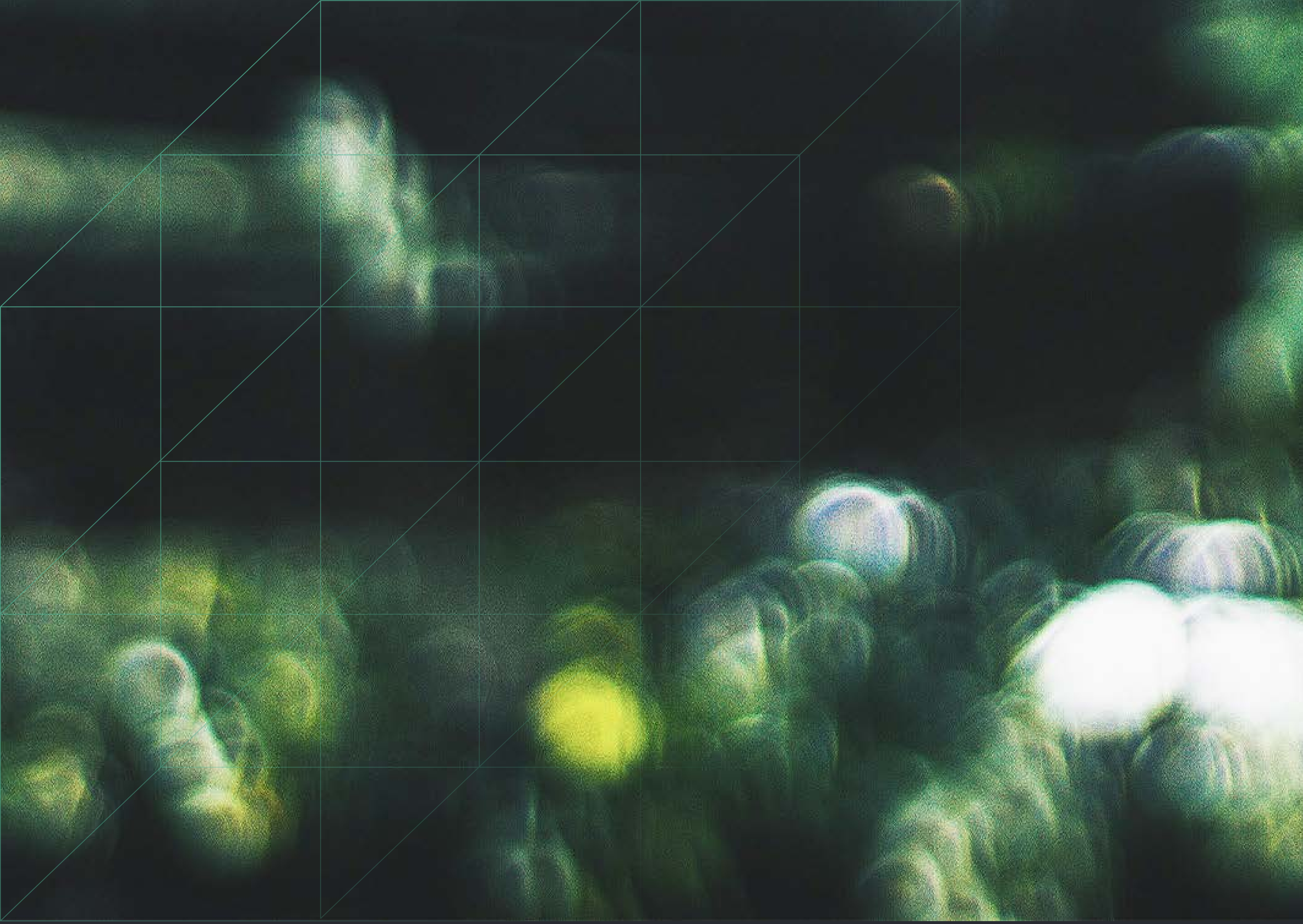

# Battery storage

## Stability for the energy transition

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TION

# Foreword

Dear readers,

In the interest of environmental protection, energy systems around the world must undergo fundamental transformation. Decarbonizing power generation is a cornerstone of the energy transition, and significant progress has been made in building out renewable energies such as wind and solar power to replace power generation using fossil fuels. There is broad consensus that growth in renewables needs to accelerate, but this will bring new challenges. Since wind and solar are dependent on weather conditions, they are intermittent, unlike conventional power plants which provide constant baseload power. This raises the concern that power grids could become unreliable, with accompanying increases in electricity prices, as the proportion of renewable energy increases. Nevertheless, it is important to note that in many countries wind and solar are now the cheapest sources of electricity. That competitiveness has been highlighted by the recent spikes in electricity prices in Europe, which are partly the result of the rising cost of fossil fuels. This increases the competitive advantage of renewables.

If power grids cannot accommodate an increasing proportion of renewables, the energy transition will be at risk. More energy storage solutions will be needed, to ensure that power grids are not a bottleneck in the energy transition.

Scalable, affordable energy storage technologies are already widely available, and among these technologies, battery energy storage systems (BESSs) have emerged as a frontrunner. For good reason: BESSs are based on proven and scalable technologies. The battery storage sector has the potential to achieve growth rates similar to those achieved by wind and solar over the past decade. BESSs are also an attractive investment opportunity with higher expected returns than wind and solar plants, and an effective way to diversify an investment portfolio.

Our goal at Tion Renewables AG is to lead into a new era of sustainable energy. We hope this white paper will answer questions, provide food for thought, and dispel any doubts about the technical and commercial viability of BESSs. We hope you enjoy reading our white paper and invite you to share your thoughts with us.

Dr. Martin Siddiqui
Co-CEO/CFO

Christoph Strasser
Co-CEO/CIO

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# 01.

# Executive summary

Renewables are expected to account for 80–90% of power generation globally by 2050. Due to their dependence on weather conditions, wind and solar power cannot provide constant baseload power during all hours of the day, and measures have to be taken to compensate for this intermittency. The good news is that such imbalances or fluctuations can be mitigated effectively using battery energy storage systems (BESSs). BESSs have a fast reaction time in the milliseconds range and high round trip efficiency (~90%). They are better suited than other technologies for mitigating both short-term and intra-day imbalances in power generation. Thanks to significant decreases in cost, BESSs will play an important role in stabilizing the grid of the future. That is reflected in many national targets. Globally, the utility-scale energy storage market is expected to increase to a total cumulative capacity of 250GW by 2030, an almost eightfold increase over the next 8 years relative to the currently installed storage capacity.

To monetize these advantages, BESSs can participate in three main revenue streams:

- **Ancillary services:** balancing services for when there are sudden mismatches in electricity generation and consumption in the grid, caused by plant outages, sudden changes in weather, etc.

