247 ENERGY

The Case for Utility-Scale Battery Energy Storage Parks

Five grid functions. One investment case.

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May 2026

FOREWORD

A Question Already Answered

There is a question that energy investors, grid operators, and policymakers will have to answer over the next decade. It is not whether utility-scale battery energy storage parks will become essential infrastructure. That question has already been settled by the physics of grid operation and by the economics of renewable energy deployment. The real question is who will build them, where, and on what terms.

I write this paper not to sell a product but to explain a technology and the five grid functions it performs. Battery Energy Storage Parks are, in my view, among the most consequential investments available in the energy sector today. They solve a problem that is growing faster than any single policy response can address. They generate revenue across multiple simultaneous streams. And they are operational now, at scale, without waiting for a future generation of technology to mature.

The energy transition is often discussed as if the core challenge is one of generation. That narrative is incomplete. Renewable energy generation capacity is being added at record pace, and in many markets it is now the cheapest form of new electricity. The real constraint is stability. When the wind does not blow and the sun does not shine, grids need an immediate response. When a surge of solar generation floods the network in the middle of a spring afternoon, grids need somewhere for that energy to go. When a major transmission fault knocks out a section of the network, grids need a resource capable of restarting the system independently. Battery energy storage addresses all of these challenges simultaneously, and it addresses them within seconds.

The five functions described in the following pages are not theoretical constructs. They are operational realities in grid systems across the world, contracted and compensated by grid operators who have no alternative mechanism capable of responding at the required speed. Understanding these functions in depth is, I believe, the first step toward understanding why capital deployed into utility-scale battery storage today is capital well positioned for the decade ahead.

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THE CONTEXT

Grids Were Not Built for This

The electricity grids that power modern economies were designed in a world where generation was largely controllable and demand followed predictable patterns. Large thermal power stations, whether coal, gas, or nuclear, could be ramped up and down in response to shifting consumption. Frequency remained stable because the rotating mass of turbines provided physical inertia. Voltage along transmission lines was managed because generation was concentrated in large facilities close to major demand centres. The entire system was engineered around the assumption of controllable, dispatchable power.

That world no longer exists, and its disappearance is accelerating. Wind and solar generation now account for a growing share of total electricity production in most developed markets, and that share is rising year by year. Renewables are not dispatchable in the traditional sense. They produce when conditions allow. A solar farm generates at full capacity at noon on a cloudless summer day and nothing at all after sunset. An offshore wind turbine operates at its rated output during a storm and falls silent when the air is still. The grid must absorb this variability in real time, every second of every day, while maintaining the precise frequency and voltage tolerances that industrial equipment, digital infrastructure, and consumer appliances all depend on.

The conventional response to grid stress has been to build more transmission infrastructure and to keep thermal backup capacity running in reserve. Both approaches are expensive, slow, and increasingly impractical. A major transmission reinforcement project typically requires a decade of planning, permitting, and construction before it delivers a single additional watt of capacity. Keeping a gas turbine running at partial load as a frequency reserve costs money and produces emissions even when it is not generating useful electricity. Neither solution scales at the speed the energy transition demands.

Battery Energy Storage Parks change this equation fundamentally. They can absorb excess generation within milliseconds and inject it back into the grid just as fast. They require no fuel supply, no combustion, and no warm-up time. They can be sited at points of grid stress without requiring proximity to a fuel source. And they can perform multiple grid services simultaneously, generating revenue from several markets at once. For investors with a clear view of where the energy system is heading, they represent an opportunity that is both financially compelling and structurally necessary.

> ***The transition is not a generation problem. It is a stability problem. Battery storage is the only technology capable of addressing all dimensions of grid stability simultaneously, at the speed the grid requires.***

The scale of the challenge is not modest. Grids across Europe, North America, Asia, and the Middle East are all facing versions of the same structural pressure. The intermittency of renewables creates surpluses and shortfalls that can occur within minutes and persist for hours. Grid operators are raising capacity payments and ancillary service fees because the scarcity of fast-response resources is genuine and growing. The market signals are clear, and the regulatory direction in most jurisdictions is toward greater integration of storage into grid planning frameworks rather than less.

