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DATA CENTERS WHITE PAPER

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Enabling the AI Revolution with Utility-Scale Battery Energy Storage Systems

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An urgent challenge is facing the world's energy and technology sectors: how can the Artificial Intelligence (AI) boom be powered quickly, reliably, and safely while keeping climate emissions in check?

Leading tech companies are in a race against time to secure reliable, large-scale power sources for their energy-hungry data centers. In the United States, data centers are projected to increase their share of total electricity consumption from 4% today to 12% by 2030,[1] with an additional 50 GW of data center capacity expected to be built during this period. Given this pressing AI-driven demand, solutions are beginning to emerge.

One key learning so far is that utility-scale battery energy storage systems will be a critical part of the answer to powering data center expansion. These systems are quick to deploy, have intelligent operational capabilities, and can function as both generation and transmission assets – all while rapidly improving in cost competitiveness.

Energy storage is ideally positioned to drive the AI revolution through three primary use cases:

- **Installed at data center load** – providing low-emission, cost-effective, and reliable firm generation and/or backup power, while also reducing the grid connection needs for data centers.
- **Combined with utility-scale solar and wind in renewable energy power purchase agreements** – providing round-the-clock clean power under a PPA.
- **Utilized as electricity transmission assets** – accelerating data center deployment in grid-constrained areas.

This white paper explores these applications in depth, highlighting how **battery storage powers the AI revolution**.

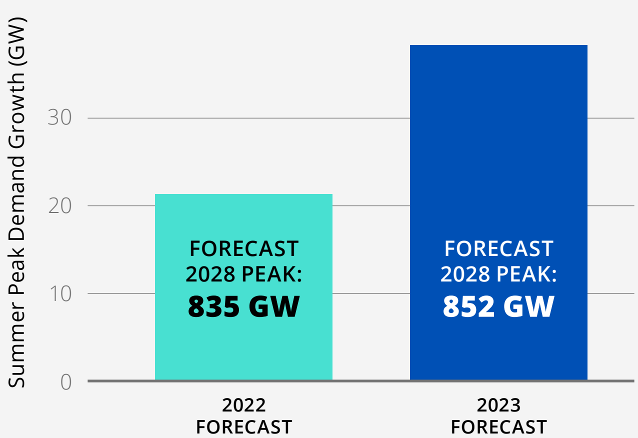
Introduction

Rapid Data Center Demand Growth and Electricity Procurement Challenges

U.S. grid operators have been waking up to the development. Between 2022 and 2023, grid planners nearly doubled their five-year load growth forecasts, with some warning that even these estimates may fall short.[2]

FIGURE 1.

5-year Nationwide Growth Forecast



U.S. grid planners foresee peak demand growth of more than 35 GW through 2028

Source: Grid Strategies and E3

The International Energy Agency (IEA) updated its two-year global energy use forecast in July 2024, factoring in projections for electricity consumption driven by data centers and AI.[3] The IEA estimates that, collectively, these digital technologies accounted for nearly 2% of global electricity demand in 2022 – a figure that could double by 2026, approximating the electricity usage of a country the size of Japan.[4]

Data center demand growth is uneven across the globe, leading to interconnection delays at certain sites targeted by developers.

In West London, a historic data center hub, new facilities must wait until 2030 to connect to the grid.[5] Similarly, in Ireland – where data centers accounted for 21% of national electricity demand in 2023[6] – the state-owned grid operator has set specific requirements for connecting new data centers, prioritizing those that can generate their own electricity. By 2031, 28% of electricity demand in Ireland is expected to come from data centers and "other new large energy users."[7]

In both Dublin and Frankfurt, Germany, new data center developments can wait from three to more than five years to be supplied with the power they need for full operation.[8]

