Power grid modernization

The catalyst to resilience and energy transition

How can IBM help

Between extreme weather, regulatory demands, and the global push for sustainable and renewable energy, energy and utility companies face a tall order in today's geopolitical landscape. Digital transformation is required for energy companies to successfully navigate energy transition. From data management to customer engagement to generative AI, IBM's enterprise-ready artificial intelligence platforms, consulting services, and data-driven solutions use the latest digital technologies to transform and prepare the utilities sector for the future. For more information, visit ibm.com/industries/power-utilities

How AspenTech can help

Increasing demand for electricity, gas, and water faces challenges from aging infrastructure and support for clean energy. Aspentech's Digital Grid Management solutions support an evolution to intelligent, secure, and reliable utility networks for a sustainable future. For more information, visit aspentech.com/en/industries/power-generation-transmission-and-distribution

Key takeaways

Managing renewable intermittency effectively is a key capability that utilities must develop to support the clean energy transition.

Self-optimization, interconnectivity, and flexible load management help boost resilience and reliability.

Seven in 10 pioneering utilities use predictive analytics to optimize energy supply and demand management. Improving data sources, data management, and data access will enhance utilities' ability to avert, spot, and bounce back from disruptions.

Effective generation management and the integration of renewables and distributed energy resources (DERs) are crucial for balancing demand and supply.

67% of optimizing utilities manage microgrids as a local energy service and as a reliable resource to help operate the grid. Managing renewable intermittency effectively is a key capability that utilities must develop to support the clean energy transition.

Planning, forecasting, and simulation capabilities help anticipate grid dynamics and guide where investments are needed.

Nearly two-thirds of surveyed utilities create asset failure forecasts to evaluate impact on network performance. Fostering operational excellence across utility stakeholders using these methods can optimize grid efficiency, asset utilization, and overall system performance.

Adapting to the future

Electric grids, pivotal to society, require continuous investment to enable resilience and security. The energy landscape is transforming, driven by a surge in renewable energy sources and the proliferation of DERs as well as electrification expansion with electric vehicles and other end-user devices.

Utilities confront the challenge of managing both large-scale renewable resources and the intricacies of distributed systems, necessitating a paradigm shift in grid operations from unidirectional to bidirectional systems.

The energy mix now includes a diverse range of intermittent resources—solar, wind, geothermal, hydropower, nuclear, hydrogen, and fossil fuels. Meanwhile, developments such as electrification of industry, smart buildings, and increased adoption of energy-intensive technologies like artificial intelligence are escalating demand. This transformation is further complicated by extreme weather events, cybersecurity threats, and aging infrastructure, all of which underscore the need for a digital, data-driven grid.

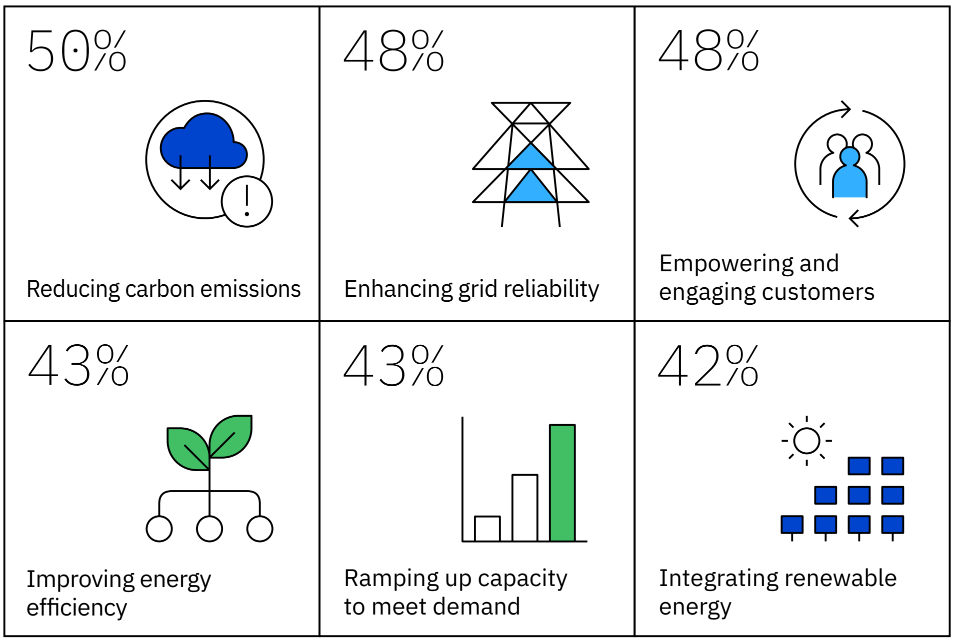
Advanced technologies such as automated control, forecasting, and energy storage are critical in enabling grid reliability amid fluctuations in supply and demand. Digital tools offer a pathway to upgrading antiquated infrastructure, enhancing grid management, and improving performance. Real-time monitoring and predictive analytics are crucial for mitigating disruptions and preserving power reliability.

In new research from the IBM Institute for Business Value, we found that utilities are committed to building a smarter grid. In our survey of nearly 600 global C-suite and senior utility executives, all say their organizations have a grid modernization strategy and execution plan. We found that utilities are spending, on average, 9.8% of their annual revenue on grid modernization investments, which is over 40% of their overall transmission and distribution investments.[1]

Still, utilities have made varying levels of progress in creating a resilient and adaptable grid, managing intermittency with flexibility, and accommodating growing demand. In fact, 21% report having made no progress. For all, further embracing grid modernization is critical to supporting the clean energy transition and maintaining a reliable, affordable, and secure grid (see Figure 1).

Figure 1

Top goals in grid modernization efforts



Q. What are the key goals of your organization's grid modernization efforts? Select up to 6.

In our survey analysis, we identified four groups based on their grid modernization strategies, including demand flexibility, grid optimization, energy exchange, and smart assets. By identifying with the group most similar to them, and understanding the respective behaviors, strategies, and actions, utilities can make better-informed decisions and tailor strategies accordingly.

One group, Pioneering Integrators, is further along at advancing the grid and self-reports outperforming peers for innovation, resilience, and digital maturity. However, none of the groups fully demonstrate these capabilities (see Figure 2). Continuous improvement remains necessary for all utilities in this evolving grid modernization journey. The level of improvement required will vary depending on the group type, with more advanced groups like Pioneering Integrators needing to focus on refining their strategies, while other groups may need to prioritize foundational investments and capabilities.

Pioneering Integrators are the most advanced in grid modernization, excelling in demand flexibility, energy exchange, and utilization of digital twins to simulate and optimize grid performance. However, they are less advanced in leveraging self-monitoring assets to minimize outages and asset damage, as well as integrating advanced metering infrastructure (AMI) 2.0 with automated outage management customer communication systems.

Energy Optimizers are strong in demand flexibility and grid optimization, demonstrating a high commitment to smart asset integration. Nevertheless, they are less advanced in implementing bidirectional networks, which highlights a gap in the adoption of renewable energy exchange.

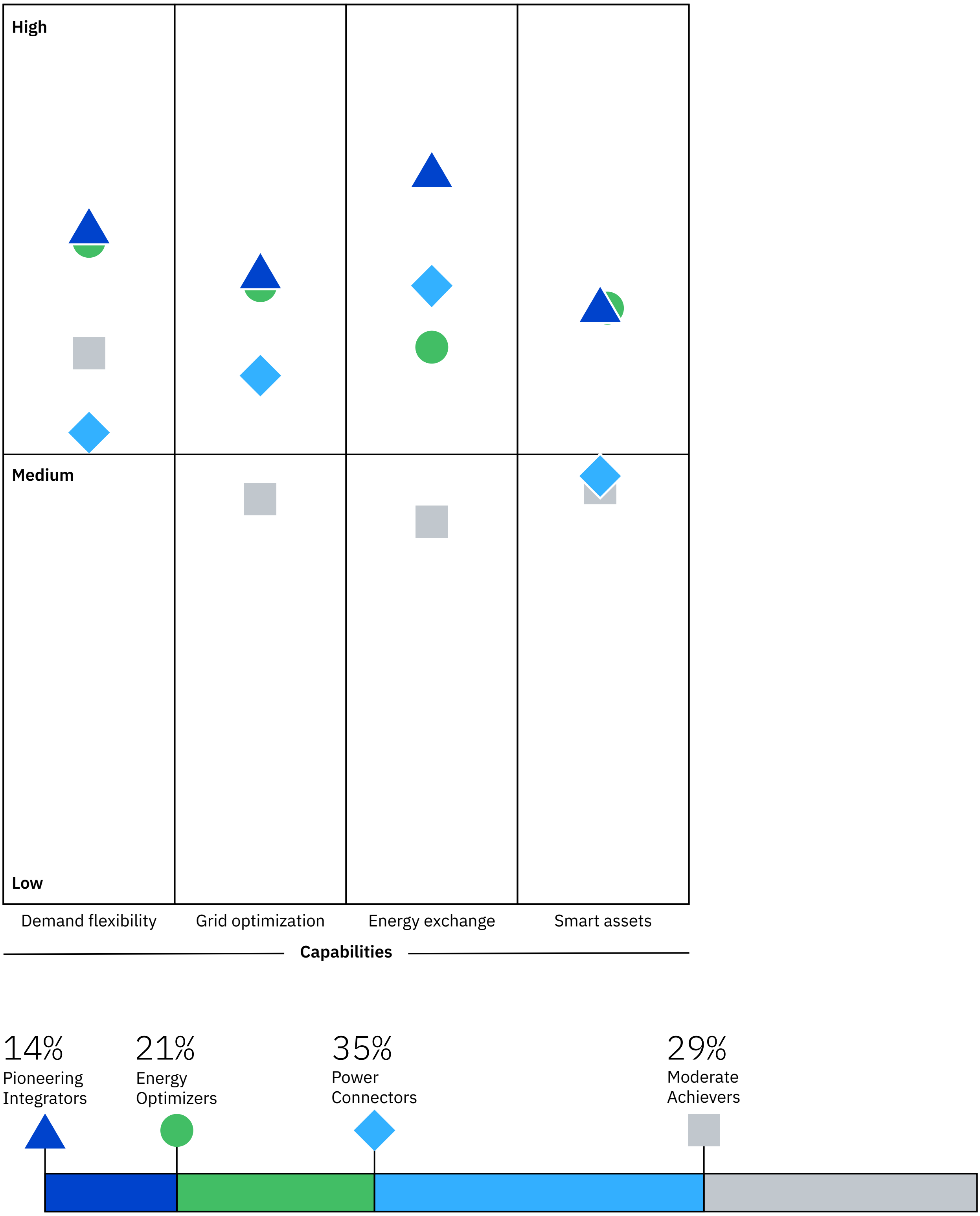
Power Connectors have a relatively strong focus on energy exchange and prosumer engagement. enabling the flow of energy both to and from consumers. However, their progress in demand flexibility is less advanced, and their use of smart assets remains limited. While they do employ digital twins for optimizing power flow, their overall approach to grid optimization is still developing.