FUNCTION ONE

Frequency Regulation

The Foundation of Grid Stability

Grid frequency is the heartbeat of an electricity network. In most of the world, alternating current systems operate at either 50 Hz or 60 Hz, and the tolerance for deviation is narrow: a sustained frequency deviation of more than half a hertz is enough to trigger automatic disconnection of sensitive industrial equipment, and a deviation beyond two or three hertz can cause cascading failures across the entire network. Maintaining frequency within this tight band is one of the most fundamental responsibilities of a grid operator, and it is a task that must be performed continuously, in real time, without interruption.

Frequency deviates whenever the balance between generation and demand is disturbed. If a large power station trips offline unexpectedly, generation drops while demand remains constant, and frequency falls. If a major industrial consumer disconnects suddenly, demand drops while generation continues, and frequency rises. In a traditional grid with large thermal generators, the rotating inertia of turbine masses provided a natural buffer: the kinetic energy stored in spinning rotors would automatically and immediately resist frequency changes, buying time for operators to bring additional capacity online. As thermal generation is displaced by wind and solar, this inertia is diminishing, and frequency deviations are becoming sharper and faster.

Battery energy storage systems respond to frequency deviations within milliseconds. This response time is not incremental; it is transformational. A gas turbine providing frequency response typically requires several seconds to detect a deviation, initiate a ramp, and begin injecting additional power into the grid. A battery storage system can complete the same task before most control systems have even registered that a problem exists. The response is electronic rather than mechanical, and it is bounded only by the speed of digital control systems and the physical capacity of the inverter hardware.

This speed advantage translates directly into commercial value. Grid operators across Europe and beyond have created dedicated frequency response markets that pay storage operators to hold capacity available for deployment at any moment. Products such as Frequency Containment Reserve, Automatic Frequency Restoration Reserve, and similar instruments in other jurisdictions provide contracted income streams that are independent of the spot electricity price. These contracts are typically structured on a capacity basis: the storage operator is paid for the megawatts of response capability they make available, regardless of whether the response is actually called upon. The result is a predictable revenue stream that underpins the investment case for storage assets even before considering other income sources.

> ***A battery energy storage system provides frequency response in milliseconds. That speed cannot be replicated by any thermal generation technology, and no amount of capital investment in conventional plant can close that gap.***

The growing penetration of inverter-based generation across global grid systems is not a temporary trend. It is the structural direction of travel. As the share of renewable generation continues to rise, the premium placed on fast-response frequency services will rise with it. Grid operators are already adjusting their market designs to reflect this reality, creating products specifically designed for battery storage and tightening the response time requirements in ways that effectively exclude slower technologies. Investors in battery storage parks today are positioning themselves in a market where their core service is becoming more valuable, not less, as the energy transition progresses.

FUNCTION TWO

Load Levelling and Peak Shaving

Deferring Infrastructure, Reducing Cost

Electricity demand does not flow evenly through time. In virtually every market in the world, consumption is concentrated around predictable peaks: mornings when households and businesses start their days, evenings when industry winds down and domestic activity intensifies. These peaks can be two to three times the level of overnight consumption, and they impose costs on the entire system far beyond what average load patterns would require. Grid infrastructure, from transmission lines to local substations to generation capacity held in reserve, must be sized for the peak rather than the average. The result is a substantial stock of capital equipment that sits underutilised for most of its operating life, paid for by all consumers through network charges regardless of when they consume electricity.

Battery energy storage parks address this structural inefficiency directly. By charging during periods of low demand and low prices and discharging during periods of high demand and high prices, storage assets smooth the load profile seen by the grid. A storage system that captures surplus overnight generation and releases it during the morning or evening peak effectively reduces the maximum demand the network must serve, allowing grid operators to defer or avoid costly infrastructure investments. This capability, often called load levelling or peak shaving depending on the specific application, is valuable both at the transmission level and at the distribution level, where local network congestion is an increasingly common and expensive problem.

