ELECTRIFICATION SERVICE | WHITEPAPER

THE FUTURE OF ELECTRIFICATION SERVICE: 2026–2035+

A roadmap for achieving operational certainty, energy resilience and business continuity in an increasingly complex energy landscape

ENGINEERED TO OUTRUN

“The vase is broken, the damage is done – it will be very difficult to put the pieces back together. This will have permanent consequences for the global energy markets for years to come.

Governments will review their energy strategies. There will be a significant boost to renewables and nuclear power and a further shift towards a more electrified future.”

Fatih Birol, Executive Director, International Energy Agency, April 2026, commenting on the effects of the closure of the Strait of Hormuz.

Welcome to our exploration of the future of electrical service

The energy systems that power our world were built for a different era – designed when demand was predictable, power flowed in one direction, and experienced teams knew these systems inside out. That context has changed, and many of the assumptions behind it no longer hold.

Today, the energy trilemma – resilience, affordability, clean energy – has moved from the risk register to the operations floor. Geopolitical instability is reshaping supply chains. Electrification is accelerating faster than infrastructure can respond. AI and data centers are placing demands on grids never designed to meet them. At the same time, a significant share of the workforce that has kept these systems running is nearing retirement, taking irreplaceable knowledge with it.

These are not future scenarios. They are the conditions under which utilities, data centers, industrial and commercial operators are running their businesses today.

This whitepaper is our contribution to the debate about what comes next. It offers a structured way of thinking about the challenges through four horizons, from the pressures of today to a transformed service model likely to evolve by the 2030s and beyond. Along the way, we look at how technology is progressing, what the workforce challenge really means, and how financial and operating models will need to change to maintain operational resilience.

We also ask some uncomfortable questions in addressing a gap many businesses recognize but struggle to close. There is often a clear understanding of what should be done – invest in condition-based maintenance, apply total cost of ownership thinking, plan seriously for workforce resilience – but action does not always follow. In our experience, that gap is less about technology and more about how decisions are made, funded and prioritized.

The aim of this paper is intended to provoke, to challenge and to invite a more serious conversation about what electrical service must become to support the energy transition, and the economic and social ambitions that depend on reliable power.

At ABB, our 140-year history of working alongside customers worldwide shapes our perspective. It is informed by an installed base of more than 18 million assets, a global and experienced workforce, and ongoing investment in technology research and development.

While this is an evolving conversation, the direction is clear. Companies that treat energy and electrical infrastructure as a strategic asset, and service as a long-term partnership, will be significantly better placed to manage what comes next. The window to act is narrowing.

Stuart Thompson
President of Electrification Service, ABB

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THE FUTURE OF ELECTRIFICATION SERVICE

What will electrical service need to deliver when energy becomes the binding constraint on growth? The question is no longer about technology evolution alone, but about how service ensures resilience, controls cost and enables compliance under structural pressure.

The electrical infrastructure that supports modern economies is under simultaneous pressure from multiple directions. Aging assets, accelerating electrification demand, a structural workforce shortage and tightening regulatory obligations are converging at precisely the moment when the cost of getting infrastructure decisions wrong has never been higher.

This whitepaper sets out a structured view of where the electrical service industry stands today, where it is heading across four horizons to 2035 and beyond, and what companies need to do differently to stay ahead of these pressures.

Each horizon reflects a shift in how companies respond to the energy trilemma: resilience comes first, affordability follows close behind and clean performance is no longer optional.

This paper brings those shifts into focus, setting out the practical steps companies can take to strengthen energy resilience, improve decision-making and build the operational certainty required for the years ahead.

The four horizons
The whitepaper organizes the path forward into four periods:

The Four Horizons

AS IS (2026)

The baseline conditions described above – converging pressures, underinvestment and a widening gap between operational ambition and infrastructure reality.

2026–2030

The technology building blocks – condition-based asset monitoring, AI-assisted diagnostics, augmented and virtual reality remote support, and the early deployment of automated inspection platforms – begin to compound. The CapEx-to-OpEx transition accelerates, with outcome-based service models becoming increasingly mainstream.

2030–2035

Sector boundaries begin to dissolve. Data centers become grid-stabilizing assets. Industrial microgrids create bilateral relationships with utility networks. The service model evolves to meet a more complex, interconnected power ecosystem.

2035–ON

AI, automation and digital asset management become table stakes. The real disruption is organizational: who holds authority, who is accountable and whose judgment carries weight when intelligent systems can see risks and inefficiencies before people do.

These are not predictions. Some of the technology and ways of working described here are already in development or in use. Longer-term solutions reflect current product development and active research directions across the industry.

Looking toward 2035 and beyond, the scenarios presented will be shaped by external factors – regulation, economic growth, geopolitics and other market developments that no single business can control. Few people in 2016, after all, would have predicted that 2026 would see two simultaneous wars and an explosion of investment in artificial intelligence.

The aim of this whitepaper is to provoke debate and invite challenge. What does the future of electrification service look like from an industry perspective – and what will it take to make it work in the medium and long-term for utilities, industrial businesses and data centers that depend on reliable power and the workforce delivering this resilience?

Operational challenges that demand immediate attention

Five pressure points define the current environment:

Cost and competitiveness: Energy now accounts for more than a quarter of average industrial operating costs, and nearly six in 10 companies identify rising prices as a major threat. But cost is only part of the pressure: power availability and grid constraints are increasingly determining where companies can operate and how fast they can grow.

The reliability and downtime crisis: Unplanned downtime costs the world's largest companies around $1.4 trillion annually. Nearly seven in 10 industrial facilities experience outages at least monthly. Running equipment to failure costs up to 10 times more than proactive maintenance – yet the behavior persists.

The investment gap: More than eight in 10 senior leaders say total cost of ownership should guide capital decisions. Fewer than four in 10 actually apply it. The gap is not a knowledge problem, it is a structural one.

The workforce shortage: Up to 1.5 million additional qualified power engineers will be needed globally by 2030. Four in 10 power executives already cannot find the engineers they need today. This shortage is demographic and structural – it will not resolve itself.

Regulatory acceleration: Mandatory carbon disclosure and increasingly stringent environmental regulation are forcing infrastructure investment decisions to board and CFO level. Regulatory compliance as an investment driver has grown from 18% to 31% since 2022.

Taken together, these pressures expose a deeper issue. Most companies are not lacking awareness of the risks; these pressures show up as day-to-day trade-offs and constraints. What is often missing is a clear, consistent way to translate that awareness into action at the level where investment and risk decisions are made. That is where the focus needs to shift.