Moderate Achievers have made solid progress in meeting demand flexibility but are being outpaced by their peers in energy exchange and grid optimization. They have yet to fully integrate third-party data sharing for smart asset management.

Source: IBM Institute for Business Value

Figure 2

Pioneering Integrators and Energy Optimizers do not choose among resilience, digitalization, and energy transition—they pursue all of them.



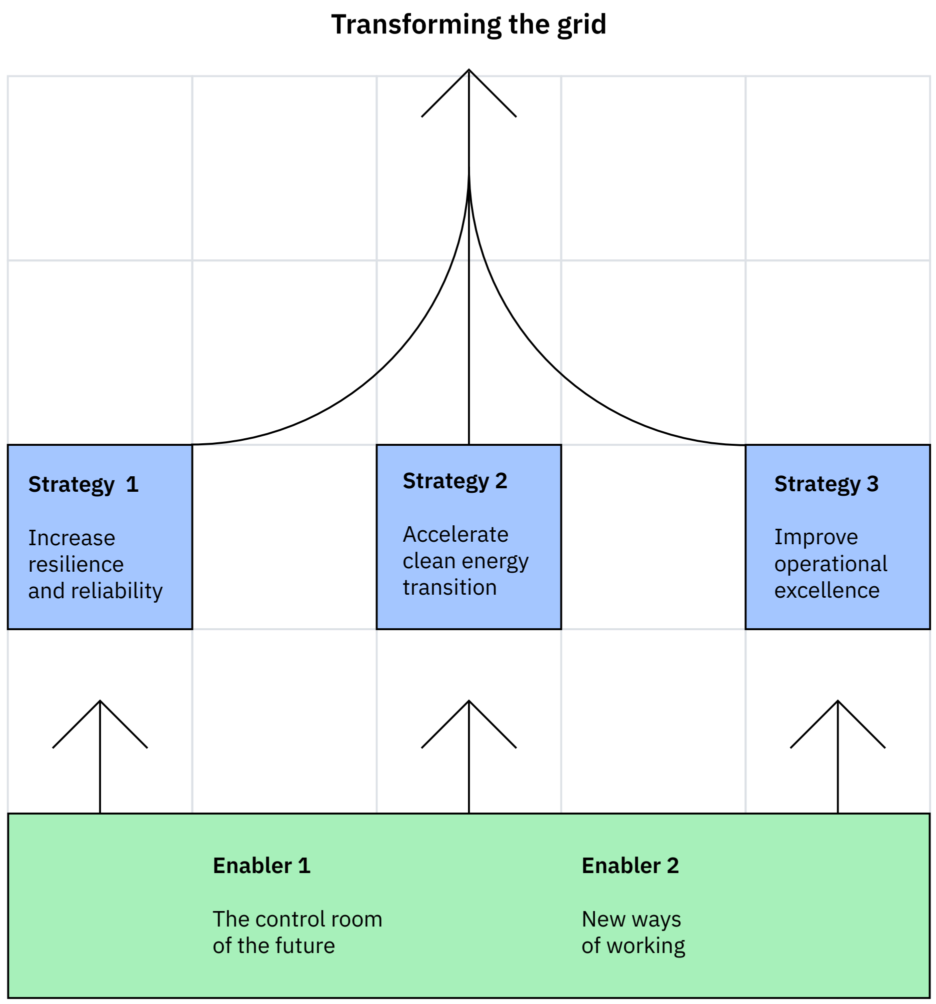
Source: IBM Institute for Business Value

Note: Percentages show a group's representation within the total survey population. Due to rounding, percentages may not add to 100%. Figure displays average capabilities across groups.

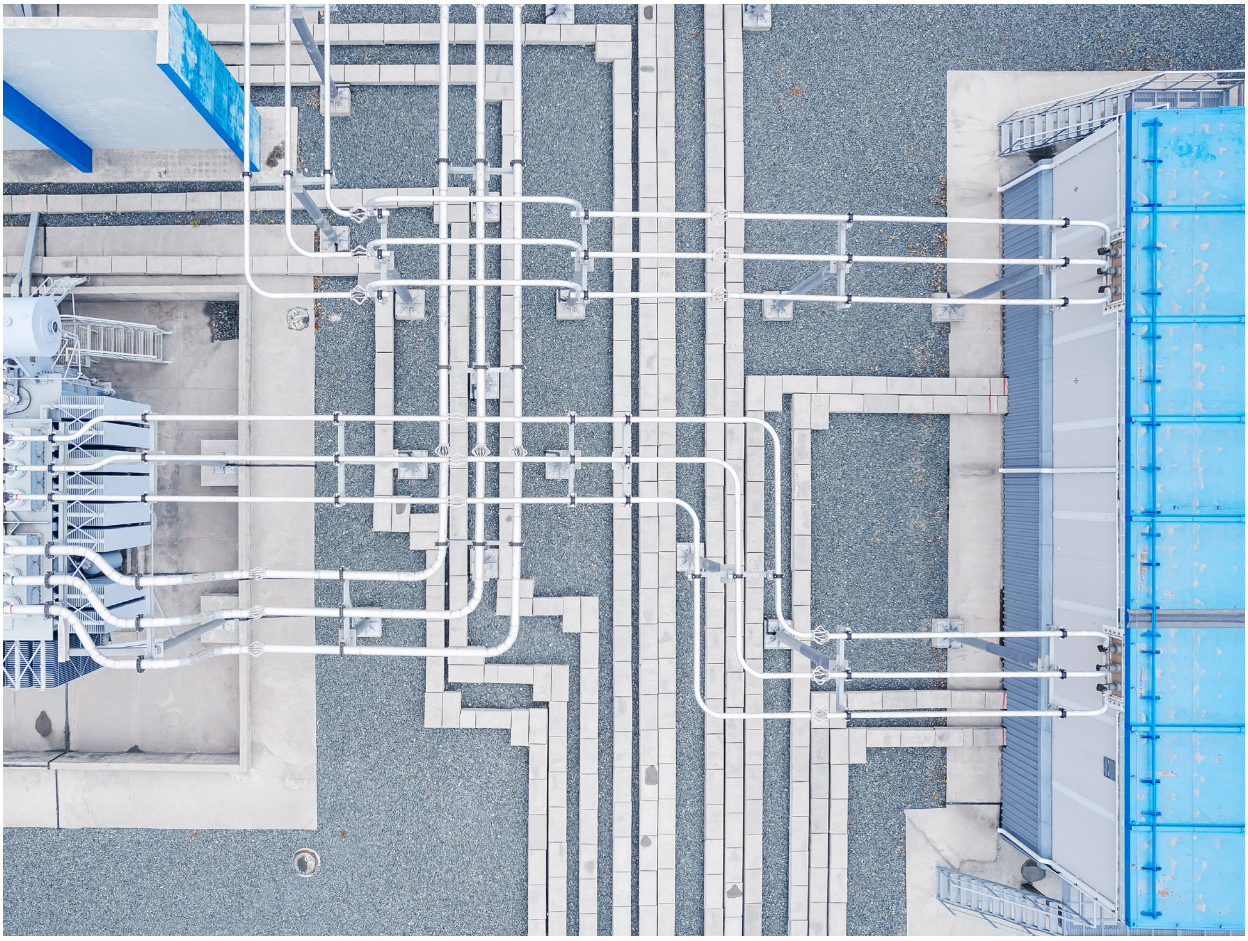
Our data shows that to be future-ready, utilities need to excel across three key strategies, leveraging two enablers (see Figure 3). This report dives deeper into these strategies and enablers, describing each group's efforts to support their operational priorities. We also present four case studies, and an action guide that offers a three-step plan for moving forward.

