucial role. Unlike conventional renewable systems that passively follow grid conditions, grid-forming systems actively establish and maintain grid voltage and frequency, much like traditional synchronous generators. This shift from grid-following to grid-forming is essential to ensure stability in modern power systems.

One way to understand the importance of grid-forming is through the concept of Short-Circuit Ratio (SCR), which measures grid strength. High SCR means a strong and stable grid, while low SCR indicates a weak grid vulnerable to disturbances. Many renewable energy bases connect to relatively weak grids with low SCR, making grid-forming technology indispensable for maintaining system stability and preventing issues like voltage instability and frequency fluctuations.

Globally, approaches to grid-forming technology vary. Developed regions focus on distributed energy integration and digital solutions, leveraging virtual power plants and active consumer participation. Australia, for example, has deployed multiple ARENA-funded large-scale grid-forming battery projects that have moved the technology from experimental to investable, addressing challenges such as long distances, weak connections, and high renewable penetration. Developing regions, on the other hand, often face the dual challenge of weak grid infrastructure and rapid energy transition. Countries like Saudi Arabia and Brazil are deploying grid-forming solutions combined with ultra-high voltage transmission to stabilize their evolving grids.

China's approach is notable for its state-led policy framework driving rapid deployment of grid-forming energy storage alongside ultra-high voltage transmission networks. This model supports large-scale renewable integration and grid stability across vast distances.

Kehua Digital Energy, recognized as a grid-forming expert, has been at the forefront of this technology. Since early involvement in microgrid projects, Kehua has advanced grid-forming control technology and achieved major breakthroughs, including black-start capabilities. With over 400 grid-forming microgrid systems deployed globally and over 3GW cumulative shipments of grid-forming energy storage, the company has successfully completed comprehensive grid-forming energy storage grid-connection tests and delivered multiple large-scale projects worldwide, demonstrating practical and scalable solutions that support the global energy transition.

Grid-forming BESS projects supplied by Kehua across Northern China

As grid-forming technology matures and costs decline, it is poised to become a standard feature in power grids, much like transformers today. This technology not only stabilizes grids with high renewable penetration but also accelerates progress toward cleaner, more reliable electricity systems aligned with global carbon reduction goals.

Understanding and embracing grid-forming technology is vital for utilities, developers, and policymakers aiming to build resilient, future-ready power systems. It represents the foundation for a stable, flexible, and sustainable energy future in a world increasingly powered by renewables.

100MW / 200MWh BESS project supplied by Kehua in Bulgaria

KEHUA TECH

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UK grid connections overhaul aggressively trimmed BESS pipeline

Reform to the way that the UK grid connection queue is handled was a much-needed, long overdue initiative, write Solar Media Market Research analysts Josh Cornes and Charlotte Gisbourne.

Developers around the country were buying up cheap grid, at both transmission and distribution level, with some having no intention on building the projects, and some not even securing land. Other developers mothballed projects yet sat on the grid connection, all of which led to a build up of "zombie projects".

The reform was announced back in October 2024 by the National Energy System Operator (NESO), with a lot of hope to advance projects and help clear the unfeasible projects out the way.

Various protections were implemented for projects that met specific criteria. Existing grid connections from 2025-2027 couldn't be touched, and projects submitted before December 2025 also received protection.

With over 100GW meeting the above criteria, NESO's hands were tied, meaning the reform effectively just removed unfeasible BESS projects from the queue by issuing Gate 1 offers without a firm connection date.

Over 153GW battery storage projects were removed, as previously reported by Solar Media Market Research.

The UK will not realistically need the 100GW of energy storage due to connect by 2035: the headline target for 2030 is 27GW, with 33GW currently due to connect by then, making Phase 2 projects unattractive at best. This suggests NESO expects some developers to drop their projects completely, a likely outcome if developers unhappy with Phase 2 or Gate 1 offers drop out.

Recent development activity

This is all in the context of a large amount of BESS development activity in the run-up to the issuing of Gate 2 offers. Submissions in 2025 were over 96GWh, an increase of 25% from 2024.

Broadly, the UK is moving towards larger projects, with the average submitted capacity in 2025 being over 400MWh compared to 257MWh the year prior. There has been an increased interest in long-duration energy storage (LDES) with multiple projects over the usual two-hour duration, such as the AW2 Uskmouth BESS, aiming for up to five hours. This is largely due in part to the new Cap and Floor Scheme.

LDES was counted in a separate technology pot from BESS in grid connection reform but is also at full capacity up to 2035, with offers issued partially based on when applications were made – the earlier ones took priority, and 5.6GW was not prioritised.

While investor interest in battery storage on a global scale is high, the UK is not the most sought-after market. Strong government support has improved its standing but without a likely connection date in the next decade, NESO's reform could dampen investment.

This could see the current application slump that began in Q4'25 continue to early 2026 as focus is shifted onto currently planned sites.

The UK grid-scale battery storage market grew 45% by operational capacity in 2025, with 4GWh coming online during the year, bringing total operational capacity to 12.9GWh. The 4GWh was a 30% yearly increase.

