Battery energy storage

Key role in ensuring electricity system flexibility

Edison themes

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Battery energy storage provides flexibility and stability to electricity grids. An increase in electricity grid system volatility is expected as markets shift from fossil fuels to intermittent renewables to meet net zero targets and battery storage will be essential in complementing this implementation of renewables. The battery storage sector benefits from rising volatility in the electricity market by charging batteries when electricity prices are low and releasing to the grid when prices are high. The current energy crisis has brought volatility together with higher prices to the system earlier than expected. Battery energy storage will play a role in two of our global themes: decarbonisation and energy transition.

Capacity needs to grow significantly

National Grid estimates that current battery storage capacity of 1.6GW in the UK will rise to 16GW by 2030, while global installed capacity needs to grow from 16GW at the end of 2021 to 680GW by 2030 to meet the International Energy Agency's (IEA) global energy roadmap, *Net Zero by 2050*. 6GW were added globally in 2021, up by 60% from 2020, and this was led by the United States with 2.9GW, followed by China with 1.9GW and Europe with 1GW. This growth will need to increase significantly to meet the 2030 capacity target, with the IEA estimating that an average of 80GW will need to be added per year to 2030.

Favourable investment and regulatory environment

Battery storage developers should benefit from an increasingly favourable investment and regulatory environment, supporting targeted renewables penetration over this decade. For example, under the US Inflation Reduction Act, standalone battery energy storage projects became eligible for investment tax credit subsidy from January 2023, which is expected to reduce capital costs by c 30% and will be in place for 10 years. For Europe, Deloitte estimated in January 2021 that distribution grids will need investment of €375–425bn out to 2030, while UK regulator Ofgem has already approved £40bn in grid investment for 2021–26. We expect these estimates to be revised upwards to take into account the most recent energy security packages in the EU, such as the REPowerEU plan that was announced in response to the Russian invasion of Ukraine and the more recent Green Deal Industrial Plan, and the UK. Recent projects in the UK include Fotowatio Renewable Ventures' £1bn partnership with Tyler Hill Renewables to develop, build and operate up to 1GW in battery energy storage systems (BESS) projects in the UK over the next five years.

'There's a huge advantage in being active now. As a result of the energy crisis, we've had volatility reach record levels, and batteries make money off the highs and lows.' James Bustin, investment manager, Gresham House

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Companies mentioned in this report

ABB
ADS-TEC Energy
Aggreko
Atlantica Sustainable Infrastructure
Azelio
Brenmiller Energy
CATL
Dominion Energy
Duke Energy
EDF Renewables
Eguana Technologies
Enel
Energy Vault
Entech
Exide Industries
Fluence
Foresight Solar Fund*
Fotowatio Renewable Ventures
Gore Street Energy Storage Fund
Gresham House Energy Storage Fund*
Iberdrola
Invinity Energy Systems
Largo Clean Energy
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NHOA
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SaltX Technology
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Critical in supporting renewables growth

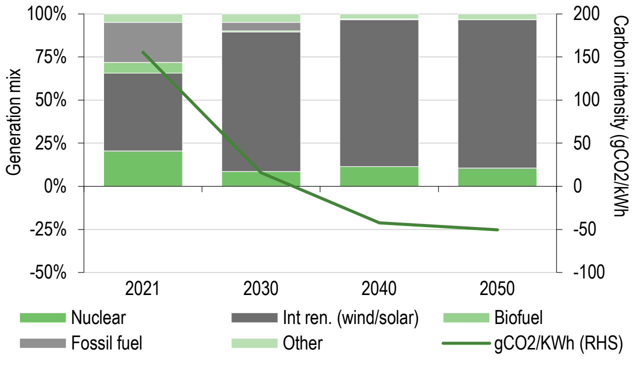
Battery Energy Storage Systems (BESS) are utility-scale energy storage units based on batteries that import and store electricity, increasingly generated by wind and solar power, and release it to the national grid and microgrids when demand, and prices, are higher. BESS also play a crucial role in micro-grids, self-sufficient energy systems that serve a discrete geographic footprint, such as a hospital, university or neighbourhood. They are essential to the realisation of governments' commitments to net zero by 2050, as countries transition from emission-intensive coal- and gas-fired power generation to mainly zero carbon energy generated from renewable sources. For example, the UK, National Grid expects gas usage in the power sector to be no more than 2% by 2035, while wind and solar will provide 78% of electricity output (Exhibit 2)