- **Wholesale trading:** charging (buying electricity) during periods of low prices and discharging (selling electricity) during periods of high prices on spot markets at electricity exchanges

- **Capacity markets**: generation capacity procured by grid operators for pre-defined periods in the future

Investors can expect to generate returns of between 8–10% from these revenue streams for BESSs located in Germany and the UK. Due to exposure to market prices and the current relatively less proven nature of the technology, debt ratios are lower than for renewables at present. This may change in future as the technology stands the test of time and debt providers become more experienced in financing BESSs. Increased access to debt financing is likely to bring upside potential for equity investors. BESSs will benefit from the increasing power price volatility driven by increases in the proportion of renewable energy in the grid. That is in marked contrast to renewable power plant revenues, which could potentially be cannibalized by their own build-out. BESSs are thus an excellent way to provide additional diversification in the portfolio of a company such as ours, which is already invested in wind and solar parks.

# 02.

# The energy transition will require battery storage

In the midst of the energy transition, we face the challenge of intermittent renewables giving rise to three types of imbalances in the power grid. These can be categorized by their timescale:

## 01. Short-term imbalances:

Generation and consumption of electricity in the grid have to be balanced to keep the frequency of the grid's alternating current at a constant level. Within seconds after an imbalance occurs, fast frequency response capacity is activated to absorb the shock. Conventional power plants provide inertia to the grid because their turbines rotate at a frequency which is synchronized with the frequency of the grid. When an imbalance occurs, this rotational inertia slows down the change in frequency for a few seconds, giving the grid operator time to activate reserve capacity. Most types of wind and solar plants do not provide rotational inertia to the grid. This means that new sources of fast frequency response are required in grids with large proportions of intermittent renewables.[1] By short-term imbalances we mean the first 15 to 30 minutes of an imbalance, even though the cause of an imbalance may in fact last longer. During that timeframe, the imbalance must be addressed by using fast frequency response capacity. Subsequently it can be absorbed via other mechanisms.

## 02. Intra-day imbalances:

Generation from renewables tends not to match the daily pattern of electricity consumption. When weather conditions are good, other sources of electricity have to reduce their output to allow renewables to feed all their power into the grid. When consumption exceeds generation from renewables, other generators must increase their output. These intra-day imbalances, which occur on most days of the year and can last for several hours, lead to volatility in electricity spot market prices. This volatility increases as the proportion of renewables in the grid increases.

## 03. Seasonal imbalances:

The distribution of renewable power generation over the course of the year does not match seasonal consumption patterns. Efficient long-term energy storage solutions, which can store energy for several months with low losses, are therefore required. Of the three types of imbalances, this is the only one for which BESSs are not a suitable solution—other technologies are required.

To grasp the full potential of BESSs as a mitigant for the imbalances caused by renewables, it is helpful to understand how a BESS functions and to know its main components.

[1] NREL: "Inertia and the Power Grid: A Guide Without the Spin"

INFOBOX

## What a BESS consists of

A BESS consists of hardware and software components.

The hardware includes battery modules (consisting of many lithium-ion battery cells), battery racks and a power conversion system, which converts the direct current of the battery into the alternating current of the coupled power grid.

The key software components are the energy management system (EMS), the battery management system (BMS) and a supervisory control and data acquisition system (SCADA). The EMS acts as a higher-level operating system that can also integrate external systems. The function of the BMS is to monitor the performance data of the battery modules and to regulate their charging and discharging. The SCADA controls, monitors and protocols all BESS processes.

Housed in a container, the BESS is shielded from weather, and the BESS's environment is protected from fire.

## Attributes of lithium-ion batteries as BESS components

Different types of batteries can be used for large-scale energy storage, but the dominant technology is the lithium-ion battery. Lithium-ion batteries have several key benefits allowing them to effectively mitigate the short-term and intra-day imbalances described above.

Key benefits of lithium-ion batteries:

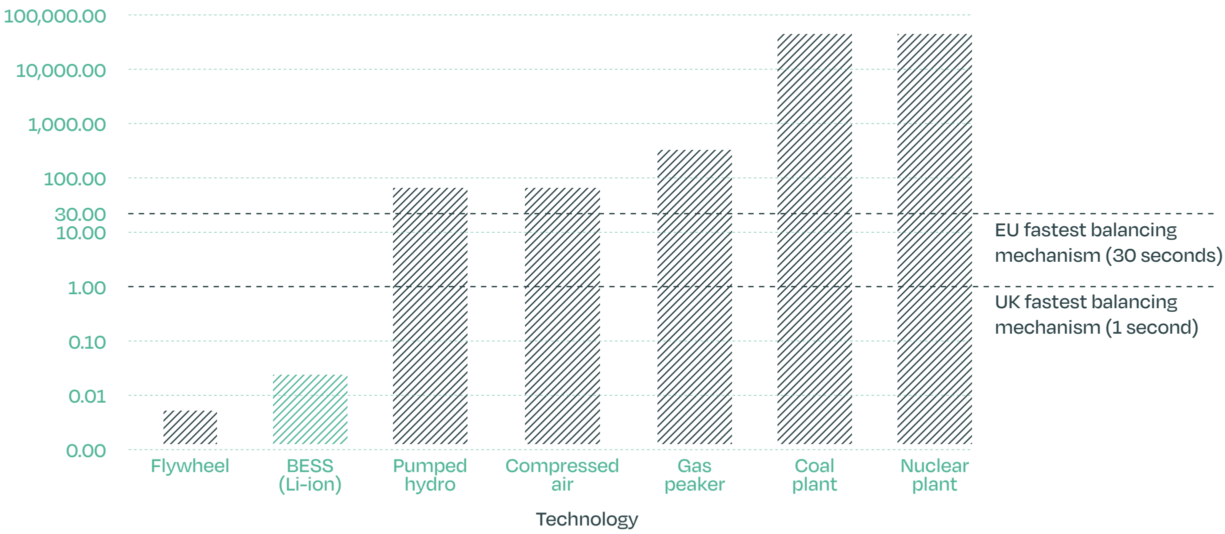
- They can start charging and discharging at full capacity within milliseconds.
- They can both increase and decrease the load in the grid.
- They can store electricity for several hours or days.
- They can charge and discharge multiple times per day.
- They can perform up to approximately 10,000 charging cycles during their lifetime.[2]
- They have a high power density (power capacity divided by weight).
- They have a high round trip efficiency (energy discharged divided by energy charged).