However, as expected of a maturing market, the growth rate did fall slightly compared to the 53% seen from 2023 to 2024. There were also fewer sites completed in 2025 compared to the year prior, but with secured grid connections, the path forward is clear for at least 33GW to be deployed by 2030. ■

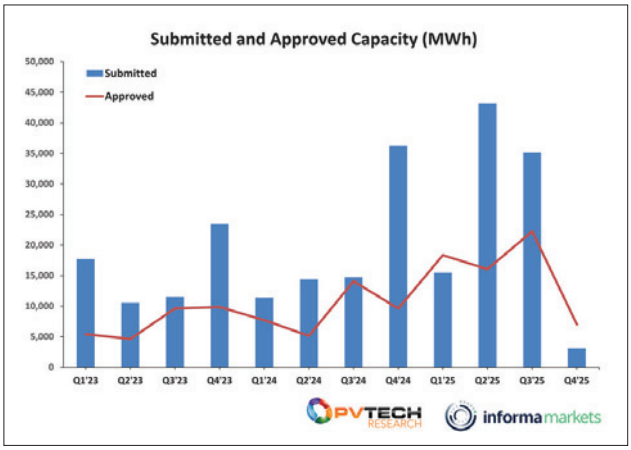


Fig 1: Grid reforms played a large part in the turbulent quarterly application pattern from Q4'24 onward.

Introducing the Megatrends report

The Solar Media Market Research and editorial teams join forces for the inaugural Megatrends Report, utilising our analysis and expertise to identify the trends that will define the energy transition up to the year 2030 and beyond.

From energy demand and data centres, to grid reforms and PV technology via AI and Cybersecurity, the team's deep understanding of the subject matter and access to proprietary research combine to offer unique and powerful insight into the energy transition.

The report covers:

- **Energy demand and data centres**
- **Diversification of manufacturing capacity**
- **AI and Cybersecurity**
- **Meeting growing energy demand while balancing the grid**
- **Grid reforms**
- **PV Technology**

Available as a downloadable resource and online across our editorial properties, the report will evolve over the next four years, with regular updates meaning it will remain the most vital piece of in-depth commentary across the renewable energy industry.

The full report will be available in March 2026, but to whet your appetite, we've released a teaser PV Technology article from the report for you to sample right now.

You can use the QR code below to read the first part of the Megatrends report and register for notifications around the launch and future updates.

Register for Megatrends report updates

IPP Zelestra discusses its 'industry-first' PPAs and tolls in Spain and Italy

Zelestra made headlines in 2025 with first-of-their-kind tolls and PPAs involving BESS in Italy and Spain respectively. Company executives talk Cameron Murray through what was novel about the deals and how the one in Italy relates to the country's MACSE auction.

The firm is headquartered in Bilbao, Spain, but is active globally and has a 25GWh BESS pipeline with major projects announced in Italy, Spain, Chile and India last year. Its overall portfolio is 32GW across carbon-free, renewables and storage.

"BESS technology is at the core of our strategy, as it enables us to help design complex solutions for customers to meet their needs," the company says.

Those complex solutions were applied in two notable deals involving long-term offtake for BESS announced in summer 2025.

In July, the company signed what it described as the first solar-plus-storage power purchase agreement (PPA) in Spain with utility EDP, for a 170MWp solar, 100MW/400MWh BESS project in Trujillo, which started construction in the second half of 2025.

Then in September, Zelestra announced a long-term toll with utility BKW for up to 2GWh of BESS in Northern Italy, with construction expected in 2027 for commercial operation in 2028.

In this Q&A, chief product officer Stefano Breda and Italy CEO Eliano Russo discuss the deals, how they were structured, why they are industry-firsts, and how they fit into the broader development of the industry. Russo also discusses at length the firm's approach to Italy's MACSE auction, in which Zelestra was ultimately not successful – though this was the result of a conscious strategic decision, he explains.

Stefano Breda on Spanish announcement: 'This is PPA 2.0'

You announced an industry-first solar-plus-BESS hybrid PPA in Spain with EDP in July. Can you unpack the PPA in a bit more detail to illustrate what was new about it?

It was the first time in Europe we have designed a structured solution with solar and BESS, and it was driven by the needs of our client and the discussions we were having with them. The PPA enables the construction of a large scale solar + BESS project with 170MWp of solar and 100MW, 4-hour BESS.

What were the key challenges in structuring the PPA and how did you come to solutions for them?

Structuring the PPA required a lot of in-depth discussion with our client to define an optimal tenor, profile and battery size for both parties. At the end of the process, we have a solution that perfectly meets the needs of both parties.

Our client achieves their objective to obtain guaranteed supply beyond solar generation hours with a competitive price, and Zelestra unlocked the construction of a large-scale 170 MWp solar plant with a 100MW, 4-hour BESS backed by a long-term contract with an attractive return and a Tier-1 customer.

What benefits does that bring versus a solar-only PPA?

The PPA mitigates price cannibalisation risk and generates a higher grid decarbonisation impact since the energy discharged by the battery will usually be displacing gas generating units.

Some characterised the Spain PPA as the first solar-plus-BESS PPA in all of Europe, do you have views on this?

As far as we know it was indeed the first in Europe. It is a 'PPA 2.0' – it moves the market forward and responds to the challenges of delivering guaranteed supplies for customers in specific blocks of the day in markets that already have a high penetration of wind and solar.

Solar and BESS have been deployed side-by-side for years in Europe, so why might this be the first such PPA?