For commercial and industrial consumers, peak shaving represents one of the most direct and calculable sources of value from energy storage. Large industrial facilities are typically billed in part on the basis of their maximum demand in a given settlement period. A brief production surge or the simultaneous startup of multiple large machines can drive up the peak demand reading for an entire billing month, increasing costs substantially. A storage system that clips these demand spikes, holding the facility within a lower demand ceiling, delivers savings that can be precisely quantified against the tariff structure that applies. For investors in storage parks that serve industrial offtake markets, this creates a direct link between storage capacity and auditable cost reduction for the end customer.

At the grid level, the investment case for peak shaving is typically captured through capacity markets and through congestion relief contracts with network operators. Transmission System Operators and Distribution System Operators in many jurisdictions are actively seeking storage as an alternative to network reinforcement, recognising that a storage asset positioned at a point of network congestion can deliver the same effective capacity as a new cable or transformer at a fraction of the cost and in a fraction of the time. These contracts, sometimes called Distribution System Operator flexibility services or Transmission Constraint Management, represent a growing source of contracted revenue for well-positioned storage assets.

The economic logic of load levelling is likely to strengthen over the medium term for a structural reason: the growth of electric vehicle charging and the electrification of heating are adding new, lumpy demand patterns that stress local networks in ways that traditional demand management programmes cannot easily address. The periods of peak demand are becoming less predictable and more geographically distributed, creating congestion in parts of the network that were previously operating comfortably within their rated capacity. Battery storage, which can be installed quickly and repositioned if necessary, is better suited to addressing this evolving pattern of network stress than any fixed infrastructure alternative.

FUNCTION THREE

Voltage Support

Stabilising the Network Under Pressure

Voltage is the second fundamental parameter of grid stability, and it is the one that most directly affects the quality of power delivered to end users. While frequency is a systemwide measure of the balance between generation and demand, voltage is a local property that varies across different points in the network. Industrial equipment, data centres, and sensitive electronic systems all require voltage to be maintained within narrow limits: too high and insulation can be damaged, too low and equipment will trip offline or fail to perform as designed. Managing voltage across a geographically dispersed network, under conditions of variable generation and changing load, is one of the more technically demanding aspects of grid operation.

Voltage instability is becoming more common as the composition of the grid changes. Traditional synchronous generators, the large rotating machines at the heart of thermal power stations, naturally produce reactive power as part of their operation, and reactive power is the primary tool for controlling voltage in an alternating current network. As synchronous generators are retired and replaced by wind turbines and solar inverters, the natural supply of reactive power diminishes. Modern inverters can be configured to provide reactive power support, but only if they are properly specified and operated with this capability in mind. Battery energy storage systems with four-quadrant inverters are particularly well suited to voltage support because they can both absorb and inject reactive power continuously, independently of whether they are charging or discharging active power at any given moment.

This capability has commercial significance that extends beyond the technical function. Grid operators in most jurisdictions pay for reactive power services, either through direct compensation mechanisms or through access to the network. Storage assets that can demonstrate certified reactive power capability have access to a revenue stream that is largely invisible to operators of simpler assets. The reactive power market is not the largest source of income for a storage operator, but it is a relatively stable and predictable one, and it can be stacked on top of frequency response and capacity contracts without significantly affecting the storage asset in terms of state of charge management.

There is a broader investor consideration here as well. Voltage instability at the distribution network level is one of the key constraints that is limiting the pace of electric vehicle adoption and the rollout of rooftop solar in densely populated areas. Network operators are under regulatory pressure to accommodate both trends, and they are increasingly willing to pay for storage solutions that relieve voltage pressure rather than imposing connection restrictions. The value of voltage support is therefore not only the direct service payment; it is also the option value of owning an asset that becomes more strategically important as the grid continues to evolve.

FUNCTION FOUR

Black Start Capability

Restoring the Grid After a Major Failure

A total grid blackout is among the most serious events that can befall a modern economy. The loss of electricity to industrial facilities, hospitals, data centres, water treatment plants, and transport systems simultaneously creates risks that cascade well beyond the immediate disruption to power supply. The process of restoring a blacked-out grid is complex, time-consuming, and constrained by the need to rebalance supply and demand at each stage of energisation. It requires generation assets capable of starting and operating without an external electricity supply, which is why the capability is known as black start.