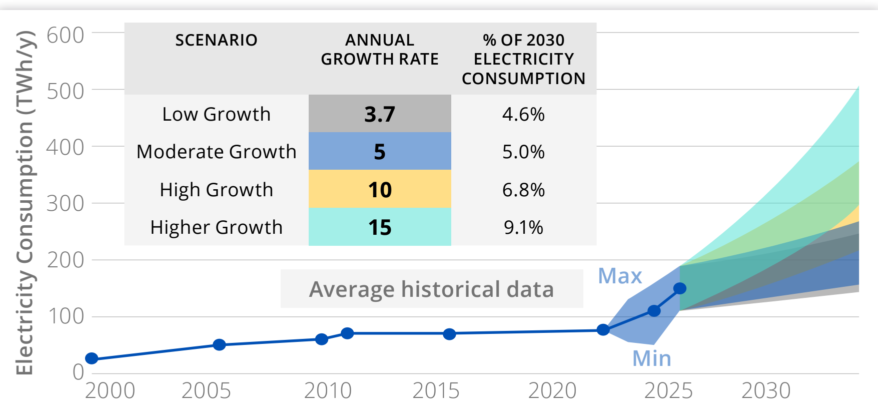
In Australia, over 4.4 GW of data center projects are under development on the country's grid, putting strain on an already stretched electricity network. In response to the pressure on networks, almost 4.7 GW of utility-scale batteries commenced construction in the first nine months of 2024.[9]

FIGURE 2.

Projections of potential electricity consumption by U.S. data centers: 2023-2030. % of 2030 electricity consumption projections assume that all other (non-data center) load increases at 1% annually.

Scenarios for AI-energy demand growth

Source: EPRI



SCENARIO	ANNUAL GROWTH RATE	% OF 2030 ELECTRICITY CONSUMPTION
Low Growth	3.7	4.6%
Moderate Growth	5	5.0%
High Growth	10	6.8%
Higher Growth	15	9.1%

In the U.S., data center electricity demand is also concentrated, with 15 states accounting for 80% of the nation's total consumption. Virginia leds this trend, particularly in and around Loudoun County, which has emerged as a major data center hub.[10] Dominion serves Loudoun County and expects load to grow from 2.8 GW in 2022 to over 7 GW by 2032 – more than doubling in a decade. Other key regions for data centers include Texas, Arizona, Ohio, and the Midwest.[11] The concentration of demand in these regions places additional pressure on the electricity grid and its resources, including the ability to receive new grid connections for data centers, which now can be delayed for years in markets with high levels of data center growth.

Given that data centers require power supply at higher reliability standards than typical utility customers, grid planners and operators must ensure these needs are met through capacity resources. These resources are required in addition to regular generation to ensure system reliability during peak conditions, when energy demand surges or supply is reduced due to outages.

Energy consultancy E3 estimates that an additional 20 to 100 GW of generation capacity will be necessary in the U.S. by 2030 to meet the energy and grid reliability demands of data centers. E3's analysis puts the requirement for additional capacity resources between 5 to 20 GW.

FIGURE 3.
2030 Resource Capacity with 75% Renewables to Meet Data Center Energy Demand with Varying Efficiency Improvements