Utility-scale batteries have historically relied heavily on revenues from ancillary services. With the recent fall in battery prices, the commercial model is now changing, and while ancillary services still constitute an important revenue stream, energy shifting revenues are increasing. This is particularly important for co-located assets that might have certain restrictions on charging that prevent them from offering ancillary services to the grid at all times.

On the other side co-located projects benefit from shared infra-

Credit: Zelestra

Zelestra's José Cabrera solar PV plant in Spain, inaugurated in November 2025.

structure and lower development costs compared to stand-alone projects. For all these reasons we think that co-located solar + BESS projects will grow rapidly in Europe and a PPA market for such projects will develop.

Eliano Russo on Italy: 'Decision not to proceed with MACSE was correct'

Can you give some more details on the toll with BKW and how it may have also been an industry-first deal in Italy?

The agreement with BKW marks one of the first true Virtual Tolling structures ever applied to utility-scale battery storage in Italy, and in many respects, it can be considered an industry-first. Until now, Italian BESS projects have been mainly fully merchant or supported only by the Capacity Market, which is not sufficient on its own to unlock long-term project finance.

By contrast, the Zelestra–BKW contract establishes a stable and predictable tolling fee over multiple years, creating the level of cash-flow visibility that lenders require. It essentially imports into the Italian storage market a contractual architecture used historically for gas-fired generation but never tested in this form for batteries. For the first time, a BESS in Italy receives a long-term fixed remuneration from an external counterparty without transferring ownership or operational control.

Zelestra continues to manage dispatch and optimisation, while BKW takes the variable revenues linked to the MGP and transforms them into a predictable fixed payment stream. This hybrid risk-allocation is still rare even in the more mature European markets and represents a step forward in establishing batteries as a bankable infrastructure asset class.

It is also one of the first transactions where a non-Italian utility enters the Italian BESS merchant market through a structured agreement, signalling a new level of confidence in the fundamentals of the Italian system and confirming Italy's rise as one of the most attractive storage markets in Europe after Great Britain and Spain.

What are your plans for the capacity of the projects which are not covered by the toll?

Zelestra will evaluate the most value-accretive allocation for the remaining portion of the project, which may include additional contractual arrangements or other optimisation strategies, depending on market conditions and counterparties' needs. This optionality ensures that we can tailor the remaining capacity in the way that best supports the project's long-term performance while keeping open all avenues for future commercial partnerships.

Did you take part in the MACSE auction?

Zelestra did take part in the first MACSE auction with a project in southern Italy as the auction deems. As you know, projects in northern Italy are eligible only for the Capacity Market.

Nevertheless, although the company presented a competitive and robust bid, the auction cleared at levels far below the expectations that had guided much of the industry's preparation. Several participants bid extremely aggressively, with projects in brownfields and with most certainly a technology advantage, which pushed clearing prices down significantly. In some zones, competition was intense and structurally oversubscribed.

Given the clearing levels, moving forward would have required accepting revenue conditions that were not aligned with Zelestra's financial discipline or with the quality and maturity of its projects. In this context, the decision not to over-discount was strategically correct, especially considering that tolling agreements can ultimately deliver a more favourable balance of predictability, risk allocation and economic return than many of the awarded MACSE contracts.

How does the existence of MACSE's long-term contracts affect the market for PPAs and tolls for BESS in Italy?

MACSE has introduced an important reference point into the market, but its impact on private contracts such as tolls and PPAs is nuanced.

On one hand, the existence of a long-term state-backed remuneration framework provides a floor for market expectations and reinforces the legitimacy of storage as a bankable asset class.

On the other hand, because MACSE cleared at relatively modest remuneration levels, it has increased interest in bilateral solutions that can offer higher value and more tailored risk-sharing.

Corporates, utilities and traders now understand that if they want access to flexible capacity over the next decade, they cannot rely solely on MACSE; they must seek private agreements that secure dispatchable resources ahead of their competitors.

This dynamic enhances the attractiveness of tolling agreements, which combine long-term visibility for developers with market exposure for offtakers, and it accelerates the emergence of an Italian storage market where merchant optimisation, bilateral contracting and flexibility services coexist.

The Zelestra–BKW structure is therefore not only innovative in itself; it anticipates the direction the Italian BESS market is moving following MACSE and positions Zelestra advantageously within this evolving landscape. ■

Year in Review 2025: perspectives on energy storage software

Andy Colthorpe hears from software specialists discussing key points to consider when leveraging smart technologies, in edited excerpts from the annual *Energy-Storage.news* Year in Review series, 2025-2026 edition.

BESS industry maturing through 'growing pains' says Wärtsilä software VP

Luke Witmer, VP of software engineering at Wärtsilä Energy Storage, explains that the biggest steps forward in software development and adoption are taken in the field.

One of the big players in global battery energy storage system (BESS) integration with over 18GWh of projects deployed or contracted for customers at more than 130 sites worldwide, Wärtsilä has always emphasised its track record in software as core to the company's offerings.

Luke Witmer, who has held various software-focused roles since before Wärtsilä's 2017 acquisition of Silicon Valley energy storage pioneer Greensmith Energy brought the GEMS digital energy management and bid optimisation platform into the portfolio and marked Wärtsilä's entrance into the energy storage space, discusses some of the industry's big-picture topics from a digital technology perspective.