Running through all four horizons are six questions that every serious operator needs to be asking now about their electrical systems:

1. How much is actually known about the real condition of electrical assets?
2. What is actually causing the outages – and has anyone looked beneath the symptoms?
3. Is the investment framework keeping pace with genuine risk exposure?
4. Are sustainability commitments integrated into financial strategy – or confined to compliance reporting?
5. Is the workforce resilience plan keeping pace with operational ambitions?
6. Are organizations designing for the 2030s – or still managing the legacy of the 1990s?

These questions are the starting point for the kind of conversation this whitepaper is designed to provoke.

HORIZON AS IS (2026)

The energy trilemma – resilience, affordability and clean energy – is no longer a risk-register item. It has arrived as a daily operational reality and constraint for every utility, industry and data center. Every decision should now be answering three questions:

- Does this increase resilience (avoid downtime, ensure supply)?
- Does this improve affordability (reduce total cost of ownership)?
- Does this enable clean performance (meet regulatory and supply-chain pressure)?

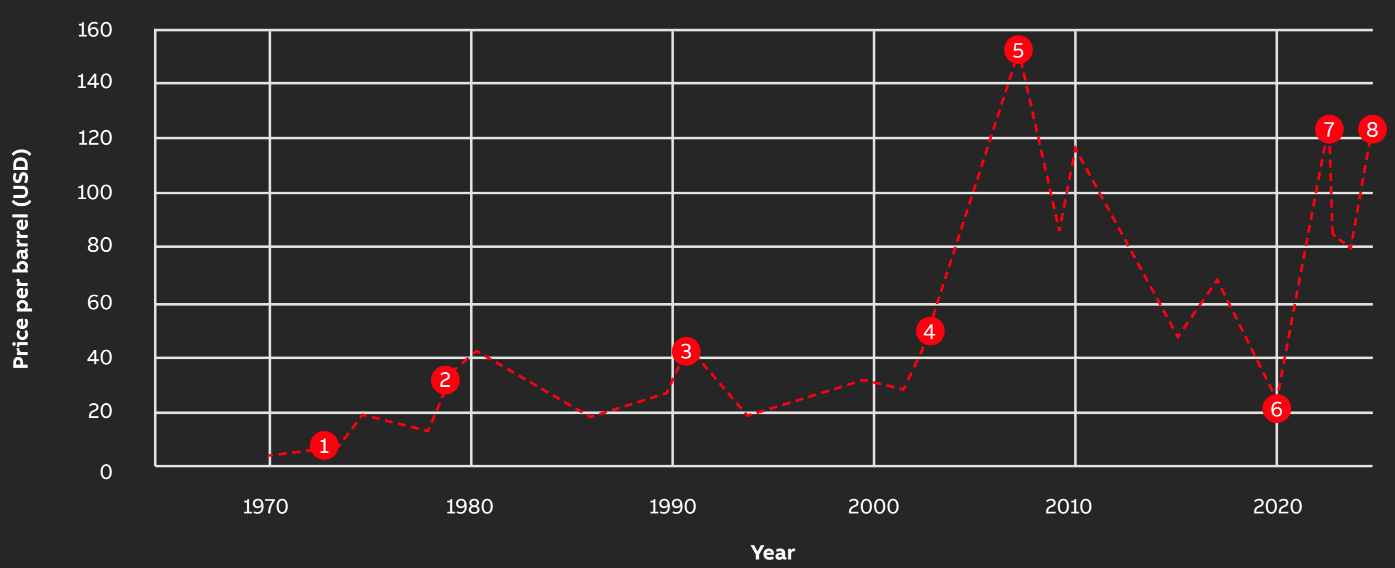
Understanding why requires a short look at recent history and our current geopolitical reality.

How energy shocks reshape industries
Energy shocks are not new. The 1973 OPEC embargo on Middle East oil exports triggered a wave of fossil fuel conservation measures – fuel-efficient cars, insulation standards, industrial efficiency programs. France responded with nuclear substitution, reducing hydrocarbon dependency by design. Efficiency and electrification become resilience strategies, not sustainability choices, transforming supply-chain vulnerability into a locally managed, high-performing asset. The pattern is consistent: shocks force step-change improvements in resilience and efficiency.

The long-term effect of today's shock is unknown, but geopolitical instability and the energy crisis caused by two simultaneous wars make it more complex than the oil shock of the 1970s, and it will have more long-lasting and profound effects. Concerns around Russia's war in Ukraine were already driving a structural step-change in European energy security investment.

The effective closure of the Strait of Hormuz in 2026 – through which roughly 20% of global seaborne crude and LNG flows – multiplied those concerns and is the most visible reminder in a generation that energy supply is not a given. Energy security has moved from strategic concern to operational risk. Even if the situation is resolved and shipping lanes are opened, restarting oil fields and gas processing plants – even those undamaged by drone strikes – will take months. Inflationary pressure on chemicals, steel, cement, food production and logistics compounds long after hostilities ease.

HISTORICAL OIL PRICE SPIKES (1970–2026)



1 1973: OPEC Embargo Start
2 1979: Iranian Revolution
3 1990: Gulf War 1 (Invasion)
4 2003: Gulf War 2 (Invasion)
5 2008: Commodity Supercycle Peak
6 2020: COVID-19 Demand Crash
7 2022: Russia-Ukraine War Spike
8 2026: Iran War (Current Shock)

Sources for chart: U.S. Energy Information Administration (EIA) Annual Energy Review; Energy Institute Statistical Review of World Energy; Federal Reserve Economic Data (FRED); Market Index Spot Prices (2025–2026).

The modern equivalents of the post-OPEC energy efficiency response are already being implemented and will likely accelerate. These include the widespread electrification of industrial processes, the surge in the adoption of EVs, distributed on-site generation and behind-the-meter storage. These are primarily resilience investments, with affordability and clean benefits layered on top. They fundamentally increase demand for service models that can manage complexity, volatility and uptime at scale.

The evolution of electrical service
Electrical infrastructure was built for constant, predictable loads and serviced reactively when it failed. Equipment was designed for human interaction at every point – buttons, handles, lockout mechanisms designed for a technician's hands. The service model was reactive to failures or schedule based. It worked when energy was predictable, affordable and abundant.

The installed base that accumulated is now approaching end of designed life at the same time that impulsive loads increase and demand for reliability and uptime is at an all-time high. Technicians maintain switchgear installed 40 to 50 years ago, and with millions of installations worldwide, the scale of what is at stake – financially, materially and for energy supply security – is enormous.

A changing paradigm
Distribution networks were originally built like a one-way street—power flowed down from high-voltage transmission, through medium-voltage substations, to consumers. Today, because of local solar and storage, the distribution grid has become a dynamic, two-way ecosystem requiring rapid digital automation to keep the lights on.

“Asset management is not going to stop things breaking – but it is going to be the difference between an unplanned shutdown and a planned one.”

