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Modernizing the investment approach for electric grids

Customer and community expectations for the US electric grid are evolving. Utilities must adapt by pursuing integrated modernization plans.

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The future of the power grid has arrived. Utilities, policy makers, and communities have agreed for years that the aging electric transmission and distribution (T&D) grid in the United States needs to be significantly upgraded to withstand the challenges of the future. Recent events and trends across a number of fronts have made the situation more urgent than ever:

— *Customer needs are evolving, sharply accelerated by COVID-19.* Operating the grid safely and reliably at a low cost has long been so-called table stakes for T&D operators. But that is no longer enough. Customers were already increasingly adopting digital and mobile channels—a trend that has been rapidly accelerated by the COVID-19 pandemic and the subsequent physical-distancing measures. With greater acceptance of working from home, access to reliable electricity service has become paramount. And the economic slowdown and uncertainty will further highlight the importance of T&D rate affordability.

— *Increasing operational risks are changing the calculus for new investments.* Climate change and cyberattacks pose increasing levels of risk—and they are here to stay. On the US climate front, for example, recent wildfires have affected California's networks, blackouts have hit New York City, and coastlines have been battered by a plethora of catastrophic hurricanes. According to a recent McKinsey Global Institute report on climate risk, the chance of a once-in-a-century hurricane is likely to double in some parts of southeastern United States and triple in some parts of Southeast Asia by 2040.[1]

— *Distributed energy resources (DERs) are changing the grid's value proposition.* The T&D grid faces increasing pressure to integrate new technologies—such as electric vehicles (EVs), distributed solar generation, and energy storage—in a rapid, safe, and low-cost way. While grid planners, control-center operators, and engineers face significant challenges in managing the complexity of the two-way electric grid, they can take advantage of new capabilities to support grid operations, such as smart inverter control and vehicle-to-grid and managed charging. Increased automation and control capabilities at the "edge" of the electric grid are no longer thought experiments; they are now an operational reality. As indicated by the rise in flexibility contracts tendered in the United Kingdom's distribution flexibility markets (1,900 megawatts to be tendered in 2020 across UK distribution-network operators[2]), the role of DERs in managing the grid is here to stay.

— *Grid-technology innovations are creating opportunities to drive value across T&D workflows.* While utilities in more advanced economies have already gone through several rounds of investments in grid-modernization technologies such as smart meters, grid management systems (DMS/TMS), asset-management platforms, and geospatial information systems (GIS), these systems were largely viewed as isolated solutions serving siloed system requirements. Today, advanced cloud technology, software engineering models, and data-governance practices are paving the way for transformational use cases that cross the boundaries of individual systems.

As a result of these shifts, modernizing the grid is now critical. Utility companies have responded by proposing comprehensive grid-modernization plans. Yet only $2 billion out of $14 billion of requested grid-modernization investments were approved in 2018.[3] Clearly, there is a disconnect between what utility companies are proposing and what regulators see as appropriate.

Utilities that hope to better align their strategic goals with grid investments should pursue an integrated modernization plan. With that in place, they can make a series of no-regrets moves to ensure they are making the right decisions.

[1] For the full McKinsey Global Institute report, see "Climate risk and response: Physical hazards and socioeconomic impacts," January 16, 2020, on McKinsey.com.
[2] "Market changing standard contract for flexibility delivered," Energy Networks Association, April 6, 2020, news.energynetworks.org.
[3] Autumn Proudlove et al., *50 states of grid modernization: Q4 2018 quarterly report & 2018 annual review*, North Carolina Clean Energy Technology Center, February 2019, nccleantech.ncsu.edu.

The looming challenge of grid modernization

Historically, utilities' grid-modernization choices haven't always delivered the expected benefits. Billions of dollars were spent to develop the so-called smart grid as part of the American Reinvestment and Recovery Act of 2009. As a result, penetration of advanced metering infrastructure (AMI) in the United States exceeded 70 percent of households and promised to deliver savings and new capabilities.

However, results have been mixed. Stakeholders can reap ample gains by using AMI and customer systems, including reduced costs for metering and billing, lower utility capital expenditures from reductions in peak demand and better asset utilization, and faster outage restoration that costs less.[4] Yet utilities have on many occasions failed to use AMI data to engage customers on their energy use, leading to the rejection of several recent AMI proposals in Kentucky, Massachusetts, New Mexico, and Virginia. Indeed, just one utility out of 52 surveyed has deployed AMI and is harnessing the full suite of available use cases.[5] Despite accelerated capital investments in the grid by US utilities over the past ten years, the System Average Interruption Duration Index is consistently above its 2000 level, reflecting the increase in frequency and severity of major events (Exhibit 1).