We have seen software move progressively into the mainstream. Of course, it has always been crucial, but there's more emphasis on software in recent industry conversations. What have been the most significant steps forward in the adoption of software solutions to address energy storage industry challenges?

The most significant steps forward in adoption have resulted from real operational challenges and lessons learned in the field. Early deployments revealed critical gaps: some battery power plant controllers (PPCs) focused solely on control without appropriate operator interfaces or integrated data collection capabilities. Many off-the-shelf solutions struggled with the scale of today's gigawatt-hours-sized plants and also couldn't meet stringent response time requirements—particularly when handling the data throughput demands of large installations.

Wärtsilä's GEMS Rack. Luke Witmer has been instrumental in the platform's development and evolution.

Credit: Wärtsilä

Forward-thinking providers recognised these challenges early and developed solutions capable of handling multi-gigawatt-hours-scale operations while maintaining high-resolution cell-level data collection necessary for performance analytics, anomaly detection, and remote operations and maintenance. The industry is now recognising that software quality directly correlates with operational reliability and long-term value.

Having watched systems like GEMS evolve from 1MWh pilots to controlling 1GWh+ sites globally, I've observed three fundamental shifts over the last few years.

First, we've moved from basic control to predictive intelligence. Software is no longer just a dashboard—it's an optimisation engine. Many operators today leave up to 20% of their battery capacity unused as a 'safety buffer' due to a lack of data confidence. With machine learning tools that identify anomalies at the cell level, operators can reclaim that capacity. On a 100MW system, that represents approximately US$20 million in recovered value through better analytics.

As large lithium iron phosphate (LFP) battery assets enter their second and third years of operation, we're seeing challenges that are effectively mitigated by advanced software. Features like sophisticated cell balancing, real-time anomaly detection, and energy capacity estimation provide significant operational value. Additionally, ultra-fast controls now enable battery systems to absorb rapid load fluctuations—such as the synchronised GPU cluster ramps in AI data centres—before they impact grid equipment, leveraging batteries as stabilising grid assets.

Perhaps most significantly, we've reached the frontier of grid-forming software. For a century, grid stability relied on the physical inertia of spinning turbines in fossil plants. We've now proven we can replicate that inertia digitally, allowing batteries to form the grid voltage rather than simply following it. This capability is essential as traditional power plants retire. We just completed the delivery of our second massive grid-forming battery in the UK, at 600MWh, which I think is the world's largest grid-forming battery. This technology is mature and ready, but you need the right partners to ensure your success.

Finally, as energy and ancillary service markets fluctuate between scarcity and saturation, automated bidding solutions leveraging probabilistic electricity price forecasts—informed by live grid situational awareness, including local congestion data—

enable optimised battery plant operations across varying market and renewable energy conditions. Customers are adopting these solutions because they address expensive operational problems at a fraction of the cost.

More mature markets such as ERCOT, CAISO and the UK have seen some intense competition. What are the optimisation strategies or technologies that are needed to ensure success in mature markets?

In markets like ERCOT, CAISO, and the UK, the easy money is gone. Success in 2026 isn't about how many megawatts you deploy—it's about algorithmic agility and cost-effectiveness across capex, opex, and revenue capture. Many developers have historically focused too heavily on upfront capital costs. However, selecting the right software—while potentially appearing expensive initially—pays off quickly when the alternative means an asset that can't qualify for new markets, consistently misses high-price events, or achieves only 90% availability compared to the 98% possible with appropriate software and lifecycle agreements.

Market dynamics have fundamentally changed. In ERCOT, the new RTC+B rules (effective December 2025) mean optimal battery decisions now change every five minutes. Operators still relying on manual bidding or static day-ahead strategies are leaving 20-30% of revenue unrealised. Competition has compressed profit margins significantly—operators can no longer afford to hold back 20% of energy capacity as a "safety buffer" due to SoC uncertainty. In many cases, that 20% represents the entire profit margin for smaller utilities.

From project conception through delivery and into commercial operation, many elements require optimisation to compete successfully. Critical areas we focus on include sizing methodologies during the proposal stage, financial modelling informed by real-world lifecycle scenarios, delivery optimisation spanning shipping logistics through rapid market qualification, and operational intelligence through our GEMS IntelliBidder and Dispatcher products.

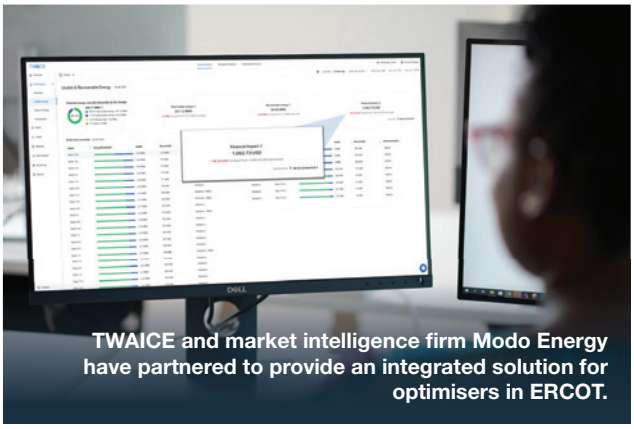
These increasingly leverage probabilistic optimisation techniques with forecast error awareness. The right approach combines all these elements with experienced partners who understand each domain.