Figure 3

Key strategies and enablers for future-ready utilities



Source: IBM Institute for Business Value



Strategies that transform utilities

Several critical strategies help utilities ensure their grids are resilient, adaptable, scalable, and operationally optimized. These strategies collectively enhance a grid's capacity to withstand disruptions, integrate renewable energy sources effectively, and manage operations with greater efficiency.

Strategy 1
Increase resilience and reliability

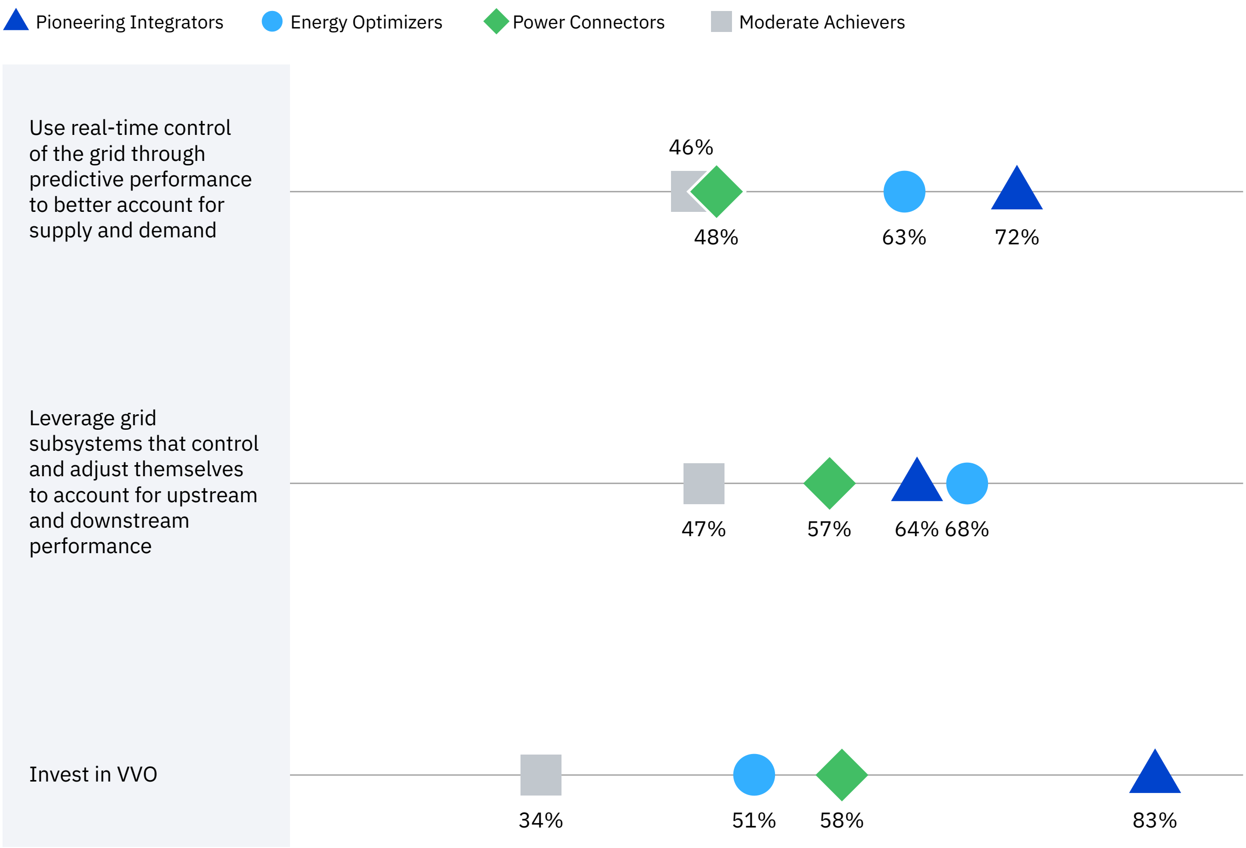
Building grid resilience requires a comprehensive approach to strengthen its ability to prevent, detect, and recover from failures or disruptions. Key tactics include grid self-control and optimization, interconnectivity and integration, and flexible load management via tools such as dynamic pricing or demand response.

Grid self-control and optimization

Grid self-control and optimization are key to allowing the system to respond efficiently to real-time changes (see Figure 4). By employing predictive performance analytics, utilities can better understand supply and demand fluctuations, enabling proactive adjustments to maintain grid stability. Additionally, subsystems autonomously adjust based on upstream and downstream performance, decreasing the need for manual intervention. For example, investing in Volt/VAR optimization (VVO) enhances grid efficiency by controlling voltage and reactive power, reducing energy losses, and improving overall grid reliability.

Figure 4

Tactics to enhance the grid's ability to adapt to real-time changes.



Q. How modernized are the above predictive capabilities in your organization? Percentages show responses of 3 and 4 on a 4-point scale where 1 = Not at all and 4 = To a large extent. Q. In which of the above grid management and monitoring technologies has your organization invested / does it plan to invest?

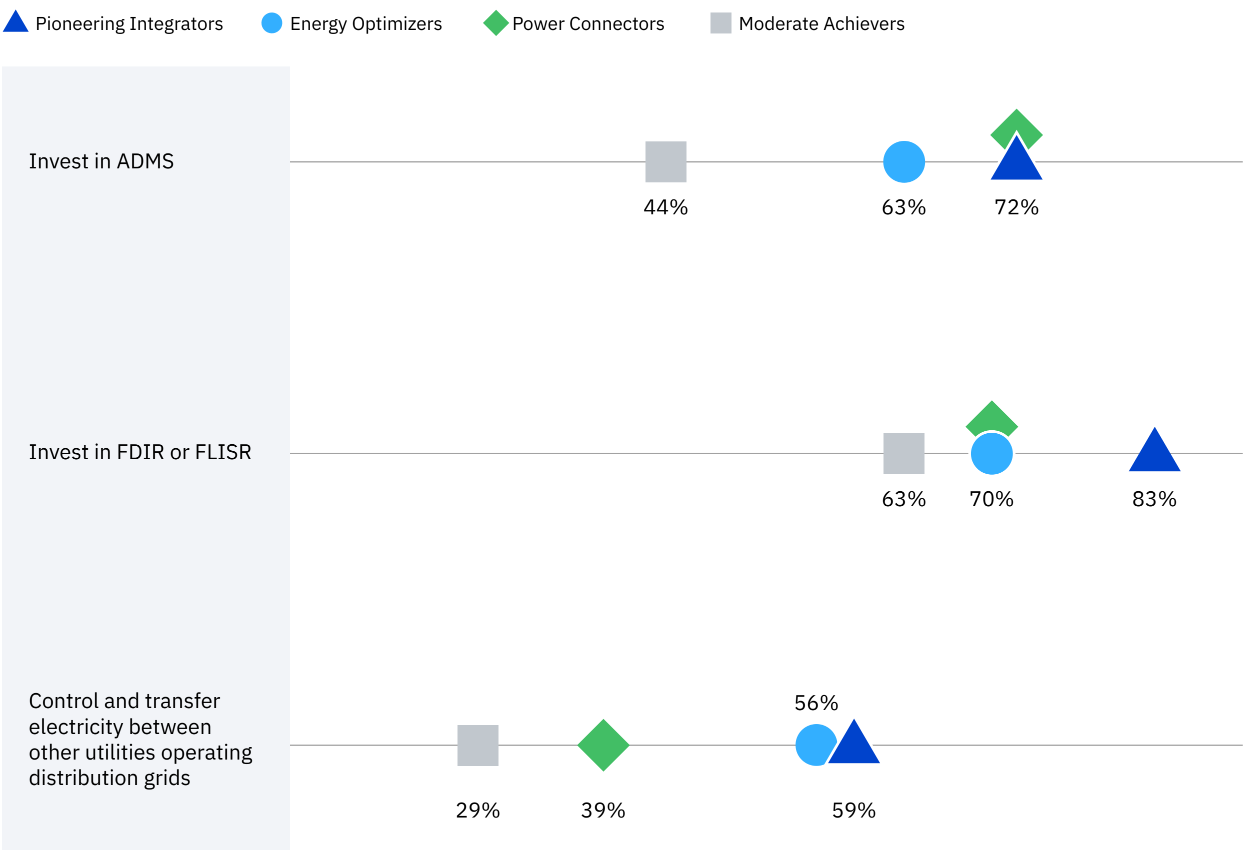
Grid interconnectivity and integration

Interconnectivity and integration play a critical role in improving grid reliability and efficiency by facilitating coordination across grid components (see Figure 5). Adopting an Advanced Distribution Management System (ADMS) allows utilities to monitor, control, and optimize grid operations in real time. Pioneering Integrators and Power Connectors tend to leverage ADMS more extensively, enabling proactive decision-making and efficient grid administration.