Historically, black start capability was provided by hydroelectric plants, certain gas turbines, and diesel generators. These assets could be brought online independently and used to energise sections of the network, progressively connecting larger generation units until normal operation could be restored. As the mix of generation changes, the availability of these traditional black start resources is under pressure. Many of the thermal plants that historically provided this service are being retired, and their replacement with battery storage is both technically feasible and increasingly recognised by grid operators as the preferred path forward.

Battery energy storage systems with black start capability can energise a transmission or distribution circuit within seconds of receiving the command, without any external power supply. They can hold a stable frequency and voltage as other generation assets are connected sequentially, absorbing the transient imbalances that inevitably occur as each unit comes online. They can be cycled repeatedly through the restoration process if the initial attempt fails, without the fuel supply or warm-up constraints that limit conventional black start plant. For grid operators who have seen the consequences of prolonged restoration events, the reliability advantages of battery-based black start are compelling.

From an investment perspective, black start contracts are among the most attractive in the grid services market. They are typically long-term, often running for ten years or more, and they are structured as availability payments rather than utilisation payments. The contracted party is paid for holding the capability available, not for the frequency with which they are called upon to use it. In a well-run storage portfolio, a black start contract anchors a portion of the asset revenue with near-certainty for the duration of the contract term, significantly reducing the overall revenue risk of the investment. Competition for these contracts is limited by the technical requirements, which not all storage configurations can meet, giving operators with properly specified assets a structural advantage in the procurement process.

> ***Black start contracts are among the most durable revenue instruments in the grid services market. They are paid for capability, not utilisation, and they run for long terms. For investors, they represent an anchor of income certainty in an otherwise variable revenue stack.***

The strategic importance of black start capability is also increasing in a geopolitical context. Grid resilience has moved up the agenda of energy policymakers across the world following a series of high-profile grid failures and as awareness of cyber and physical vulnerabilities has grown. Governments and regulatory bodies are investing in the identification and procurement of resilience-enhancing grid services, and black start capability is consistently near the top of the list. Operators of storage assets with certified black start capability are likely to find themselves in a strong position as these procurement programmes expand.

FUNCTION FIVE

Renewable Energy Time-Shifting

Bridging Generation and Demand

The fundamental challenge of renewable energy is not that it is intermittent in an unpredictable way. In most cases, the patterns of wind and solar generation are reasonably foreseeable hours or even days in advance. The challenge is that these patterns do not align with the patterns of demand. Solar generation peaks in the middle of the day, when industrial and commercial demand is present but residential demand is lower. Wind generation is often strongest overnight or during storm events, when demand across the economy is at its lowest. The result is a growing misalignment between when electricity is produced and when it is consumed, a misalignment that manifests in negative electricity prices during periods of surplus and scarcity premiums during evening peaks.

Battery energy storage resolves this misalignment directly. A storage asset that charges when generation exceeds demand and discharges when demand exceeds generation performs what is commonly called renewable energy time-shifting or energy arbitrage. The economic value of this function is the spread between the price at which electricity is purchased for charging and the price at which it is sold during discharge. As the penetration of renewables increases and the frequency of negative or near-zero prices during generation peaks grows, the average arbitrage spread available to storage operators tends to increase. The asset that is positioned to capture this spread is not simply providing a financial service; it is performing an essential physical function for the grid, storing electrons that would otherwise be curtailed and making them available at a time and place where they can be used.

The interaction between time-shifting and renewable energy curtailment is particularly important for investors to understand. When the grid cannot accommodate all available renewable generation, the operators of wind and solar farms are instructed to curtail their output. In many cases, this curtailment is compensated through contract-for-difference mechanisms or capacity guarantees, which means that electricity is effectively paid for twice: once to the renewable generator for not producing it, and again to conventional backup plant for producing a replacement. A storage asset positioned at or near a point of regular curtailment can purchase this excess generation at close to zero cost, store it, and sell it during the subsequent scarcity period, capturing a spread that reflects the true cost of the inefficiency it is resolving.