Analytics provider TWAICE on operationalising data in 2026

Lennart Hinrichs, executive VP and general manager Americas at TWAICE, discusses how the industry's approach to battery analytics is changing.

The past three or four years have seen battery data analytics come into the spotlight across the energy storage industry, giving battery energy storage system (BESS) operators more visibility and therefore more decision-making power on the necessary trade-offs between protecting asset health and earning revenues.

Cloud-based analytics software solutions, whether from third-party providers like TWAICE or created in-house, are helping



TWAICE and market intelligence firm Modo Energy have partnered to provide an integrated solution for optimisers in ERCOT.

Image: TWAICE

BESS projects and portfolios enhance safety, get improved terms on insurance and financing, match cycle life to the business case and ultimately optimise performance.

Is there a growing awareness of the role of data analytics, and what do you think are the next steps for analytics providers?

Absolutely. With tougher operating economics and growing portfolios, operators are paying more attention to data and analytics.

As providers, we must focus on system-level analytics. While cell-level data is important, the most relevant metric for owners is what occurs at the point of interconnection (POI); analytics should therefore monitor the entire chain, including modules, racks, power conversion system (PCS), and transformers, to account for round-trip efficiency (RTE) and grid delivery requirements.

We also need to provide a 'single pane of glass' at fleet scale. As asset owners scale from pilot projects to gigawatt-hour portfolios, analytics tools must be able to handle billions of data points daily across diverse technologies and multiple integrators and present workflows, for both engineers and financial asset managers.

Analytics providers must move from reactive to proactive operations. Analytics should move away from merely alerting to automated, prescriptive actions that prevent downtime and penalties, translate failure modes into dollar impact (e.g., US$/MWh, avoided fines), and provide audit-ready evidence for lenders, insurers, and warranty claims.

We heard in the 2025 BESS Pros Survey from TWAICE that the role of analytics is shifting from a primary one of delivering safe operations to actively monetising storage assets. What does that really mean, and how can the industry best support this shift?

It means operators want assets that consistently earn revenue, not just assets that avoid incidents. To support that shift, you need: reliable, enriched telemetry; analytics that convert health and availability into dollars (expected revenue, avoided penalties); data ownership and a clean database to prove underperformance or support warranty claims; and cross-functional teams (ops, trading, finance) who share one source of truth. ■

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‘NEM-specific battery optimisers’ capture more revenue during market volatility around AU$20,300/MWh NSW price spike

BESS equipped with optimisation platforms not specifically designed for Australia’s National Electricity Market (NEM) missed revenue opportunities during the 10 October 2025 price spike, Sahand Karimi, co-founder and CEO of OptiGrid tells George Heynes.

When optimisers aren’t designed for the NEM’s unique volatility and constraint patterns, their decisions will not be optimal, especially in volatile events,” explains Karimi of BESS optimisation specialist OptiGrid.

As reported by *Energy-Storage.news*, the price cap event on 10 October marked the first instance in which electricity prices in New South Wales (NSW) reached the new Market Price Cap of AU$20,300/MWh (US$13,307/MWh).

This event revealed flaws in optimisation systems that use generic trading strategies across different electricity markets. These systems often fail to account for the unique 5-minute settlement (5MS) structure and complex constraint patterns present in the NEM.

While some battery storage systems successfully captured revenue from the extreme pricing, others failed to maximise their potential due to algorithmic limitations that prevented optimal bidding strategies during rapid market movements.

The technical challenges became apparent as prices spiked to the updated Market Price Cap within single trading intervals, leaving little time for manual intervention.

“Given the 5-minute market granularity, some volatility events in the NEM happen very quickly, leaving little time for human traders to respond,” Karimi says.

Generic optimisation platforms typically struggle with the NEM’s rapid price movements because they lack the sophisticated scenario modelling required for effective bidding in volatile conditions.

The Australian market’s unique combination of renewable energy variability, thermal generation constraints, and network limitations creates volatility patterns that differ significantly from other global electricity markets.

“Fundamentally, intelligent bidding means considering a range of scenarios that might unfold in upcoming intervals and placing volume bids across different markets to achieve the optimal outcomes while minimising the risk of dispatch under less-ideal scenarios,” Karimi explains.

This approach requires a deep understanding of how constraint patterns interact with pricing dynamics in the NEM.

Network constraints compound optimisation challenges

Network constraints compounded the optimisation challenges, simultaneously driving the price spike and limiting some battery storage outputs.

Two outage-based constraints restricted supply from NSW generators and interstate imports while also creating binding limitations on battery dispatch through the NEM Dispatch Engine.

“Even where batteries were intended to dispatch, some couldn’t run at full capacity,” Karimi notes.

These constraint-related limitations revealed another weakness in generic optimisation systems: their inability to anticipate and respond to the interconnected nature of supply constraints and pricing volatility in the NEM.

Instead, battery storage systems using NEM-specific algorithms were better positioned to navigate these complex interactions.

The performance gap between different optimisation approaches became more pronounced as prices collapsed below -AU$600/MWh later that evening.

Battery storage systems with generic trading algorithms faced the risk of discharging at highly negative prices, potentially erasing gains from the earlier price spike. This volatility pattern is characteristic of the NEM but may not be adequately modelled in optimisation systems designed for other markets.