Exhibit 1: Video showing AES Alamitos' battery energy storage system

Source: Fluence

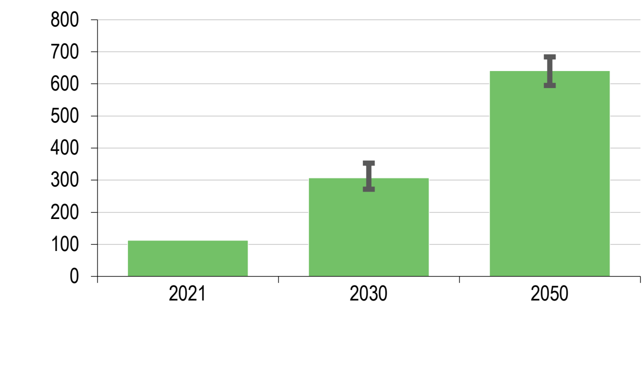
This increasing dependence on intermittent wind and solar generation requires more flexibility to meet electricity demand. Current system flexibility is mainly provided by the gas system, which can respond to changes in the supply-demand balance at short notice and the wide spread between peak and trough net demand in a way that intermittent renewables cannot. Both solar and wind have low load factors (electricity generated as a proportion of the maximum potential generation over the available period), with the load factor, or capacity factor averaging 11% for solar photovoltaics, 27% for onshore wind and 40% for offshore wind in the UK over the last five years. In 2021 in the United States, the capacity factor was 24.4% for photovoltaic solar and 34.4% for wind. To manage this shift to intermittent renewables, electricity storage will become increasingly important in the future to allow the system to operate without interruption.

Exhibit 2: UK generation mix (LHS) and carbon intensity (gCO₂/kWh)



Source: National Grid, Future Energy Scenarios 2022. Note: Based on an average of Consumer Transformation, System Transformation and Leading the Way scenarios, which are all consistent with 1.5˚C.

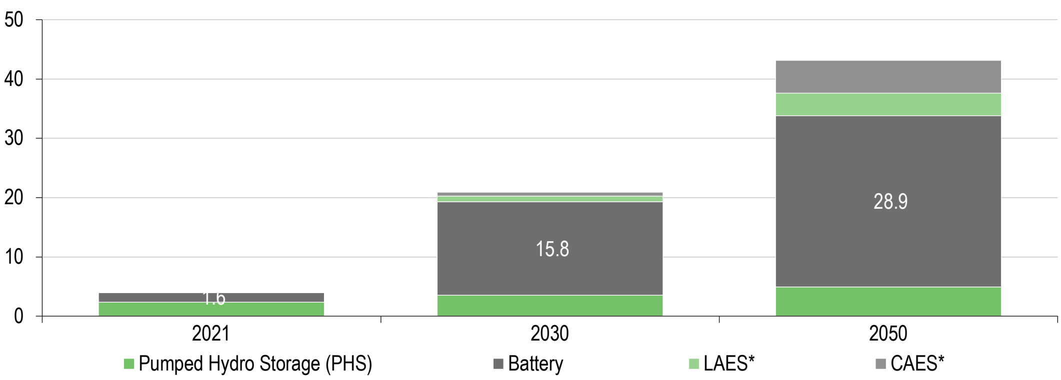
Exhibit 3: Power generation from wind and solar (TWh)



Source: National Grid, Future Energy Scenarios 2022. Note: Based on an average of Consumer Transformation, System Transformation and Leading the Way scenarios, which are all consistent with 1.5˚C.

In 2021, pumped storage hydropower (PSH) was the main technology deployed for energy storage in the UK, but the growth in BESS is expected to increase its market share and to overtake PHS to become the dominant technology in National Grid's 2030 and 2050 scenarios, growing from 40% of storage capacity in 2021 to 67% by 2050. This will be supplemented by a combination of PHS, compressed air energy storage (CAES) and liquid air energy storage (LAES). Hydrogen storage will also become increasingly important for longer-term storage and National Grid estimates that up to 56TWh of hydrogen storage will be required by 2050.

