AQUILA CLEAN ENERGY

BATTERY ENERGY STORAGE SYSTEMS (BESS) – ENHANCING SYSTEM STABILITY AND EFFICIENCY

White paper

CONTENT

Introduction

Sustainable energy systems based on fluctuating renewable energy sources require storage technologies for stabilising grids and for shifting renewable production to match electricity demand. The stability of grids and hence the security of energy supply depends on a constant balance between generation and consumption, which intermittent renewable resources such as wind and solar cannot sustain on their own. Moreover, the rapid growth of renewable energies and their integration within the grid is increasing pressure on power networks. Thus, the need for battery energy storage systems (BESS) to provide grid balancing, keep pace with rising renewable capacity and further reduce carbon emissions has never been more urgent. Indeed, during peak demand hours, BESS can be discharged to regulate, balance and stabilise the energy grid, whereas by charging batteries during periods of low consumption, utilities and independent power producers can reduce the cost of energy they provide.

There are several demand drivers for the expansion of BESS capacity, namely the sharp and continuing fall in costs of battery storage technologies, making battery optimisation even more affordable, and the significant drop in lithium prices after the spike witnessed in 2022, which will benefit battery development pipelines. Greater volatility in trading markets and increasing opportunities to participate in ancillary services related to frequency response and balancing, as well as the optimisation of electricity wholesale markets, are also further boosting the revenue potential of battery storage.

The battery storage segment thus offers investors sustainable investment opportunities that also increase diversification within their renewable energy portfolios. This paper will explore why batteries offer a high degree of flexibility as short-term storage devices and why they are a key component of a renewable energy system.

1. The technological framework of battery storage

As short-term storage devices, batteries offer a high degree of flexibility by balancing power outputs and scheduling discharges to efficiently manage their energy and increase potential revenues. Batteries have lower capacities and discharge times compared to long-term storage. While pumped-storage power plants, hydrogen applications and other long-duration technologies offer opportunities to compensate for weekly, monthly and seasonal differences via in certain cases just a few cycles per year or to build up longer-term reserves, batteries can go through several cycles per day. Thus, the roles of BESS and pumped hydro energy storage are largely complementary, generally operating most economically in the under ten-hour and over ten-hour duration spaces, respectively.

The majority of newly installed large-scale electricity storage systems in recent years utilise lithium-ion chemistries for increased grid resiliency and sustainability. The capacity of lithium-ion batteries to make energy available again quickly thus makes them the ideal short-term supplement to the fluctuating daily generation of renewable electricity compared to other technologies. This is particularly the case due to a cost-learning curve resulting from the industrialisation of lithium-ion production in the transport sector and the high efficiency of lithium-ion when storing electricity. These factors are expected to continue in the foreseeable future and hence lithium-ion is forecasted to maintain its lead over alternative storage technologies such as flow batteries for potentially up to ten-to-twelve-hour storage duration.

In the field of lithium-ion batteries, a key distinction is made between lithium nickel manganese cobalt oxide (NMC) and lithium iron phosphate (LFP). NMC has been for many years the technology of choice for the transport sector, home solar systems, power tools and utility-level storage due to its higher energy density and the resulting low weight compared to other technologies. However, despite a lower energy density and thus a higher weight compared to NMC for the same performance, LFP chemistry is increasingly gaining market share due to the technology's clear advantages in other respects. In particular, the non-use of critical raw materials such as cobalt and nickel makes LFP more cost efficient to manufacture whilst also increasing its life cycle compared to nickel-based lithium-ion chemistries.

Furthermore, LFP's lower energy density increases thermal stability, reducing the risk of fire accidents, while also being less of a concern for the energy storage segment given weight and space are less material issues for stationary systems. Indeed, as evidenced by chart 1 below, LFP is expected to remain the dominant chemistry for energy storage until the end of the decade and beyond, driven by a substantial ramp-up in manufacturing capacity by Chinese, American and European battery makers and the use of ever larger prismatic cells for energy storage, allowing for more energy storage capacity per unit and greater system integration efficiency.

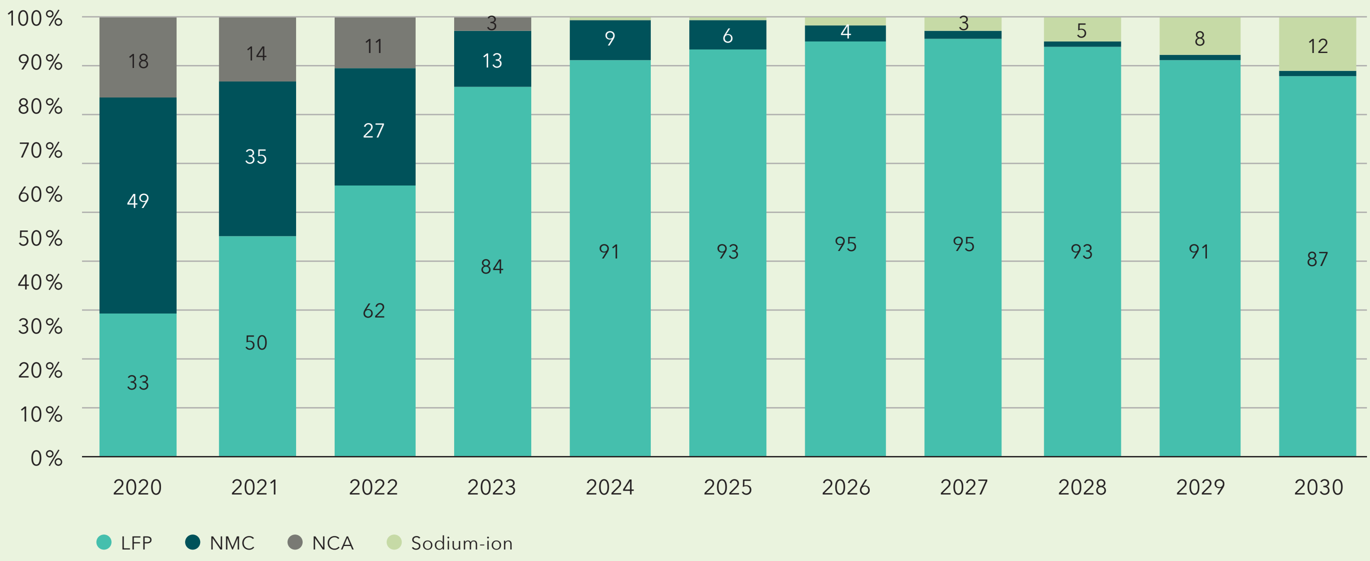
As a result, LFP chemistry is increasingly becoming the preferred choice for large stationary battery storage, which has a much lower sensitivity to weight compared to other sectors. LFP is also being used more and more in cost-sensitive automotive applications. LFP batteries are designed to handle utility-scale renewable power generation and energy storage capacities up to several hundred megawatt-hours, given their ability to endure high load currents with a long cycle life. All lithium-ion batteries also benefit from technological progress and massive economies of scale due to their use in the fast-growing electric vehicle market, resulting in batteries experiencing substantial price drops in the past few years and making BESS a far more competitive business case.