Source: E3

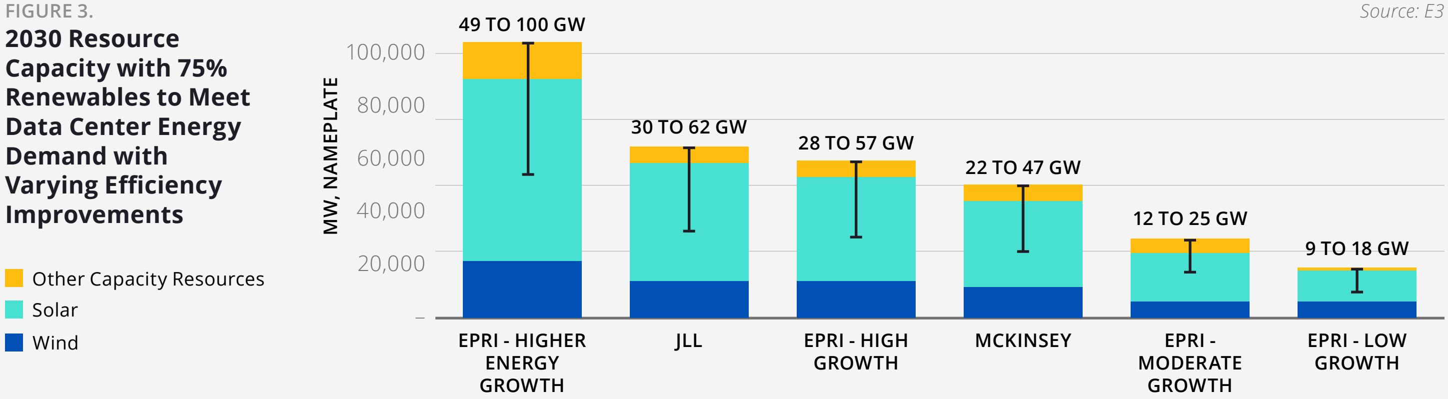


FIGURE 4.
Effective Capacity Contribution of Renewables and Other Capacity Resources to Meet Incremental Data Center Peak Demands

Source: E3

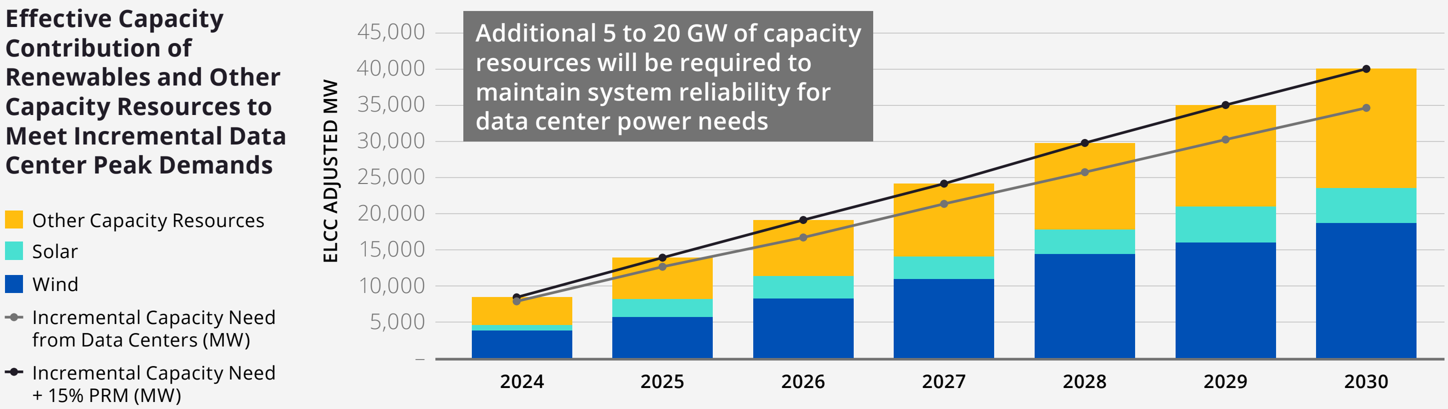
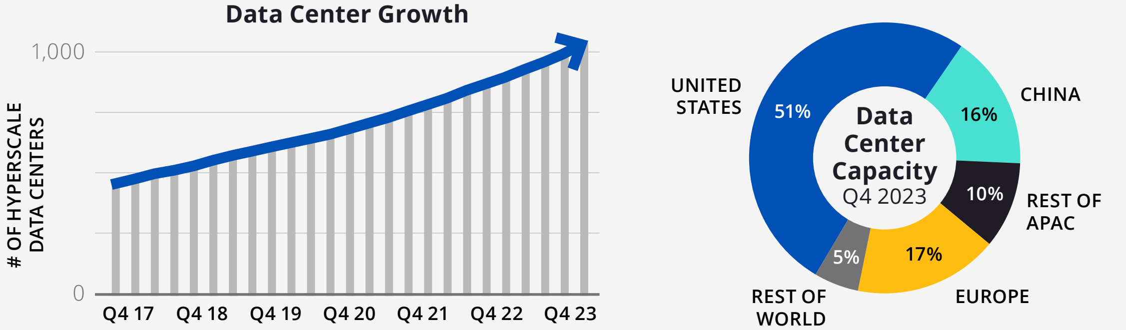