Historical electrical timeline (1880s–2026)

1882

The Birth of Commercial Utility (US & Germany)
Thomas Edison opens the Pearl Street Station in New York City (DC). Simultaneously in Germany, Oskar von Miller and René Thury demonstrate early long-distance DC transmission over 57 km, kicking off the global push for commercial power.

1886

The Transformer & First AC System (US & Italy)
William Stanley builds the first practical commercial AC transformer system in the US, building upon European open-core patents. This allows electricity to be stepped up for transmission and safely stepped down to medium and low voltages for local distribution.

1891

The War of the Currents Settled (Germany)
The Lauffen-to-Frankfurt long-distance transmission demonstration in Germany proves three-phase AC power can be sent over 175 km at 75% efficiency. This establishes AC as the standard architecture for national power grids over Edison's DC.

1910S

The Invention of the Induction Disc Relay (Protection)
As distribution networks expand, protecting them becomes critical. The invention of the inverse-time induction disc relay introduces reliable overcurrent protection. If a fault occurs on a medium-voltage line, the relay isolates that specific section, preventing widespread blackouts.

1930S

The Automatic Circuit Recloser (Distribution Resiliency)
The hydraulic automatic circuit recloser is introduced to medium-voltage overhead distribution lines. Since most distribution faults (like tree branches touching a wire) are temporary, the recloser automatically clears the fault and resets the power without requiring a utility worker to physically drive out and replace a fuse.

1954

The First Commercial HVDC Link (Sweden)
Following 25 years of research by Dr. Uno Lamm and his team at ASEA (merged to become part of ABB and now Hitachi Energy), the world's first commercial High-Voltage Direct Current (HVDC) transmission link goes live in Sweden, utilizing mercury-arc valves to send 20 MW of bulk power across a 98 km submarine cable.

1960S

Solid-Insulated MV Underground Cables (XLPE)
Cross-linked polyethylene (XLPE) insulation transforms medium-voltage distribution. Replacing cumbersome paper-insulated, lead-covered cables, XLPE allows utilities to reliably bury medium-voltage lines (typically 10 kV to 35 kV) underground through densely populated cities and suburbs.

1970S

SCADA & Computerized Substation Dispatch
Utilities globally deploy SCADA (Supervisory Control and Data Acquisition) systems. For the first time, operators can monitor medium-voltage substations, remotely open or close circuit breakers, and read telemetry from a centralized control room.

1980S

Metal-Clad Vacuum Circuit Breakers
Medium-voltage substations phase out bulky oil and gas circuit breakers in favor of vacuum interrupters. Vacuum breakers quench electrical arcs safely and cleanly within a tiny vacuum chamber, dramatically reducing maintenance, fire hazards and substation footprints.

1990S

Introduction of Microprocessor-Based (Digital) Relays
The transition from mechanical induction discs to solid-state, microprocessor-based protective relays begins. These digital devices provide highly precise fault localization, event logging and communication capabilities directly from the medium-voltage substation.

2000S

The Smart Grid, AMI and FLISR
Advanced Metering Infrastructure (AMI)—or smart meters—deploys globally. Simultaneously, utilities introduce FLISR (Fault Location, Isolation and Service Restoration). Using digital distribution automation, FLISR automatically detects a medium-voltage line fault, isolates it and reroutes power around the break within seconds.

2010S

Solid-State MV Substation Transformers (SST)
As rooftop solar and local wind generation spike, power begins flowing backward up the distribution ladder. Power electronics advance to create Solid-State Transformers (SSTs) for medium-voltage applications, allowing active management of voltage fluctuations caused by intermittent renewables.

2018

Eco-Efficient, SF_6-Free Medium Voltage Switchgear
Recognizing that Sulfur Hexafluoride (SF_6)—the standard gas used to insulate medium-voltage switches—is a potent greenhouse gas, major manufacturers successfully commercialize vacuum-interruption technology combined with pure air insulation for MV distribution, eliminating the environmental risk.

2021

Cloud-Based Virtual Power Plants (VPPs)
Distributed Energy Resources (DERs) at the low and medium voltage levels—such as commercial battery banks, rooftop solar and EV fleets—are aggregated via cloud software. This allows decentralized consumer assets to act collectively as a single power plant to stabilize the grid.

2026

Edge AI & ADMS Autonomous Distribution
Advanced Distribution Management Systems (ADMS) infused with Edge Artificial Intelligence operate autonomously. Real-time AI models dynamically balance bidirectional power flows from millions of electric vehicles and local solar arrays, adjusting medium-voltage grid topology instantly to prevent overload from data centers and heavy industrial electrification.

The market today: pain points, constraints and what is at stake

For a generation, the tension between energy security, affordability and sustainability was something most businesses managed at arm's length – a policy question, a risk register entry, a procurement consideration.

The luxury of that degree of separation has disappeared.

Geopolitical instability, accelerating electrification and the explosive growth in power-hungry AI infrastructure have collapsed the timeline on decisions that operators once had years to make. The pressure points set out below are not projections. They are the conditions under which businesses are running their operations today.

The starting point is cost – and how profoundly its nature has changed. Energy now accounts for more than a quarter of average industrial operating costs. But rising prices are only part of the story. Power availability and grid constraints are increasingly determining where companies can operate and how fast they can grow. Businesses that treat this as a procurement problem are already behind those that treat it as a strategic one.

Unplanned downtime now costs the world’s largest companies around $1.4 trillion annually, roughly 11% of total revenues. A single unplanned outage in a capital-intensive facility can cost as much as $2.3 million per hour – and for most operators, outages are a recurring condition rather than an occasional crisis. Running equipment to failure and fixing it costs up to 10 times more than proactive maintenance. Most senior leaders understand this. The harder question is whether their decision-making structures allow them to act on it.

That gap between knowledge and action is where things get uncomfortable. More than eight in 10 senior leaders say total cost of ownership should guide investment decisions – yet fewer than four in ten actually apply it. The barrier is rarely technical. It is almost always a financing and procurement model problem, and one that existing service structures are already designed to solve.

The workforce dimension compounds every other pressure on this list. Experienced specialists are retiring and the knowledge they carry is not being replaced in equal measure. The shortage of qualified power engineers is structural and sector-wide, and every business facing these pressures is doing so with a shrinking pool of people qualified to address them – at precisely the moment when the complexity of what they manage is increasing.

Regulation, meanwhile, is accelerating the timeline on all of the above – and businesses know this. Since 2022, regulatory compliance has nearly doubled as a primary driver of energy investment. Companies treating this as a reporting burden are missing the more important signal: regulation is forcing the infrastructure investment conversation to board and CFO level. Those who move early gain an advantage. Those who wait to be compelled will face a constraint.

As is (2026) what pain points are businesses facing today?