Emerging technologies such as sodium-ion batteries might capture some market-share from LFP in the next few years, especially in China, which has been promoting national targets and standards for sodium-ion batteries to accelerate its commercialisation, thereby reducing lithium supply bottlenecks (see chart 1 below). The gradual introduction of sodium-ion cells, assuming the expansion of localised supply chains for the technology outside of China, will thus be another key tailwind for long-term growth in BESS buildout, further enhancing cost efficiencies due to the abundance of sodium compared to lithium supply and its low extraction and purification costs.[1]

1 PV Magazine, 'Sodium-ion batteries – a viable alternative to lithium?' (2024), available at: link

CHART 1: **BATTERY STORAGE CHEMISTRY MIX OUTLOOK**[2]

based on gigawatt-hours in %



At Aquila Group, most of our projects are using LFP as the leading chemistry in the utility-scale battery storage segment and combine the ideal technical characteristics with our focus on sustainability. All of Aquila Group's European projects are developed by the business unit Aquila Clean Energy, which generates value by strategically selecting sites that offer the best infrastructure potential and develops hybrid clean energy projects that optimise the grid connection. Aquila Clean Energy's in-house expert teams in investment, development, procurement, construction and markets management have built an integrated and sustainable clean energy business by applying a holistic and industrial approach.

Aquila Clean Energy's BESS development portfolio has projects totalling over 4 GW in capacity, spread across Germany, Spain, Portugal, Italy, Greece, Belgium, the Baltics and Nordics. Aquila Clean Energy is targeting more projects in these markets as well as new opportunities across Europe and APAC until 2030, benefitting from attractive remuneration for system flexibility, capacity markets and ancillary services (see chart 13 below).

2. The business case for battery storage

Batteries are an important component in the energy system to solve the challenges related to the reliability of fluctuating renewable energy by storing surplus electricity for the periods when wind and solar energy is not available. This flexibility of supply is the basic prerequisite for increasing the integration of renewable energy sources and thus enabling a higher share of renewable energy feeding into electricity grids.

2.1 Renewable synergies

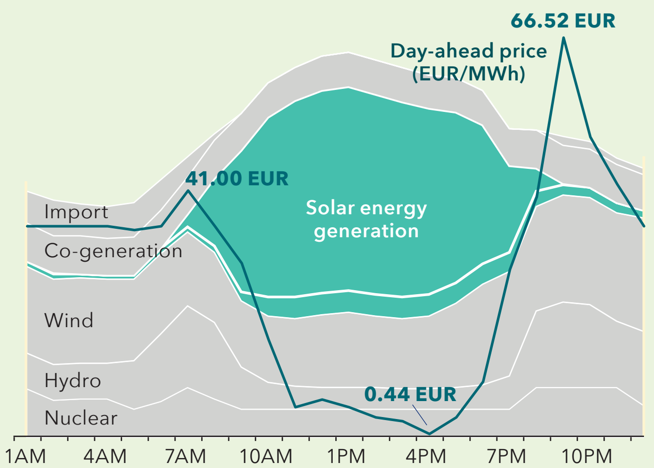
Mature renewable technologies such as wind and solar PV offer opportunities to sustainably reorganise energy systems. However, energy security and affordability are key components for an effective transition that would ensure fundamental acceptance. Despite renewable technologies having already significantly surpassed grid parity and offering advantages even when compared to the operation of existing thermal power plants[3], these advantages are only recently beginning to fully materialise for consumers in real terms. Indeed, the market consensus is that a more promising macro environment, with commodity and electricity prices having fallen last year from the highs reached in late 2022 and inflation in the Eurozone expected to reach the European Central Bank's target of 2.0 %, should result in a reduction in interest rates in the second half of 2024. These developments should help accelerate investment in renewables, given the lower cost of debt and discount factors underlying this scenario.

2 Bloomberg New Energy Finance (BNEF), '1H 2024 Energy Storage Market Outlook' (2024), excludes other battery technologies other than lithium-ion and sodium-ion batteries as well as non-battery technologies such as thermal storage, gravity-based storage and mechanical storage. NCA, NMC and LFP refer to lithium-ion battery chemistries, NCA is lithium nickel cobalt aluminium oxide, NMC is lithium nickel manganese cobalt oxide and LFP is lithium iron phosphate.

3 Levelised costs of electricity generated by renewables match or are lower than those of conventional power plants.

However, a very inelastic demand for energy allows for fossil fuel power plants to continue to set the price on the market, despite renewable energy production dampening the impact of the high prices of fossil fuel generation. Thus, to ensure the stability of electricity grids, a constant, sensitive balance between generation and consumption in real time is needed. Whilst conventional power plants generate a stable and controllable base load depending on demand, renewable technologies are dependent on the weather, posing challenges to energy security due to the volatility inherent in their production. As evidenced in chart 2 below, the daily pattern of solar energy generation increases volatility in daily price spreads. The high midday solar output meets or exceeds energy demand, reducing prices, whereas a constant evening demand which cannot be met after sunset causes prices to surge. An increased solar PV capacity buildout alone would amplify this volatile pattern, hence requiring grid flexibility solutions.

CHART 2: **ENERGY MIX IN SPAIN ON A REPRESENTATIVE DAY**[4]



In this context, the use of flexible gas-fired power plants could be seen as a good counterpart to renewables, given the rapid startup and shutdown of gas-fired power plants according to the feed-in from renewable sources. However, the minimum load and ramp requirements do not make it a good complement for renewables. Moreover, the technology is not compatible with net zero emission scenarios and the dependency on exporting countries raises questions about the long-term sustainability of this model.

Batteries have become increasingly competitive in terms of costs and flexibility, as well as boosting the efficiency of the energy system. While gas-fired power plants can compensate for bottlenecks in the energy supply by producing when renewable generation is not sufficient, the technology does not provide a solution for surpluses during other hours. In contrast, BESS can be charged during these surplus periods and thus mitigate grid-related and economic curtailments for wind farms and solar PV plants. In hours marked by low production from renewable sources, the corresponding emission-free electricity can be fed back into the grid.[5] An added benefit would be a lower reliance on energy imports, which would have a positive impact on energy sovereignty and security whilst also limiting the effects of volatile commodity prices.

Continued seasonal smoothing of renewable energy production, benefitting from regional interconnection and technological diversification, would also eliminate the need for gas-fired power plants as a bridging technology. The advantages of seasonal smoothing are evidenced in Europe by the negative correlation of solar-PV compared to wind and hydropower as well as the regional differences between high wind speeds along the coasts and high solar irradiation in southern Europe, with all technologies complementing each other. The Iberian Peninsula illustrates this correlation, as its natural resources and geography offer very good and equivalent conditions for all three technologies, which would result in a smoothed, stable generation profile. Nevertheless, there continue to be significant daily fluctuations which must be balanced by flexible generation and demand for which lithium-ion batteries are the ideal solution.

However, contrary to the daily or weekly flexibility requirements, there persists a demand for long-duration energy storage to address the seasonal and regional variability in renewable energy generation. While lithium-ion batteries play a significant role in short-term flexibility, they are likely uncompetitive for durations exceeding ten to twelve hours. Emerging technologies offer promising solutions to meet this demand. Hydrogen, in particular, has garnered increasing interest due to its ability to provide seasonal buffering. For instance, it can store energy generated during the summer from solar PV systems for use during the winter months when PV generation is typically low.

Combining renewables and batteries in one portfolio therefore creates significant positive effects. In the case of Iberia, while different solar assets display a strong correlation in revenues (> 0.75), batteries have weak to no correlation (< 0.25) to renewable assets (see chart 3), indicating their ideal complementing potential to a renewable asset portfolio. Moreover, BESS can be leveraged to improve the value of renewable projects by improving capture rates or mitigating technical curtailments by grid operators. The co-location with solar PV parks would allow the battery storage systems to charge any technically curtailed energy during the day and discharge it at night without curtailment. Indeed, technical curtailments are becoming a growing problem at times of unforeseen surpluses in wind and solar generation, given the transmission and distribution (T&D) network constraints in many European countries.