## Short-term storage to mitigate short-term imbalances

The main advantage of BESSs over other technologies is their fast activation time. They can supply electricity to the grid at full capacity within as little as 0.02 seconds, whereas conventional power plants have an activation time of at least a few minutes (e.g., gas peakers) or even hours (e.g., coal plants).[3] Flywheels have very fast reaction times, but they are currently too expensive to be used at scale and are therefore not a viable alternative to BESSs.[4] As shown in figure B, batteries are currently the only scalable technology with an activation time below the threshold for all types of frequency response services procured by grid operators in the UK and the EU.

**Activation times, in seconds[5]**

(Figure B)




[2] IEEE: "Comparative Review of Energy Storage Systems, Their Roles, and Impacts on Future Power Systems"
[3] Energy Brainpool: "FLEXIBILITY NEEDS AND OPTIONS FOR EUROPE'S FUTURE ELECTRICITY SYSTEM"
[4] ScienceDirect: "Storing Energy with Special Reference to Renewable Energy Sources"
[5] ScienceDirect: "Overview of energy storage systems in distribution networks: Placement, sizing, operation, and power quality"

INFOBOX

## Levelized cost of electricity (LCOE)

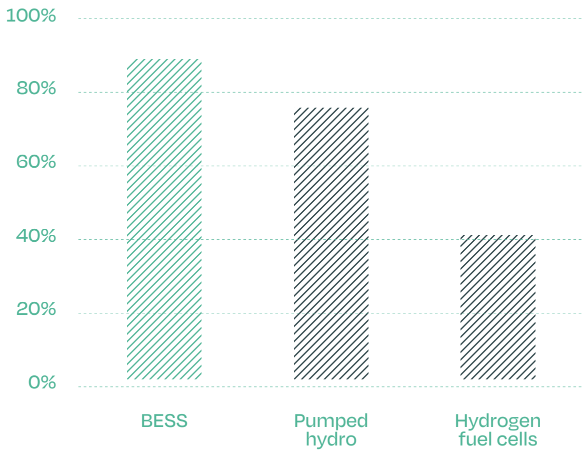
LCOE is the ratio of all discounted costs over the lifetime of a project to the discounted sum of the electricity supplied. Essentially, it relates lifetime costs to lifetime energy production. This measure is used because it allows for the comparison of technologies (e.g., wind, solar, natural gas) of different life spans, project sizes, capital costs, etc.

## Intra-day storage to mitigate intra-day imbalances

For bridging intra-day gaps between supply and demand, BESSs are a very suitable technology thanks to their high efficiency and low cost. When charged with 1MWh, they can discharge around 0.9MWh, resulting in a round-trip efficiency of around 90%, which is higher than other energy storage technologies such as pumped pumped hydro storage (70–85%) or hydrogen fuel cells (30–50%).

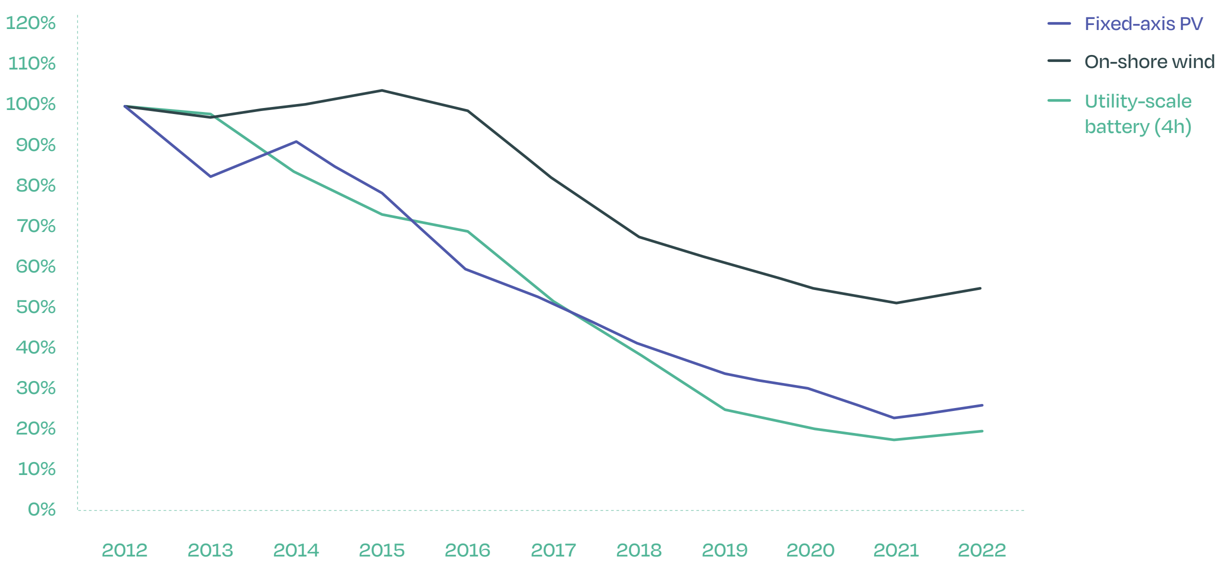
With a self-discharge rate of 0.15–0.3% per day, lithium-ion batteries are not, however, the most efficient technology for seasonal energy storage. While storing electricity in a BESS for days or weeks is technically feasible, the BESS would be idle most of the time and the fixed cost would be distributed over fewer cycles, driving up the cost per cycle. More cost-effective alternatives for medium- to long-term energy storage include pumped hydro and compressed air.[7]

**Round trip efficiency**[6]
(Figure D)




## Recent development

**Historic levelized cost of electricity, by technology**
(Figure E)




[6] IEEE: "Comparative Review of Energy Storage Systems, Their Roles, and Impacts on Future Power Systems"
[7] Greentech Media: "The 5 Most Promising Long-Duration Storage Technologies Left Standing"

| | | 2012 | 2022 | Change (%) |
|---|---|---|---|---|
| Utility-scale battery (4h) | USD/MWh | 721 | 153 | (79) |
| Fixed-axis PV | USD/MWh | 164 | 45 | (72) |
| On-shore wind | USD/MWh | 82 | 46 | (44) |

Figure E – Historic levelized cost of electricity, by technology [8]

Until just a few years ago, lithium-ion batteries were too expensive to be used for energy storage at scale. Partly as a result of the rise of electric vehicles, lithium-ion battery technology, which has been around since the 1970s in commercial applications such as calculators[9], has improved enormously. Thanks to improvements in technology, supply chains, and economies of scale, the levelized cost of electricity (LCOE) for a BESS (4-hour duration) has decreased from USD 721/MWh in 2012 to USD 153/MWh in 2022.[10]