The algorithmic limitations exposed during the 10 October event extend beyond individual trading decisions to broader strategic positioning. Generic optimisers may not adequately account for the importance of grid connection location and quality, which proved critical when network constraints limited battery output during the price spike.

“This underlines the importance of location and grid connection in capturing rare high-price events,” Karimi concludes.

The performance disparities observed during the price cap event highlight a growing challenge for battery storage operators in the NEM: the need for optimisation systems that understand the market’s unique operational characteristics.

As Australia’s energy transition accelerates and extreme pricing events become more frequent, the limitations of generic trading algorithms will likely become more pronounced.

OptiGrid’s Karimi explored optimisation strategies for battery storage systems in Australia’s NEM in an interview with *ESN Premium* earlier this year. ■

Standardisation is making US BESS an easy target for cyberattacks

April Bonner speaks with Phil Tonkin, field chief technology officer at Dragos, and Dr. Peter Fox-Penner, a Brattle principal, on BESS cybersecurity.

In December 2025, consultancy firm The Brattle Group and cybersecurity solutions provider Dragos released the whitepaper 'Securing Battery Energy Storage Systems from Cyberthreats: Best Practices and Trends'.

The whitepaper recommends strategies for creating secure systems, verifying supply chains, organising network architecture, and strengthening operational resilience to improve cybersecurity for battery energy storage systems (BESS).

BESS installations have become more standardised to reduce costs and simplify the system. Consequently, organising cyberattacks has become easier because less sophistication is required to be successful.

This has been an ongoing concern in the industry, but Brattle and Dragos claim that the issue will continue to grow if it is not properly addressed.

Dragos is a cybersecurity firm specialising in cybersecurity software designed for industrial settings, such as industrial control systems (ICS), supervisory control and data acquisition (SCADA), distributed control systems (DCS), and operational technology (OT).

The Brattle Group meanwhile provides consulting and expert testimony in economics, finance, and regulation for corporations, law firms, and public agencies.

BESS firms see cybersecurity as a critical topic

In March of last year, Adile Ajaja, director of operations, IT and cybersecurity at provider of fully integrated BESS and a utility subsidiary, EVLO, wrote in a guest blog for ESN, that "No utility is safe from hackers, often backed by nation-states or organised groups. It only takes one breach to unleash widespread disruption, making utilities a prime target for those looking to exploit critical infrastructure or geopolitical gains."

Ajaja continued, "Now, more than ever, it's crucial for utilities and their energy storage providers to actively prevent and plan against cybersecurity threats. Fortunately, there are a growing number of security options to deploy and best practices to offer guidance."

Because BESS contain various technologies, often from different countries, implementing cybersecurity best practices is a global concern for the BESS industry.

Katherine Hutton, product manager of cybersecurity at energy storage technology and energy software services provider Fluence, wrote:

"The operational role and architecture of BESS determine how security must be managed. Cyber-capable components such as battery management systems (BMS), power conversion systems (PCS), and energy management systems (EMS) each contain software and communications pathways that require secure maintenance throughout the system's life."

Hutton added that remote access of these units was essential but needed strict protocols to prevent misuse.

BESS vulnerabilities

Tonkin states that the main vulnerability of BESS is their direct connectivity to the internet.

He explains that the distributed nature of these sites means they often rely on commodity communication services, such as cellular or satellite, to connect, especially given their remote locations and high volume.

This approach expands the attack surface because it uses uniform technology and layered networking from IT, which increases vulnerability. Managing these systems requires ongoing operational instructions and involves multiple parties, further increasing exposure.

Tonkin further explains that BESS have not been specifically targeted in coordinated cyberattacks; instead, their vulnerabilities make them easier targets.

He explains, "There have been a number of cases where people who operate (BESS) have been hit by commodity malware, not necessarily a targeted adversary that's gone after those assets, but somebody who's just found them to be exposed when scanning generally for vulnerabilities. So, criminal groups are getting into them, but not necessarily through a deliberate targeted attack."

Tonkin says, "We identify two main types of ransomware groups. The first is organised teams that target specific victims, purchasing access and maintaining persistence to maximise their impact. These teams usually work collaboratively. The second type consists of opportunists who use scripts they've bought or created to scan for vulnerabilities, quickly exploiting them to encrypt files and demand ransom. Generally, the latter group is more active in this space, rather than targeted attacks aimed at particular organisations."

Tonkin and Fox-Brenner assert that electric grids are vulnerable to attacks from state adversaries, activist groups, and ransomware groups. They warn that as the importance of

these grids for stability grows, the chances of deliberate targeting will also rise.

Under the foreign entity of concern (FEOC) rules, US downstream project suppliers and upstream manufacturing facilities are ineligible for significant aid from prohibited foreign entities (PFEs) if they hope to qualify for tax credits.

China is classified alongside countries such as Russia, Iran, and North Korea, which face substantial US market restrictions. Notably, China's extensive involvement across almost the entire supply chain — apart from software, which is already limited — keeps the primary concerns centered on China.

The industry continues to debate whether Chinese suppliers can stay competitive, considering the higher costs for buyers and the tariffs on Chinese BESS, which hit about 55% starting January 1, 2026.

When considering the vulnerability of BESS and BESS equipment based on its country of origin, Fox-Brenner says:

"There have been documented cases of Chinese equipment used in BESS systems, like specifically inverters, where we have found so-called backdoors to them, or hidden communication equipment."