FIGURE 5.
Hyperscale Data Centers

Source: Synergy Research Group

Led by United States, worldwide capacity of hyperscale data centers continues to grow



EXAMPLE

Google Emissions Impact

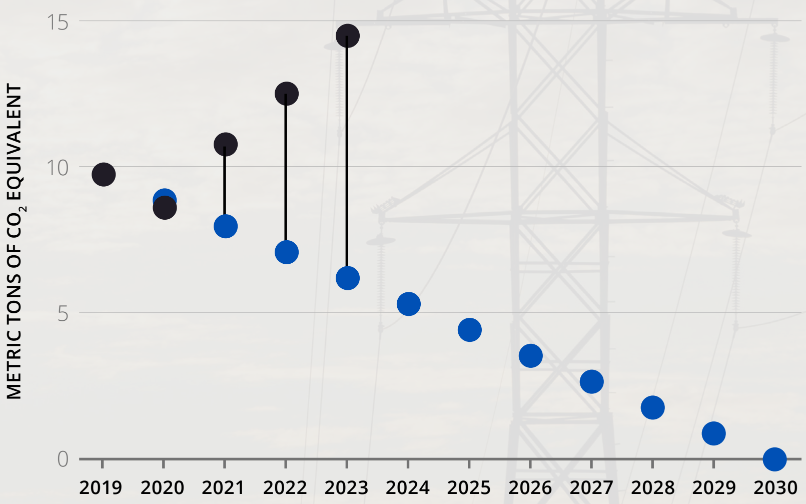
Between 2010 and 2023, Google invested $3.1 billion in renewable energy and signed 115 PPAs, securing 14 GW of renewable capacity,[12] with a goal to operate on carbon-free electricity 24/7 by 2030.[13]

However, rising electricity demand from data centers led to Google's 2023 carbon emissions being 48% higher than in 2019. As demand for AI services grows, cloud providers like Google and Microsoft are expanding their hyperscale data center footprint, further increasing emissions. By 2030, cloud providers like Google Cloud and Microsoft Azure are projected to handle 60 to 65% of AI workload demand in Europe and the U.S.[14]

Microsoft's emissions have also risen nearly 30% since 2020,[15] reflecting an industry-wide trend.

Google's Emissions

Artificial intelligence is putting the tech giant's climate goals in peril



AI is threatening Google's climate goals

Note: Blue dots represent linear decline to net-zero emissions goal

Source: Bloomberg

Use Case 1: On-site Generation Systems

Data center developers are fundamentally rethinking their energy supply strategies regarding on-site generation, including how firm power, necessary back-up power, and the grid connection is secured.

Professional services provider Turner and Townsend reports that many data center developers now say that access to adequate power is delaying projects. The *2023 Data Center Cost Index* highlights this shift in priorities among data center developers:

- **80%** reported "delays or challenges in securing power ... had a severe impact on data center delivery."
- **82%** prioritized power availability over delivery costs.
- **92%** considered access to power more important than the data center's location.[16]

In response, data center owners are exploring ways to take greater control of their energy supply. Nearby generation that can directly power the data center, paired with energy storage, is emerging as an increasingly attractive solution.

Circumventing the Queue

Co-located energy systems can include generation sources like solar or thermal power and may be paired with energy storage, which can significantly reduce the energy demanded from the grid by the data center. This is key because it reduces the total amount of MW requested in an interconnection application by a data center, which is key for both reducing costs and critically also allowing for faster interconnections where the data center can connect based on existing grid infrastructure.