4 Omie, as at 3 May 2024, available at: link
5 See below section '2.5. ESG opportunities and risks' and Aquila Capital, 'Lifetime avoided emissions for battery energy storage systems' (2023), available at: link

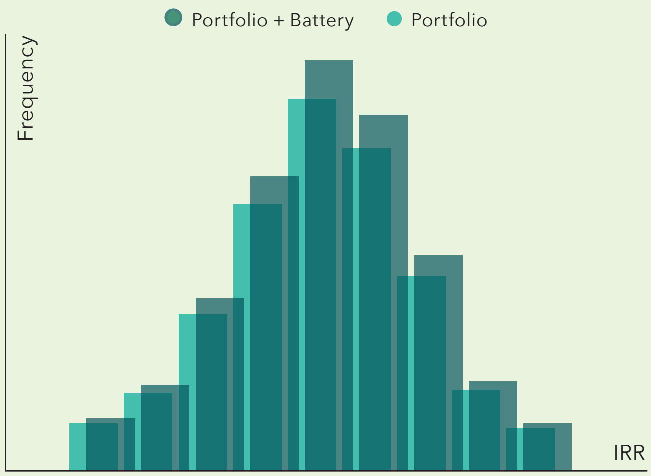
Co-located batteries are thus an increasingly crucial application in light of the rapid buildout of renewable capacity, which would otherwise make curtailments by grid operators a more constant threat. In situations where renewable power plants are located in areas with poor grid connections, the maximum output of power plants is often capped at a specific power level by the energy utility. The co-location of batteries can also help resolve this issue by ensuring that batteries are charged during periods of overproduction or grid curtailments and discharged when power plant production is below the maximum permitted level.

The benefits of portfolio diversification with BESS can also be seen in the illustrative chart 4. The addition of co-located and standalone battery investments in a renewable energy portfolio shifts the IRR distribution of the portfolio to the right (i.e. higher average IRR returns due to higher merchant IRR of BESS versus renewables) and reduces the width of the distribution (i.e. lower volatility of returns), highlighting the potential for investors of BESS as a sustainable complementary investment opportunity that also increases diversification within their renewable energy portfolios.

CHART 3: **ILLUSTRATIVE REVENUE CORRELATION MATRIX OF SELECTED RENEWABLES AND BATTERIES**[6]

	SOLAR Spain	WIND Greece	SOLAR Portugal	BATTERY Belgium
SOLAR Spain	1	0.58	0.97	-0.12
WIND Greece	0.58	1	0.67	0.25
SOLAR Portugal	0.97	0.67	1	-0.02
BATTERY Belgium	-0.12	0.25	-0.02	1

CHART 4: **ILLUSTRATIVE IRR PORTFOLIO COMPARISON**[7]



Battery storage can also play a significant role in supporting grid operators directly by preventing grid congestion, providing voltage control, providing or absorbing reactive power and restoring power after blackouts ('black-start'). This is especially relevant in Europe, where EUR 584 billion of investment in T&D is estimated to be needed by 2030 to modernise grids and accommodate growth in renewable capacity.[8]

2.2. Revenue streams

Technological progress and fundamental changes in Europe's electricity sector are leading to the adoption of BESS facilities with higher capacities and longer discharge periods, enabling the realisation of economies of scale and opening up the potential to serve a number of different markets on a technology basis. There are three main market categories from which BESS generate their revenue streams, the design and maturity of which still varies greatly across Europe:

- **Ancillary services:** daily auctions for primary, secondary and tertiary reserves;
- **Wholesale electricity market:** day-ahead, intraday and imbalance markets;
- **Long-term auctions:** e.g. capacity markets and grid support services such as voltage control, reactive power and black-start.

6 Aquila Capital, based on information available on Entsoe Transparency Platform and EEX from January 2015 to March 2023. The correlation matrix is calculated based on hourly revenues (price times production) aggregated monthly.
7 Aquila Capital, based on data from 500 scenarios calculated for the original EMEA portfolio and the portfolio with the addition of co-located and standalone battery investments.
8 European Council on Foreign Relations, 'Gridlock: Why Europe's electricity infrastructure is holding back the green transition' (2023), available at: link

Ancillary services
Ancillary services relate to frequency response and balancing and may have different names and definitions across markets. Frequency response services refer to any services that can be provided by market participants in connection with unexpected changes to the transmission system frequency, such as providing or consuming additional energy. When realized production or demand for electricity deviates from forecasts, batteries can efficiently restore a stable frequency. There are three key types of ancillary services, all of which are paid for by the transmission system operator (TSO):

1. Frequency Containment Reserve (FCR): FCR, also known as primary reserve or frequency regulation, is a crucial ancillary service that maintains the grid's frequency within acceptable bounds (50 Hz in Europe). As electricity demand and supply continuously fluctuate, FCR providers adjust their output within seconds to balance these changes and stabilise the grid frequency. FCR providers, such as power plants or energy storage systems, must be capable of rapidly responding to frequency deviations to ensure grid stability.

2. Automatic Frequency Restoration Reserve (aFRR): aFRR, also referred to as secondary reserve is another ancillary service used to restore grid frequency following significant disturbances. While FCR responds to rapid frequency changes, aFRR provides longer-term frequency restoration by adjusting generation or consumption levels over minutes to hours. Grid operators use aFRR to counteract sustained imbalances between supply and demand, helping to bring the grid frequency back to its nominal value.

3. Manual Frequency Restoration Reserve (mFRR): mFRR, also called tertiary reserve or manual frequency control, is a supplementary ancillary service utilised during extreme grid events or when primary and secondary reserves are insufficient. Unlike automatic reserves, mFRR involves manual intervention by grid operators or market participants to restore grid frequency. This service is typically activated during rare but severe events such as large generator failures or major grid disturbances, where immediate action is necessary to prevent cascading failures and blackouts.

These ancillary services work in tandem to maintain grid stability and ensure reliable electricity supply, with each service playing a specific role in responding to different types and magnitudes of grid disturbances. Power systems must always be balanced by grid operators, given the high variability of demand (e.g. summer peak consumption, temperature swings, end-user consumption changes) and supply (e.g. plant outages, intermittent wind and solar production). These system imbalances are balanced in real time via the primary, secondary and tertiary reserve which forces market participants to achieve full activation within pre-defined timeframes. These reserve mechanisms ensure the system frequency gradually recovers to the 50 Hz level (see chart 5 below). A majority of BESS revenues is expected to transition away from existing ancillary services to wholesale market optimisation in the next four to five years, with more markets benefitting from attractive remuneration for system flexibility, arbitraging opportunities from real-time imbalance trading and long-term renumeration via capacity markets, as discussed below.