## Ambitious BESS build-out targets

The future viability of BESS technology is reflected in national storage targets (figure F). Germany currently has 0.9GW of installed battery storage capacity, and is aiming for 26GW by 2037, implying a compound annual growth rate (CAGR) of 25% over the next 15 years. The UK is also well positioned, with installed storage capacity of 2.3GW and an ambitious goal of 12GW by 2030. The buildout of battery storage capacity is expected to be concurrent with the phase-out of coal in many electricity grids. This is no coincidence, as the phase-out of conventional generation capacity will lead to higher proportions of renewables with high intra-day volatility, while at the same time removing inertia from the grid, which will need to be offset by technologies such as BESSs.[11,12,*]

| | Coal phase-out | Renewable electricity target | Current battery storage capacity (2022) | National battery storage target | CAGR |
|---|---|---|---|---|---|
| Germany | 2030 | 100% by 2035 | ~0.9GW | 21–26GW by 2037 | 23–25% |
| UK | 2024 | 100% by 2035 | ~2.3GW | 20GW by 2030 | 31% |
| France | 2024 | 40% by 2030 | ~0.4GW | 2.5GW by 2030 | 26% |
| Spain | 2030 | 74% by 2030 | ~0.1GW | 2.5GW by 2030 | 50% |
| Italy | 2025 | 70% by 2030 | ~0.2GW | 1.5GW by 2030 | 29% |

Figure F – National battery storage targets, by country (Europe) [13]

[8] BloombergNEF: "1H 2022 LCOE Update"
[9] MDPI: "Brief History of Early Lithium-Battery Development"
[10] BloombergNEF: "1H 2022 LCOE Update"
[11] BloombergNEF: "European Energy Storage Market Overview"
[12] BloombergNEF: "EU Renewable Energy Targets 2030"
[13] TransnetBW GmbH: "Szenariorahmen zum Netzentwicklungsplan Strom 2037 mit Ausblick 2045, Version 2023"
[*] BloombergBNEF's definition of energy storage includes stationary batteries used in various applications. It excludes pumped hydro storage.

# 03.

## How batteries generate revenue

In the previous section we explained how BESSs mitigate the imbalances which result from having a higher proportion of intermittent renewables in the power grid, and why BESSs are well-suited for this task. Of equal importance is how BESSs monetize their advantages, and their commercial viability.

For most BESSs there are three revenue sources available: ancillary services, wholesale trading, and capacity markets.

## Ancillary services

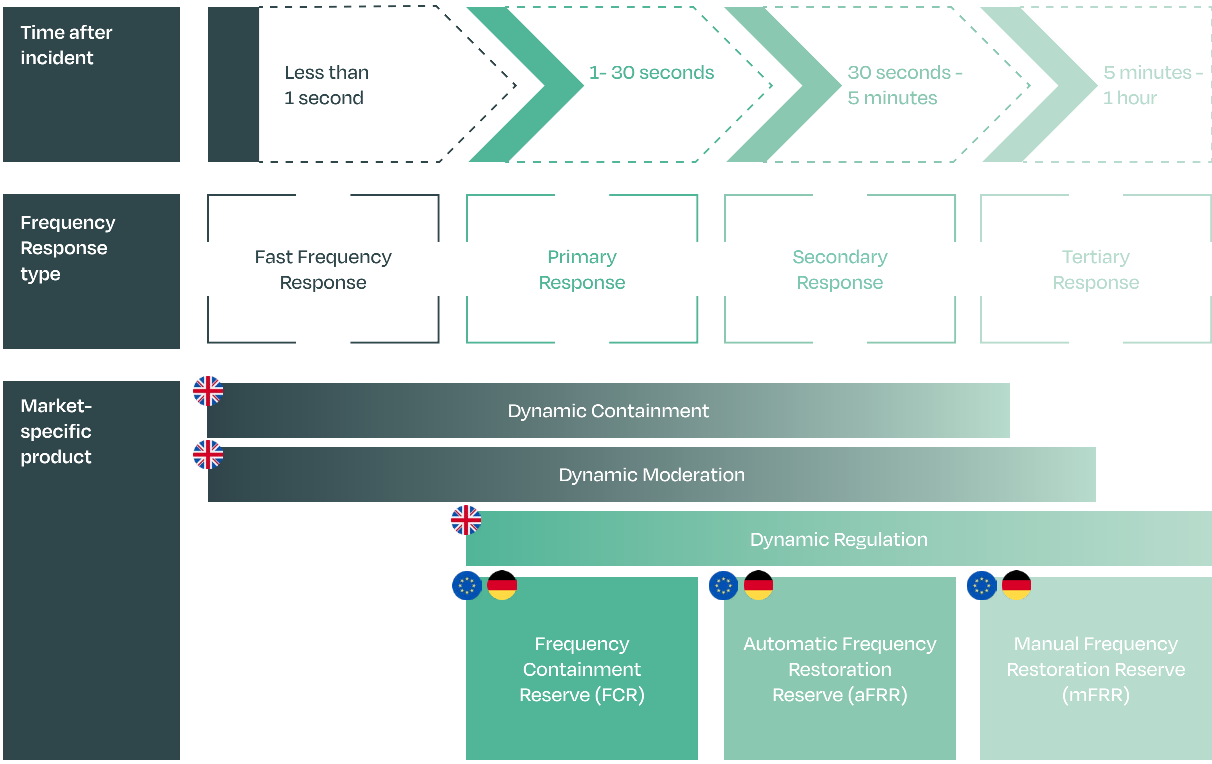
Ancillary services are usually procured by the grid operator via tenders, with bids submitted by BESS operators. The most important ancillary service is frequency response. This service is required when a sudden mismatch in electricity generation and consumption occurs in the grid, caused for example by grid or plant outages, sudden changes in weather, or unexpected variations in demand. Such incidents lead to a change in the grid's frequency, which must be kept close to 50 or 60 Hertz (depending on the country). These incidents can last from a few seconds to over one hour. The market for frequency response is divided into primary, secondary, and tertiary response. Primary response is the first response activated when an imbalance occurs. Typically, if the imbalance lasts for more than 30 seconds, secondary response takes over, and after 5 minutes tertiary response is activated. Some grid operators, such as National Grid in the UK, have introduced an additional category that requires an even faster response (<1 second) than primary response. Due to their fast response time, batteries can participate in all types of frequency response markets.

The fastest response services are usually the most lucrative ones, as only a few technologies meet the technical requirements. Figure G shows the different types of frequency response services currently being procured by the operators of the UK grid and the continental European grid (including Germany), based on the relevant time period after an incident, and the various types.

From a BESS owner's perspective, one of the advantages of deploying a battery to provide frequency response services rather than for wholesale trading is that the former is less costly. Frequency response is usually required for less than an hour, sometimes only minutes, so the batteries need to be discharged only partially. The chemical compounds inside the battery cells degrade with each charging cycle; therefore, they can only run a limited number of cycles before they need to be replaced. The implicit cost resulting from each cycle is known as degradation cost. This cost is lower if the battery only needs to run a partial cycle.