Further, a larger onsite battery system can provide the necessary power and allow the data center to operate in an islanded mode without grid connection for some period of time. This setup can reduce grid connection costs and avoid interconnection delays, effectively "bridging the gap" when full utility service is unavailable,[17] which is valuable for technology players looking to get ahead in the AI race. In these cases, on-site storage enables advanced capabilities such as grid-forming and black start functions, allowing data centers to operate as islanded microgrids during grid outages.

While battery storage is most cost effective at utility scale with four to six hours of capacity, an on-site solar-plus-storage system can reliably provide 14 to 16 hours of electricity directly to a data center in most active markets. Applications for this solution are expected to grow in number as demand for resilient and self-sufficient power options increases.

Additional Benefit: Plugged in On Site

Battery energy storage systems can effectively provide backup power while decreasing reliance on diesel generators – thereby reducing Scope 1 emissions while delivering additional benefits, explored in the next section of this paper.

Attitudes toward diesel generators are changing rapidly among data center operators. Digital infrastructure provider Vertiv has noted that emissions-free alternatives, like large-scale battery storage, are now being considered for "sustained or even continuous operation."[18]

Replacing on-site diesel generators with battery storage allows a data center to become a more flexible participant in the electricity network. On-site storage can perform functions that thermal backup generation cannot, such as peak shaving, providing ancillary services, and preventing curtailment of on-site solar power. This shift enables data centers to transition from being energy "sinks"– inflexible loads – to flexible assets.[19]

In Summary

In the context of the AI boom, large-scale on-site generation paired with storage presents a compelling value proposition:

- Rapid deployment enables data centers to be developed with reduced dependence on the grid, directly addressing one of the primary obstacles for tech players racing to develop more data centers.
- Once grid-connected, data centers with on-site storage become flexible assets, helping to lower system costs.
- Replacing diesel generators for backup power reduces Scope 1 emissions.

EXAMPLE

On-Site Generation for Google

In 2022, Fluence installed a 2.75 MW battery storage system at Google's St. Ghislain data center in Belgium – Google's first zero-emission backup project.

Integrated by Centrica Business Solutions, the system provides clean backup power during outages and participates in the ancillary services market. Using advanced software, the battery serves as part of a virtual power plant, enhancing grid stability and supporting Google's 2030 carbon-free energy goal.

This collaboration highlights how on-site storage can reduce diesel generator reliance, improve grid resilience, and position data centers as flexible, emissions-free energy assets.[20]

Use Case 2: Renewable Energy Power Purchase Agreements and Hybrid Applications

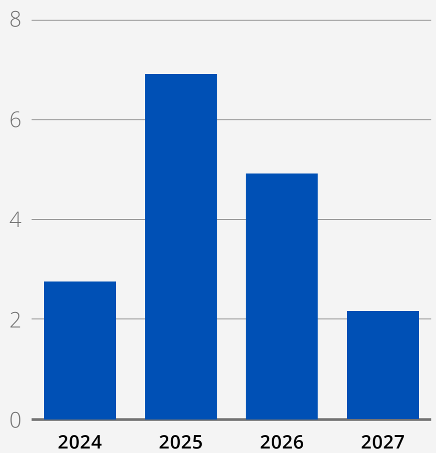
Massive investment in new generating capacity will be necessary to meet the exponential growth in AI-driven data center demand. Given the scale of the challenge, a diverse portfolio of electricity offtake agreements will be required – creating strong momentum for renewable energy power purchase agreements (PPAs).

With the U.S. expected to need new generation investment in the region of $50[21] to $100 billion,[22] some utilities have turned back to gas-fired generation to bridge the short-term supply gap, with plans to add 16.9 GW of new capacity being reported.[23]

By contrast, in Europe, data center demand is projected to primarily drive investment in clean energy and flexibility solutions, given stringent European regulations.[24]

FIGURE 7.