Fault detection, isolation, and restoration (FDIR) or fault location, isolation, and system restoration (FLISR) technologies provide self-healing mechanisms, quickly identifying and resolving issues to reduce outages and boost service reliability. Pioneering Integrators invest significantly in this area, creating a self-adjusting network that delivers balanced power distribution. The ability to transfer electricity between utilities enhances flexibility, sharing resources during peak demand or system disruptions.

Figure 5

Tactics to improve the grid's ability to integrate new energy sources and respond to disruptions across interconnected systems.



Q. In which of the above grid modernization control center technologies has your organization invested / does it plan to invest?
Q. In which of the above grid management and monitoring technologies has your organization invested / does it plan to invest?
Q. What stage is your organization at in managing increasing demand and intermittent supply? Percentages show responses of 4 and 5 on a 5-point scale where 1 = Not considering, 2 = Evaluating, 3 = Piloting, 4 = Rolling out, and 5 = Fully implemented.

Flexible load management

Dynamic pricing and demand response programs are sample tools utilities can use to drive helpful behavior with energy consumption, allowing the utility to maintain a balanced and reliable grid. Notably, 82% of Pioneering Integrators use real-time pricing, adjusting rates minute-to-minute to reflect market fluctuations, compared to just half of their peers. Demand response initiatives motivate consumers to reduce usage during peak periods, preventing costly plants from operating. Cloud-based demand response systems, used by 58% of utilities, automatically adjust consumer energy use based on grid conditions, balancing supply and demand without manual input.

Demand response initiatives motivate consumers to reduce usage during peak periods, preventing costly plants from operating.

Case study

NESO: Building a power system that's fit for the future[2]

NESO, the National Energy System Operator for Great Britain, is responsible for managing the electricity grid's operation. Historically, the system was balanced using a mechanism primarily designed for fossil fuel-based power generation. However, with the increasing integration of renewable energy sources such as wind and solar farms, the grid became more volatile and unpredictable.

To address these challenges and transition toward a zero-carbon future, NESO embarked on a project to transform its balancing system. Working with IBM, they built an Open Balancing Platform (OBP), a secure-by-design, hybrid cloud core architectural system. This platform aimed to manage a larger number of smaller generation units and adapt to new requirements and innovations more quickly.

Post-implementation, NESO has experienced significant improvements, including a 283% increase in battery dispatch volumes, a 90% reduction in user input, and an estimated 37,400 metric tons of CO_2 saved.

The OBP gives NESO the control to reserve excess green energy using battery storage sites. Surpluses in wind or solar energy can be dispatched to batteries, which are then charged for later use. The implementation of battery units reduces reliance on gas-fired generation in times of need by ensuring that renewable energy doesn't go to waste. This transformation has enabled NESO to keep pace with the evolving energy landscape, facilitating a smoother shift toward a net-zero carbon future.

Strategy 2
Accelerate clean energy transition

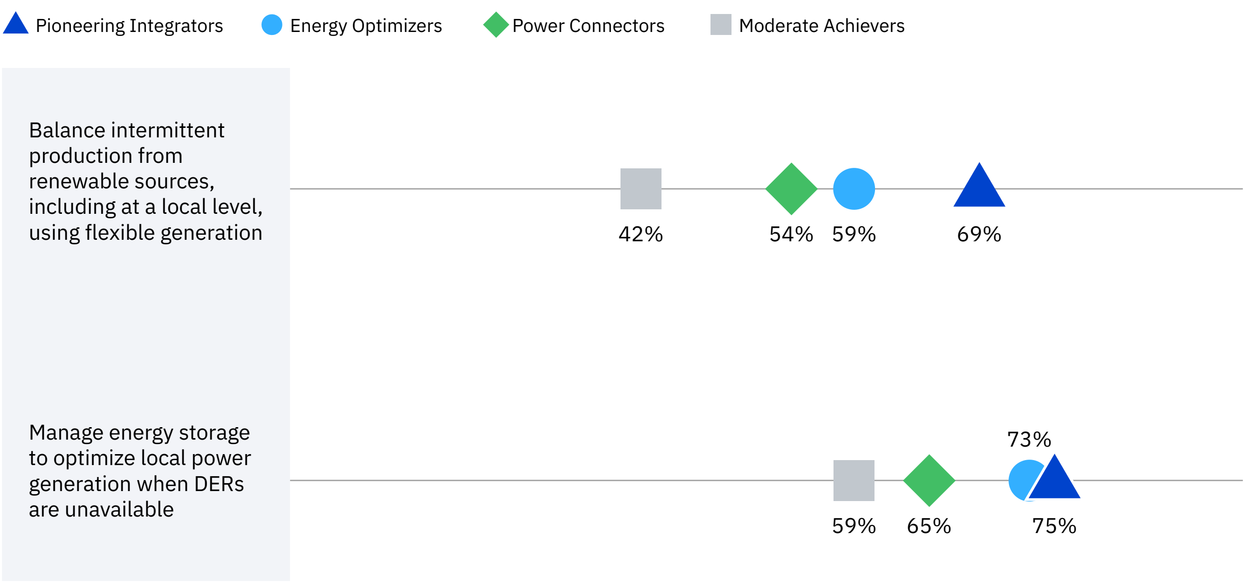
With the acceleration of intermittent renewable generation sources, utilities are challenged to maintain the stability of the grid. Significant grid transformation with investment in both physical (such as batteries) and digital assets (such as DERMS software) are required to help ensure utilities can maintain a resilient and reliable grid. With renewable energy generation often intermittent, utilities must accelerate the transition to clean energy. Flexible generation management, large-scale renewable energy integration, and DER integration are critical to meeting rising demand while fostering reliability and sustainability.

Generation management

Generation management involves using batteries or other generation sources capable of quickly ramping up or down to maintain a stable energy supply (see Figure 6). Energy storage systems, such as batteries and pumped hydro, store excess energy during peak production and release it during low production periods, enabling consistent grid performance.

Figure 6

Tactics to adapt to changes in renewable energy availability.



Q. To what extent are you executing the above energy management capabilities? Percentages show responses of 3 and 4 on a 4-point scale where 1 = Not at all and 4 = To a large extent. Q. How modernized are the above distributed energy capabilities in your organization? Percentages show responses of 3 and 4 on a 4-point scale where 1 = Not at all and 4 = To a large extent.

Large-scale renewable energy integration

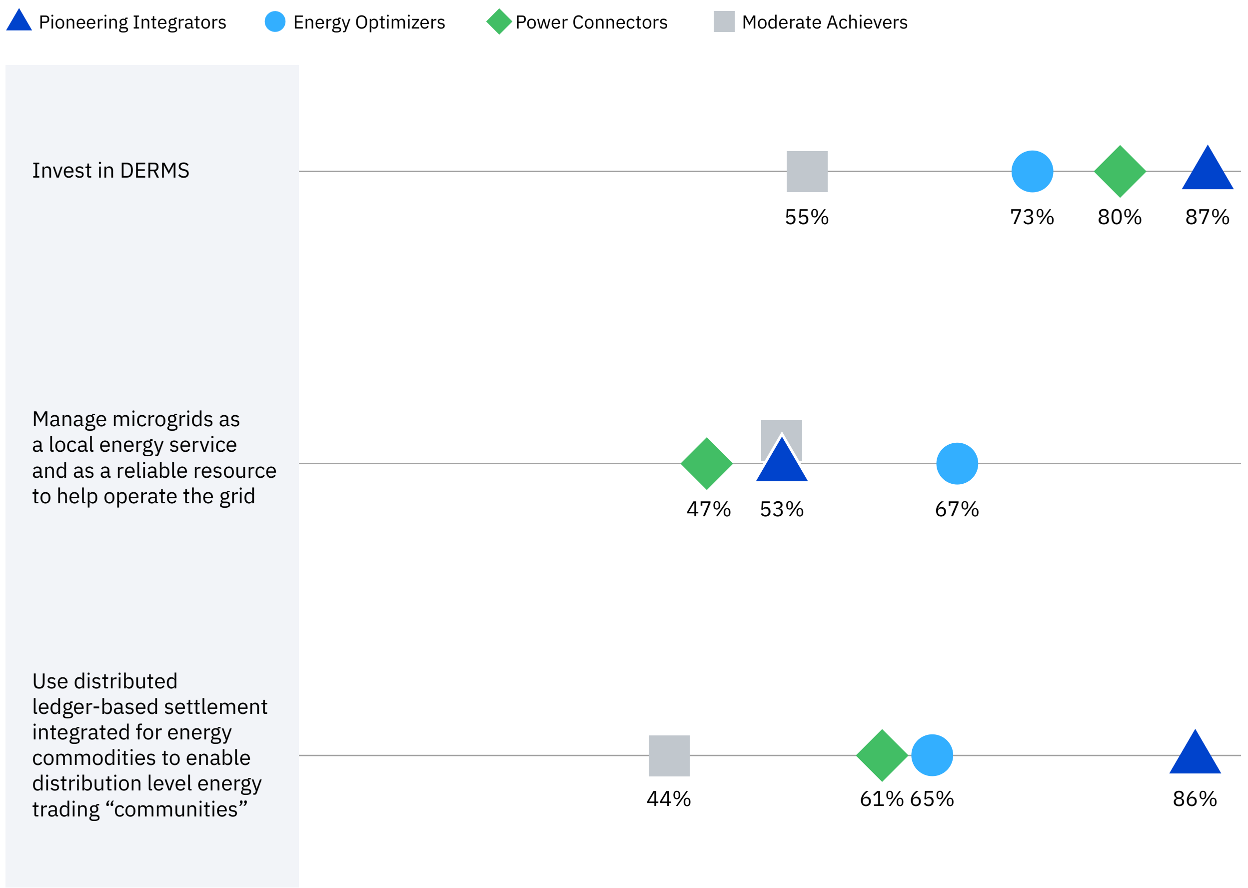
Successfully incorporating renewable energy from naturally replenishing sources such as solar, wind, and hydro requires enhancing grid capacity and integrating forecasting models to predict energy production and consumption. Pioneering Integrators and Energy Optimizers exceed their peers by 43% in improving predictions through real-time data analysis. By continuously monitoring energy generation and consumption, utilities can optimize the integration of renewable sources.