CHART 5: **OVERVIEW OF ANCILLARY SERVICES**

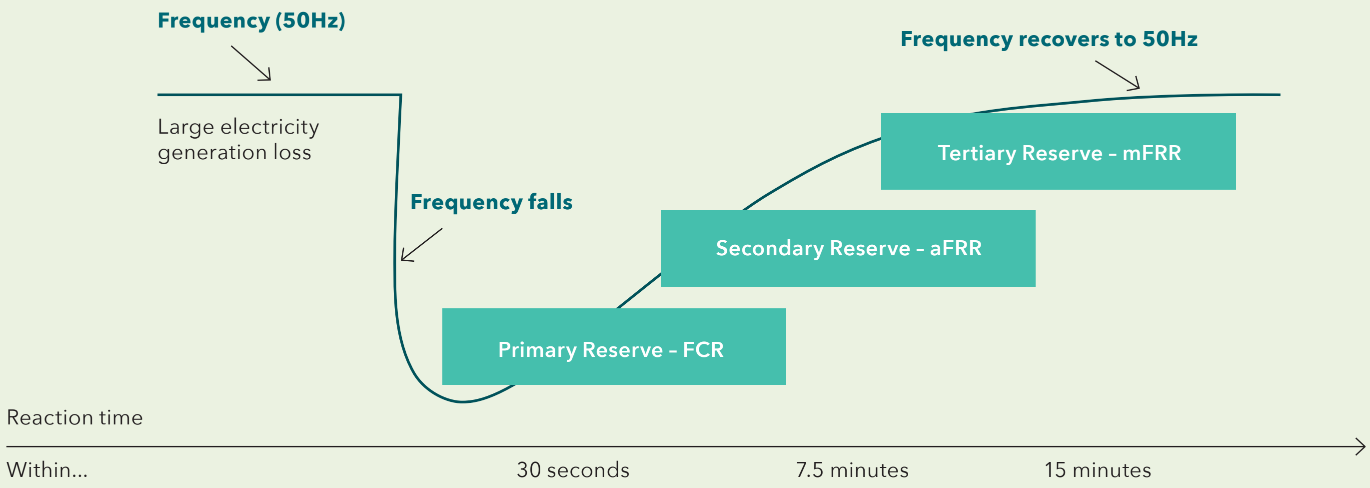
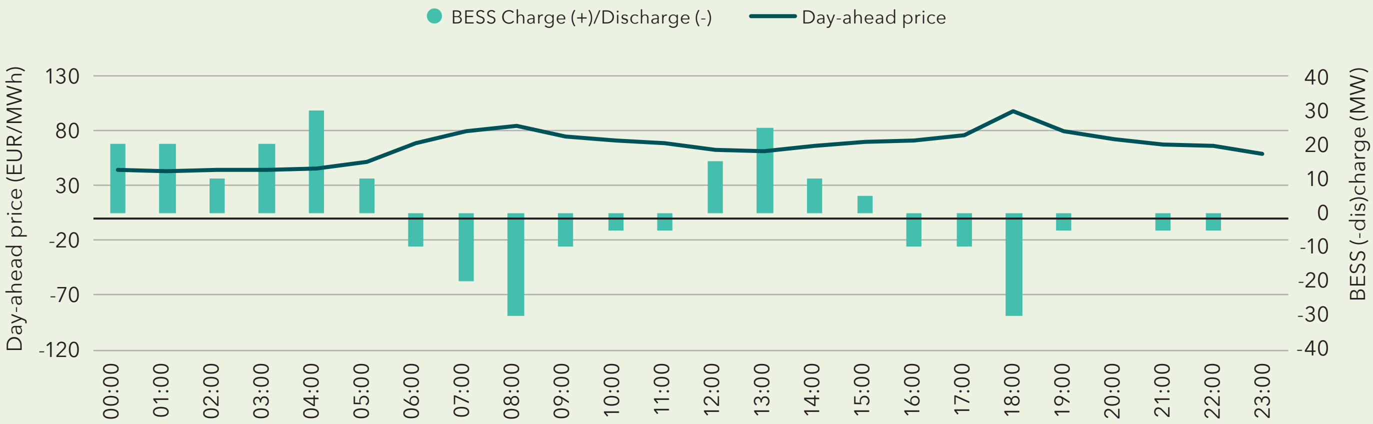


CHART 6: **EXEMPLARY BEHAVIOUR OF A 50 MW/100 MWH BESS IN GERMANY'S DAY-AHEAD MARKET**[9]



Wholesale market optimisation
Wholesale market optimisation involves leveraging the energy storage assets to maximise revenues by price optimisation and time shifting in an auction for electricity delivered on the next day (day-ahead auctions) or the continuous market for energy deliveries (intraday market) close to real time, where batteries can earn by arbitraging price spreads (e.g. charging the battery at low prices and discharging at high prices, see chart 6).

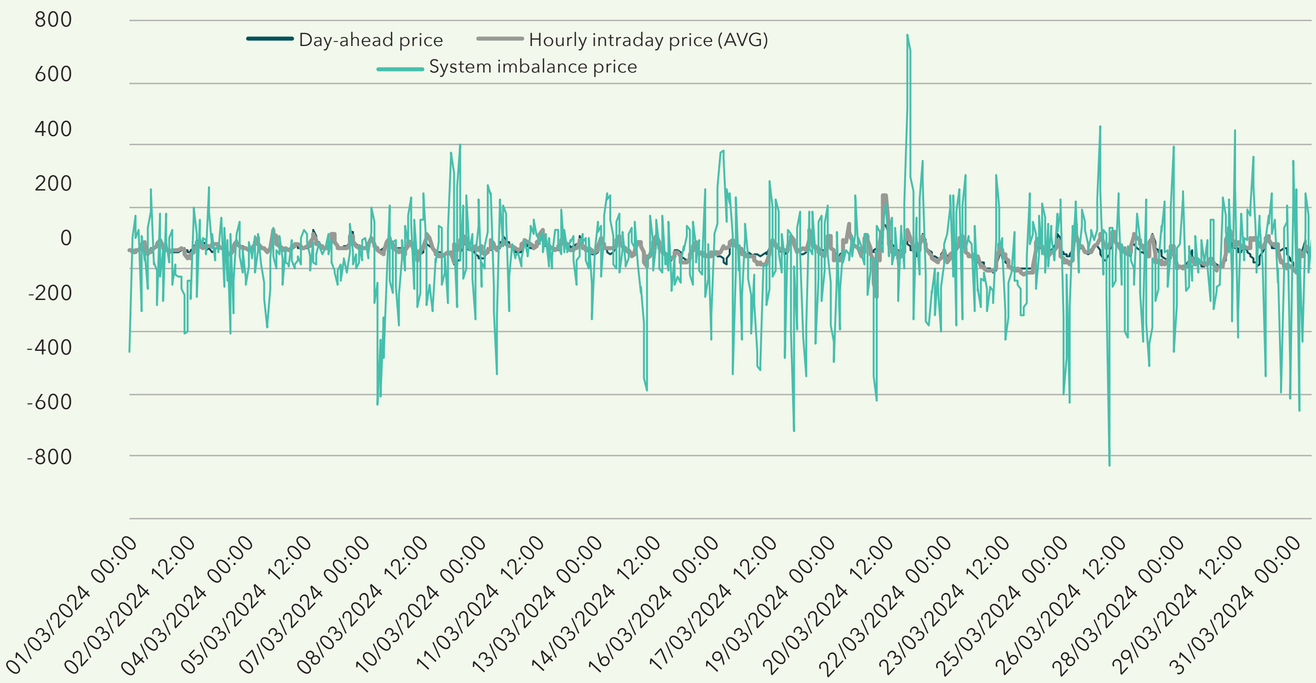
Another key revenue source for BESS in wholesale markets is imbalance steering, whereby batteries try to anticipate system needs, adjusting their trading positions to gain additional revenue by deviating their charging and discharging patterns in the opposite direction to the imbalance position of the system, hence taking advantage of high volatility and price spikes. Elevated volatility can thus be seen as a positive dynamic for BESS operators, by profiting from purchasing electricity from renewable sources at low prices to charge their batteries and then feeding power into the grid at high prices when production from renewables is low. Whilst a rapid BESS buildout is expected to lower volatility in power markets, a growing share of renewables in the energy mix will act as a contrasting force to drive volatility higher again. Accounting for additional revenue opportunities from this close to real time volatility in mid- to long-term forecasts is generally quite challenging, thus these are typically underestimated in consultants' forecasts for BESS revenue stacking.