Total Planned Natural Gas Generation Capacity (GW)



Source: RMI

In the Asia-Pacific region, emerging data center locations like India, Vietnam, Malaysia, and Indonesia are experiencing rapid growth[25] – countries in which electricity demand is growing fast, yet renewable PPA marketplaces are nascent.

Meanwhile, established hubs in Australia, Japan, Singapore,[26] and Taiwan[27] are also seeing rising data center demand while simultaneously pursuing ambitious decarbonization goals.

Changing PPA Landscape

The renewable energy PPA landscape appears to be changing. In Europe, data center operators are utilizing PPAs and renewable energy certificates (RECs) to meet climate commitments,[28] while in the APAC region, pioneering PPA deals have emerged in countries like Australia[29] and Malaysia.[30]

In the U.S., demand from data centers could reinvigorate the PPA market, where renewable PPA adoption declined by 16% in 2023.[31] PPA prices have been rising, with solar prices up 3% in Q2 of 2024 and wind prices increasing by 7% in Q2, marking a 13.5% year-on-year rise. Delays in permitting and interconnection have been identified as major factors constraining PPA volume and driving up prices.[32]

For example, the Midcontinent Independent System Operator (MISO) network in the U.S. has faced significant interconnection constraints. In this region, interconnection fees averaged $69/kW from 2010 to 2018 but surged to $404/kW between 2019 and 2021, driving up regional PPA costs.[33]

Hybrid Renewables Rising

The co-location of storage with renewable projects can help reduce grid connection costs and speed up interconnection. Storage allows for better control of electricity feed-in at the interconnection point, increasing grid operator acceptance. Additionally, pairing storage with solar and wind projects improves load factor, all of which contribute to more favorable PPA pricing and encourage faster transactions.

Hybridizing utility-scale solar with two, four, six, or even eight-hour storage systems is becoming increasingly common. Co-located storage offers substantial systemic benefits and cost savings. Most importantly, these hybrid systems reduce the need for additional generation and transmission infrastructure, lowering costs for electricity consumers.

Cost Competitiveness

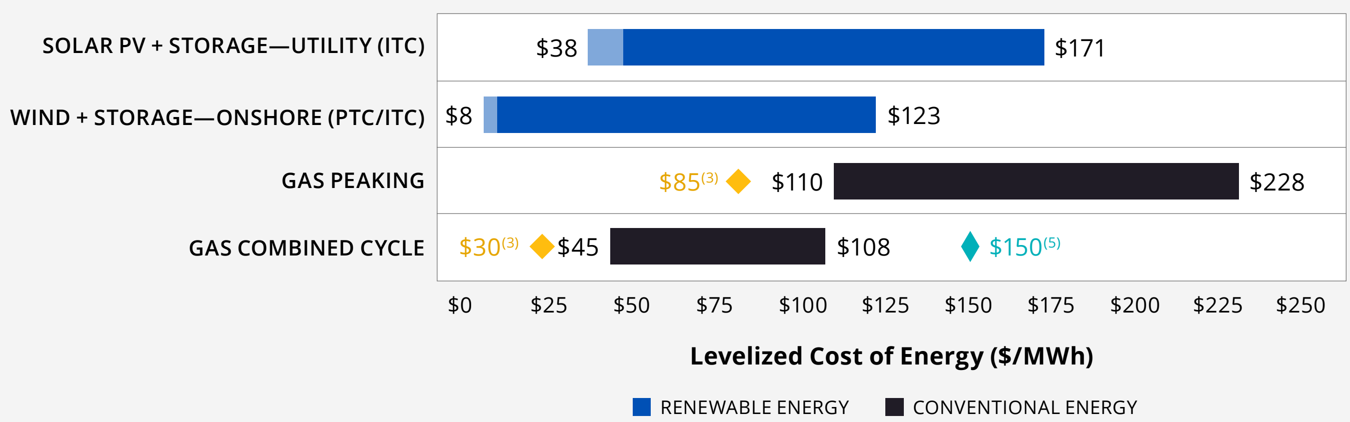
Alongside its increased utility, co-location of renewable generation with battery energy storage is becoming increasingly cost effective. Innovations such as enhanced lithium-ion battery density and declining manufacturing costs have made storage-coupled solar and wind competitive with combined cycle and peaking natural gas in a variety of scenarios.