Exhibit 4: Storage capacity (GW) by type (excludes hydrogen storage)



Source: National Grid, Future Energy Scenarios. Note: Batteries are expected to be lithium based. *Compressed storage (CAES/LAES) expected to play a role beyond 2030.

BESS good for short-duration storage: Highly efficient and affordable

The type of services that each of these systems can provide is related to the amount of time storage can discharge at its rated power capacity before depleting its energy capacity, ie the storage duration of the system. For example, a BESS with 1MW power capacity and 4MWh of energy capacity has a storage duration of four hours. Lithium batteries are suitable for short-term storage, typically of up to two hours duration, so they are used to manage short intraday variations in demand and supply.

Lithium-ion-based batteries with low round-trip losses and fast response times are increasingly affordable for short-duration applications, with prices for stationary applications (ie grid management) having declined by two-thirds over the last decade. However, other battery chemistries can provide longer-duration storage than currently associated with lithium batteries.

Exhibit 5: 1.8MWh flow battery system from Invinity Energy at the European Marine Energy Centre (EMEC) hydrogen R&D facility on the island of Eday in the Orkney Islands. EMEC's Neil Kermode with Michael Matheson MSP and Graeme Harrison of Highlands and Islands Enterprise (HIE).

Source: Invinity Energy Systems, Colin Keldie EMEC

Alternative battery technologies to conventional lithium-ion are being commercialised. For example, Invinity Energy System's vanadium flow technology has several key characteristics that provide an advantage over lithium-ion for storage durations of over two hours. The batteries are non-flammable, as their electrolyte is around 70% water, and do not require integrated fire suppression systems to be installed, unlike lithium-ion batteries. They exhibit fast response times comparable to lithium-ion and do not suffer from capacity degradation over time. The longer lifetime of the technology (at least 25 years compared with up to 10) means that the total cost of energy stored over the lifetime of a project is substantially less. Invinity is already shipping BESS based on vanadium flow technology and completed deliveries of products totalling over 4.3MWh to customers in North America, Europe and Asia during FY22. During Q422 the company signed new deals totalling over 30 MWh. EnerVenue's metal-hydrogen batteries are offered with a warranty extension of no less than 88% capacity over 20 years. Urban Electric Power has adapted the alkaline battery technology used in conventional non-rechargeable double AA batteries (for example) for deployment in large-format rechargeable batteries for energy storage applications. In April 2022, Canadian zinc-air battery maker e-Zinc raised $25m in a Series A financing to support the production of its first commercial long-duration energy storage system, which it claims can discharge energy over a period of several days. Form Energy is developing an iron-air battery capable of storing electricity for 100 hours. Pacific Northwest National Laboratory in the United States is working on a battery with a molten salt electrolyte, which remains solid at room temperatures and thaws out when heated, and could potentially store energy for several months. In November 2022, the US Department of Energy announced that it was making nearly $350m available for emerging long-duration energy storage demonstration projects capable of delivering electricity for 10–24 hours or longer.

Alternative technologies offer longer-duration storage

PHS, CAES and LAES can charge and discharge over a longer period of time – up to 14 hours – but PHS and CAES require high capital expenditure, take time to construct and are location specific, while LAES has the lowest round-trip efficiency of c 60%. In contrast, BESS based on lithium-ion chemistry have energy efficiencies of 80–90% when new, although this degrades over time. (As noted above, vanadium flow chemistry does not degrade.) Emerging technologies such as gravitational storage are not yet modelled by National Grid, but these can be used for durations of up to several days. Swiss company Energy Vault is developing gravity batteries. Azelio and Brenmiller Energy are both developing thermal energy storage technologies. Azelio claims that its technology, which is based on recycled aluminium, provides electricity for 13 hours at continuous operating power and has a 30-year lifetime. SaltX Technology has developed a patented nanocoated salt suitable for high temperature thermochemical energy storage.