9 Aquila Capital, based on publicly available market data for 1 January 2023. More details on the German BESS market can be found in an earlier analysis by Aquila Capital, 'System Stability and Efficiency through Battery Storage – A Turning Point of the Sustainable Transformation?' (2021), available at: link

Chart 7 below illustrates system imbalance prices in Belgium, which tend to be more volatile than day-ahead or intraday prices in either direction, reflecting the 'shock' response of the system when market participants produce more or less electricity than they have sold or bought. This phenomenon typically occurs when there is a deficit in nuclear supply due to ramping down and maintenance works or when renewables output is suddenly lower than expected (e.g. low wind or cloudy day), driving up the imbalance price as other power units scramble to fill the unexpected gap in demand.

CHART 7: **SYSTEM IMBALANCE MARKET PRICES IN BELGIUM**[10]

(in EUR / MWh)



Long-term auctions

To encourage private sector investment in new electricity generation plants and ensure sufficient capacity (safety margin) between peak demand and installed capacity, several transmission network operators have implemented capacity mechanisms that offer electricity generators additional revenue streams through capacity payments, in addition to the incomes from the wholesale market and ancillary services, as well as greater visibility through long-term contracts for investors.

Currently, six countries in Europe (Belgium, Ireland, France, Poland, the United Kingdom and Italy) have established capacity markets approved by the European Union through different auctions that allow the participation of energy storage systems. The auction dates and contract periods differ from one country to another. In addition to these capacity mechanisms, there are other subsidy programmes across Europe that provide recurring revenues for successful projects procured through auctions. For example, in Greece, this process involves an operational subsidy implemented through a contract-for-difference (CfD) like mechanism.

10 Aquila Capital, based on publicly available hourly market data from 1 to 31 March 2024. Other sources: Elia, Regelleistung.net and Entsoe Transparency Platform.

Storage systems in Greece submit a bid price (EUR/MW/year) which becomes their annual reference revenue for a ten-year support plan. The portion of annual reference revenue not obtained from electricity markets (DA, ID, Balancing Market) is guaranteed as part of the support plan.

In Germany, subsidy schemes operate differently by means of innovation tenders, providing developers with fixed premiums to encourage the deployment of renewable energy and storage projects throughout the country. These premiums are awarded for twenty years, however come with certain restrictions on battery utilisation (e.g. not charging the battery with grid electricity) which reduces the value of the battery from an overall system perspective.

In Italy, Terna, the country's transmission system operator, launched a 'Fast Reserve' pilot project that will procure 250 MW of BESS capacity for delivery between 2023 and 2027. This 'Fast Reserve' project provides assets with capacity-based renumeration and allows new categories of resources to participate in the ancillary services market, with the objective of testing their performance before full integration.

Optimisation strategy
The key to a successful BESS project is the optimisation of the above-mentioned revenue streams during the lifetime of the assets and within its technical constraints. Some of the revenue streams can be stacked on top of each other and therefore require a multi-market optimisation approach. This is done on a 24/7 basis and for certain markets like intraday or imbalance close to real-time. It requires complex optimisation algorithms that can analyse the large required real-time data for market prices, fundamental factors like weather forecasts and any other variables impacting the optimal usage pattern of the battery system. The aim is to optimise the charge and discharge behaviour to maximise overall revenues across the different wholesale and ancillary service markets. For a co-located asset, the battery optimisation also needs to consider the interaction between the renewable asset and the battery on the jointly used grid connection. Combined renewable energy and battery portfolios, like the ones managed by Aquila Clean Energy, can thus benefit from the synergies of a joint optimisation.

2.3. Cost efficiency

A key competitive driver for BESS is the substantial drop in global energy storage system costs in the past few years as a result of economies of scale, intense market competition and technological progress in alternative battery compositions (see chart 8). This trend was further reinforced by a considerable drop in lithium-ion battery pack prices (see Chart 9), decreasing by 90 % since 2010, and extensive battery supply due to increased competition in the sector. Costs are expected to continue to fall as improved battery cells and system designs are adopted and competition continues. In 2024, a further drop in lithium-ion battery pack costs is expected as the twenty major lithium-ion battery manufacturers have announced a 50 % planned manufacturing capacity expansion.[11]

According to the International Energy Agency (IEA), increased manufacturing is projected to reduce global average lithium-ion battery costs by a further 40 % from 2023 to 2030, with innovation lowering upfront costs and bringing about additional performance improvements in the form of higher energy densities and longer useful life.[12] Battery manufacturing capacity is set to increase nearly fourfold from 2023 to 2030 if all announced plants are built in full and on time, reaching a level of circa 8 TWh per year that would be sufficient to remain on track with the battery requirements of the Net Zero Emissions (NZE) Scenario by 2050. Battery production is also set to diversify in the coming years, with China's share of lithium-ion battery manufacturing capacity expected to decrease from nearly 85 % in 2023 to 67 % in 2030, a shift primarily driven by significant investment in Europe and North America in the coming years.[13] These positive trends will reduce supply chain risks and ensure a sustained acceleration in BESS buildout.

11 BNEF, 'Energy Storage: 10 Things to Watch in 2024' (2024).
12 International Energy Agency (IEA), 'Batteries and Secure Energy Transitions' (2024), available at: link
13 IEA, 'Batteries and Secure Energy Transitions' (2024), available at: link

CHART 8: GLOBAL AVERAGE CAPEX FOR FULLY INSTALLED ONE-, TWO-, FOUR-HOUR DURATION LARGE ENERGY STORAGE SYSTEMS AT BEGINNING OF LIFE[14]

in real 2023 USD / kWh (based on usable capacity)

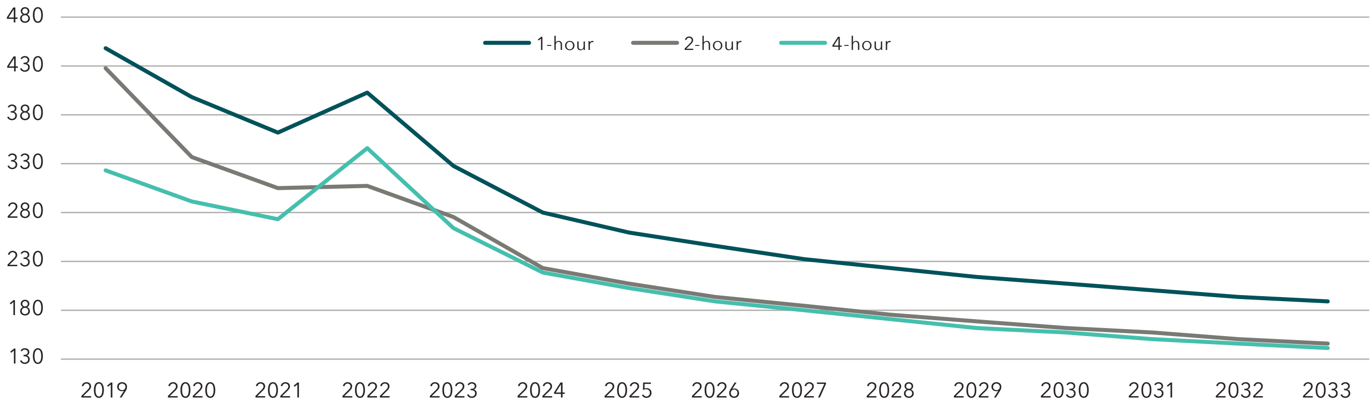
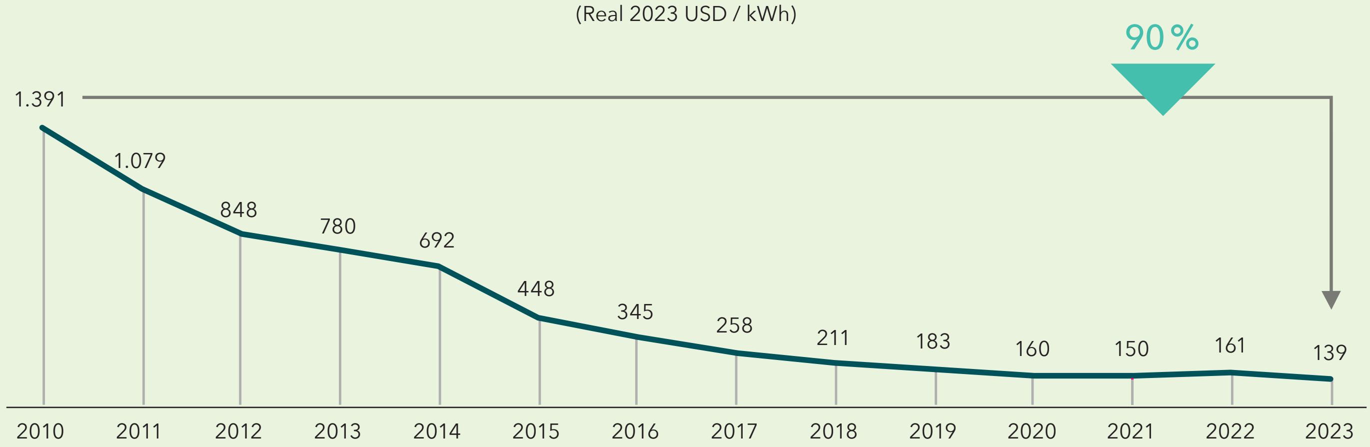