Distributed energy resources integration

DERs are smaller, decentralized energy systems (often behind-the-meter and <1 megawatt) that can include renewable or nonrenewable sources, used to meet local energy needs and enhance grid resilience. Integrating DERs enhances grid flexibility and efficiency (see Figure 7). Standardized interconnection for DERs simplifies integration and reduces complexity. About 60% of utilities have adopted these standards, yet many miss out on sharing hosting capacity information with third-party providers and customers. This collaborative approach could improve planning and optimization.

Figure 7

Tactics to help ensure the grid operates efficiently.



Q. In which of the above grid modernization control center technologies has your organization invested / does it plan to invest?
Q. How modernized are the above distributed energy capabilities in your organization? Percentages show responses of 3 and 4 on a 4-point scale where 1 = Not at all and 4 = To a large extent.

Investment in Distributed Energy Resource Management Systems (DERMS) helps utilities monitor, control, and optimize DERs. Pioneering Integrators and Power Connectors stand out in using DERMS to reduce transmission losses and improve power supply sustainability. Additionally, managing microgrids enables greater resilience and adaptability, providing backup during outages. Energy Optimizers are stronger than their peers in this area, helping them address grid reliability in regions with high renewable energy integration.

Moreover, a trend in this space involves the application of blockchain technology. Distributed ledger-based settlement systems are being integrated to facilitate energy commodities trading at the distribution level, thereby fostering the emergence of "energy communities." These blockchain-powered platforms enable peer-to-peer transactions, empowering individuals and local entities to buy, sell, or trade excess energy produced by their DERs. This development not only promotes decentralization and democratization of energy markets but also encourages greater utilization of renewable energy sources.

Distributed ledger-based settlement systems are being integrated to facilitate energy commodities trading at the distribution level, thereby fostering the emergence of "energy communities."

Case study

Iberdrola: Using DERMS to assess flexibility on a renewables-heavy grid[3]

Iberdrola is leading Spain toward a future powered by 100% renewable energy. Since 2007, the company has focused on clean energy, starting with wind power and expanding to solar, energy storage, smart grids, and digital technologies. More recently, Iberdrola has promoted the use of DERs such as solar panels, EV chargers, and storage systems to help customers save money while increasing carbon-free electricity generation.

To scale renewables and DERs, Iberdrola is testing technologies with the Flexener consortium. As renewables are intermittent, grid reliability depends on flexible technologies that manage DERs, such as charging EVs during peak solar generation. AspenTech Open System International's (OSI's) DERMS helps optimize and control DERs in real time, maximizing their operational and financial benefits. It provides visibility and control for Iberdrola, ensuring DERs are used efficiently and benefit both customers and the grid.

Through the Flexener project, Iberdrola tested DERMS in managing EV chargers, batteries, and HVAC loads, proving its capability to integrate renewables and optimize customer participation. Key lessons included the importance of customer communication and ensuring seamless interoperability across different systems. DERMS also enables aggregating DERs into a Virtual Power Plant, participating in energy markets like traditional power plants. Iberdrola's experience with DERMS is shaping its future DER programs, driving Spain toward its 2050 net-zero target.

Strategy 3
Improve operational excellence

Operational excellence is crucial for optimizing grid efficiency and asset availability. Strategic planning and modeling and asset monitoring and automation play vital roles in enhancing utility operations.

Strategic planning and modeling

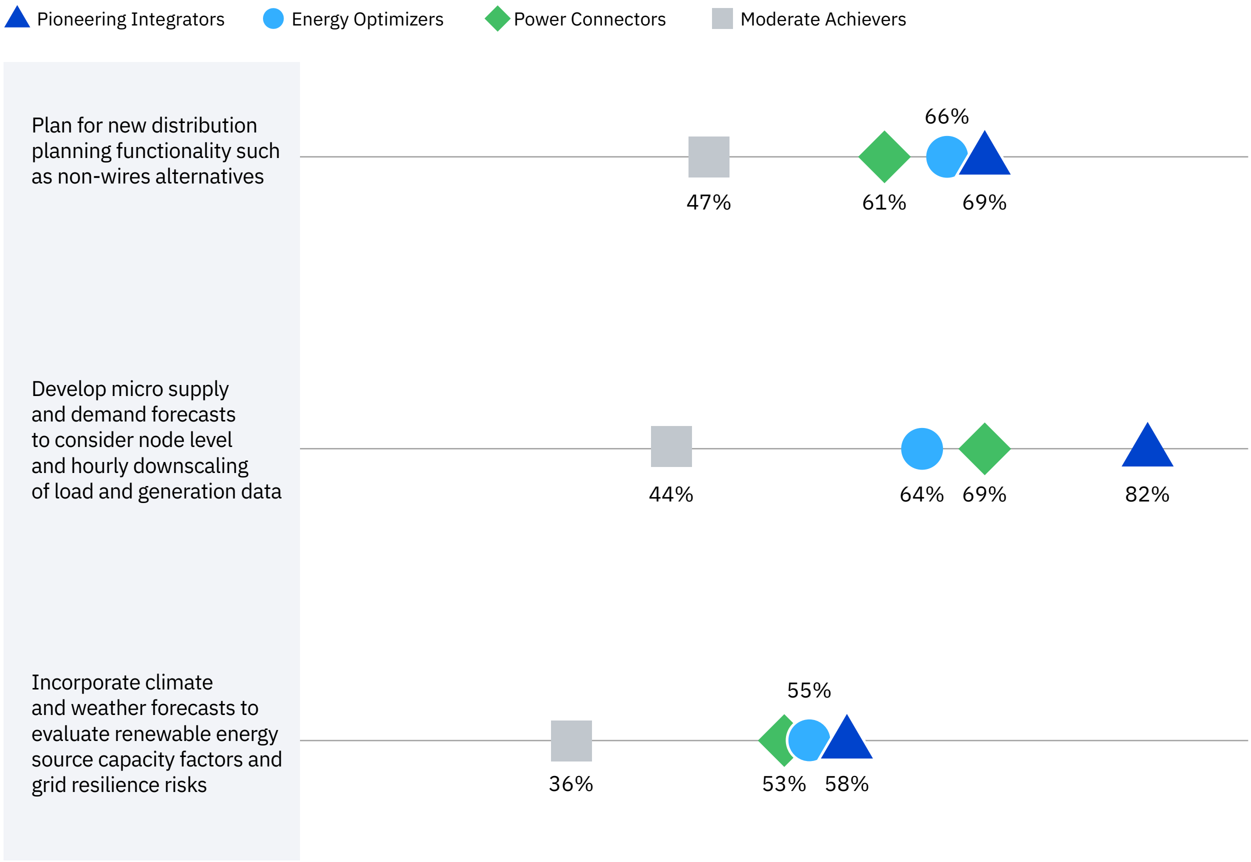
Advanced planning and demand modeling are essential for managing energy consumption and optimizing supply (see Figure 8). Incorporating non-wires alternatives, such as energy storage, demand response, and distributed generation, helps manage grid congestion and reduce infrastructure upgrades. Detailed forecasts enable utilities to synchronize supply and generation, preventing overloads and minimizing waste. Pioneering Integrators lead in forecasting at a granular, node-specific level, accurately predicting energy demand and usage fluctuations while accounting for factors such as weather and demographic changes.

Incorporating climate and weather forecasts significantly enhances the management of renewable energy resources. By leveraging detailed meteorological predictions, operators can accurately estimate the capacity factors of renewable sources such as wind and solar. This foresight allows for better scheduling of power generation and grid balancing.