The most recent Lazard LCOE analysis illustrates this development (see Figure 8).[34] The lower left end of the cost range for solar-plus-storage and wind-plus-storage includes additional bonuses, such as the Energy Community Tax Credit Bonus from the IRA. This analysis shows that both technologies, when paired with four-hour storage, are cost competitive with combined cycle and peaking gas.

Lazard observes in its 2024 analysis: “Other key takeaways include the need for diverse generation fleets to meet increasing power demands (driven by AI, data center deployment, etc.).”

FIGURE 8.

LCOE Comparison: Renewable Energy vs. Conventional Energy



Source: Lazard (edited: Climate Copy)

(3) Reflects the average of the high and low LCOE marginal cost of operating fully depreciated gas peaking, and gas combined cycle. Analysis assumes that the salvage value for a decommissioned gas or coal asset is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating gas assets across the U.S. Capacity factors, fuel, variable and fixed operating expenses are based on upper- and lower-quartile estimates derived from Lazard’s research.

(5) Reflects the LCOE of the observed high case gas combined cycle inputs using a 20% blend of green hydrogen by volume (i.e., hydrogen produced from an electrolyzer powered by a mix of wind and solar generation and stored in a nearby salt cavern). No plant modifications are assumed beyond a 2% increase to the plant’s heat rate. The corresponding fuel cost is $6.66/MMBTU, assuming ~$5.25/kg for green hydrogen (unsubsidized PEM).

In Summary

Renewable energy hybrid projects are well suited to meet the growing demand for long-duration clean power from data centers. With rising energy needs, tech companies are expected to accelerate long-term PPAs with renewable-hybrid project owners and developers in current market conditions.

Key benefits of hybrid solar-storage projects include:

- Delivering the firm capacity needed to support data center expansion.
- Leveraging tech companies' large balance sheets and energy needs, making them ideal candidates for long-term, clean power PPAs with hybrid projects.
- Avoiding grid bottlenecks that slow PPA transactions, as storage hybridization can alleviate congestion.
- Enhancing cost competitiveness through declining battery prices and additional revenue streams, such as energy arbitrage trading.

Battery Storage under PPA

PPAs with battery energy storage are becoming more common. In December 2023, Meta signed a solar-plus-storage PPA with clean energy developer and Independent Power Producer (IPP) Ørsted, contracting most of the output from the Eleven Mile Solar Center in Arizona.[35]

The project includes a 300 MW solar farm paired with a 300 MW / 1200 MWh energy storage system supplied by Fluence, supplying Meta's data center with 24/7 reliable and clean power. Any excess energy supports local utility customers, enhancing grid stability.

Salt River Project (SRP), the local utility, has actively promoted solar and storage in Arizona and plans to expand to 1.1 GW of battery storage by the end of 2024, with a goal of adding 7 GW of renewables by 2035.

The Meta deal reflects a growing trend among tech companies. In 2023, AES Clean Energy contracted more than 1 GW of storage, securing similar clean power deals for Amazon, Google, and Microsoft.[36]

Photo courtesy of Ørsted

Use Case 3: Supporting the Electricity Network

The rapid increase in AI-driven electricity demand is emerging at a time when grids are already under pressure from electrification and the shift to renewable resources. To navigate these challenges effectively, utilities and network operators need to develop detailed resource plans. Optimizing existing grid infrastructure will be both faster and more cost effective than extensive network expansion. Case in point: U.S. utility Dominion Energy recently requested $63.1 million for transmission upgrades benefiting a single data center, with costs spread across its customer base.[38]

Even before the recent data center demand surge, the U.S. interconnection queue faced significant delays. By the end of 2022, there were 2.6 TW of power projects awaiting grid connection, with solar, wind, and storage making up nearly all this capacity.[39] These projects accounted for 95% of the year-over-year increase, including 1 TW of solar and 1 TW of energy storage.

