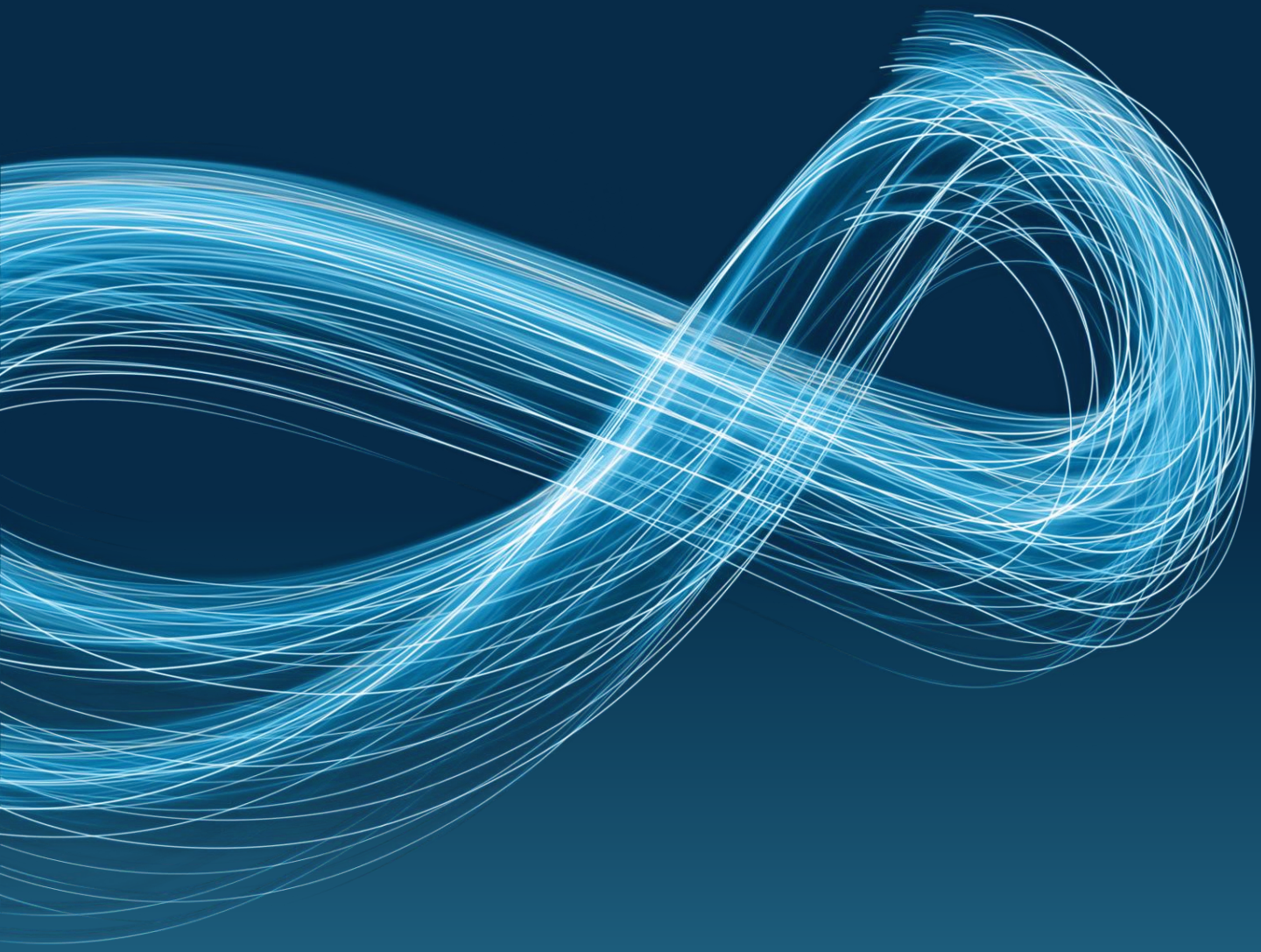
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Battery Storage:

The Missing Link in the Energy Transition



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The Missing Link in the Energy Transition

For years, battery energy storage systems were viewed primarily as a supporting technology for renewable energy. Their function seemed straightforward: absorbing excess electricity when generation exceeded demand and releasing it when needed. Today, that perspective is no longer sufficient.