Pain point	The numbers	Why it matters
Energy as a structural cost burden.	Energy accounts for 25.4% of average industrial operating costs; 59% cite rising energy costs as a major threat. Energy demand in the US projected to increase by 26% by 2035.	Energy is no longer a variable cost business can manage tactically. Power availability, tariffs and grid constraints are becoming fixed constraints on growth and site selection. The constant squeeze is essentially unchanged since 2022 – companies are adapting to a new normal of persistent cost volatility. Power availability, not market demand, is becoming the critical path for growth.
Cost of unplanned downtime.	Unplanned downtime now costs the world’s largest companies around $1.4 trillion annually, roughly 11% of total revenues. Costs ~$125,000 per hour on average to over $2.3 million per hour in capital-intensive industries like automotive and semiconductors.	Nearly seven in 10 (69%) industrial plants experience outages at least monthly. Generally running to failure costs up to 10x more than proactive maintenance. Outages increasingly affect not only production but also control systems, safety systems and recovery time, extending mean time to repair. Across manufacturing sectors, **the average cost of unplanned downtime is roughly $125,000 to $260,000 per hour**, with large plants losing upwards of $50 billion annually in the US alone. Global data-center electricity consumption **will more than double from 448 TWh in 2025 to 980 TWh by** 2030.
The execution gap	An ABB survey of 2,700 senior decision makers across 15 countries and 15 industries revealed that more than eight in 10 (81%) say total cost of ownership (TCO) should guide investment; only 37% apply it.	According to an industry report, despite 92% of plant and facility managers across energy, utilities and heavy industry surveyed reporting that maintenance improved uptime, 21% still operate a run-to-fail strategy. Those using a condition-based approach reported 42% uptime improvement versus 35% for those with a time-based schedule. According to research commissioned by ABB, 87% of senior decision-makers expressed interest in outcome-based maintenance agreements, with six in 10 (60%) planning to increase maintenance investment over the next three years. Four in 10 managers (44%) say capital budget limits prevent TCO-based decisions. Industrial leaders have committed to electrification targets, but far fewer are on track due to infrastructure, skills and planning constraints.
Workforce constraints	Global power sector will need **between 450,000 and 1.5 million additional power engineers by 2030** to deliver grid expansion, electrification and energy transition projects. Yet **40% of power executives already report difficulty hiring skilled engineers today**; Supply of qualified engineers – not demand – is the growth limiter	Electrical engineering talent “becoming harder and harder” to find Retiring Specialists not replaced in equal numbers; lack of skilled operators and maintenance staff undermines reliability, even where infrastructure exists. Skills shortages in the power sector are now directly linked to slower global emissions reductions.
The effect of regulation	More regulation requires companies to account for their resource and carbon footprints and in some cases commit to reduction targets; companies are now expected to measure and disclose Scope 1, Scope 2, and Scope 3 emissions under the global ISSB climate disclosure standard – switching from fossil fuel to electricity changes the scope category, not the reporting requirement.	Globally, mandatory carbon disclosure is expanding across industry sectors Reporting and compliance can be a burden, but noncompliance is costly and damages reputation and customer relationships. Expanding carbon disclosure regimes are pushing industrial companies to invest in new monitoring, reporting and verification systems as regulators force a shift from voluntary estimates to audit-ready data.

HORIZON 2026–2030

Electrification increases demand. Decentralization increases complexity. Digitalization creates visibility. AI turns that visibility into decisions. Four forces are simultaneously converging on utilities, industrial operators and data centers – and companies that treat them as sequential will underperform those that treat energy as an integrated system problem.

The required technologies already exist. The constraint is execution and integration. The commercial models to deploy them are being established now. The current window is not about access to technology, but about building the operating model that translates data into decisions and decisions into financial outcomes.

This horizon marks a fundamental shift: Energy moves from infrastructure to operating system. Resilience is actively managed, not assumed. Cost is dynamically optimized, not passively incurred. Clean energy is measured in every decision. The companies that integrate these dimensions first will structurally outperform.

Where this leads: a day in 2035
To understand the journey and the destination, start with an imagined working day for an electrical service field team in 2035. All elements are grounded in active R&D and confirmed technology development, with some speculative elements.

An automated platform at the customer factory performs an autonomous inspection of a substation switchgear room – collecting thermal, acoustic and visual data, identifying an anomaly, flagging it for human intervention before the shift ends. This is communicated automatically to the service organization where it is picked up by an "expert's assistant" agentic AI system.

This automatically processes the report, books the closest available field technician, makes an appointment with the customer contact, and books an expert in another country. On the strength of the customer's maintenance report, it generates a spoken and written visit brief, and readies a digital twin with virtual overlay of images of inspection data for the field technician.

The field technician uses a self-driving EV to reach the customer, receives a safety briefing and begins pre-work inspection, equipped with an AR headset. Equipment history, recommended procedure and step-by-step guidance appear sequentially. Agentic AI sets up a link with the remote expert who watches live and gives verbal guidance while sharing the technician's view in real time. This is a 2035-scale version of a system which exists and is proven today.

A 30-year-old switchgear panel is assessed via a digital twin: result, 12 more years of serviceable life with a vacuum breaker retrofit. No full replacement is required – extending safe operating life, preserving capital and materials. The on-site Battery Energy Storage System-as-a-Service has already shifted peak load overnight, reducing peak costs, enabling grid interaction, and generating new revenue streams.

The technology building blocks: asset management, automation and AI
Three interlocking technology capabilities underpin the 2026–2030 transformation. None is a standalone product – they compound each other. Asset management and monitoring, incorporating AR/VR remote guidance, create the data and the expert reach. AI turns that data into decisions and closes the experience gap. Humanoids begin to eliminate the human from the highest-risk interactions and exoskeletons aid heavy lifting. Together they address the numbers challenge – fewer available technicians; and the skills challenge – technicians with less experience – simultaneously.

Horizon 2026–2030: the technology building blocks now being deployed

Capability	What is happening and what it delivers
Asset management, condition monitoring & AR/VR	Condition-based monitoring is growing but not yet dominant – 99.9% of maintenance is still reactive. 24/7 self-service troubleshooting and remote expert guided repair with live AR annotations are already operational and proven: maintenance resolved in hours not days, on-site CO_2 emissions cut by up to 60%. Digital retrofitting extends asset life 20–30 years without replacing underlying hardware. Domain knowledge and data advantage compounds: our installed base of 18 million+ devices deployed globally, plus decades of technician reports create predictive models as a usable and unique dividend derived from that installed base. Experienced technicians now video their work on site; footage becomes VR training content and AR guidance overlays for the next generation – institutional knowledge preserved rather than filed away or lost to retirement.
Automated platforms and applications in electrical service	Currently in R&D and evaluation phase – not yet commercially deployed. The two motivations: safety (eliminate the human from high-risk live switchgear interactions) and uptime (inspection without equipment shutdown). Three use case categories in development: inspection (passive data collection), light manipulation and heavy manipulation.
The influence of AI	AI's role is to generate actionable information, not raw data: customers want a red light to flash, a clear action required – not raw numbers from a dashboard. Global installed base creates training data for predictive models that cannot be easily replicated. AI-assisted dispatch sends technicians when data requires it, not when the calendar says a visit is due. AI – often through AR and VR – can bring all technicians up to the performance level of a 15-year veteran, addressing the skills challenge as well as the talent pipeline challenge.