Advanced planning and demand modeling are essential for managing energy consumption and optimizing supply.

Figure 8

Tactics to anticipate and manage energy consumption patterns.



Q. Where has your organization implemented / does it plan to implement interconnection? Q. To what extent has your organization incorporated the above forecasts into grid modeling? Percentages show responses of 3 and 4 on a 4-point scale where 1 = Not at all and 4 = To a large extent.

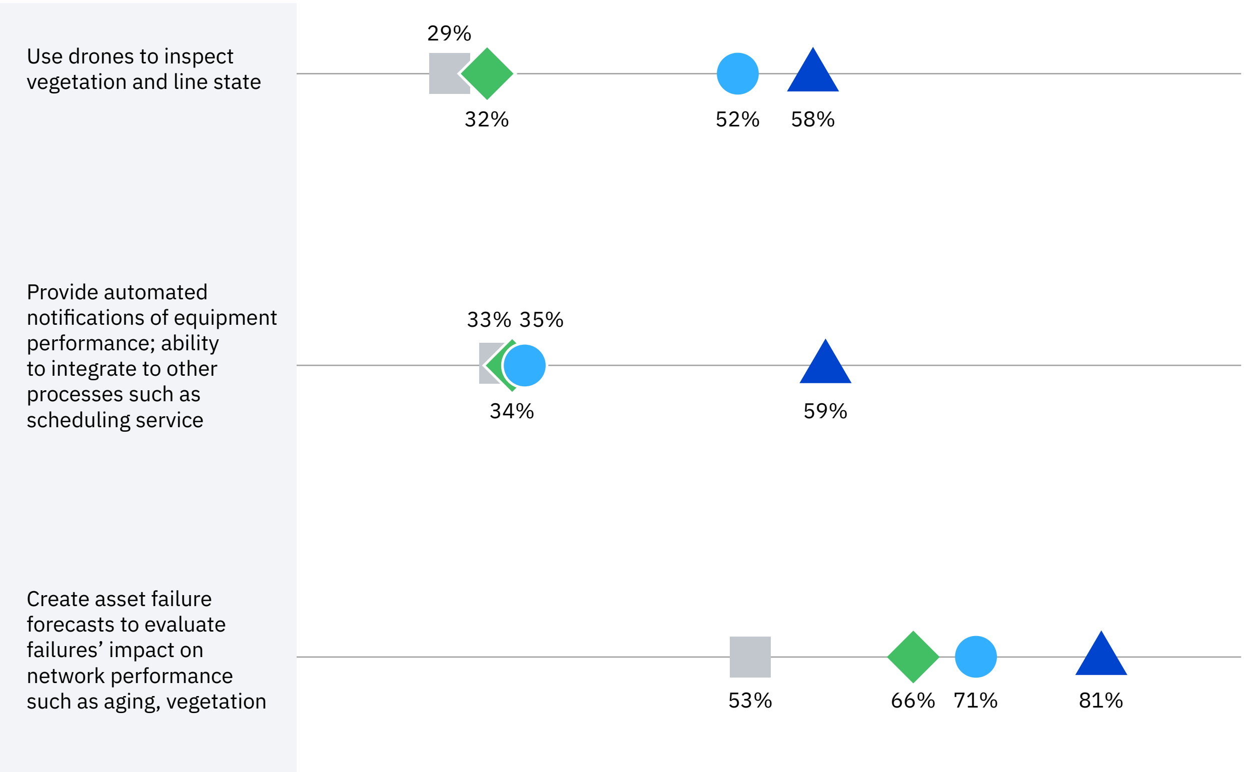
Asset monitoring, automation, and maintenance

Continuous asset monitoring, automation, and maintenance are crucial for maintaining grid infrastructure (see Figure 9). Real-time tracking of equipment performance allows utilities to address issues early, preventing costly failures. More Pioneering Integrators and Energy Optimizers use drones for vegetation and line condition inspections, detecting potential outage risks such as tree branches encroaching on power lines. Automated alerts for potential failures enable timely service interventions, fostering reliability. Predictive analytics further allow for anticipatory maintenance, reducing disruptions and enhancing grid resilience.

Automated alerts inform maintenance teams about equipment performance, potential failures, or anomalies. These alerts can be integrated into service scheduling processes to promote timely repairs or inspections. Predictive analytics further allow for anticipatory maintenance, reducing disruptions and enhancing grid resilience.

Figure 9

Tactics to extend asset life.



Q. At what stage is your organization in adopting the above strategic asset management initiatives? Percentages show responses of 4 and 5 on a 5-point scale where 1 = Not considering, 2 = Evaluating, 3 = Piloting, 4 = Rolling out, and 5 = Fully implemented. Q. At what stage is your organization in implementing the above smart assets? Percentages show responses of 4 and 5 on a 5-point scale where 1 = Not considering, 2 = Evaluating, 3 = Piloting, 4 = Rolling out, and 5 = Fully implemented. Q. To what extent has your organization incorporated the above forecasts into grid modeling? Percentages show responses of 3 and 4 on a 4-point scale where 1 = Not at all and 4 = To a large extent.

Case study

E.ON: Using quantum computing to help tackle complexity[4]

E.ON, one of Europe's largest energy companies, operates a 1.6-million-kilometer energy network serving 47 million customers across 17 European countries. As Europe transitions to renewable energy, E.ON faces growing complexity in managing the dynamic energy grid, with power coming from smaller, more variable sources such as solar and wind, and consumption patterns changing due to electric vehicles and intelligent home systems.

To tackle this complexity, E.ON is exploring quantum computing with IBM. Quantum computers can potentially solve complex problems more efficiently than classical supercomputers, offering new efficiencies and competitive advantages for E.ON.

Working together, E.ON and IBM Quantum teams developed a path toward quantum advantage for energy pricing, including an algorithm for managing weather risks. Each run of this algorithm asks the question, "If we offer energy at a certain price, what will that cost us given a certain set of weather conditions over the course of a contract?" Running this algorithm many times provides information that can be used to make hedging decisions.

Enabling transformation

Key enablers drive grid modernization, including the development of advanced control rooms and adopting new ways of working. These innovations enhance decision-making and optimize grid performance.

Enabler 1
The control room of the future

The control room of the future leverages advanced technologies and data systems for more effective grid management (see Figure 10). Network model data, including geospatial information and real-time operational data, provides situational awareness and a comprehensive view of the grid's layout and performance, enabling real-time decision-making. Integrated multisource data streams from AMI, IoT devices, and Supervisory Control and Data Acquisition (SCADA) systems offer a holistic view of grid performance, improving response times and resource optimization.

Automation of dynamic network configurations allows for rapid fault assessment and optimization of power flow. It highlights the real-time, dynamic nature of the process, emphasizing that the grid's configuration is not static but continually evaluated and modified as needed to maintain optimal performance.

The future control room also integrates third-party DERs into a "system-of-systems" approach for comprehensive management of all resources across a utility network. By receiving telemetry from these DERs, the control center gains more visibility into their performance, enabling better integration and management. Additionally, remotely dispatching grid-scale storage assets from the control center offers a level of flexibility and scalability, allowing utilities to store energy when it's abundant and release it during peak demand.

Figure 10

Tactics to improve decision-making and support new technologies.

	Pioneering Integrators	Energy Optimizers	Power Connectors	Moderate Achievers
Invest in network model data such as multisource third-party grid-scale	86%	66%	60%	51%
Enhance situational awareness by integrating multisource data streams (AMI, IoT, SCADA) in the control center	70%	58%	63%	43%
Automate dynamic network configuration analysis and adaptation for sectionalizing studies	59%	42%	45%	40%
Integrate third-party DER assets and provide telemetry to the control center	59%	49%	60%	41%
Remotely dispatch grid scale storage assets	57%	52%	40%	39%

Q. In which of the above grid modernization control center technologies has your organization invested / does it plan to invest?
Q. What advanced monitoring and control capabilities has your organization developed / does it plan to develop?

Enabler 2
New ways of working

Modernizing the grid requires utilities to adopt talent initiatives and invest in specialized skills. Talent initiatives bolster utilities' capacity to tackle complex modernization challenges and leverage opportunities from advanced technologies (see Figure 11).

Cross-disciplinary collaboration among engineers, IT specialists, and cybersecurity experts fosters innovative grid optimization solutions. Pioneering Integrators cultivate a data-driven culture, embedding analytics into daily operations to improve decision-making and resource management. Training programs help ensure employees stay current with the latest technologies and modernization methodologies. Mentorship programs offer practical experience in grid modernization projects, nurturing talent and facilitating knowledge transfer.

Utilities invest in IT and OT skill development to keep up with the demands of an increasingly complex energy landscape. In the IT area, across all surveyed utilities, 70% have invested in data analytics, enabling them to leverage vast data from grid operations, energy generation, and consumption for performance optimization and trend prediction. Nearly two-thirds of Pioneering Integrators, Energy Optimizers, and Power Connectors (compared to just 47% of Moderate Achievers) recognize that cybersecurity skills are critical as grid systems become increasingly interconnected, requiring professionals to protect against cyber threats and help ensure digital infrastructure reliability and security.