As power systems move toward higher shares of renewable generation, Battery Energy Storage Systems (BESS) are evolving into a strategic infrastructure layer that sits at the intersection of generation, networks and consumption. The question is no longer whether storage will be needed, but how storage and grids can work together to ensure reliability, adequacy and flexibility in an increasingly complex electrical system.

The scale of the transformation is already visible. According to the International Energy Agency, global battery storage additions reached 108 GW in 2025, a year-on-year increase of approximately 40%, while total installed battery storage capacity worldwide is now around eleven times higher than in 2021. Notably, about 80% of new deployments are utility-scale projects, underlining the growing role of storage as critical power infrastructure rather than a niche technology. Drawing on CESI's experience in grid studies, system planning and battery testing, the integration of storage and networks is becoming one of the defining challenges of the energy transition.

The dual challenge: adequacy and flexibility

The rapid expansion of solar and wind generation is transforming how electricity systems operate. Renewable capacity continues to grow, while conventional thermal generation is gradually declining. Although this shift is essential for decarbonization, it also creates a structural challenge: renewable capacity does not always coincide with electricity demand.

In Italy, CESI's analysis of the Terna and Snam PNIEC Policy scenario indicates that installed solar and wind capacity could increase by approximately 50 GW by 2030 compared with 2025 levels, while available thermoelectric capacity may decline by around 12 GW. The critical issue is that installed renewable capacity cannot be assumed to be fully available during periods of peak demand. A combination of resources, including storage, flexible generation, demand-side participation and grid development is needed.

This is where battery storage, alongside other flexibility resources such as pumped hydro, demand response and flexible consumption, becomes increasingly valuable. By shifting energy across time and responding within seconds to changing grid conditions, BESS can help bridge the gap between intermittent generation and demand while supporting system reliability.



Beyond storage: a network asset

Modern utility-scale battery installations are far more sophisticated than a collection of battery cells. They include power conversion systems, transformers, battery management systems, energy management platforms, cooling equipment, fire protection systems, communication infrastructure and advanced control technologies.

At the distribution level, utilities are also evaluating storage to defer or optimize selected network reinforcements investments, increase renewable hosting capacity, reduce transformer overloads, mitigate voltage deviations and manage peak demand associated with accelerating electrification and electric vehicle charging.



Their role extends well beyond energy shifting.

Today, storage systems support frequency regulation, voltage control, peak shaving, congestion management, renewable integration, resource adequacy and a growing range of ancillary services. Their fast response capabilities make them particularly effective in managing short-term flexibility requirements and maintaining grid stability in systems increasingly dominated by inverter-based resources.

The value of a BESS therefore depends not only on its installed capacity, but also on where it is located, how it is connected to the network and how it is operated within the broader electricity system. Storage and grids are becoming inseparable components of a single infrastructure ecosystem.