CHART 9: LITHIUM-ION BATTERY PACK PRICES[15]

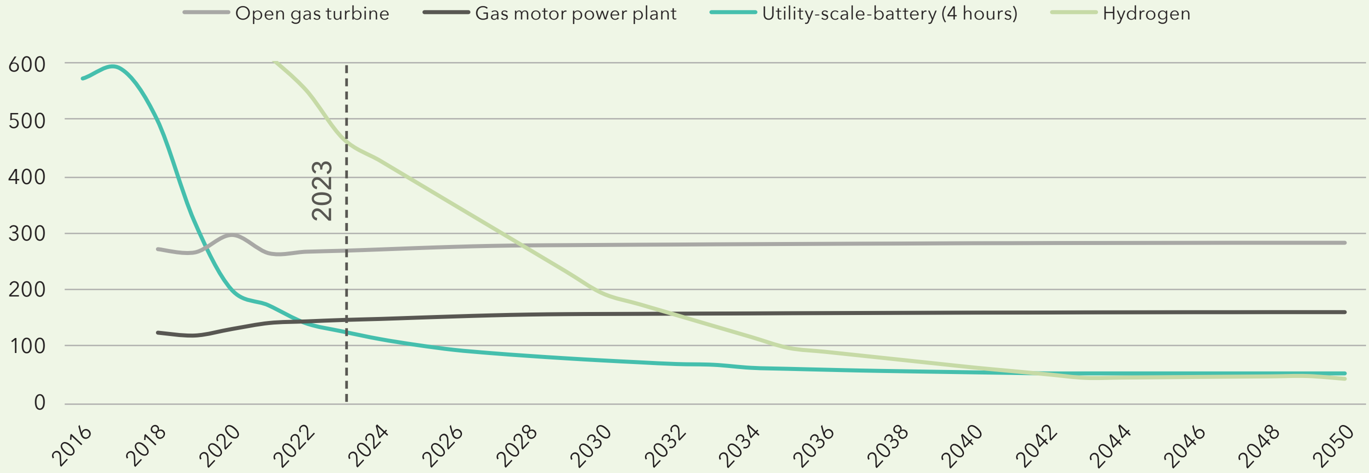
(Real 2023 USD / kWh)



Battery storage offers great potential for countries that are planning a comprehensive phase-out of base-load capable fossil and nuclear power plants, considering the corresponding capacities can only be replaced by the stabilisation of renewable production. At 125 USD / MWh, four-hour duration utility scale battery storage has already surpassed traditional gas motor power plants as the cheapest mitigation technology (see chart 10 below), having already become approximately 78 % cheaper than in 2016 and expected to become even more competitive in the coming years. It should also be noted that to remain on target with the net zero emissions scenario by 2050, the energy-intensive process required to produce and store hydrogen will necessitate the input of renewable energy sources, this use case will be another important catalyst for BESS expansion.

14 BNEF, 'Energy Storage System Cost Survey 2023' (2023). Includes costs for battery rack, balance of system and energy management system, power conversion systems, transformers, other expenses and system integrator margins. Costs vary widely by region, with turnkey energy storage systems deployed in China costing significantly less than in Europe and the US, given China's well-established battery manufacturing capacity, mature supply chains, oversupply of battery cells and intense competition among battery makers.
15 BNEF, 'Localization and the Cost of Batteries' (2024).

CHART 10: **LEVELISED COST OF ENERGY (LCOE) OF FLEXIBLE ENERGY SOLUTIONS**[16]
(USD / MWh)



Thus, lower battery supply chain prices, battery improvements including the uptake of larger cells at a record pace and intense competition in the sector will continue to drive down costs for BESS projects even further, whereas stationary storage project hour durations are expected to grow as use cases evolve to deliver more energy. In Europe, this is exemplified by plans from the Italian grid operator Terna to introduce auctions for long duration energy storage systems (including lithium-ion and pumped hydro), targeting 9 GW / 71 GWh of additional storage capacity by 2030. The first such auction is expected by 2025, targeting first delivery in 2027 or 2028.

2.4. Regulatory framework

However, a prerequisite for accelerating the development of BESS in Europe is also a corresponding regulatory framework that offers operators a positive and stable market environment in the long term. Several countries have yet to open up power and ancillary services markets and adopt regulations that ease interconnection constraints and clarify battery storage participation models in their markets. European Union (EU) countries are increasingly adapting their regulatory frameworks; however, the lack of a harmonised and heterogeneous strategy continues to require a selective approach. For example, Italy, Portugal and Spain continue to have restrictions on the participation of batteries in ancillary markets (e.g. primary reserve), even though their market designs are now subject to expected changes that would improve framework conditions for BESS rollout. In anticipation of these changes, Aquila Group is implementing co-located battery storage at most of its operational and development solar PV parks in these countries, as a means to maximise value creation and mitigate any potential technical curtailments.

A project at the EU level, Picasso, is aiming to harmonise the Eurozone's market design, whilst the Benelux countries and Germany already have a market design that provides a good basis for investing in BESS, including a constant optimisation of the battery across different market segments. However, the regulatory classification of BESS remains a critical open point, insofar as its current dual role as electricity consumer and producer can create a risk of double surcharges, grid connection bottlenecks, transmission fees and taxes.

Furthermore, a strong tailwind for BESS expansion will be the launch of a new technology-neutral capacity market in Germany by 2028, as part of a reform of the country's electricity market design. An agreement was also reached to procure 10 GW of flexible gas-fired power plants which will need to switch over to hydrogen fuel before 2040, with tenders designed to be integrated in the future capacity mechanism. The fact that this capacity market will not discriminate on the basis of technology is a significant opportunity for BESS developers and operators. Other European markets which have introduced similar mechanisms, such as the UK, Belgium, Italy and Poland, have experienced high volumes of participation from battery groups and have ensured a solid revenue stream for BESS projects. The framework designs in those countries also further contributed to unlocking project finance for new standalone batteries. The backdrop for this proposal is the

16 BNEF data (2023).

governing coalition's plan to procure up to 25 GW of new energy capacity, which initially envisaged hydrogen-ready gas-fired power plants (H2-ready gas peakers) as the exclusive source of electricity. However, the high cost of subsidies for that proposal led the government to reduce capacity from H2-ready gas peakers to only 10GW, paving the way for a technology-neutral capacity market to help fill the shortfall. A final proposal by Germany's business ministry will be presented in the summer of 2024.