The long-term outlook for arbitrage revenues is a subject of active debate among energy economists. Some argue that as more storage is built, spreads will compress as the market becomes more efficient. This is a legitimate consideration, and it argues for ensuring that storage investment cases are not built on arbitrage revenues alone. The more robust position, and the one that reflects actual market design in most jurisdictions, is that time-shifting revenues will coexist with frequency response, capacity, and network services revenues in a stacked revenue model. Each source of revenue is drawn from a different market, operates on a different time scale, and responds to a different set of dispatch signals. A storage asset operated with the right software and market access can participate in all of these markets simultaneously, switching between them as relative prices and operational constraints dictate.

The time-shifting function also underpins the environmental value proposition of utility-scale storage, which is increasingly relevant for investors with sustainability mandates. Each megawatt-hour of renewable generation that is stored and subsequently delivered to the grid in place of fossil generation represents a direct, measurable emissions reduction. This substitution is trackable, auditable, and increasingly reflected in the regulatory and market frameworks that govern grid operation. As carbon accounting requirements tighten and the value of avoided emissions is more formally integrated into market pricing, the contribution of storage to decarbonisation will be reflected in commercial terms, not only in sustainability reporting.

Revenue Stacking and Asset Economics

The five functions described in the preceding sections are not mutually exclusive. A single battery energy storage park, operated with appropriate software and market access, can participate in frequency response markets, load levelling contracts, reactive power services, black start agreements, and energy arbitrage simultaneously. This capability, known in the industry as revenue stacking, is the defining economic characteristic of utility-scale storage and the primary reason that the investment case for well-positioned assets is more robust than a single-revenue comparison might suggest.

The mechanics of revenue stacking require explanation. Different grid services operate on different time horizons. Frequency response operates on a second-by-second basis. Load levelling typically operates across daily cycles. Black start contracts are rarely called upon but must be available at any time. Energy arbitrage responds to price signals that shift across hours and days. A battery storage system does not perform all of these functions at exactly the same moment; rather, it is dispatched by a management system that optimises the allocation of its capacity across multiple markets according to the relative value of each service at any given time. When frequency response is more valuable than arbitrage, the system prioritises frequency response. When a black start event is required, all other activities pause and the black start function takes precedence. The software that enables this optimisation is as important to the revenue outcome as the hardware itself.

The risk profile of stacked revenue streams is more favourable than any single stream in isolation. Frequency response revenues reflect the value of fast-response capability, which tends to be highest when renewable penetration is growing and grid inertia is falling. Arbitrage revenues reflect the volatility of electricity prices, which tends to be highest during periods of strong renewable generation combined with demand variability. Capacity revenues reflect the adequacy of total system generation, which tends to be strongest when traditional thermal capacity is retiring faster than new firm capacity is being added. These drivers do not all move in the same direction at the same time, which means that a portfolio of revenues drawn from all of them is inherently more stable than a bet on any single market.

Asset lifetime economics for utility-scale battery storage have improved substantially over the past decade, and the improvement trajectory continues. Battery cell costs have fallen by more than 90 percent since 2010, and further cost reductions are expected as manufacturing capacity continues to expand. The combination of lower capital costs, longer asset lifetimes enabled by improved battery management, and higher revenue capture through more sophisticated software optimisation means that the internal rates of return available to storage investors today compare favourably with other infrastructure asset classes. This is particularly true in markets with well-designed capacity and ancillary services frameworks, where the revenue certainty is highest and the competition for contracted positions is most structured.

Project financing for utility-scale storage is also maturing. Early storage projects were largely funded on corporate balance sheets because lenders were unfamiliar with the technology and uncomfortable with the revenue risk. That is changing rapidly. Infrastructure debt funds, development finance institutions, and commercial banks have all developed track records with storage assets, and project finance structures with 15 to 20-year debt maturities are becoming more common. The availability of long-term financing at infrastructure rates of interest further improves the equity return profile for project investors, particularly in markets where contracted revenues provide sufficient certainty to underwrite the debt service.

TIMING AND URGENCY

Why the Window Is Now

The investment case for utility-scale battery storage is not simply a matter of recognising a long-term trend. It is a question of positioning ahead of a structural shift that is already underway, at a moment when the competitive landscape still rewards early movers with access to the best sites, the most favourable permitting conditions, and the most attractive contracted positions.