Why integration matters

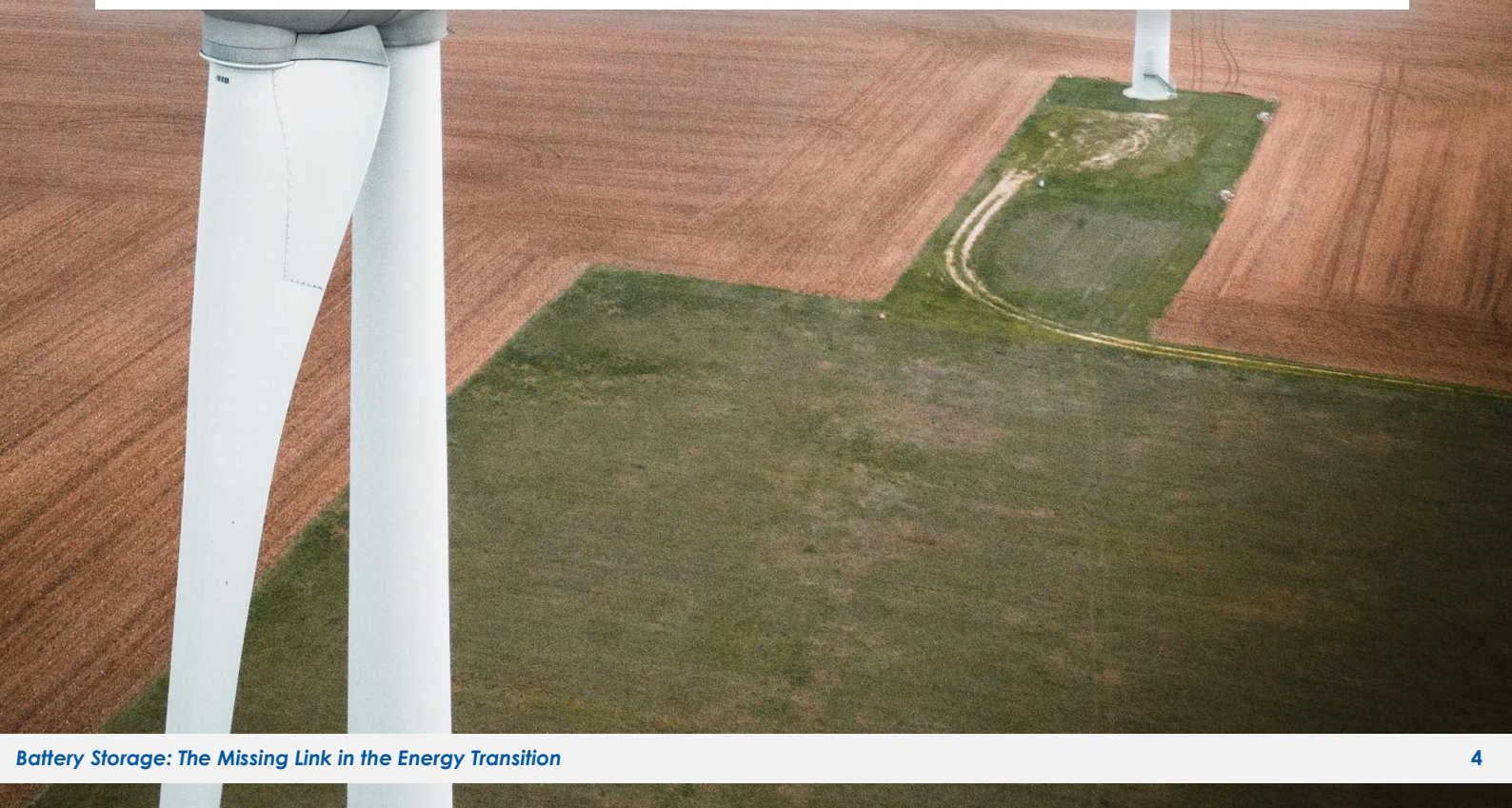
The growing penetration of storage is creating a new reality for network operators, developers and policymakers. Storage and transmission can no longer be planned independently, a principle increasingly reflected in transmission planning strategies across Europe and in Italy.

The effectiveness of storage depends heavily on the surrounding grid. A battery located in the wrong area may deliver limited system benefits even if technically sound. Conversely, strategically located storage can alleviate network constraints, defer costly infrastructure investments, increase renewable integration and strengthen operational resilience.

This evolving relationship is driving a shift from viewing storage as a standalone energy asset to recognizing it as an essential network resource.

