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THE POWER GRID OF THE FUTURE

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FOR MANY TRADITIONAL GRID companies, things look like they're about to get a lot harder. Power network operators are coming under mounting pressure from multiple disruptive forces, including distributed generation, increasing customer demands, and a growing volume of data from smart meters.

Were large numbers of consumers to disconnect from the grid and generate electricity locally, many companies would struggle to recover their investments. Widespread grid defection would take time and may not happen in many markets, but grid companies still need to prepare for an evolving energy landscape that will create many challenges—and also some potential opportunities. For example, changing regulation may enable companies to respond by offering new services such as electric-vehicle charging and peer-to-peer trading platforms.

Regardless of how these forces play out, significant investment will be needed—more than \$300 billion from now until 2030, according to International Energy

Agency estimates—as grid companies modernize. With such sums at stake, companies must plan ahead to ensure that they make the right investments and choose the best no-regrets actions.

Multiple Pressures

Grid operators face uncertainties and greater operational complexity arising from emerging power generation and digital technologies, changing consumption patterns, and new market opportunities.

Distributed Power Generation and Storage Technologies.

Falling equipment costs are encouraging a rise in the localized generation of distributed energy, challenging grid companies' ability to manage power flows. In South Australia, hikes in grid power rates and cheap installation costs have already resulted in rooftop solar providing up to 40% of the state's energy requirement at certain times of the year. Rapid growth in energy storage systems due to declining costs will likewise support the adoption of distributed generation and

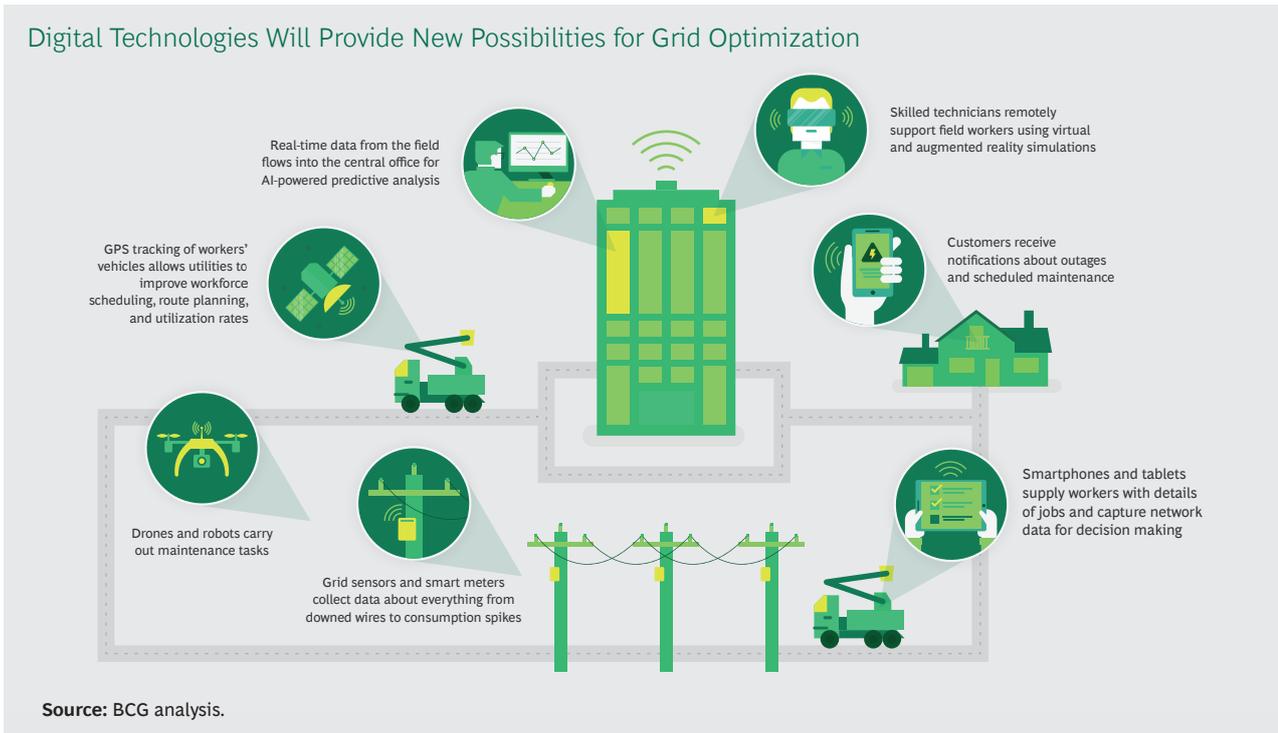
could exacerbate defection from the grid. But storage could also help grid operators manage demand peaks and prevent overloads, reducing the need for expensive investments.