Similar bottlenecks exist elsewhere. Projects in Germany face permitting and transmission delays,[40] Japan struggles with balancing its islanded grid,[41] and Australia's National Electricity Market (NEM) contends with volatility from high solar penetration, and increasingly unreliable and aged coal-fired generators.[42]

Partner to the Grid

Electricity network projects are notoriously slow to deliver. By contrast, utility-scale storage can be quickly and strategically deployed at transmission and distribution points where grid congestion or load growth is occurring.

These targeted energy storage deployments enable full utilization of existing grid capacity. Due to contingency planning for grid safety and reliability, transmission networks often operate below their maximum capacity. Battery storage can provide backup power and / or function as a transmission asset, allowing grid operators to plan on use of the storage system in contingency events and therefore increase their use of existing transmission lines. This particularly helps grid operators who are dealing with high demand areas, like those caused by a cluster of data centers.

In Summary

To strengthen networks and achieve system-wide savings, grid operators and utilities worldwide should increasingly utilize energy storage to ensure resiliency with higher levels of renewable energy.

- Transmission congestion is already a major concern and is likely to worsen.
- Storage can improve the load factor of existing generation, particularly renewables, helping to reduce marginal peak demand and the need for additional capacity expansion.
- Battery energy storage enhances grid utilization, reducing the need for slow and costly grid upgrades.

EXAMPLE

Grid Boosters in Germany

Battery storage projects are increasingly demonstrating their role in grid reliability. A key example is the 250 MW Grid Booster project in southwest Germany, the world's largest storage as a transmission asset project at the time it was announced in October 2022. Supplied by Fluence for the Transmission System Operator (TSO) TransnetBW, the project will support grid stability at a crucial hub in the German state of Baden-Württemberg.

The Grid Booster will help meet Germany's n-1 principle, which requires extra grid capacity to cover potential faults. By using battery storage as backup, the grid can operate closer to full capacity while ensuring reliability.

Fluence also partnered with TSO TenneT in 2023, announcing a 200 MW storage system for two additional Grid Booster projects in Germany. These Fluence Ultrastack™ systems will help optimize transmission capacity, essential for transferring wind energy from the north to the industrial south.[37]

Key Takeaways

The rise of generative AI has captured imaginations while presenting new challenges for the technology and energy sectors. The urgent demand for electricity generation and grid capacity is driving a re-evaluation of data center design and grid integration strategies.

Battery storage is proving its capability at scale by shifting abundant solar generation from daytime to evening peaks in key regions, accelerating grid enhancement, and enabling optimal network utilization. In this context, energy storage has demonstrated its effectiveness as a powerful solution to AI-related energy demands across multiple applications.

This white paper has outlined how battery storage can:

- Deploy rapidly in on-site generation systems, enabling data centers to reduce their reliance on the electricity network and bypass lengthy connection delays.
- Facilitate the transformation of data centers into flexible grid assets, helping lower system costs for utilities and consumers.
- Decrease the need for diesel generators as backup power, reducing Scope 1 emissions.
- Provide the firm capacity needed for data center expansion within solar-hybrid projects.
- Support clean energy goals under renewable PPAs and improve PPA pricing efficiency, accelerating adoption.
- Offer cost competitiveness when paired with wind or solar, compared to peaking and combined-cycle natural gas plants.
- Reduce the need for capacity expansion by increasing the load factor of existing renewable generation.
- Enhance grid utilization, deferring costly, time-consuming, and complex grid upgrades.

The tech industry has long been a catalyst for renewable energy development. Now, with surging AI-driven electricity demand, it is poised to stimulate a new wave of capital toward clean generation and enabling technologies, including battery energy storage.

Endnotes

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