The importance of this integration is particularly evident in Italy's storage outlook. According to the Terna-Snam 2026 scenario framework, Italy could require approximately 130 GWh of storage energy capacity by 2030. To achieve the 2030 targets, the document identifies a need for approximately 50 GWh of new utility-scale storage capacity, including around 24 GWh in addition to the capacity already planned under the MACSE mechanism.

Project development activity reflects the scale of the opportunity. CESI's analysis indicates that by August 2026 Italy had received approximately 3,500 grid connection applications for BESS projects, alongside nearly 6,000 renewable generation connection requests, reflecting the strong level of investor interest in storage and renewable development. Not all these projects will ultimately be built, highlighting the importance of robust technical and economic screening from the earliest planning stages.





Confidence starts before commissioning

The success of battery storage projects depends on much more than equipment selection.

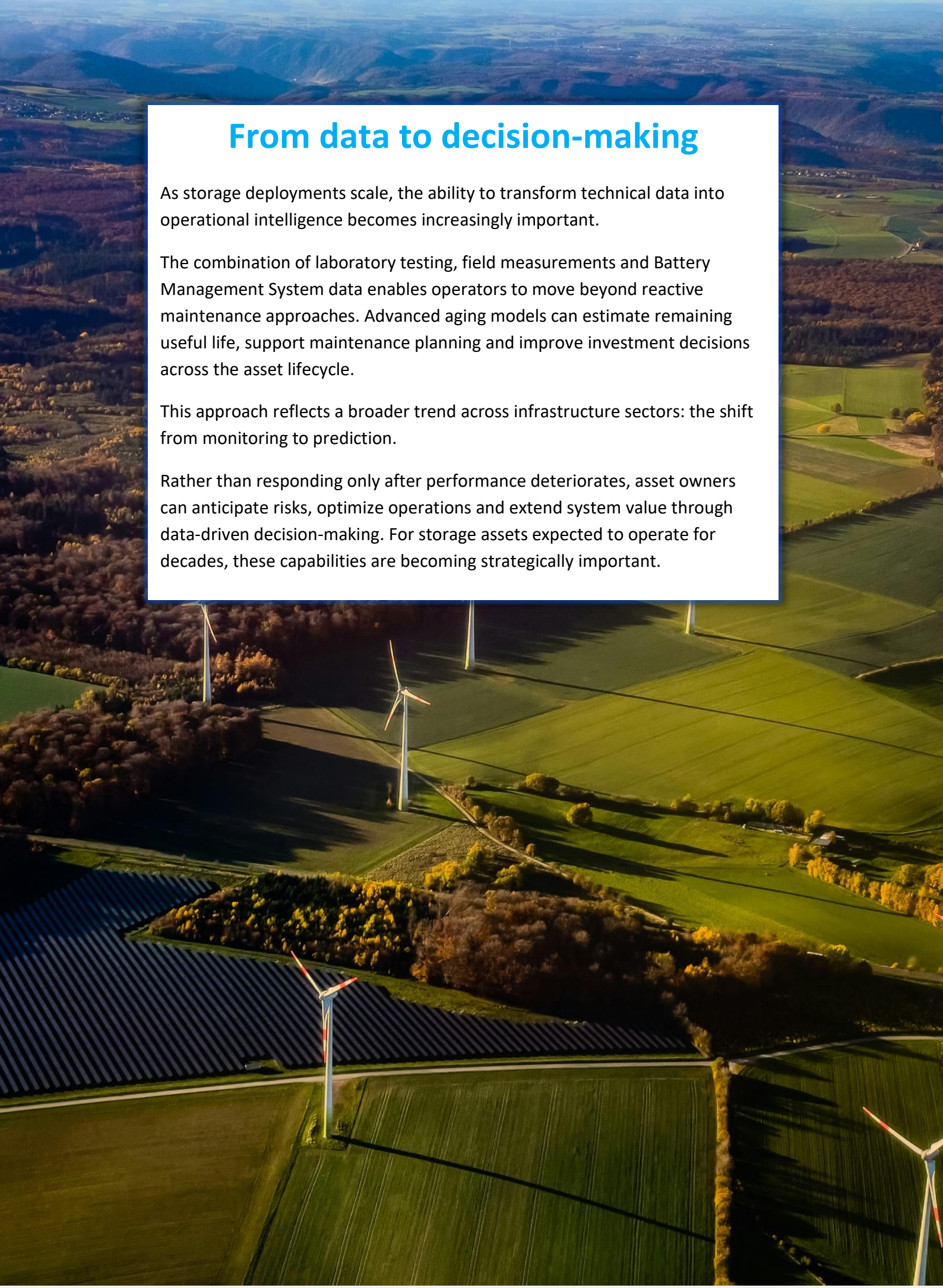
Before a system is energized, comprehensive grid integration studies are needed to evaluate system impacts, power quality, harmonic performance, insulation coordination, temporary over voltages and ride-through capabilities. Electromagnetic Transient (EMT) models are increasingly used to simulate inverter and plant controller behavior and identify potential interactions between storage assets and surrounding network infrastructure. CESI regularly supports these assessments through power system studies and advanced simulations aimed at identifying operational risks before commissioning.