For long-term or seasonal storage, hydrogen is considered to be most suitable as it can be stored indefinitely, although the round-trip losses are greater than for BESS and, so far, the electrolyser and fuel cell technology required have not benefited from economies of scale. Energy Vault has been selected to deploy and operate a proposed green hydrogen energy storage system in California, capable of powering about 2,000 customers for up to 48 hours during planned outages and periods when the powerlines serving the surrounding area must be turned off for safety because of the high risk of wildfires. National Grid estimates that hydrogen storage in the UK will need to reach up to 56TWh under its most optimistic scenario. This is slightly higher than the 51TWh gas storage capability available at the newly reopened Rough gas storage facility and dwarfs the total estimated electricity storage capacity of 170GWh required by 2050 to meet the National Grid's net zero scenarios.

Favourable investment and regulatory backdrop to growth

National Grid estimates that current battery storage capacity of 1.6GW in the UK will rise to 16GW by 2030 and 30GW by 2050. Beyond 2030, vehicle to grid and green hydrogen are likely to absorb some of the growth in low-carbon flexibility, and other storage technologies (such as CAES) may begin to play a role. Nevertheless, battery storage is still expected to grow steadily.

Total global installed battery capacity was 16GW by the end of 2021 and this will need to expand significantly to 680GW by 2030 according to the IEA. 6GW were added globally in 2021, up by 60% from 2020, and this was led by the United States with 2.9GW, followed by China with 1.9GW and Europe with 1GW. This growth will need to increase significantly to meet the 2030 capacity target, with the IEA estimating that an average of 80GW will need to be added per year to 2030.

In Europe, hundreds of billions of euros of investment are required to support the targeted renewables penetration over this decade. A study by Deloitte for two European electricity industry associations, published in January 2021, estimated that distribution grids will need investments of €375–425bn to 2030. In May 2022, the EU launched REPowerEU, which set out pathways to reduce dependance on Russian gas. While the report acknowledged that BESS will be required, it did not provide details of how this would be achieved and policy has yet to translate into tangible actions. UK regulator Ofgem has already approved £40bn in grid investment for 2021–26. Deloitte's estimate and the UK's approved investment predate the most recent energy security packages in the EU and UK, so will likely need to be revised upwards. Under the US Inflation Reduction Act, standalone BESS projects become eligible for investment tax credit, which is expected to reduce capital costs by c 30% and will be in place for 10 years. Battery storage developers will be among the beneficiaries of this massive investment and increasingly favourable regulatory environment.

In October 2022, President Biden announced that the Department of Energy was awarding $2.8bn in grants from the Bipartisan Infrastructure Law to 21 projects, boosting the domestic supply chain for battery materials. This is the first set of projects funded by the President's Bipartisan Infrastructure Law, which will invest more than $7bn to ensure that domestic manufacturers will have the critical minerals and other necessary components to manufacture the batteries needed for the United States to meet its climate goals.

Battery energy storage demand for lithium has been incorporated into our recent cyclical outlook for lithium supply and demand (please see our note Lithium's adolescence). The lithium industry is evolving rapidly to cope with the dominant driver of demand, namely electric vehicle batteries, and we see a fivefold rise in demand for lithium by 2030. The global lithium industry will have the ability in the longer term to meet this demand (there are a wide range of near- and far-term projects outlined in our note), although the timing of the supply response to the acceleration in demand is highly uncertain. We have also accounted for a rise in battery recycling in our estimates, and believe there will be circular solutions for batteries as they reach the end of their design life.

Investing in the sector

Investment opportunities in the sector are spread across the supply chain:

Integrated BESS: ABB, ADS-TEC Energy, CATL, Eguana Technologies, Entech, Exide Industries, Fluence, Invinity Energy Systems, Largo Clean Energy, Leclanché, Mitsubishi Power, NeoVolta, Powin Energy, Schneider Electric, Sunworks, Tesla, Varta.

System integrator: Aggreko (following the acquisition of Younicos), NHOA (formerly Engie EPS), SolarEdge Technologies, Sunnova Energy, SunPower Corp, Wärtsilä.

Infrastructure owner/operator: Atlantica Sustainable Infrastructure, Dominion Energy, EDF Renewables, Duke Energy, Enel, Fotowatio Renewable Ventures, Iberdrola, NextEra Energy, SMS, Tyler Hill Renewables, Vattenfall.