Changing Customer Usage. The increasing popularity of electric vehicles and heat pumps is placing new pressures on grid operations. We anticipate that the global market share of electrified powertrains will grow rapidly, while heat pumps—which are cheaper than other comparable heating systems and also provide cooling in summer—could supply about 5% of European Union peak demand by 2030. (See *The Electric Car Tipping Point: The Future of Powertrains for Owned and Shared Mobility*, BCG report, January 2018.)

Home charging of EVs (which typically occurs during peak evening hours), coupled with midday spikes in power sold back to the grid from rooftop solar installations, will create more volatile daily demand patterns. Increased usage of heat pumps for buildings could also create system overloads. To cope with these new demands and avoid overloads, companies will need to invest in capacity additions, transformer upgrades, and protective devices.

Digitization. Digital technologies are set to transform grid operations. Increasingly, drones will carry out inspections, replacing workers in the field, while sensors enable real-time network monitoring. (See the exhibit.) Predictive maintenance, based on machine learning and artificial intelligence, will reduce power outages and improve companies’ investment and maintenance decisions. And robotic process automation will speed up back-office functions. Sensor, data collection, and storage costs are one-tenth what they were ten years ago, and the resulting proliferation of data and advanced analytics will also boost efficiency. (See the sidebar, “The Benefits of Digital.”) But while digital transformation of the grid is an opportunity, it also adds complexity and involves fundamental changes in operating models.

New Markets. Increased grid automation and the adoption of advanced 5G sensors will open up new market opportunities for grid operators. For instance, greater connectivity will enable them to provide services aimed at the smart-home market. Consumers will optimize their smart devices using data provided by grid operators, which, in turn, will be able to mine smart-meter data for customer-targeting insights that can be



THE BENEFITS OF DIGITAL

Digitization is a no-regrets step for all grid companies. A digitally connected workforce and “self healing” technologies—which enable grids to automatically detect and isolate problems and minimize their impact on customers—are certain to be part of grid infrastructure regardless of the dynamics of individual markets.

Companies will need to process an increasing amount of information from the grid and from digital consumer devices. We expect the volume of data handled by an average grid company to grow tenfold over the next five to ten years owing to increasing adoption of smart meters, smart plugs, sensors, and other Internet of Things devices. Some current examples:

- Advanced analytics and artificial intelligence are significantly enhancing predictive maintenance, using computer simulations and tapping new sources of grid data to predict asset failures. In our experience, these technologies can reduce maintenance expenditure by up to 20%. (See “[How Utilities Can Boost Workforce Productivity with Digital](#),” BCG article, March 2018.)
- Power grid outages can be resolved faster with new digital technologies. Data from smart meters and machine learning technologies enable computer systems to accurately locate faults and automatically assign workers to fix them. Customers can also be notified by smartphone text about the status of problems and their likely duration.
- By applying forecasting methods based on algorithms and using satellite and aerial imaging, companies can predict the growth rate of vegetation near power lines. In this way, they are able to mitigate the impact from fallen branches and

overgrown vegetation that can cause major power outages. These methods have allowed some companies to reduce the amount they spend on vegetation management by 20%.

- Big data analysis can be used to reduce distribution losses and improve meter reading effectiveness by identifying instances of meter manipulation, inconsistent readings, and other suspicious consumer behavior. In our experience, advanced analytics can reduce losses by up to 15%.
- Predictive modeling and artificial intelligence can help in the planning of future grid investments by improving forecasts of the growth in distributed energy sources and EV charging and by managing changes in power flows.

To achieve the maximum benefit from new digital technologies, grid operators will need to plan future investments carefully to avoid the risk of stranded assets. Forward-thinking companies should draw up an integrated grid plan, mapping out the potential capex requirements for their investments, smart-grid devices, and future platform developments. Companies will have to carefully quantify their investments in order to prioritize future capex spending and get buy-in from regulators.