However, models are only as reliable as the data used to build them. Independent testing therefore plays a critical role throughout the project lifecycle.

At KEMA Labs, battery research is complemented by multidisciplinary capabilities that combine battery testing, Electromagnetic Compatibility (EMC) assessments, Accelerated Life Testing (ALT), plant controller validation and IEC 61850 communication testing. This integrated approach provides deeper understanding of how batteries, power electronics, control systems and communication infrastructure interact within complex BESS architectures.

Laboratory testing can replicate real-world environmental and electrical conditions, including charging and discharging cycles, temperature extremes, humidity exposure and accelerated aging scenarios. Such testing provides valuable insight into battery reliability, degradation mechanisms, operational safety and expected service life.

Recent research involving Lithium Iron Phosphate (LFP) batteries has demonstrated how laboratory aging campaigns can support the development of thermal and semi-empirical models capable of predicting capacity fade, State of Health (SoH) and battery lifetime under real operating conditions. Results highlighted temperature and state of charge among the most significant drivers of long-term degradation.



From data to decision-making

As storage deployments scale, the ability to transform technical data into operational intelligence becomes increasingly important.

The combination of laboratory testing, field measurements and Battery Management System data enables operators to move beyond reactive maintenance approaches. Advanced aging models can estimate remaining useful life, support maintenance planning and improve investment decisions across the asset lifecycle.

This approach reflects a broader trend across infrastructure sectors: the shift from monitoring to prediction.

Rather than responding only after performance deteriorates, asset owners can anticipate risks, optimize operations and extend system value through data-driven decision-making. For storage assets expected to operate for decades, these capabilities are becoming strategically important.

The road ahead

Battery storage is rapidly becoming one of the foundational technologies of the modern power system. Yet its success will not be determined solely by the number of gigawatt-hours deployed.