R&D anticipating and shaping the future of electrical service

The capabilities described in this whitepaper do not emerge fully formed. Behind each of the technology directions outlined – from asset health management to automated inspection platforms to AI-assisted field operations – sustained research and development work underway today, some of it still in evaluation or early deployment phases.

Understanding what that work looks like in practice matters, because the pace at which it moves from laboratory testing to the field will determine how quickly the operational improvements described in the 2026–2030 and 2030–2035 horizons become standard practice.

Turning data into decisions

The scale of that data advantage depends on solving a specific operational problem. Decades of service reports – many handwritten, in multiple languages, in inconsistent formats – represent a substantial repository of operational knowledge that has historically been difficult to access and nearly impossible to use at scale.

With new AI-based processing techniques, researchers – and ultimately field technicians – are now able to extract structured, actionable information from this material: site names, asset identifiers, observed conditions, identified risks and recommended actions – in seconds, regardless of format or language.

This will certainly create more data, but the aim is to use that data to generate better recommendations – the specific next step a technician needs, drawn from the most relevant prior experience repository available. A field service engineer preparing for a site visit can access the history of that specific site, together with patterns drawn from across a global installed base of comparable assets.

This capability is being developed alongside knowledge graph architecture – a method of storing and structuring data that reflects the relationships between assets, observations and outcomes, rather than simply archiving records. The result is that in addition to entries containing the right keywords, a search returns all connected information relevant to the subject of the enquiry. For a field engineer working against the clock in a complex facility, the ability to quickly access relevant information and guidance results in a material efficiency improvement.

Completing the picture, agentic AI systems – in which multiple specialized AI agents collaborate to execute complex tasks, with a supervisory layer checking reliability and alignment – are being developed to further automate the preparation and follow-up work that currently places demands on engineer time. These systems will become part of the digital ecosystem that supports field operations, accessible from a mobile device.

Automated inspection: the application layer

The development of automated inspection platforms – for example, quadruped robots capable of traversing electrical facilities and collecting thermal, acoustic and visual data – is at an active prototype and research stage. Commercially available platforms, already capable and relatively low-cost, are being assessed and adapted for service-specific applications: e.g. the ability to inspect switch rooms and identify anomalies safely before any human technician enters the room or approaches unsafe equipment.

The critical contribution of research and development in this context is the application layer – the service domain knowledge required to make a general-purpose robot useful in a specific, high-risk electrical environment and the integration of what the robot observes with the broader asset management and maintenance data systems it feeds. Safety use cases are the clearest near-term priority: positioning automated platforms to engage earthing switches, or to make initial assessments of conditions before a human technician enters a live switchgear room, reducing direct exposure to risk.

For tasks involving heavier physical loads – like racking large equipment, replacing large and heavy components – research teams are also evaluating exoskeletons, which augment rather than replace the technician. The technician's judgment and dexterity, combined with powered load assistance, may be better suited to occasional high-payload operations than a heavy-manipulation robot used infrequently. Humanoid robotic platforms capable of this class of task are evolving rapidly and are part of the longer-term research horizon.

Predictive asset health at scale

A third research focus is the development of more sophisticated asset health prediction from sensor data that already exists in the field. Many installed devices – circuit breakers are a clear example – carry sensors that generate continuous data streams. The challenge is not access to the data; it is the ability to generate meaningful, reliable service-related recommendations from it.

Research and development work in this area is focused on building AI-based systems that can identify deterioration patterns in asset behavior – changes in mechanical drive train signatures, emerging thermal anomalies and performance degradation that does not yet constitute a fault – and translate these into specific, time-bounded predictions about maintenance needs. The goal is to enable operators – in partnership with service providers – to make maintenance scheduling decisions based on actual asset condition rather than on calendar intervals, resulting in the option to extend and actively monitor the useful life of assets where the data supports it, and to intervene before failure where it does not. Both scenarios will be cost-efficient and will promote asset reliability and up time.

The compound effect of these three development directions – intelligence extracted from historical data, real-time site visibility from monitoring and automated platforms and predictive health assessment of individual assets – is a service capability that looks substantially different from what is operationally standard today. This research and development work is the foundation on which that transition is being built.

Sustainability is never a non-financial issue: It is a direct driver of cost, risk and revenue – translate it or lose the room

Reducing energy and material intensity directly improves operating margins with emissions reduction as a measurable secondary effect.

These days, sustainability narratives without financial translation fail at decision level with decision-makers. The only language that scales is TCO, margin, and competitive advantage. Carbon footprint per quotation – every service proposal now includes a page showing carbon avoided versus full replacement, materials saved, and emissions reduction – is exactly this framing in practice.

A retrofit saves 80% of steel and copper within the switchgear, reduces downtime from weeks to hours, and lowers capital requirement by 30%. Copper and steel from the installed base can be infinitely recycled with the same characteristics. Reducing resource use is a financial saving and an environmental win.

Compliance also drives investment

Regulation is now an enforced financial variable, not a future risk. The regulator is coming for operators, and electrical service solutions must plan for and comply with new and emerging environmental laws and carbon reduction targets. Execution support in compliance becomes a source of competitive advantage.

Regulatory tightening – particularly in the EU via the Corporate Sustainability Reporting Directive, Corporate Sustainability Due Diligence Directive, Carbon Border Adjustment Mechanism, EU F-gas SF6 phase-out, Scope 3 supply-chain pressure and emerging data center efficiency standards – is now among the most powerful forces shaping industrial energy decisions.

Regulatory compliance as an investment driver has grown from 18% to 31% since 2022, while operator and supply-chain requirements on saving energy and reducing carbon more than doubled from 14% to 29%.

By 2030, the distinction between resilience, affordability and clean energy disappears in practice. Every operational decision – maintenance timing, load management, equipment replacement – simultaneously affects uptime, cost and emissions.

The companies that integrate these trade-offs in real time will outperform those that optimize in silos. Electrification service becomes the system that makes this integration possible.

HORIZON 2030–2035

A new power ecosystem – integrated, dynamic and actively managed in real-time

By the early 2030s, the distinctions between sectors that seem clear today begin to dissolve, creating a new and more complex electrical power ecosystem.