Grid operators across the world are committing to storage procurement targets that will require substantial increases in installed capacity over the next five to ten years. These targets are driven by the retirement of legacy thermal generation, the continued rollout of renewable capacity under national climate commitments, and the explicit recognition by regulators that storage is the most effective available tool for managing the transition. The procurement frameworks being designed today will determine who captures the contracted revenue streams of the next decade, and those frameworks typically favour operators who can demonstrate operational track records rather than those entering the market for the first time.

The development pipeline for utility-scale storage is also constrained by factors that are not easily accelerated. Grid connection capacity at the points in the network where storage is most valuable is limited, and connection queues at the relevant grid operators are long. Planning and permitting processes for large installations, while typically shorter than those for generation projects, still require time and local engagement. Equipment supply chains, while far more robust than they were three years ago, are not unlimited, and operators who secure equipment orders early are better positioned than those who wait for prices to fall further. The combination of these development constraints means that the first-mover advantage in storage project development is real and material, not simply a sales narrative.

There is also a regulatory window consideration. The capacity market and ancillary service frameworks that currently provide the most favourable contracted revenue terms for storage were designed in part to attract investment into an emerging technology. As the technology matures and the supply of contracted positions is more fully allocated, the terms available to new entrants are likely to become less generous, not more. Investors who commit to storage during the period of strong regulatory support, before that support is reduced as the technology is deemed fully commercial, capture a structural advantage that is difficult to replicate later.

None of this is to suggest that the window will close in the near term or that storage will cease to be a compelling investment once the current phase of market development concludes. The demand for grid flexibility is structural and growing. But the combination of falling costs, strong contracted revenue terms, maturing financing markets, and growing regulatory urgency that characterises the present moment is not one that will persist indefinitely. The case for moving decisively is not driven by urgency for its own sake. It is driven by a clear analysis of where the market is now and where it is heading.

Our Approach to Utility-Scale BESS

247 Energy develops, builds, and co-invests in utility-scale Battery Energy Storage Parks at 100 MW and above. This activity is led by a dedicated entity within the 247 Energy Group. We are not a manufacturer of battery cells, a seller of hardware, or an engineering procurement and construction contractor working on a fixed fee. We are developers and operators with a long-term stake in the assets we build, which means our interests as a business are aligned with the performance of the assets over their full operational lifetime.

Our current European project pipeline spans two regions and five countries, with a combined capacity of 505 MW / 2,025 MWh under development. These projects are at various stages of development, from early site identification and grid connection application through to advanced permitting and financing. We also pursue similar investments in Asia and the Middle East, markets where the need for grid stabilisation is acute and the regulatory environment for storage is developing rapidly.

Our approach to each project is shaped by the five-function framework described in this paper. We do not develop storage projects that are designed to capture only one or two revenue streams. We seek sites and grid connection points where the full stack of frequency response, capacity, voltage support, black start, and arbitrage revenues can be captured simultaneously, because we believe that the stacked revenue model is both more financially robust and more valuable to the grid operators we partner with. The software and market access arrangements we put in place for each asset are designed to maximise this stacked revenue potential from the first day of commercial operation.

We work with co-investors and project developers who share our long-term view of grid infrastructure. Our pipeline represents a substantial deployment opportunity for capital seeking exposure to the energy transition in its most operationally concrete form. We are not proposing a fund structure or a financial product. We are proposing a direct engagement with the development and operation of assets that perform essential functions for grids that cannot function without them.

For parties interested in exploring co-investment in our current or future projects, we welcome direct engagement. We are in a position to discuss specific opportunities in detail, including grid connection agreements, permitting status, revenue modelling assumptions, and financing structures, under appropriate confidentiality arrangements. Our goal is to find partners who understand what they are investing in, share our conviction about the structural importance of this asset class, and are prepared to take a long-term view of the value it represents.

> ***We do not build storage parks to sell them. We build them to operate them, because the long-term performance of these assets is where the real value of the investment is captured.***

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