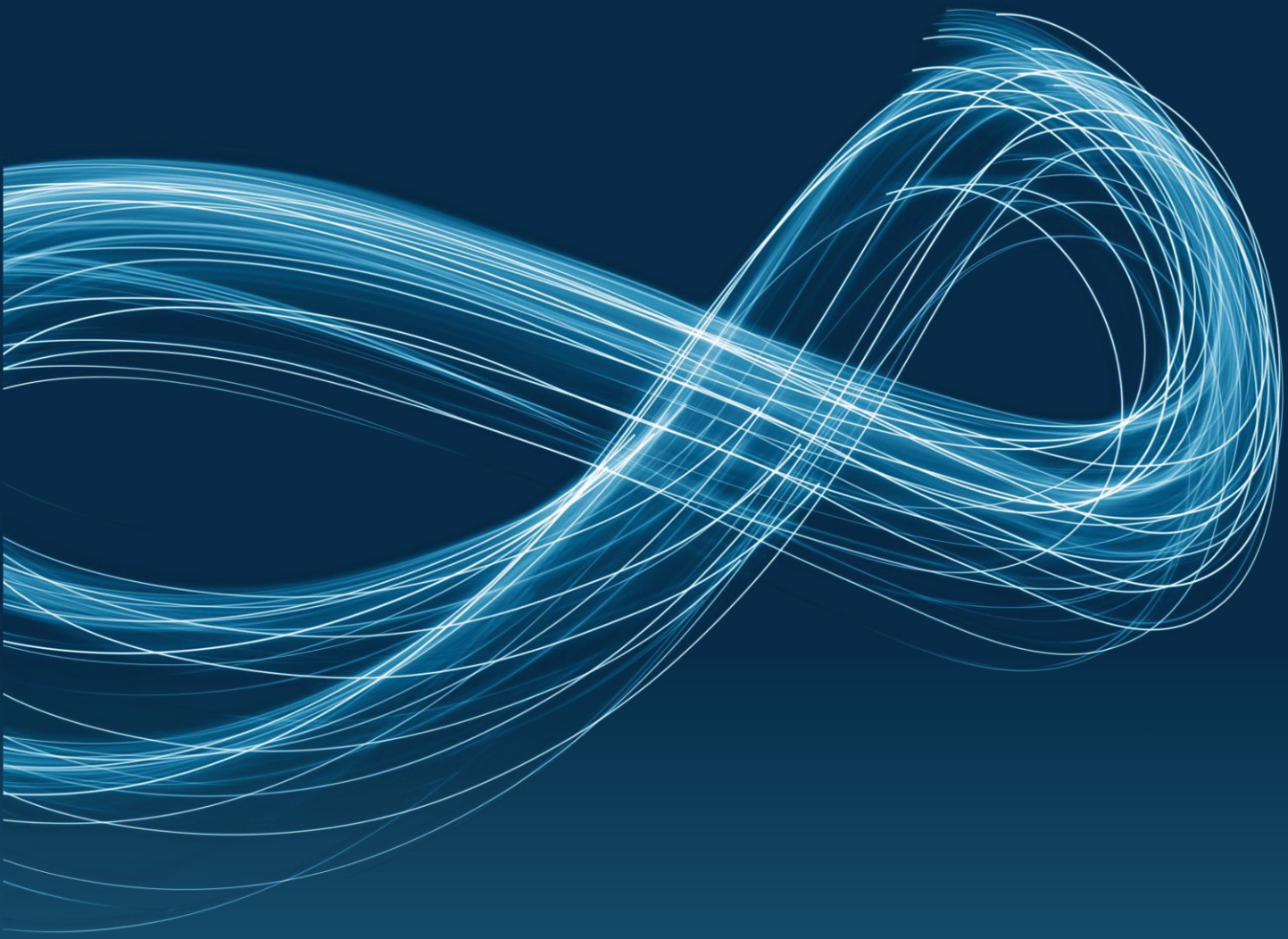
The real challenge lies in orchestration: ensuring that batteries, grids, renewable generation and digital control systems operate as an integrated whole. Rising renewable penetration, accelerating electrification and the emergence of large new loads such as data centres are reshaping electricity demand and placing unprecedented flexibility requirements on power systems.

In this context, storage and networks must be planned, tested and operated together.

For developers, utilities and investors, that means validating models early, supporting them with independent testing, conducting rigorous grid studies and maintaining technical oversight from procurement through commissioning and operation.

Battery storage is no longer simply about storing energy. It is increasingly about connecting renewable generation, electricity demand and network infrastructure into a resilient, reliable and flexible system capable of supporting the next phase of the energy transition.





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