Figure 11

Talent + grid modernization = a winning combination.

	Pioneering Integrators	Energy Optimizers	Power Connectors	Moderate Achievers
Encouraged grid innovation collaboration among different disciplines such as engineers, IT specialists, cybersecurity experts	81%	70%	69%	55%
Built a data-driven culture	76%	62%	55%	55%
Trained employees on the latest technologies and methodologies relevant to grid modernization	69%	59%	60%	50%
Offered mentorship programs to gain hands-on experience in grid modernization projects	64%	49%	53%	44%

Q. What progress has your organization made on the above talent initiatives to support your grid modernization efforts? Percentages show responses of 3 and 4 on a 4-point scale where 1 = No progress and 4 = Significant progress.

OT skills are also crucial for successfully integrating renewable energy, improving physical grid infrastructure, and advancing telecommunications. As the grid evolves to accommodate more renewable energy sources, nearly 60% of surveyed utilities have hired skilled professionals to manage complex systems that optimize energy generation, distribution, and storage. Their expertise ensures seamless integration of renewable energy while maintaining grid stability.

Additionally, with the expansion of physical grid infrastructure, nearly two-thirds of Pioneering Integrators (compared to 53% of their peers) have invested in professionals that can monitor and maintain critical assets, helping ensure reliability and efficiency. In telecommunications, 54% across all surveyed utilities have invested in skills to enable the implementation of advanced communication networks that are critical for real-time grid management and responsiveness.

As the grid evolves to accommodate more renewable energy sources, nearly 60% of surveyed utilities have hired skilled professionals to manage complex systems that optimize energy generation, distribution, and storage.

Case study

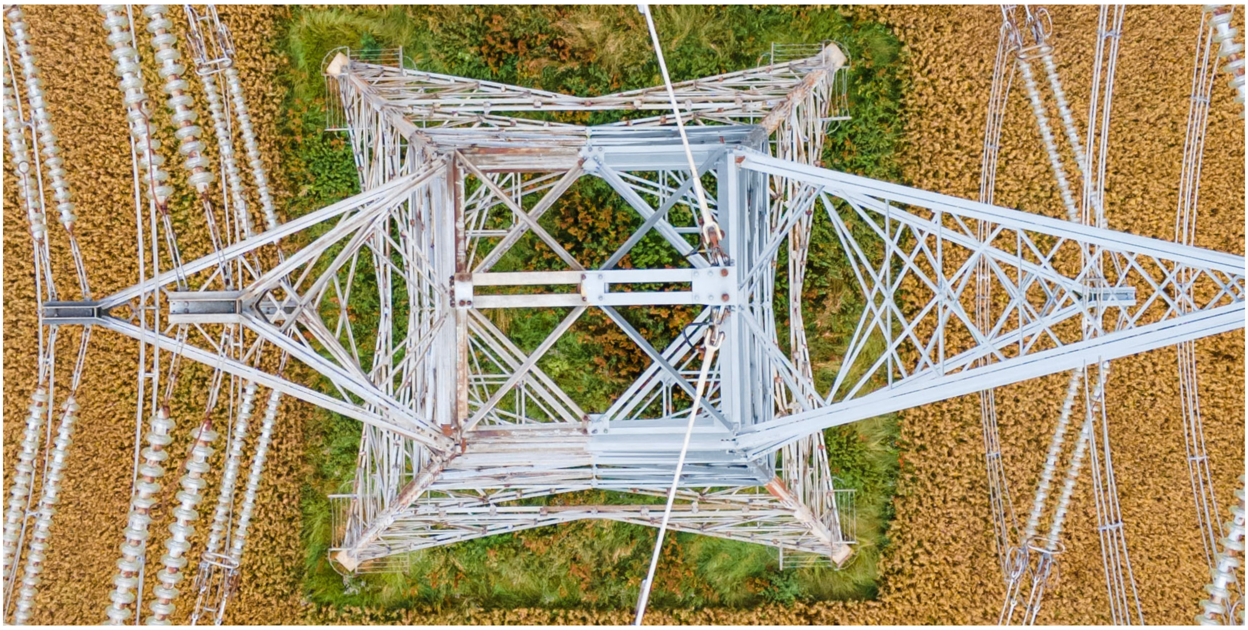
Austin Utilities: Increasing resilience and reliability with cloud-based SCADA to drive automation[5]

Austin Utilities, a community-owned electric, water, and natural gas utility in southeastern Minnesota, upgraded its SCADA system to enhance resilience, reliability, and operational efficiency. The utility, serving over 12,000 customers, had faced challenges with its on-premises SCADA, including heavy maintenance, staffing demands, and cybersecurity risks.

Seeking a more effective solution, Austin Utilities considered both virtual machine and cloud-hosted options. They determined that while both solutions would cost similarly over seven to eight years, the cloud-based option was more cost-effective and aligned with their existing cloud infrastructure.

Austin Utilities chose AspenTech OSI Monarch SCADA for its cost savings, enhanced cybersecurity, and seamless implementation. The cloud solution eliminated the need for in-house staff to perform software updates and provided stronger security protocols.

The implementation process was smooth, with minimal issues. This upgrade not only saved over $100,000 but also improved system maintenance efficiency, bolstered cybersecurity, and provided actionable data to optimize utility operations and customer service. The solution also enhanced their ability to gather and analyze data, providing insights for leadership and operators to improve service reliability and decision-making.



Action guide

Embarking on the path to a modern, adaptable grid necessitates continuous advancement, robust planning, and relentless cultivation of the three strategies. Each step propels utilities closer to a reliable, efficient, and sustainable energy future.

To assist utilities in advancing their efforts, we've compiled a three-pronged plan. The recommendations present a spectrum of immediate, near-term, and long-term options that you can tailor to your grid modernization scenario.

We've identified *immediate actions* that are necessary for establishing the fundamental infrastructure needed for grid resilience and enhancing grid flexibility, forecasting, and operational efficiency. By prioritizing these, the grid will be better positioned to manage both critical challenges and future renewable energy variability.

Near-term actions are important, but they require a more time-intensive, phased approach to implement. *Longer-term actions* build upon the foundational systems established in the immediate actions to further modernize and optimize the grid.

01

Strengthen grid resilience through technology and automation

Immediate

- Deploy advanced monitoring systems, such as ADMS, across critical grid infrastructure to continuously track performance, leverage applications such as VVO and FLISR, trigger alerts for potential issues, and facilitate timely interventions. Given that only 38% of surveyed utilities have automated notifications for equipment performance, this presents a significant opportunity to enhance their operational efficiency and reliability.
- Invest in real-time DERMS and demand response platforms that integrate with consumer devices such as smart thermostats and appliances, enabling automatic adjustments to energy consumption based on grid conditions. Only a third have rolled out or fully implemented control and transfer of electricity between residential and commercial buildings (for example, "prosuming" or "vehicle-to-grid" technology).
- Collaborate with cybersecurity experts to protect the grid from evolving threats, while scaling up installation of smart meters and energy management systems to gain real-time insights and optimize distribution.

Near-term

- Incorporate self-governing repair and restoration systems capable of autonomously addressing minor grid faults, reducing recovery times and enhancing grid uptime. This can be rolled out progressively after basic resilience measures are set up.
- Invest in automation technologies that enable dynamic electricity rerouting and load balancing, helping ensure efficient energy delivery and preventing congestion during peak demand. This can be implemented after making sure that foundational monitoring and demand response platforms are functional.

Longer-term

- Strengthen grid hardware infrastructure through the widespread deployment of sensors, advanced equipment, and storage solutions such as batteries and electrolyzers. This will enable more effective grid management, enhance flexibility, and support the integration of renewable energy sources.

02

Enhance energy flexibility to better manage renewable variability

Immediate

- Deploy advanced grid analytics and AI-driven forecasting tools to predict renewable generation patterns, enabling real-time adjustments to energy distribution and improving the grid's ability to manage fluctuations.

Near-term

- Invest in versatile hybrid energy storage systems capable of accommodating both electricity and thermal energy, enabling the grid to adapt more effectively to fluctuations in renewable generation. This is further down the priority list than predictive tools and real-time grid management.
- Set up decentralized microgrid networks in high-demand zones to promote local energy production and distribution, maintaining grid stability during periods of renewable generation downtime. Only half of executives surveyed say their organizations are managing microgrids as a local energy service. Rollout of microgrids will depend on site-specific factors and may require a more detailed phased approach.

Longer-term

- Improve grid compatibility by standardizing communication protocols between renewable energy sources and grid systems, enabling smooth integration of new energy assets. This technical upgrade should follow after foundational systems like analytics and storage are in place.
- Construct infrastructure supporting EV charging networks, incorporating EV load management into grid operations to avoid overload and optimize grid utilization during off-peak hours. Only half of utilities use vehicle-to-everything technology to integrate EVs onto the grid as active assets. This can be phased in alongside other flexibility measures.