"I'm not aware of similar findings for equipment originating from other countries. Now, there aren't nearly as many manufacturers and volumes coming out of other countries, because China dominates the inverter market. But China is unique in that we have found instances of communications equipment in Chinese inverters and some other solar equipment that is unique," he continues.

Tonkin adds, "Adding to this, the specific security and geopolitical issues involving the Chinese government raise concerns about how remote connectivity and undocumented components might lead to actions by China or hinder security efforts due to strained relations. For instance, Chinese-made components were hard to maintain during COVID because Chinese engineers couldn't access other countries to perform upkeep"

Further stating, "In cybersecurity, it's crucial to keep devices patched and maintained as vulnerabilities are identified. These flaws aren't usually intentional but result from code defects or new functionalities. Fixing these issues requires a continuous relationship between the asset owner and the original developer, so that when new vulnerabilities emerge, the owner can request updated firmware or software to address the problems."

Implementing cybersecurity best practices

The whitepaper emphasises that a proactive cybersecurity approach helps asset owners and operators reduce risks and save resources. Addressing common threats during design and construction enables companies to deploy controls more efficiently and economically.

Although new threats will continue to emerge, requiring ongoing adaptation, many effective solutions are already available and can be implemented early to avoid costly retrofits later. As BESS capacity approaches levels similar to large baseload power plants, the companies assert that protecting these assets is vital not only for operators but also for national energy security.

Tonkin says that Dragos often works with major utilities implementing BESS, gaining insight into their cybersecurity practices driven by regulations. Traditional investor-owned utilities prioritise control centre security, but grid-scale implementations raise concerns about layered controls.

EPC contractors, often new entrants, trust suppliers and focus on low costs, risking gaps. Larger utilities tend to follow best practices, but industry-wide awareness is limited. Collaborations with OEMs like Fluence and vendors such as Tesla reveal that security design depends on trusted partners who embed controls from the start. Many smaller projects rely on system integrators to layer controls, often resulting in vulnerabilities due to lack of partnership and oversight.

Dragos's field chief technology officer further states that lack of education on cybersecurity best practices is a significant barrier to implementation.

"I used to work for National Grid, a utility in the Northeast, and we had 600 people in our security team. That's a bigger capability than the size of some of these utilities as a whole. So if you're dealing with a local cooperative, we tend to find that the local energy co-ops might have one person that does the IT and security and the operational technology they're delivering, having to deliver a lot more broad capabilities with reduced access to specific skills," Tonkin says.

He explains, "As an industry, cybersecurity must support smaller entities by providing secure products and accessible training programs. Initiatives like Dragos's Community Defence Programme, which provides software at no cost, and the OT-CERT programme, offering plans and best practices, help peers collaborate and address security challenges. This report, developed with Brattle, aims to inform and motivate action based on solid technical rationale."

Bill of Materials (BOM)

Another recommendation from the whitepaper to reduce cyberattacks is to mandate verified Hardware and Software Bill of Materials (HBOMs and SBOMs) for OEMs and vendors. This helps identify and evaluate whether software components originate from trustworthy sources and allows analysis of geographic, corporate source components, and related vendors.

In the event that an HBOM and SBOM cannot be acquired, Tonkin says, "If you can't get it, and therefore you can't fully understand where the risks might be or what might manifest because of that—it could be unknown vulnerabilities, or it could be that there's something hidden in it, or it doesn't behave the way it's supposed to—you can mitigate a lot of those things through good defense in depth and controls. So, if there's a hidden back door into a device, it can't be exploited if it can't communicate out to its command and control server, or if someone can't gain access to exploit it." ■

The challenges of building out a flexibility-as-a-service platform in Germany Terralayr

Cameron Murray hears from Philipp Mann, CEO of German flexibility-as-a-service platform Terralayr, about the challenges and progress in disrupting the conventional model of BESS offtake.

The firm deploys build-own-operate grid-scale BESS projects but its main differentiator is its flexibility-as-a-service platform LAYR, which allows BESS owners and optimisers to rent out or procure BESS flexibility under tolling agreements at different durations and sizes by virtualising projects' capacity.

CEO Mann recently discussed the challenges and progress in growing third-party usage of LAYR (full version of this Q&A on Energy-Storage.news).

Energy-Storage.news: Does the LAYR platform still need time to be proven out, and how long for, before it is mainly third-party assets?

Philipp Mann: LAYR has already been proven in live operations on Terralayr's own assets and third-party assets. Established players such as Vattenfall, Stadtwerke Duisburg Energy Trading and our Designated Optimisers are dispatching via LAYR already.

The core infrastructure of LAYR is in place for scaling third-party usage. We are, of course, continuously adding more features and use cases to equip our customers and partners with the tools that make operating and trading flexibility more comfortable and profitable.

As trust, track record and integrations deepen, we expect third-party assets to become an increasingly important share of the platform. Further established players will go live throughout this year.

Is LAYR the only way you are commercialising/ optimising your projects, or are some via conventional, direct deals?

Yes, all assets are run via LAYR, as it is uniquely positioned as a BESS commercialisation platform, enabling multiple revenue streams for us:

- Merchant Optimisation via our ETF-Model
- Tolling (contracted revenues) with our partners Vattenfall/RWE dispatching via LAYR and
- Virtual Battery Auctions as a proprietary channel enabling additional levers of portfolio management.