- Data centers act as grid-stabilizing assets.
- Industrial microgrids create new bilateral relationships with utility networks.
- Utilities manage bidirectional power flow from a multitude of distributed energy resources that they don't control, and which are unpredictable.

Energy is no longer delivered. It is co-managed across a network of assets, engineers and algorithms.

What changes is not structure alone but the physics of value creation:

- Engineer productivity becomes the constraint → scarce expertise must scale globally
- Equipment productivity becomes the lever → every asset must deliver more uptime, more output, more life
- Energy productivity becomes the objective → every unit of energy must do more work per cost and per emission

This means that resilience becomes distributed (across assets and decisions); affordability becomes dynamic (optimized in real time); clean energy becomes system-dependent (not asset-dependent).

The service model that worked when sectors were distinct will not be adequate for what they are becoming. The role of service shifts from maintaining equipment to maximizing the productivity of engineers, equipment and energy.

The sectors today
Each sector faces the same underlying challenge: how to increase the productivity of engineers, equipment and energy under rising demand and constraint.
Today, the energy trilemma plays out differently across sectors, but the underlying challenge is consistent: aging infrastructure, rising demand intensity, cost pressure and regulatory obligations are converging simultaneously. No sector is insulated. The companies treating electrical infrastructure as a strategic asset – frequently managed in partnership with expert electrical service providers – are already pulling ahead. These are some of the challenges facing key sectors today.

Challenges facing sectors today

Sector	Core challenge (AS IS)	The service response	Examples
Utilities	Aging distribution networks; shift to distributed/bidirectional power flow; renewable integration at grid edge	Asset life extension; monitoring and modernization of aging switchgear and transformer fleets; advisory for grid operators managing Distributed Energy Resources (DERs) and microgrids	Hydropower: SF6 retrofit, downtime cut from weeks to hours; regulatory compliance and carbon footprint addressed simultaneously
Industry: manufacturing, chemicals, steel, cement	Energy = 30–50% of production cost; power quality issues in automated facilities; 'run to failure' culture entrenched; CSRD and Emissions Trading Scheme (ETS) obligations tightening	Strategic asset management; proactive maintenance; power system studies; brand-agnostic advisory as basis for trusted partnership	Steel manufacturer: quarterly maintenance cycles eliminated; 10-year no-maintenance horizon; 24/7 predictive health monitoring introduced
Oil, gas & mining	Electrification of operations; reliability in remote single-feed sites where a production stoppage has global supply chain consequences; Scope 1 carbon reduction	Microgrid design; energy storage advisory; predictive maintenance; peak shaving and power quality	Refinery: waste methane captured and used to generate electricity, stored in BESS and traded in peak energy markets – a waste stream and potent CO^2 emission become a revenue source
Data centers	99.999% uptime; AI workloads create impulsive millisecond load swings on infrastructure built for a different era; power demand set to more than double to ~945 TWh by 2030	Predictive maintenance; digital retrofitting; BESS-as-a-Service to smooth impulsive loads; DC power distribution transition delivering 10–20% efficiency gain	South American bank data center: preventive maintenance contract, downtime reduced to zero, no failures
Commercial & industrial buildings	High OpEx from reactive repairs; workforce skill shortages; legacy infrastructure unable to respond to emerging bidirectional grid demands.	AI-driven predictive maintenance; remote AR-guided repairs; digital retrofits of existing assets. Buildings shift from passive consumers to active grid participants, using AI-powered energy management to automatically 'flex' electrical loads based on price signals and renewable availability.	Our own ABB Frosinone factory retained 100% of switchgear and retrofitted digital trip units, avoiding carbon and financial cost of new equipment. Modernization and modernization kits to ensure 20th-century electrical infrastructure can meet 21st-century digital interoperability standards

Utilities
Utilities maintain the infrastructure on which every other sector depends. They manage the simultaneous pressure of integrating intermittent renewables, replacing aging distribution assets and meeting near-perfect uptime obligations for industrial and domestic customers. The issue for utilities is that the infrastructure deficit sits squarely on their balance sheet.

Industry: manufacturing, chemicals, steel, cement
"Hard-to-abate" manufacturing sectors must deal with the energy trilemma given their energy-intensive operations. These are typically 24/7 operations where energy represents 30–50 percent of total production cost and production stoppages trigger complex restart sequences. Added to which, decarbonization obligations under the EU Emissions Trading System, the Industrial Emissions Directive and CSRD reporting are tightening steadily.

Oil, gas and mining
Oil, gas and mining operators face the challenge of reducing the carbon intensity of production while maintaining uptime and resilience. Operators are simultaneously managing the consequences of elevated commodity prices, the drive to electrify their own operations and the need to reduce the carbon intensity of production. For mining, the additional challenge is reliability in remote, often single-feed operations where a production stoppage can have global supply chain consequences.

Data centers
Data centers have become essential elements of critical national infrastructure. AI development, cloud computing and the digitalization of public and private sector operations – including the military – depend on continuous, reliable operation of data centers.

Power density is increasing with every new GPU generation. Hyperscalers routinely build facilities requiring over 100 MW of power, as more computing power is concentrated into the same footprint. Uptime requirements for AI inference workloads can be measured in seconds – and in environments where a single outage affects millions of simultaneous users – financial, reputational and contractual consequences compound rapidly.

In addition, regulators are beginning to respond: in some jurisdictions, data centers are now required to install on-site energy storage or generation capacity and to feed electricity back into the national grid during peak shortages. The era of the data center as a passive grid consumer is ending – regulation is likely to mean that active participation in grid resilience becomes a condition of operation.

This is why modernizing electrical infrastructure is no longer optional for data center operators.

Commercial and industrial buildings
Battery energy storage is emerging as a leading solution for reliable and resilient electrical power in buildings, though it is not without limitations.

Commercial buildings, hospitals, airports and large industrial facilities share a common set of pressures: aging electrical infrastructure, rising energy costs, growing EV charging loads, increasingly demanding HVAC requirements and new embedded generation assets that were not part of the original design brief. For many of these facilities, battery energy storage is becoming the practical solution that ties these pressures together – smoothing grid volatility, supporting EV charging infrastructure and enabling on-site renewable generation to be stored and deployed when it is needed most, rather than fed back to the grid at negligible rates.

From pain points to practical pathways towards 2035+

The next decade is not defined by individual technologies, but by integration into a single objective: maximizing the productivity of engineers, equipment, and energy in real time.

This is the new operating model:

- Engineer productivity → scale expertise across assets and geographies
- Equipment productivity → extend life, increase uptime, reduce failure
- Energy productivity → optimize how energy is generated, stored and consumed

All three are interconnected. Improvement in one without the others is suboptimal.