The investments required go beyond traditional utility assets. To create a technology platform that can support the grid of the future, companies will need to ensure that their IT systems and the operational technology that supports existing business processes are aligned. They will also need to develop a structured roadmap that accounts for future developments, including greater automation, different programs, and the new data flows required for smart-city and other smart applications. The roadmap

THE BENEFITS OF DIGITAL continued

can also be used to retire or repurpose existing IT projects, generating savings.

Digital transformation isn't just about capex and technological change. It's also about changing organizational structures and the way people work. The integrated grid plan will need to factor in faster and more agile decision-making processes

built around data analytics. (See "[Data-Driven Transformation: Accelerate at Scale Now](#)," BCG article, May 2017.) And it will have to include changes to critical business processes. In our experience with leading companies, we've found that several hundred processes may need to be reengineered in order to prepare for the next-generation grid.

sold to retailers. It will also allow grid companies to develop "smart city" applications. Some companies, for example, are already using sensors attached to street lights to provide real-time platforms that alert drivers when parking spaces become available. Grid companies might also apply their expertise with power flows to the management of traffic lights in order to reduce congestion in urban areas.

The development of blockchain—which acts as an encrypted, immutable ledger—will enable companies to develop peer-to-peer online platforms, offering reliable, secure, and traceable transactions for localized producers and buyers of energy. The technology also facilitates the use of EV charging stations (in Germany, Innogy is piloting an EV charging network using blockchain). Grid companies will need to deal with considerable uncertainty as these nascent opportunities take shape, however.

Potential Future Scenarios

In tandem with these disruptions, energy regulators are changing their demands. Traditionally, regulators required grid operators to deliver a reliable, safe, and universal power supply at good value. But with changes in usage, they are targeting new goals: clean energy, greater customer empowerment, and open grid access for localized generators of distributed power.

Regulators are also shifting from a cost-plus compensation model—which delivers a return on top of grid operators' capital

costs—toward rewards based on efficiency and innovation. Some are redefining the role of utilities and using compensation structures that encourage the provision of new products and services. For example, New York State's regulator has announced a new model that will reward grid companies that facilitate a competitive market in distributed energy.

Energy network companies can tap opportunities offered by new technologies to realize regulators' ambitions. Distributed batteries can ensure universal connectivity, while platforms enabling EV owners to store surplus power and sell it to the grid (these are currently in development) can empower customers. Faced with the rapidly growing use of rooftop solar, Hawaiian Electric Industries has adopted a five-point plan to provide customers with affordable and reliable clean energy. (See [Retrofitting Utilities for the Power Market of the Future](#), BCG Focus, October 2016.)

As the energy landscape evolves, many energy network companies will seek value in customer-facing activities. We see three potential scenarios for grid companies, each depending on how regulations change in response to the adoption of distributed generation:

- **Widespread Defections and Reduced Demand for Grid Power.** Significant disconnection from the grid caused by distributed generation, combined with the absence of a regulatory response encouraging operators to digitize and

offer new products, could result in a vicious circle. Energy network companies would be forced to raise rates to pay for their existing investment plans, causing more customers to defect. The challenge for grid companies would be to minimize stranded assets rendered obsolete by the shift in energy usage. We think this scenario is unlikely because distributed generation is expensive and less reliable than centralized grid power.

- **Limited Defections but Increased Distributed Generation in Some Markets.** Traditional grid companies faced with limited customer defections will aim to become leaner by deploying emerging digital technologies in order to improve operational efficiencies. In markets where levels of distributed generation are moderate to high but where consumers nonetheless maintain their grid connection (as a backup or to sell surplus power to the grid), operators will need to become system stabilizers. To manage the demands from intermittent renewable-generation sources, they will have to invest in smart technologies that enable them to balance demand and supply dynamically in real time.
- **Significant Distributed Generation and Forward-Looking Regulation.** In markets with significant distributed generation in which consumers still maintain their connection to the grid and regulation shifts in response, operators will be free to generate revenues from new products and services. With the support of regulators, they will develop and manage the market platforms that enable generators of distributed energy to trade power with the grid. Under this scenario, regulators may open some of these new customer-facing services to competition. Consequently, grid companies—accustomed to operating in a regulated, noncompetitive environment—will need to develop modernization plans that go beyond growing their asset base and instead prepare them for potentially highly disruptive future developments.