Additionally, the capacity allocation can be changed throughout an asset's lifetime without being limited by the physical setup of the assets.

What are the key software and integration challenges you've had to overcome when building LAYR?

Moving away from the model of "one battery, one optimiser" to allow capacity abstraction with virtual batteries, which is a foundational capability of our platform. This allowed capacity to be dynamically reallocated without physical hardware changes.

Among other benefits, this allows for netting-off effects, where optimisers' dispatch schedules offset each other, thus saving physical cycles and hence costs for asset owners.

The telemetry scalability challenges of a rapidly growing fleet: BESS sites generate enormous amounts of data – building an infrastructure that remains responsive under this pileup without dashboards freezing and metrics lagging was an engineering challenge. Ensuring that this system operates at the highest levels of resiliency, security, and uptime is a key priority for us.

Market and regulatory integrations: we're building turnkey systems and automated workflows that consider different battery manufacturers, sometimes with incompatible communication protocols. We established a tech-agnostic middleware layer, allowing users to interact with a standard API regardless of the underlying hardware.

What is the next frontier of LAYR in terms of its capabilities?

BESS asset owners need professional risk and performance management tools. We enable them already to manage their commercialisation like a portfolio manager in the financial market via our multi-optimiser model, but will expand these capabilities further. That, for example, includes flexible allocation to short-, mid- and long-term de-risking options at the click of a button instead of months-long and costly analogue transactions.

LAYR continues to scale in its capabilities to handle different asset technologies, onboarding wider ranges of dispatch technologies, maintaining strict compliance in an evolving security landscape.

Additionally, we are further strengthening the handling of flexible connection agreements (FCAs), including ramp rates, and seeing large potential in smart load distribution across an entire portfolio of assets to reduce degradation and maximise profitable utilisation. ■

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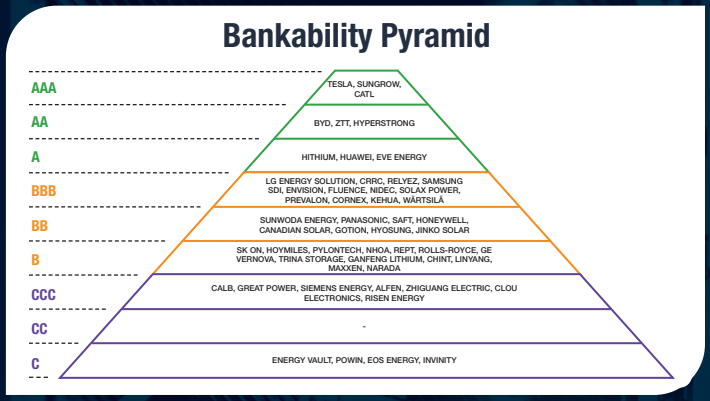

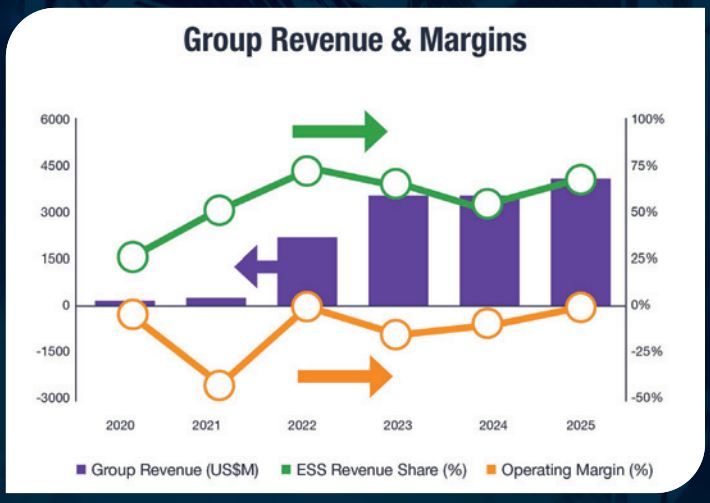

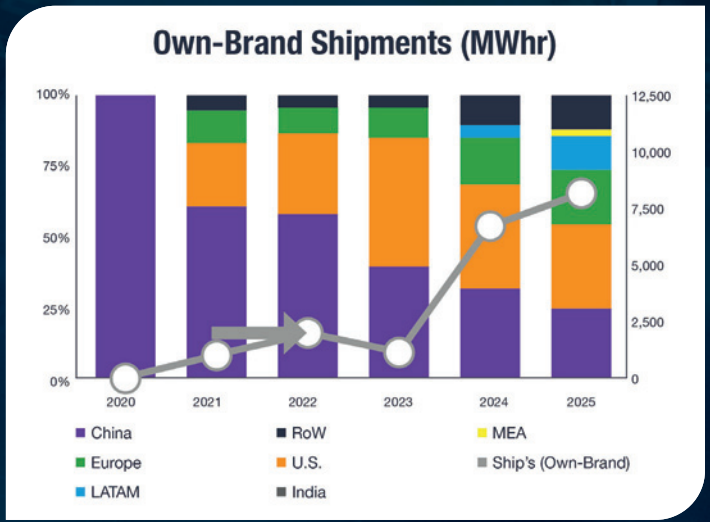

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