Five solution pathways map onto the industry and utility pain points identified in this whitepaper. The CapEx-to-OpEx transition is the red thread across all five: beginning with outcome-based maintenance contracts and energy-as-a-service, extending to monitoring subscriptions and ultimately to full energy service agreements. Asset management, automation and AI stop being separate functions and become a single operating system for the enterprise.

What unites them all is the ability to extract more value, reliability and sustainability from the infrastructure that already exists, while building the capacity to manage what comes next.

Practical pathways towards 2035

Pathway	Pain point addressed	Today (AS IS / 2026–2030)	Forward horizon (2030–2035+)
1. **STRATEGIC ASSET MANAGEMENT**	Unplanned downtime; aging infrastructure; retrofit vs. replace uncertainty	50% of electrical equipment reusable indefinitely with component upgrades; reduces operating costs by a third; extends life up to 30 years; running to failure costs up to 10× more	Partnerships with electrical service providers delivering strategic phased modernization; brand-agnostic advisory ensuring best solution rather than product pull-through; assets will be born with digital identities that track performance, risk, regulatory compliance and carbon impact in real time; maintenance plans will no longer be based on schedules or averages but on probabilistic forecasts that constantly recalibrate
2. **AI AND DIGITAL SOLUTIONS**	Reactive maintenance; data silos; skills gap	Remote monitoring; condition alerts; risk profiles and budget-allocation priorities; digital retrofitting extends asset life 20–30 years	AI-assisted dispatch; condition-based monitoring mainstream; integrated Building Management System (BMS) / Supervisory Control and Data Acquisition (SCADA) / Enterprise Resource Planning and sustainability data view; AI brings every technician to 15-year veteran's experience level; AI will increasingly surface options humans have not considered, across reliability, energy, maintenance and emissions tradeoffs; Instead of automating fixed sequences, operations will automate intent. Plants, networks and sites will dynamically adjust throughput, energy use and process paths based on fluctuating demand, grid constraints, climate conditions and workforce availability
3. **ENERGY STORAGE**	Peak demand charges; on-site renewable underperformance; diesel dependency	BESS-as-a-Service: genuinely new to market in 2026; end-to-end service covering consulting, engineering, operations, financing and long-term agreements; ABB Electrification Service believed to be the only company offering this fully integrated model at launch	Stored energy traded in frequency and voltage regulation markets makes storage investment self-funding; applications scale across data centers, manufacturing, and remote industrial sites; Energy storage will no longer sit at the edge of industrial operations as insurance against outages. It becomes part of the operating logic itself. Storage shifts from something leaders defend as resilience spend to something that actively shapes how, when and even whether industrial processes run.
4. **ENERGY & CARBON**	CapEx constraints blocking TCO decisions; Scope 1/2/3 pressure	Battery storage costs fell sharply in 2024 – economics now cost-neutral or revenue-positive in many cases through active trading; BESS-as-a-Service removes ownership barrier; carbon footprint included on every service quotation	Outcome-based service subscriptions scale across all sectors: the 'Rolls-Royce power-by-the-hour' model (see case study below) applied to electrical infrastructure management; regulatory compliance baked-in. The line between operational efficiency and carbon performance disappears. Every operational choice, from maintenance timing to throughput to sourcing, will carry an energy and emissions consequence that systems can expose instantly
5. **ADVISORY SERVICES**	Decisions made without full picture; capital misallocation; regulatory compliance burden	Power system studies; load flow analysis; TCO calculators translate operational challenge into board-level decision; moves customers from product purchase to investing in outcomes	Companies have an energy and carbon advisor, able to operate in any country, any region – and with the strategic capability to translate commercial and energy requirements into practical, cost-effective multi-year, multi-technology plans. The most advanced operators will rely on ecosystems that blend technology providers, energy partners, analytics specialists and regulatory expertise into how operations are designed and run.

HORIZON 2035–ON

A transformed service model – predictive, augmented, outcome-based

By 2035, the system operates as one integrated model. The distinction between asset management, energy management and service disappears.

The 2035-on horizon is where the four horizons converge into a single transformed model. Some elements below do not yet exist, so while not a prediction, their deployment is grounded in active R&D work and confirmed strategic direction.

A practical route map: where the evidence points

HORIZON AS IS (2026)	Most organizations are still in reactive mode: time-based maintenance, siloed data, capital constraints blocking TCO decisions, sustainability framed as compliance burden. The execution gap is real.	The trilemma is bearing down simultaneously. The organizations treating electrical infrastructure as a strategic asset are already pulling ahead.
2026–2030	Deploy condition-based monitoring across the highest-consequence assets – the financial case writes itself against $125,000-per-hour downtime. Begin the CapEx-to-OpEx transition: start with BESS-as-a-Service, extend to monitoring subscriptions and outcome-based maintenance contracts.	Capture retiring expertise now before it walks out of the door: video documentation, knowledge databases, VR training content. Work continues to realize a unified energy data infrastructure which is the prerequisite for everything that follows.
2030–2035	Automated inspection platforms operational in high-risk environments. Exoskeletons standard for heavy manipulation – the 50/50 solution combining human judgment with technological load bearing. AI-driven dispatch sends technicians by data, not calendar. The workforce is dramatically more	productive. AI brings all technicians up to the performance of a 15-year veteran. Net Zero interim targets require measurable delivery – organizations without monitoring and efficiency infrastructure in place by 2030 face regulatory and commercial consequences.
2035–ON	Digital twins of entire electrical infrastructure systems, continuously updated, make retrofit-vs.-replace decisions more data-driven. Outcome-based energy service subscriptions – the Rolls-Royce 'power by the hour' model (see case below) for electrical infrastructure – are the standard commercial	framework. The workforce is not smaller. It is different: fewer generalists, more specialists, all supported by AI and AR quality and knowledge retention tools.

POWER BY THE HOUR – THE PIONEERING ROLLS-ROYCE SERVICE MODEL

When British jet engine maker Rolls-Royce launched the Viper turbojet for the HS.125 business plane in 1962, it recognized a fundamental problem: unlike major airlines, corporate jet owners had no large maintenance departments to manage complex engine servicing. Its solution was radical. Rather than selling parts, Rolls-Royce charged a fixed hourly fee for every hour the engine flew – covering all maintenance, replacements and upgrades. By tying the manufacturer's revenue directly to engine performance and uptime, the model created a genuine alignment of interests: with their 'Power by the Hour' model, Rolls-Royce had every incentive to keep engines running reliably, while operators gained predictable costs and freedom from maintenance complexity.