**Frequency response service types**

(Figure G)



## Wholesale trading

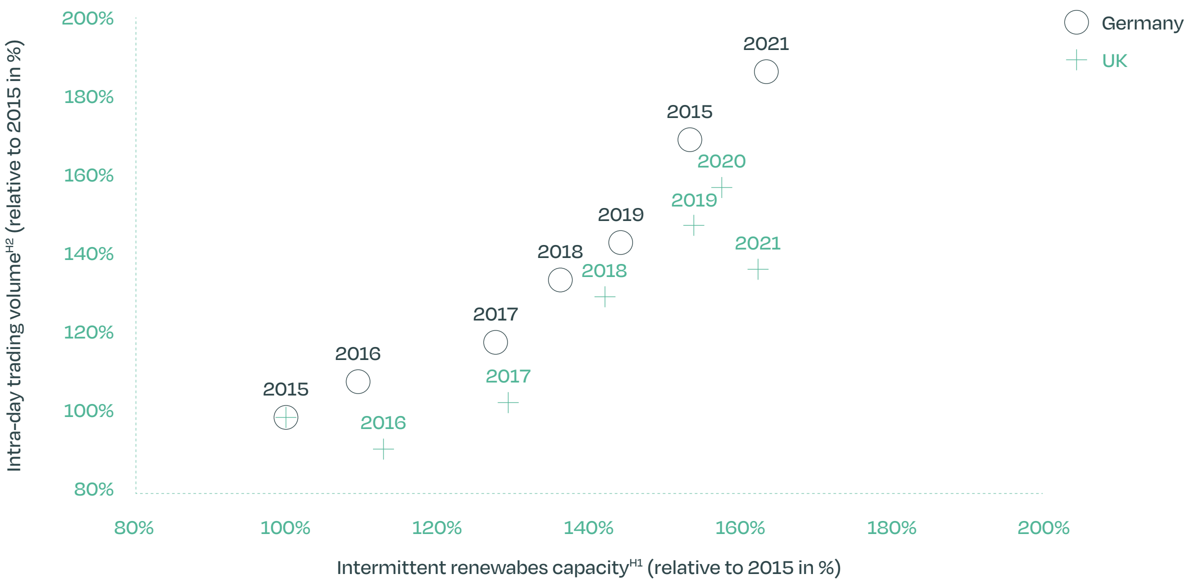
A significant share of the electricity in the grid is traded on power exchanges, where market participants such as utilities, traders or industrial consumers buy and sell contracts for the delivery of electricity during pre-defined future time periods. The spot market is the segment of this market where contracts for the same or the following day are traded. In the spot market, each day is typically divided into hourly, half-hourly or quarter-hourly periods and contracts for the supply of electricity during each period can be traded, with trading for each period starting on the day before the respective period (day-ahead market) and continuing that day until shortly before the start of the respective time period (intra-day market). The futures market is the market segment for all periods further in the future than one day. In the futures market, contracts can be traded weeks, months, or years before their delivery period.

While conventional power plant operators commonly sell their generated electricity directly to off-takers or traders in long-term contracts or in the futures market, many renewable energy producers sell a significant share of their generated electricity in the spot market[**]. The need to trade electricity in the spot market increases as more intermittent renewable energy is added to the grid. This trend can be illustrated by plotting the relative volume[***] traded compared to 2015 volumes in the intra-day market in Germany and the UK[****] each year against the relative level of intermittent renewables capacity, also with base year 2015. As shown in figure H below, there is a positive correlation between the two, suggesting that higher renewables capacity may lead to higher trading volumes.

Due to the intermittency of wind and solar energy, trading volumes evidently increase as the proportion of renewables in the grid rises. There is also an impact

**Intra-day trading volume vs. renewables capacity in the UK and Germany**[14,15]

(Figure H)

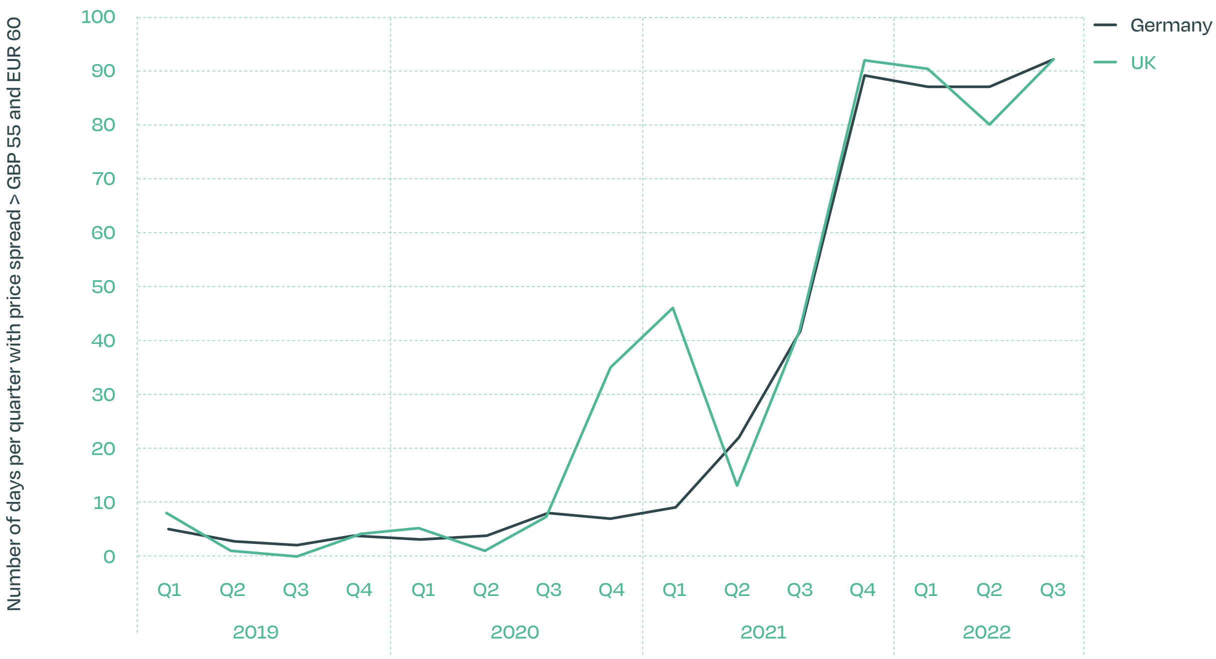



[14] BloombergNEF: "Capacity & Generation"
[15] EPEX SPOT, Annual press releases on trading results
[H1] Intermittent renewables include wind and solar
[H2] Sum of all intraday (continuous and auction) contracts traded on EPEX SPOT
[**] Small producers without in-house trading capability outsource the selling of electricity to specialized trading companies who sell it on their behalf, often in the spot market
[***] Sum of all intraday (continuous and auction) contracts traded on EPEX SPOT
[****] Intermittent renewables include wind and solar