Planning for an Uncertain Future

The speed of disruption and regulatory change—which will determine the future shape of the centralized grid infrastructure—will vary among markets, creating risk and uncertainty for companies. For instance, because the capacity required for EV charging may exceed that of distributed generation sources, vehicle owners may still need to connect to the grid. Likewise, regulators could incentivize owners of solar installations to connect to the grid in order to help balance the network.

Regulatory shifts allowing grid companies to participate in competitive markets will be relatively slow in coming, and their success is not a given. Some regulators may decide that independents, not grid operators, should act as platform providers. And changes in regulated revenue models could alter companies' risk-return profile, potentially curbing their ability to raise capital.

These uncertainties make the task of defining a strategy a difficult one for grid companies. Fortunately, operators don't need to go all in. Instead, they can refine their plans over time. But they should determine their ambition level early and set a course for modernization. By answering the following questions, they can start to formulate robust strategies for the future:

- How can we leverage disruptive technologies to drive efficiencies in our existing business model?
- How can we build a convincing case for regulators that accounts for the “functionalities” they want to achieve (open access, complete reliability, universal power provision)?
- What are the specific building blocks (assets, systems, people, and capabilities) needed to meet regulatory goals and manage the grid in the future?
- What no-regrets decisions—such as investment in digitization—can we make now, regardless of how the future evolves?

- What is the optimal roadmap for modernization, bearing in mind external factors such as the pace of rate hikes allowed by regulators?
- How will modernizing affect investor perceptions: Will our shareholders continue to view the company as a valuable investment and provide capital for our plans?
- **Build in room for flexibility.** Investment plans will need to deliver tangible short-term benefits without committing the company to potentially unnecessary long-term spending. Programs should be resilient across a range of scenarios with respect to changes in technology, business models, and customer expectations.
- **Align your IT systems with your business needs.** Applying the necessary digital levers will require investment in IT systems that can manage distributed energy sources and new applications. Grid companies are already investing heavily to upgrade their IT infrastructure. To minimize costs, managers must decide how to allocate spending so that traditional systems can be modernized, aligned with new business goals, and able to deliver new digital solutions. Finally, new digital and data science skills will have to be fostered among employees.

Guiding Principles for a Successful Transformation

The journey toward modernization can be daunting. By following the guiding principles below, companies can break through inertia and create positive momentum:

- **Have a clear vision of the future of the grid and align the organization behind it.** Strategies will vary depending on where a company sees the industry heading. It must determine where in the value chain it will be able to maximize its strengths and protect its market position. Change requires breaking down the siloed structure typical of grid companies. A change management plan that includes commitments from senior managers, an appropriate implementation timetable, and effective company-wide communication will be key.
- **Avoid building a new version of the old grid.** All grid companies will need to invest in smart technologies and equipment (including smart transformers, smart switches, and reclosers) that enhance grid automation, optimize power usage, and improve asset management. But they should avoid merely adding to their existing asset base and instead embrace new solutions. For example, some grid companies might choose battery storage to increase capacity. Others might consider demand response programs, which seek to curb consumption during peak periods without significant investment. By running pilot programs, companies can try out different options and identify the right mix.
- **Don't go it alone.** It's essential to ensure that regulators and investors are on-board. In the past, investments in systems such as smart metering were based on relatively straightforward cost-benefit assessments. But grid modernization needs to account for multiple desired outcomes and ways to achieve them. In a changing energy landscape, operators will benefit from a willingness to collaborate with other players through joint ventures. They can start by aligning their goals with those of regulators, ensuring that plans remain in step with changing regulatory structures. Savvy companies will be proactive, working with regulators and third parties on pilots that support their business case.

GRID COMPANIES NEED to act with urgency, and on several fronts, as they draw up plans for the future. No-regrets decisions are only part of the answer. Despite multiple variables, managers will need to act boldly and create a strategy based on where they want to play in the value chain. They will also have to work hand-in-hand with regulators and resist the temptation to replicate existing business models and assets.

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