It also reframed how both sides thought about investment, as the capital expenditure of engine ownership gave way to a straightforward OpEx subscription. Constant monitoring, preventive maintenance and proactive servicing replaced the anxiety of unexpected breakdowns – and when a provider's commercial success depends directly on a customer's operational success, the relationship becomes genuinely durable. Decades later, many of those original customer relationships endure: early proof that outcome-based service models, backed by the right financial structures, can establish and cement long-term partnerships that benefit both sides.

Feature	Traditional Transactional Model	Power by the Hour / TotalCare
Primary Product	The physical engine (Hardware).	Engine "Uptime" and Availability.
Revenue Stream	One-time large capex payment + sporadic spare parts sales.	Predictable, monthly "subscription" based on usage (flying hours).
Incentive Alignment	Conflicting: The manufacturer makes more money when parts wear out or break.	Aligned: Both want the engine to stay on the wing as long as possible.
Maintenance Strategy	Reactive: Fix it when it breaks or reaches a hard time limit.	Predictive: Continuous data monitoring to fix "micro-issues" before they cause failure.
Financial Risk	Airlines: They must hold cash reserves for massive, unpredictable repair bills.	Rolls-Royce: They assume the risk of repair costs; profit depends on high reliability.
Inventory	Airlines must stock their own expensive spare parts.	Rolls-Royce manages a global pool of "spare engines" to swap in instantly.
2026 Tech Integration	Manual logging and basic telemetry.	Digital Twins: Every engine has a virtual copy in the cloud simulating its wear in real time.

By 2035, the real disruption is organizational, not technical

By the mid-2030s, AI, automation and digital asset management will be table stakes. The uncomfortable question will not be whether these systems can work, but whether leaders are willing to allow them to influence – or even change – who holds authority, who is accountable and whose judgment carries weight inside the organisation.

Who is thinking about the new service governance model of the 2030s?
As machines begin to predict failure, automate response and surface strategic trade-offs, traditional leadership models start to fracture. Hierarchy alone cannot arbitrate decisions when systems see risks, inefficiencies and contradictions long before people do. Control shifts away from titles and toward those who can interpret system insight, challenge machine outputs when it matters and make human calls where ethics, safety and consequence collide.

Who is prepared to break the mold?
The most advanced industrial operations will not be run by the leaders with the most data, but by those prepared to relinquish certainty. As mass-produced car pioneer Henry Ford reputedly observed, if you ask people what they want, they will ask for a faster horse. The instinct to optimise what exists is deeply human – but it is not the same as reimagining what is possible. Companies that simply layer intelligent systems onto old structures will move faster, but not smarter. Those willing to redesign roles, incentives and decision rights around human/machine judgment will set the pace.

In the end, the dividing line is clear. Either companies choose to be shaped by intelligent systems on their own terms, or those systems will quietly expose where leadership has already stopped keeping up.

SIX OPERATIONAL RESILIENCE CHALLENGES THAT DEMAND IMMEDIATE ATTENTION

As we prepare for the future of building and maintaining safe, resilient and responsive electrical energy systems to support economic growth and social development, here is some food for thought on the next steps for electrical service.

What is actually causing the outages?
Most organizations can describe the symptoms – recurring faults, unexpected downtime, ageing equipment. Fewer have a clear picture of the underlying cause. Power system studies, load flow analysis and total cost of ownership modeling often reveal that the real problem is not the equipment that failed, but the conditions that were allowed to develop around it. That is where the conversation about genuine resilience begins.

Is the investment framework keeping pace with the risk exposure?
More than eight in 10 industrial leaders believe total cost of ownership should guide capital decisions – yet fewer than four in 10 actually apply it. The gap between what organizations know they should do and what they are able to do is rarely a technology problem. It is almost always a financing and procurement model problem. Service structures that convert capital expenditure into predictable operational cost already exist. The question is whether current purchasing and internal ownership frameworks make them easy or difficult to adopt.

Are sustainability commitments working for the business – or just for the reports?
Narratives and arguments around carbon and circularity only resonate with about a third of business decision-makers. Total cost of ownership, competitive positioning, supply-chain qualification and Scope 3 liability exposure reach all of them. This is because all utilities and most companies are, after all, a supplier or sub-supplier of a customer for whom these issues matter. Where the sustainability agenda is not yet connected to financial strategy, it is likely to be relegated to a compliance exercise rather than a source of strategic competitive advantage.

How much is actually known about the condition of electrical assets?
The gap between assumed asset condition and actual asset condition is where most unplanned outages originate. Predictive maintenance, condition indexing and digital asset monitoring close that gap – but only for organizations that have moved beyond scheduled servicing cycles. For those still managing electrical infrastructure on an age and calendar basis, rather than on condition and data, the risk is far from theoretical.

Is the workforce resilience plan keeping up with operational ambitions?
The shortage of qualified electrical engineers and technicians is structural and sector-wide. It will not resolve itself. AI-assisted diagnostics, augmented reality remote support and advanced training tools are already changing what is possible with smaller teams where specialist capacity is already stretched. Organizations that build these capabilities into their operational model now will be significantly better placed than those that treat workforce resilience as someone else's problem to solve.

Designing for the 2030s – or managing the legacy of the 1990s?
AI, automation and digital asset management will reshape how electrical systems are owned, operated and governed. The organizations that will lead that transition are not waiting for the technology to mature – they are already asking the harder questions about what needs to be redesigned, what needs to be retired and what new operational models will be required to manage infrastructure that did not exist a decade ago. Intensive energy users should be anticipating that they cease to be consumers of power and evolve into critical bi-directional participants which contribute to a resilient national grid.

Ready to build a more resilient operation?

Talk to our experts about your energy reliability and resilience goals

Contact our team

GLOSSARY

AR
Augmented Reality

BESS-AS-A-SERVICE
Battery Energy Storage Systems

BMS
Battery Management System (also Building Management System in commercial building contexts)

CBAM
Carbon Border Adjustment Mechanism (EU)

CSDDD
Corporate Sustainability Due Diligence Directive (EU)

CSRD
Corporate Sustainability Reporting Directive (EU)

DER
Distributed Energy Resource

ERP
Enterprise Resource Planning

ETS
Emissions Trading Scheme

ISSB
International Sustainability Standards Board

LNG
Liquefied Natural Gas

MTTR
Mean Time to Repair

NERC
North American Electric Reliability Corporation

OPEX
Operational Expenditure (contrast with CapEx: Capital Expenditure)

SCADA
Supervisory Control and Data Acquisition

SF6
Sulphur hexafluoride – greenhouse gas used historically in switchgear; subject to EU phase-out regulation

TCO
Total Cost of Ownership

VR
Virtual Reality

The content of this whitepaper draws on the experience and expertise of ABB Electrification Service personnel, published ABB materials and together with a variety of third-party data and reports, some of which are cited in the text.

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