on the volatility of intra-day electricity prices in some countries with high proportions of renewables in the grid such as Germany[16] and Australia.[17] Batteries can benefit from this volatility by charging (buying electricity) at times of low prices and discharging (selling electricity) at times of high prices. At times when generation from renewables is high or electricity demand is low, most or all electricity consumed is provided by renewables. During hours when the entire demand in the spot market is met by renewables, they become the marginal technology that sets the price. The marginal cost of renewables is close to zero as they do not require fuel inputs, which means prices can drop close to zero or even below zero when there is excess generation. In contrast, at times of high spot market demand or low generation from renewables, conventional power plants are the marginal, price setting generators. As the volume of electricity demanded in the spot market but not provided by renewables increases, additional conventional power plants are activated in the order of their marginal cost, starting from the lowest-cost producer, adding increasingly higher cost producers until spot market demand is met. In this mechanism, which is referred to as the merit order, the price at which supply equals demand in the spot market is always set by the most expensive generator currently active. This mechanism ensures that high prices of scarce resources required by conventional power plants, such as natural gas or carbon credits, are reflected in higher electricity prices in times of peak demand, usually causing a reduction in demand at these times. As a result of the merit order, volatility in fossil fuel prices is reflected in more volatile electricity prices, as observed during 2022. Increases in fossil fuel prices and increasing proportions of intermittent renewables both boost power price volatility, which is why wholesale trading is becoming a more important source of revenue for BESSs.

In recent years, the wholesale spot markets in the UK and Germany have provided increasingly favorable conditions for trading. The number of days per year during which the spread between the hour with the highest price and the hour with the lowest price exceeded GBP 55/EUR 60 respectively in the UK and German day-ahead markets has increased significantly since 2019, as shown in figure I.

**Trading opportunities for BESS in the UK and German day-ahead market 2019–2022** [18]
(Figure I)




[16] ScienceDirect: "Electricity prices, large-scale renewable integration, and policy implications"
[17] ScienceDirect: "On the impact of increasing penetration of variable renewables on electricity spot price extremes in Australia"
[18] Bloomberg Terminal, Hourly EPEX SPOT & APX UK Day-Ahead Auction Prices

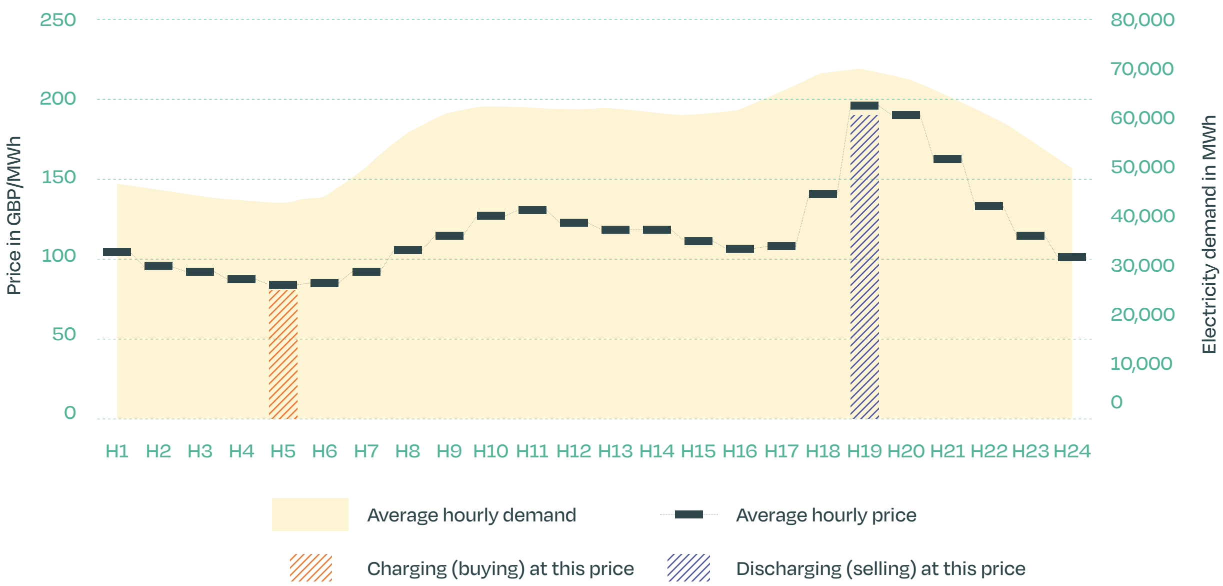
The thresholds of GBP 55/EUR 60 correspond to the approximate implicit degradation cost of a full charge-discharge cycle. The approximate degradation cost per cycle can be calculated by dividing the total capex per MW for a utility-scale BESS (estimated at approximately USD 480,000 by BloombergNEF[19] for a 1-hour system*****) by the total battery life of approximately 7,500 cycles. This gives a figure of USD 64 per cycle. As of November 2022, that is approximately GBP 55/EUR 60. Assuming no other costs, this analysis suggests that a 1-hour BESS could have performed around 200 profitable cycles by trading electricity in the day-ahead market in the UK in 2021, up from 13 in 2019.

With average hourly day-ahead price in the UK market and average hourly national demand in the UK grid****** for the full year 2021, figure J shows a typical trading cycle. The black bars indicate the hourly price, and the yellow area indicates the hourly demand. These numbers are not equal to those of any specific day in 2021, but rather show the typical pattern of demand and price levels throughout most days. Both peak in the evening hours. If one assumes a 1-hour BESS would perform one cycle to trade in the wholesale market on a day like this, that would imply the BESS should be charged between 4am and 5am at a price of approximately GBP 80/MWh (orange bar) and discharged between 6pm and 7pm at a price of approximately GBP 190/MWh (purple bar), resulting in gross revenue of around GBP 110/MWh.

A profit-optimizing strategy for a BESS usually includes more than one cycle per day, and stacking of different revenues, by participating in the wholesale market and in ancillary markets on the same day—resulting in higher total revenue. Daily price spreads sufficiently large to allow for profitable trades by BESSs occur regularly in many markets with high proportion of intermittent renewables in the grid. They are generally the result of persistent patterns of electricity generation and consumption. Revenues generated from wholesale trading are therefore a more reliable source of future income for BESSs in these markets than one might expect, but ancillary services have tended to be more lucrative in recent years.