In February 2021, the Spanish Government approved an energy storage strategy, with the approved measures aiming to increase the role of storage in the power sector by increasing system flexibility and ensuring security of supply. The roadmap foresees the country ramping up its storage capacity to 20 GW by 2030, with an additional 10 GW by 2050. While seasonal storage (e.g. large hydro reservoirs) is envisioned to increase in the next decade, most of the increase will come from shorter duration systems (e.g. batteries, vehicle-to-grid, etc.). The Government expects a greater role for storage, although different considerations are needed for various storage technologies in terms of their response time, capacity, efficiency and maturity. Storage will benefit from additional revenue streams in ancillary services, more favourable capacity markets due to a potential Capacity Remuneration Mechanism (CRM) and greater flexibility for local markets from the alleviation of grid congestion. Moreover, the Government intends to analyse the potential role of distributed storage capacity in local markets.

Thus, a beneficial regulatory framework allows BESS facilities to participate in additional revenue streams, including wholesale market optimisation and ancillary services, boosting their competitive appeal and business case compared to fossil fuel power plants.

2.5. ESG opportunities and risks

In order to maximise the potential of battery storage and to contribute significantly to sustainability goals, a comprehensive analysis of global supply chains is essential, given the dominant technology of lithium-ion batteries requires a significant supply of raw materials. In this context, mining should meet high standards on a social and environmental level. From the extraction of raw materials to production and recycling, a life cycle analysis must be carried out. The recycling of raw materials or the use of renewable energy in production could significantly reduce the CO_2 footprint of battery production. In addition, battery research will make decisive progress in reducing the need for limited raw material deposits and increasing efficiency. Alternative battery compositions already exist in the dominant lithium-ion technology. As mentioned earlier, lithium-iron-phosphate (LFP) is increasingly gaining market share as it benefits from lower costs than nickel-manganese-cobalt (NMC) chemistry, since it is less reliant on scarce raw materials. These alternative battery compositions result in more diversified supply chains, while simultaneously increasing the transparency of working conditions. Another already mentioned technology is sodium-ion which has the potential to reduce future demand of lithium for batteries.

A typical BESS asset generates emissions at the beginning of its lifetime, including emissions from resource extraction, transportation, energy consumption and other emission sources to produce the anode, cathode, battery management system and pack housing of the battery. Nevertheless, BESS have been shown to deliver positive lifetime avoided emissions after a certain payback period[17], due to the correlation between power prices, the emission intensity of the grid and price-optimised load cycles.[18]

Overall, BESS will be an increasingly integral part of the world's energy system, enabling the integration of renewable energies by freeing up grid capacity and providing ancillary services that ensure the stability of electricity grids. These benefits should be considered in conjunction with avoided emissions to fully capture the role of utility-scale battery storage in the decarbonisation of the power sector.

17 Payback period is a term used to measure the amount of time required for the BESS to recover its embodied emissions through emission avoidance.
18 Aquila Group, 'Lifetime avoided emissions for battery energy storage systems' (2023), available at: link

3. Outlook

The European Union's target of renewables meeting 45.0 % of final energy consumption in 2030 will lead to a considerable increase in the bloc's electricity demand throughout this transition, given the underlying assumption that renewable capacity will need to triple by 2030 to 1.3 TW, in line with the global goal set at the COP28. Solutions to stabilise the electricity grid's supply and demand are thus indispensable considering the urgency of these targets.

In light of this backdrop, wind and solar-PV capacities are expected to more than double by 2030. In particular, solar-PV plants will become increasingly important for the European electricity supply chain. Given these developments, grid-related curtailments are also expected to increase, and renewable energy generation will not match consumption patterns. In addition, the advancing electrification is also expected to intensify peak loads in the morning and evening hours. Thus, both the economic conditions for battery storage and system efficiency would be enhanced and costs would be streamlined.

The record-breaking growth in global wind, solar and storage installations in 2023, up 57 % from 2022 levels and driven mostly by the solar industry, is set to continue over the rest of the decade. However, limits to local grid capacity and lower realised power prices on spot markets are triggering extraordinary growth in battery energy storage buildout. 2023 saw global deployments reaching 44 GW / 96 GWh, a close to threefold increase relative to 2022 and the largest year-on-year rise on record. 2024 is forecast to see global deployments rise to 67 GW / 155 GWh, an increase of 61 % in gigawatt-hour terms (see chart 11).

As a result of government investments and policies, new utility proposals and capacity auctions are expected to substantially expand project pipelines, with annual additions in energy storage capacity forecast to increase to approximately 137 GW / 445 GWh in the year 2030, a compound annual growth rate of 21.2 % to the end of the decade relative to 2023 levels, compared to 8.9 % and 6.6 % for the global solar and wind markets during the same period. For the first time, global cumulative battery storage installed capacity is forecast to overtake pumped hydro in 2025, increasing exponentially to a total of 783 GW / 2,206 GWh by 2030, with deployment rates set to continue to accelerate into the 2030s and beyond.[19] In Europe, annual additions are expected to increase from circa 9 GW in 2023 to approximately 31 GW in the year 2030 (see chart 12). The need for enhanced system efficiency, renewable energy integration, lower energy supply costs and the imperative of avoiding emissions are the driving forces for this exponential growth market for battery storage.

CHART 11: **ANNUAL GLOBAL GROSS ENERGY STORAGE CAPACITY ADDITIONS**[20]

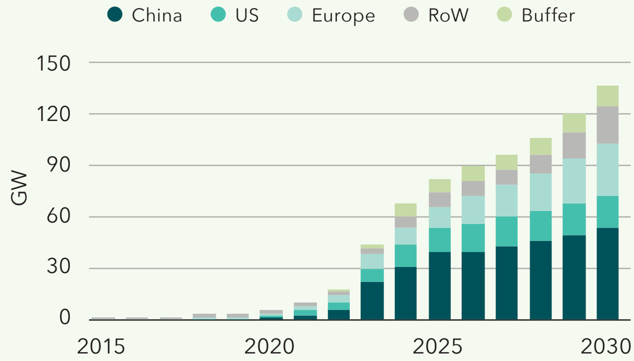
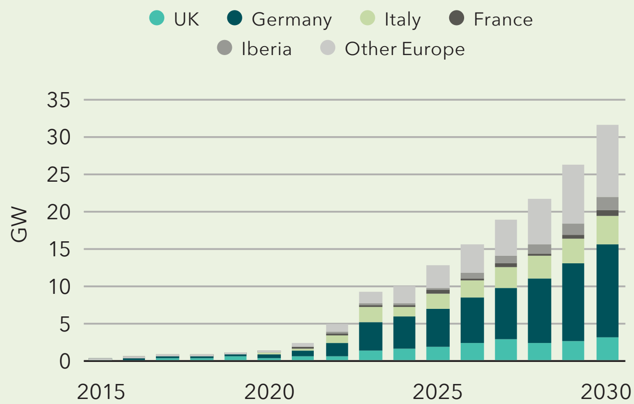


CHART 12: **ANNUAL GROSS ENERGY STORAGE CAPACITY ADDITIONS IN EUROPE**[21]



19 BNEF, '1H 2024 Energy Storage Market Outlook' (2024).
20 BNEF, '1H 2024 Energy Storage Market Outlook' (2024). 'Buffer' represents headroom not explicitly allocated to an application, 'RoW' indicates energy storage capacity additions in the rest of the world.
21 BNEF, '1H 2024 Energy Storage Market Outlook' (2024).