03

Future-proof the grid to improve usability, efficiency, and asset availability

Immediate

- Implement a digital twin of the grid to simulate and test various scenarios in real time, enabling predictive insights and proactive adjustments to enhance operational efficiency, asset management, and grid resilience. Less than a quarter of surveyed executives say their organizations are largely leveraging digital twins to better predict power flow, quality, and asset performance.
- Use real-time data and smart grid technologies to proactively monitor grid operations, making data-driven decisions to optimize resource allocation, reduce energy losses, and limit network costs while ensuring reliable performance.

Near-term

- Leverage advanced technologies for asset optimization. Predictive maintenance tools, IoT sensors, and AI-driven analytics help monitor asset health, optimize asset utilization, and limit downtime, driving operational efficiency and reducing overall costs. This requires implementation alongside other monitoring and predictive tools.
- Invest in an enterprise-wide Network Model Management technology to enable orchestrated, high-fidelity data management between IT and OT utility stakeholders. This will streamline collaboration, improve data accuracy, and help ensure seamless coordination across the utility's operational technology and information technology systems.

Longer-term

- Partner with industry leaders to devise predictive algorithms that foresee grid vulnerabilities and potential system overloads caused by extreme weather or disruptions. This may require more time and collaboration with external stakeholders.
- Adopt a continuous enhancement methodology grounded in simulation outcomes to facilitate routine testing and updates to grid resilience tactics, especially under extreme conditions. Less than half of utilities incorporate climate and weather forecasts to evaluate renewable energy source capacity factors and grid resilience risks. This will be important once the basic resilience systems are established.

About the authors

Biren Gandhi

Executive Partner, Global Center of Excellence Leader—Energy, Environment & Utilities and Global Clean Energy Offerings Leader
IBM Consulting
biren.gandhi@de.ibm.com
linkedin.com/in/gandhibiren

Biren leads IBM Consulting's global energy and utilities industry practice and community, overseeing strategy, talent management, and service offerings across more than 20 countries. He helps industry executives understand and leverage the potential of exponential digital technologies to drive successful clean energy transitions. Biren is also responsible for driving revenue growth and profitability for IBM's energy industry practice, with a focus on digital transformation, innovation, and sustainability.

Zahid Habib

Vice President, Global Industrial Sector Leader, Global Energy and Resources Industry Leader
IBM Consulting
zhabib@us.ibm.com
linkedin.com/in/zhabib1

Zahid is the Global Industry Leader for Energy and Resources industry which includes Oil and Gas, Energy and Utilities, Chemicals, Mining and Metals, and Engineering, Procurement, and Construction (EPCs) driving industry solutions at scale and go-to-market strategies. He has more than 35 years of experience in management consulting, capital projects, business transformation, AI and IoT solutions, trading systems implementations, mergers and acquisitions, and enterprise application integration.

Sally Jacquemin

Vice President and General Manager, Power and Utility Business Unit
Aspen Technologies, Inc.
sally.jacquemin@aspentech.com
linkedin.com/in/sallyjacquemin

Sally is the Vice President and General Manager for the power and utilities business at Aspen Technology, Inc. She oversees the overall business strategy, including customer engagement, organic and inorganic portfolio expansion, as well as global growth opportunities for AspenTech's Digital Grid Management product suite including the AspenTech OSI monarch SCADA, Distribution Management, Transmission Management, Generation Management, Distributed Energy Resource Management System (DERMS), and Network Model Management applications. Sally establishes and executes corporate strategies for the company's Power and Utility business segment to ensure continued innovation and market leadership.

Spencer Lin

Global Research Leader, Energy and Resources
IBM Institute for Business Value
spencer.lin@us.ibm.com
linkedin.com/in/spencer-lin-35896317

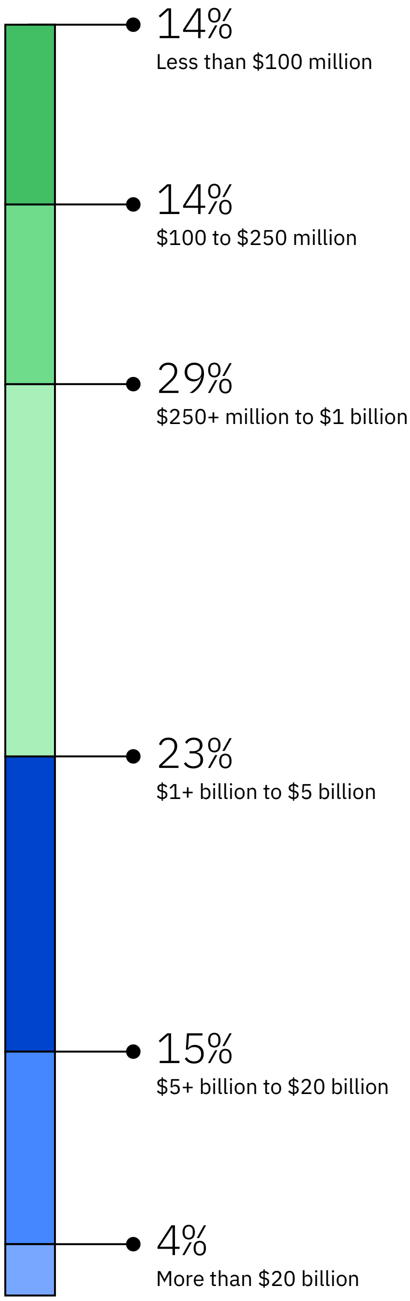
Spencer is responsible for market insights, thought leadership development, competitive intelligence, and primary research on industry agendas and trends. He has more than 30 years of experience in financial management and strategy consulting.

Study approach and methodology

The IBM Institute for Business Value (IBM IBV), in cooperation with Oxford Economics, surveyed 597 C-level executives (CEO, COO, VP IT/OT systems engineering, power generation, transmission, distribution, or retail operations) that have accountability and decision-making authority for operations (for example, grid and generation assets and their management) in 27 countries in Q1 2025.

Participants were asked a range of questions in various formats (multiple choice, numerical, and Likert scale). They were asked about their organization's expectations, results, concerns, and barriers with grid modernization. All data, financial or otherwise, was self-reported.

The overall goal of the study was to examine participants' progress in making the grid smarter, secure, resilient, reliable, and affordable with advanced technologies, equipment, and controls that communicate and work together. To accomplish this, the IBM IBV ran a series of contrast analyses, including pairwise comparisons, multiple correspondence analysis, multinominal regression analysis and data classification using hierarchical clustering highlighting performance result differences as shown in this report. Significance level for all analyses was set at ($p < 0.05$) level.



Segment	Breakdown
Transmission only	22%
Distribution only	27%
Generation and Transmission	5%
Generation and Distribution	6%
Transmission and Distribution	12%
Distribution and Retail	5%
Generation, Transmission, and Distribution	12%
Generation, Distribution, and Retail	0.5%
Generation, Transmission, and Retail	4%
Transmission, Distribution, and Retail	1%
Generation, Transmission, Distribution, and Retail	6%

Note: Due to rounding percentages may not add to 100%.

Related reports

Why the Utility of the Future Requires a Digital Grid
Jacquemin, Sally. *Why the Utility of the Future Requires a Digital Grid.* Aspen Technologies, Inc. June 2024. https://www.aspentech.com/en/resources/white-papers/dgm-why-the-utility-of-the-future-requires-a-digital-grid

Preparing electric utilities for the energy transition
Fisher, Lisa, Francis J. Puglise, Noriko Suzuki, and Jeffery Varney. *Preparing electric utilities for the energy transition: Insights from the Clean Electrification Maturity Model*. IBM Institute for Business Value in partnership with APQC. August 2023. https://ibm.co/clean-electrification

DERMS: Maximizing the Value of Distributed Resources
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Sacks, Bryan, Casey Werth, Cristene Gonzalez-Wertz, and Lisa-Giane Fisher. *The power of electrification: A path toward reliable, resilient, and renewable energy.* IBM Institute for Business Value. April 2022. https://www.ibm.com/thought-leadership/institute-business-value/en-us/report/electrification-and-renewable-energy

About Aspen Technologies, Inc.

Aspen Technology (NASDAQ:AZPN) is a global software leader helping industries at the forefront of the world's dual challenge of meeting the increasing demand for resources from a rapidly growing population, in a profitable and sustainable manner. AspenTech solutions address complex environments where it is critical to optimize the asset design, operation, and maintenance lifecycle. AspenTech® Digital Grid Management provides open, high-performance automation solutions to the power generation, electric transmission and distribution, microgrid, and oil & gas industries. For more information, or to learn more about our SCADA, GMS, EMS, ADMS, OMS, DERMS, Pipeline Management, Network Model Management and Historian solutions, visit aspentech.com

Endnotes

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3. "How Iberdrola Uses DERMS to Assess Flexibility on a Renewables-Heavy Grid." AspenTech case study. Accessed on February 28, 2025. 2024. https://www.aspentech.com/en/resources/case-studies/dgm-how-iberdrola-uses-derms-to-assess-flexibility-on-a-renewables-heavy-grid

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IBM Corporation
New Orchard Road
Armonk, NY 10504

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