**Visualization of an electricity trading opportunity on a representative day in the UK (2021 average hourly day-ahead prices)** [20, 21]

(Figure J)




[19] BloombergNEF: "1H 2022 LCOE Update"
[20] National Grid ESO: "Historic Demand Data"
[21] Bloomberg Terminal, Hourly APX UK Power Day-Ahead Auction Prices
***** The duration of a BESS is the ratio of its energy capacity (in MWh) to its power capacity (in MW). A BESS with equal energy capacity and power capacity can discharge electricity at its full power capacity for exactly one hour, and it is therefore called a 1-hour battery
****** National Demand is the sum of metered generation, but excludes generation required to meet station load, pump storage pumping and interconnector exports

## Capacity markets

On top of ancillary services, some grid operators also procure reserve generation capacity further into the future. These so-called capacity markets address intra-day or longer imbalances between demand and supply rather than the short-term imbalances addressed by frequency response. As most generation technologies can participate in capacity markets, the compensation tends to be lower than in frequency response markets or wholesale trading; therefore, capacity markets have so far not been an important source of revenues for BESS in most countries. This might, however, change in the future as capacity markets become increasingly important in some electricity markets. Entering into a capacity market contract could be an opportunity to decrease the risk profile of a BESS by accessing long-term predictable revenues.

## Optimization

BESS need to be managed in a way that optimizes their life-time profitability, considering all sources of revenues and costs. Deciding when a BESS should be used for trading or ancillary services and which state of charge the batteries need to have at each point in time is extremely complex. Therefore, most BESS are managed by utilities or traders with special expertise in this field, commonly referred to as battery optimizers. Based on all available data and the technical attributes of the BESS, the optimizer's task is to estimate the expected profit of each available revenue stream, taking into account the degradation cost, and to make sure that the state of charge of the batteries at each point in time is sufficient. The algorithms used by optimizers for wholesale trading and revenue stacking, while ensuring technical requirements are met and the battery is not damaged, are developed with the help of state-of-the art data science and machine learning techniques.

# 04.

## Risk-return profile of BESSs

We have laid out the need for battery storage as a mitigant for imbalances in the grid and showed how BESSs generate revenue.

Comparing key characteristics of BESSs and renewables can support the assessment of their risk-return profiles. The table below is based on data for stand-alone utility-scale 1-hour BESSs, versus utility-scale non-tracking on-shore wind plants and solar plants in the UK and in Germany.

**Key characteristics of BESS compared to renewables**
(Figure K)

| | BESS | Wind/Solar |
|---|---|---|
| **Equity IRR** | 8–10%[x] | 4–8%[x] |
| **Debt ratio** | 0–30%[x] | 60–90%[x] |
| **Main revenue streams** | Wholesale markets, ancillary services, capacity markets | Power purchase agreements, subsidies, wholesale markets |
| **Operational life** | 7,500 cycles (~21 years assuming one cycle per day)[x] | 25–30 years[x] |
| **Build-out of renewables** | More volatile power markets → Higher revenue potential | More hours with low or negative prices → Lower capture price (price cannibalization) |
| **Other key risks** | Changes to market design, nascent technology | Meteorological conditions, grid curtailment |

[x] BloombergNEF: "1H 2022 LCOE Update"

According to BloombergNEF, internal rates of return for BESS projects range between 8% and 10%, which is significantly above the range for on-shore wind and solar projects (4% to 8%). That difference is partly because in most battery storage projects, the proportion of contracted revenue is lower than in renewables projects. Although some providers offer revenue stabilizing products such as revenue floors, and BESSs can participate in capacity markets, most revenues are non-contracted and depend inter alia on power price volatility and developments in the ancillary services markets. By contrast, with renewables it is not uncommon to enter into a power purchase agreement (PPA) to sell up to 100% of the energy generated at a fixed price over a long period of time.

The lower proportion of contracted revenues is one reason why debt ratios (as estimated by BloombergNEF) are relatively low. BESSs are at present a relatively less proven technology than renewables, but as they become more established, lenders will become more comfortable with the technology and revenue stacks and debt ratios will increase.

Unlike a wind or solar plant, the life of a BESS is heavily dependent on cycling strategy. Depending on the revenue streams available and their profitability, more or fewer charge-discharge cycles are run per day. It is common to seek an average number of daily cycles of between one and two cycles. According to BloombergNEF, a typical BESS can perform around 7,500 full cycles during its operational life; the battery cells then have to be replaced after reaching the maximum degradation level. To obtain an approximate figure for the operational life of a BESS without cell replacement, one divides the maximum cycles figure by the anticipated number of cycles. At least one battery cell replacement is required for a BESS to achieve an operational life comparable to that of a solar plant.