4. Aquila Group BESS Portfolio Highlights

Aquila Group launched its dedicated BESS strategy in 2016 in Japan and today BESS constitutes a key contributor to our real asset growth strategy. The Group has been deploying capital into dedicated BESS projects in the EMEA region since 2020-2021. Through several funds and on behalf of its clients, Aquila Capital Investmentgesellschaft is actively pursuing an ambitious growth strategy in the European market for storage solutions and rapidly growing a portfolio of highly attractive assets. In addition, Aquila Group's business unit Aquila Clean Energy has established dedicated development expertise for standalone projects and is targeting several co-located assets. The company's BESS development portfolio maintains a project pipeline exceeding 4 GW in capacity, spread across Germany, Spain, Portugal, Italy, Greece, Belgium, the Baltics and Nordics.[22]

Aquila Group gained valuable experience from a first mover advantage standpoint in relation to one of its first co-located battery storage projects in northern Japan back in 2016, a pioneer in the sector. The project comprised a 38 MW photovoltaic plant coupled with a 19.8 MW / 11.4 MWh lithium battery storage system, in what was then the largest solar and energy storage project in Asia. A valuable insight gained from developing the project was in minimising the developmental lead time with the use of a pre-installed and containerised system whereby the battery could be deployed in weeks rather than months.[23]

In Belgium, Aquila Group's business unit Aquila Clean Energy and a partner have successfully developed and commissioned one of the largest battery storage facilities connected to the national grid in Europe. The BESS project, with a capacity of 25 MW and energy volume of 100 MWh, was completed at the end of 2022. The project is one of the first four-hour battery storage facilities in continental Europe.

Furthermore, by observing relevant ESG standards and focusing on sustainable construction and operation, the project has also set a high benchmark. Building on our expertise in the energy markets, this project increases our commitment to supporting the energy transition while offering attractive and sustainable investment opportunities for our investors. The realisation of the project on the site of a former coal-fired power plant underlines the ongoing transformation taking place within the European energy supply system. The project benefits from optimised revenues from a combination of ancillary services, wholesale arbitrage, imbalance steering and capacity markets and was awarded a 15-year capacity market contract by the Belgian TSO Elia, expected to start in 2025. The performance of the asset in 2023 was above expectations, further corroborating the business model of multi-market optimisation for BESS in Continental Europe.

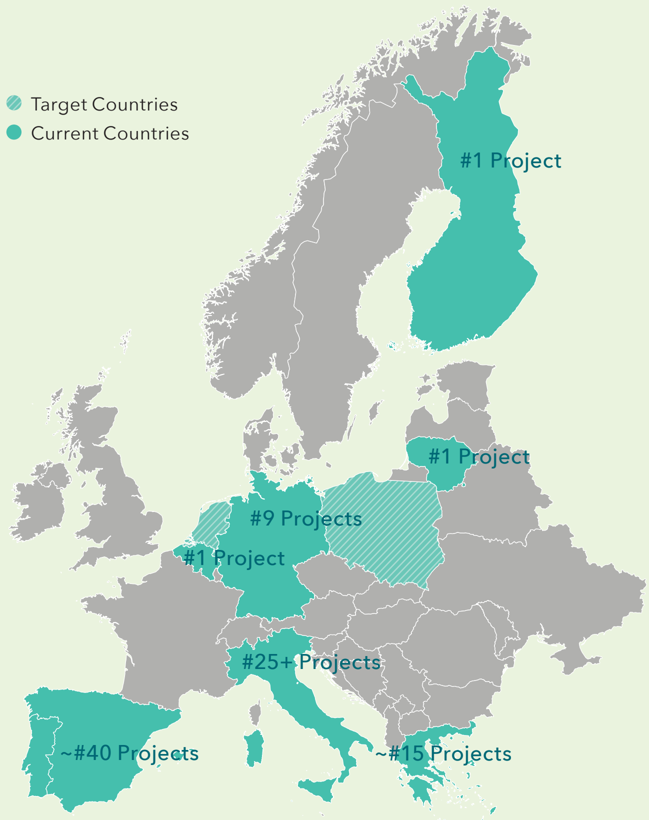
In Germany, Aquila Clean Energy is developing a large portfolio of battery storage projects consisting of 45 – 85 MW projects with two-hour storage duration, marking Aquila Clean Energy's consistent growth in Germany's stand-alone large-scale BESS market.

Aquila Clean Energy has also successfully commissioned a solar PV with co-located BESS project in Germany as of December 2023. The project was awarded the Innovation Tender Program and is eligible to receive a feed-in premium in addition to the market price. It is the first project in Aquila Clean Energy's portfolio that combines a renewable energy plant with a battery storage system. The project was initiated and developed in-house after capitalising on additional free space as a result of a repowering programme and is a stepping stone for further expansion in the more advanced German BESS market. The park has a solar capacity of 8.2 MWp along with 3.2 MW / 6.9 MWh BESS, produces clean energy enough to supply 3,500 households.

In Finland, Aquila Clean Energy is developing a large utility-scale standalone BESS greenfield project, expected to become operational in 2025 and one of the first projects of its kind in the country.

22 Aquila Group, as of May 2024. See chart 13 below.
23 Aquila Capital, 'Insights: charging ahead – renewables coupled with storage' (2018), available at: link

CHART 13: **AQUILA GROUP'S PRESENCE ACROSS EUROPE FOR STANDALONE AND CO-LOCATED BESS PROJECTS**[24]



Conclusion

The burgeoning market for battery energy storage systems presents a compelling investment opportunity amid the rapidly evolving energy landscape. As the electrification of industry and transportation accelerates and as variable generation from renewable energy sources comprises a growing share of the overall energy mix, battery storage is ideally placed to provide short-term flexibility by reducing losses and congestion in electricity grids, while also ensuring the provision of enough supply to meet peak demand through fast and accurate responses to market signals.

The synergistic potential of combinations of BESS with renewable energy, the improved economics of battery storage and technological progress in battery cells and system designs, are all facilitating the emergence of BESS as a cost-efficient and sustainable alternative to fossil fuel power plants. Changes to regulatory market designs across several European countries are also opening up additional long-term revenue streams through capacity market auctions, further accelerating BESS rollout. Moreover, greater volatility in certain trading markets, particularly in real-time imbalance markets, and wider opportunities for ancillary services are enhancing the revenue potential of BESS. Overall, battery storage increasingly offers investors attractive high-yielding sustainable investment opportunities whilst being a valuable source of diversification for renewable energy portfolios.

24 Aquila Group, via its business unit Aquila Clean Energy GmbH, as of May 2024.

About Aquila Group

Aquila Group is focused on generating and managing essential assets on behalf of its clients. Aquila Group contributes to the global energy transition and strengthens the world's infrastructure backbone by investing in clean energy, timber and sustainable infrastructure assets.

Currently, Aquila Group manages EUR 15 billion on behalf of institutional investors worldwide. Its primary objective is to continuously generate performance for its clients by managing the complexity of these essential assets.

Aquila Group manages wind energy, solar PV, hydropower and BESS assets of 19.8 GW capacity. Additionally, 2.2 million square metres of sustainable real estate and green logistics projects have been built or are under development. Aquila Group also invests in energy efficiency projects, carbon forestry and data centres. Aquila Group manages its own CO_2 footprint. Sustainability has always been part of Aquila Group's value system and is an integral part of its investment strategies, processes and management of assets. The company has around 750 employees from 60 nations, operating in 19 offices in 17 countries worldwide.

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