Investment funds: Foresight Solar, Gresham House Energy Storage Fund, Gore Street Energy Storage.

How battery storage assets make money in the UK

Battery storage assets can make money in the UK through revenues from the National Grid and through trading or merchant income. This ability to optimise battery storage across different revenue streams allows the assets to benefit from volatile energy prices and insulation from lower prices in any one source of revenue.

Revenues from National Grid

The system operator, National Grid, procures a range of so-called balancing services (paid for by charging generators and users Balancing Services Use of System, or BSUoS, charges) to ensure supply and demand are balanced. The names of these services, their terms and their relative significance are constantly evolving, but in essence they provide:

- Reserve capacity via the Reserve Capacity Mechanism: Capacity market contracts are awarded to provide back-up capacity that can generate electricity in the event of a supply shortfall. Capacity contracts are specified at different levels of duration and start dates.
- Frequency response services (FRS): short-term contracts are awarded to ensure stability in the network's operating frequency (50Hz) within parameters defined by Ofgem. These services are segmented by contract duration, and technically, by response time, amount of power delivered at various frequencies, accuracy of response and recharging parameters.

- TRIADs (three half-hour settlement periods of high demand): annual peaks in demand, typically during cold winter evenings which, by definition, determine the maximum required network of total generation capacity. Making payments to large electricity generators to meet peak demand, and charging consumers to disincentivise demand at peak times, can lessen the need for costly investment in generation and the network.

In 2021, the total value of UK BSUoS charges was £2.7bn. Battery operators, alongside providers of other forms of low-carbon flexibility, as well as natural gas generators, bid for these contracts. BESS revenues depend on the balancing service – reserve capacity, frequency response or demand-side response – although there are some regulatory limits on the involvement of BESS in the bidding process. Growth in the overall market has risen in the past couple of years as rising intermittency drives an increasing need for balancing services. This has been offset, to a certain extent, by the falling cost of providing these services.

One BSUoS segment that batteries have already penetrated is the FRS. Gresham House Energy Storage Fund reported generating 76% of its revenues from FRS in 2020. The FRS market grew strongly in 2020, but growth is not expected to continue at this pace. In October 2020, a new FRS service called Dynamic Containment (DC) was launched, with stricter performance requirements than historical FRS services such as firm frequency response (FFR), including faster response times and a much higher reporting requirement (20 times per second). Pricing fell as the number of batteries available to offer DC increased and as procurement of DC moved from daily to four-hourly, meaning that National Grid could contract less capacity during those four-hourly periods that demand for DC was lower. Nevertheless, in June 2022 batteries achieved their highest recorded revenue through DC (low), when the clearing price hit £105/MWh. Two other new FRS services, dynamic modulation and dynamic regulation, were introduced in 2022.

Trading or merchant income

In addition to revenue from the system operator, batteries can generate income directly from other market participants. The storage capacity of BESS means that operators can purchase energy from renewable sources at times when it is being produced cheaply, for example when there is a lot of wind or when demand is low and store it until demand, and thus energy prices, rise and the energy can be sold at a profit. ‘Asset optimisers such as EDF and Flexitricity deploy advanced algorithms to anticipate periods of peak or trough pricing, and BESS operators can supply energy to these electricity traders when prices are high.

Increasing price volatility underlines the need for battery storage. As the UK grid becomes more reliant on intermittent renewable energy sources, frequent variations in electricity supply are underlining an increasing need for battery storage investment. A turbulent winter period in 2020/21 saw several disruptions precipitated by low temperatures and low wind power that highlight the opportunity for battery storage operators. Having hit the highest system price in 19 years at £2,242/MWh in March 2020, this was surpassed by a system price of £4,000/MWh on 8 January 2021. Despite the current geopolitical instability, intraday and system prices have been relatively low and stable across the summer of 2022, with maximum intraday prices in the range of c £200–350/MWh and maximum system prices ranging between c £310/MWh and £400/MWh. These system prices have become more volatile in recent weeks due to high wind generation, reaching a high of £600/MWh, and this volatility is expected to increase through the winter as temperatures fall and gas supply remains tight.

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