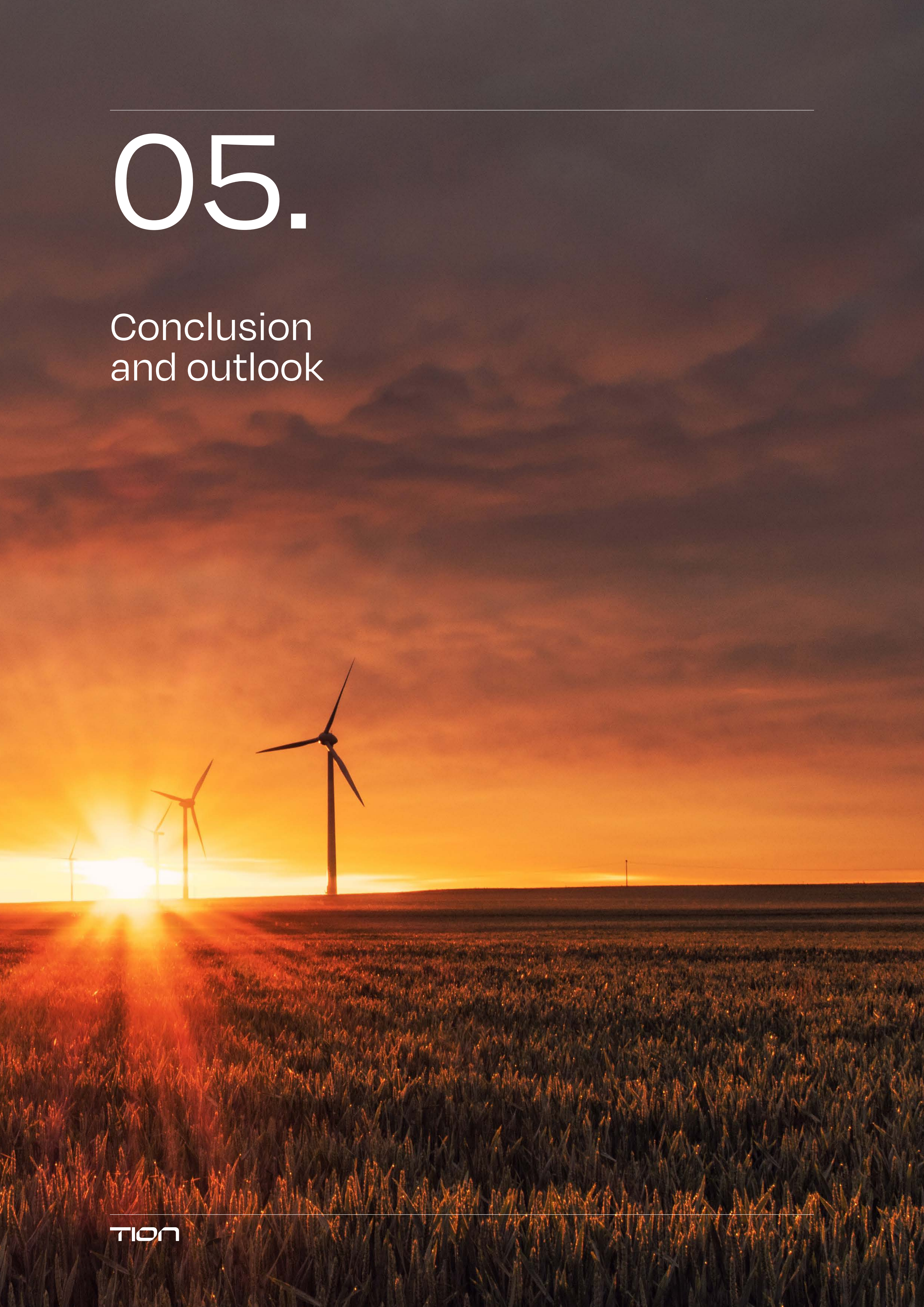
Another important consideration is the complementary nature of BESSs to renewables. On the one hand, the increasing proportion of renewables in the energy mix leads to higher intra-day volatility and subsequently to higher revenue potential, as BESS can benefit from the increasing volatility. On the other hand, increasing renewables penetration leads to an increase in hours with low or negative electricity prices when renewables production is high, thereby decreasing the profitability of renewables ("cannibalization"). In that sense, what's bad for renewables is good for BESSs, making them a natural hedge for investments in wind and solar plants.

The risk profile of BESS investments differs from renewables in other aspects too. Changes in market design and regulation may make it more difficult to access individual revenue streams. As BESSs are still in a relatively early stage of development, some technological risks, such as faster degradation of battery cells, remain. This can, for instance, lead to increased insurance costs.

Overall, it is our view that investments in BESSs offer an attractive risk-return profile, especially as a complement to renewables in an investment portfolio. We believe that long-term favorable drivers, such as improved access to financing, as outlined earlier, bring along additional upside potential for investors.

# 05.

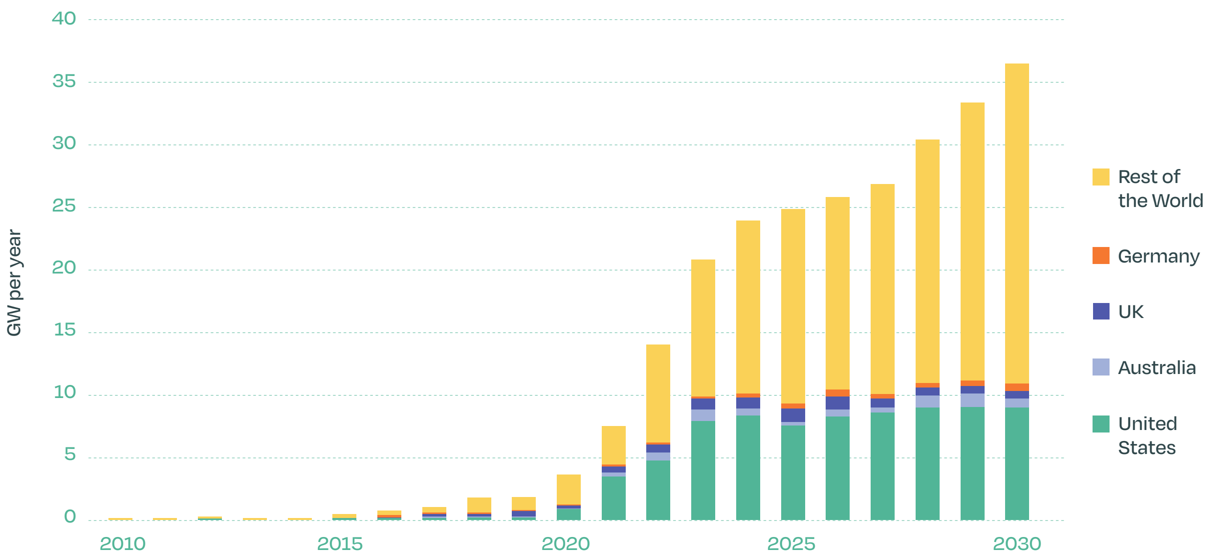
## Conclusion and outlook



BESSs are an important technology with an attractive risk-return profile. The total global cumulative utility-scale energy storage market is expected to grow to 250GW by 2030. This represents a compound annual growth rate (CAGR) of 29% from 2022 to 2030 (figure L), and an increase by a factor of 7.8 relative to the currently installed storage capacity of 32GW.

**Annual addition in energy storage capacity, by country (2010–2030e)[22]**

(Figure L)




As long as there is no finish line to the energy transition in sight, this path is not only full of challenges and obstacles, but also full of opportunities that only need to be seized. BESSs are one of these opportunities and help stabilize the power system as a whole. The revenue streams from ancillary services and wholesale trading are well established, and investment in BESSs can be very rewarding.

With a battery storage projects pipeline of more than 1.5GW, Tion Renewables AG is playing a leading role in the growing battery storage industry as we move into a new era of sustainable energy.

[22] BloombergNEF: "Global Energy Storage Market to Grow 15-Fold by 2030" (2022)

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## About Tion

Driven by the commitment to accelerating the transition toward a clean energy future, Tion Renewables AG operates a portfolio of wind and solar power plants across Europe with a capacity of 167 megawatts (MW), holds a stake in the European IPP clearvise AG, and has priority access to a pipeline of more than 5 gigawatts (GW) of wind and solar power plants as well as battery energy storage systems (BESS). By investing into both infrastructure and businesses within the energy transition space, Tion makes use of the full spectrum of opportunities offered by the increasing global efforts to decarbonize our electricity system. The Company went public in 2019 and is tradable on Xetra as well as other German open market exchanges (ISIN: DE000A2YN371). To learn more, visit www.tion-renewables.com or connect with us on LinkedIn.

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