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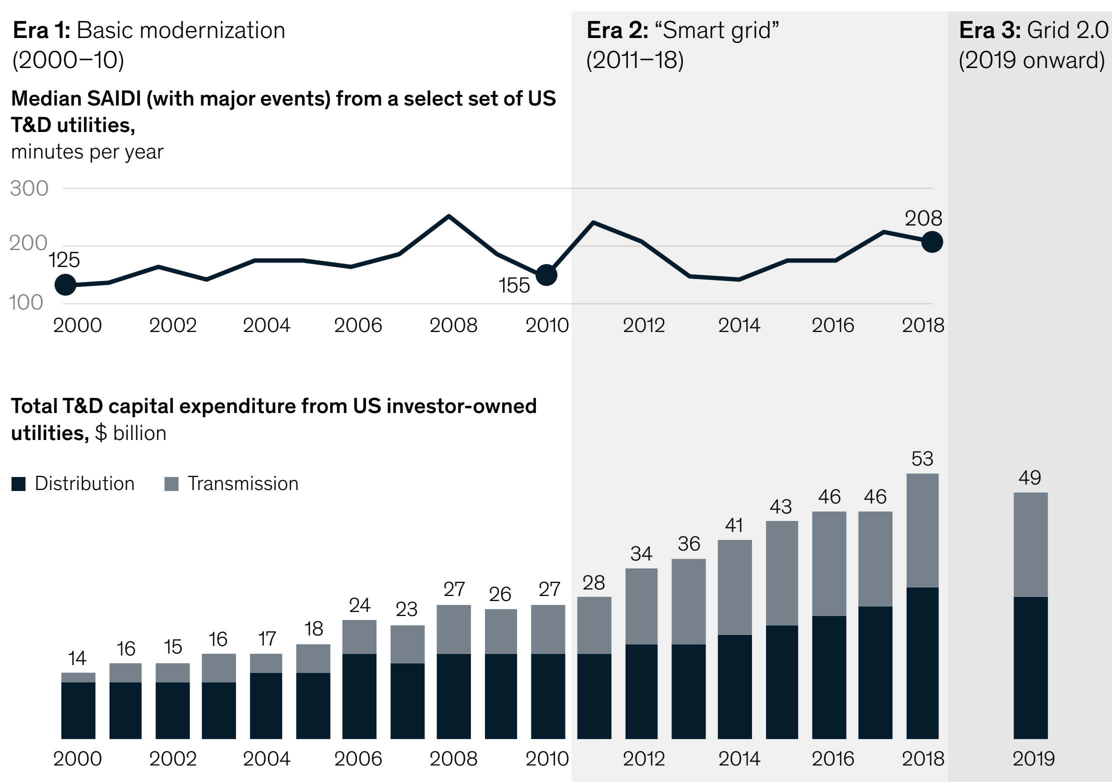
[4] *Advanced metering infrastructure and customer systems: Results from the Smart Grid Investment Grant Program*, a joint report from the US Department of Energy and SmartGrid.gov, September 2016, energy.gov.

[5] Rachel Gold and Dan York, *Leveraging advanced metering infrastructure to save energy,* American Council for an Energy-Efficient Economy, January 9, 2020, aceee.org.

Exhibit 1

Although transmission-and-distribution (T&D) spending has risen since 2000, the distribution grid System Average Interruption Duration Index hasn't fallen.



Source: ABB Energy Velocity, Energy Information Administration (post 2012 SAIDI data), Lawrence Berkeley National Laboratory (pre-2012 SAIDI data), Federal Energy Regulatory Commission (T&D capital spend data)

Grid-modernization plans are frequently more than the sum of their parts. . . . Painting the whole picture can make utilities more successful, and frequently more accountable, for regulators and stakeholders alike.

Meanwhile, despite smart-meter deployment in Denmark, Italy, Spain, and elsewhere, only 34 percent of consumers in the European Union were equipped with them in 2018.[6] That number is expected to reach only 43 percent by 2020—woefully short of the 80 percent target.

Today, utility companies can invest in several types of technologies, including equipment-health-monitoring sensors, smart capacitor banks, and new grid-scale storage projects. Our research identified several common pitfalls utilities face when determining where to make these investments:

— *A quantified value proposition is not clearly articulated.* Evolving grid outcomes (such as flexibility, resiliency, and security) have yet to be defined in industry-accepted terms, which are necessary for fact-based discussions on value. However, some states, such as Hawaii, are beginning to develop new key performance indicators (KPIs) to help inform grid planning.

— *Investments are not linked to specific use cases.* The ability to target demonstrated needs is critical to avoid investing in stranded assets.

— *Investment programs are siloed.* Many stakeholders—such as customer-facing teams, supply-chain players, regulatory bodies, and IT companies—are frequently not involved in the development of investment programs. Grid investments and other business areas are substantially interdependent; failure to document and consider these interdependencies can result in poor implementation plans.

— *Insufficient resources are allocated to development and execution of grid-modernization plans.* Investments that contribute to strategic-capability goals must be prioritized, whereas those that are irrelevant should be scrubbed from the capital plan.

— *Enterprise IT and OT systems and platforms are rigid and monolithic.* While hardware such as digital relays and smart meters are widely deployed, underlying software systems are frequently not designed to handle the volume of data streamed from the field.

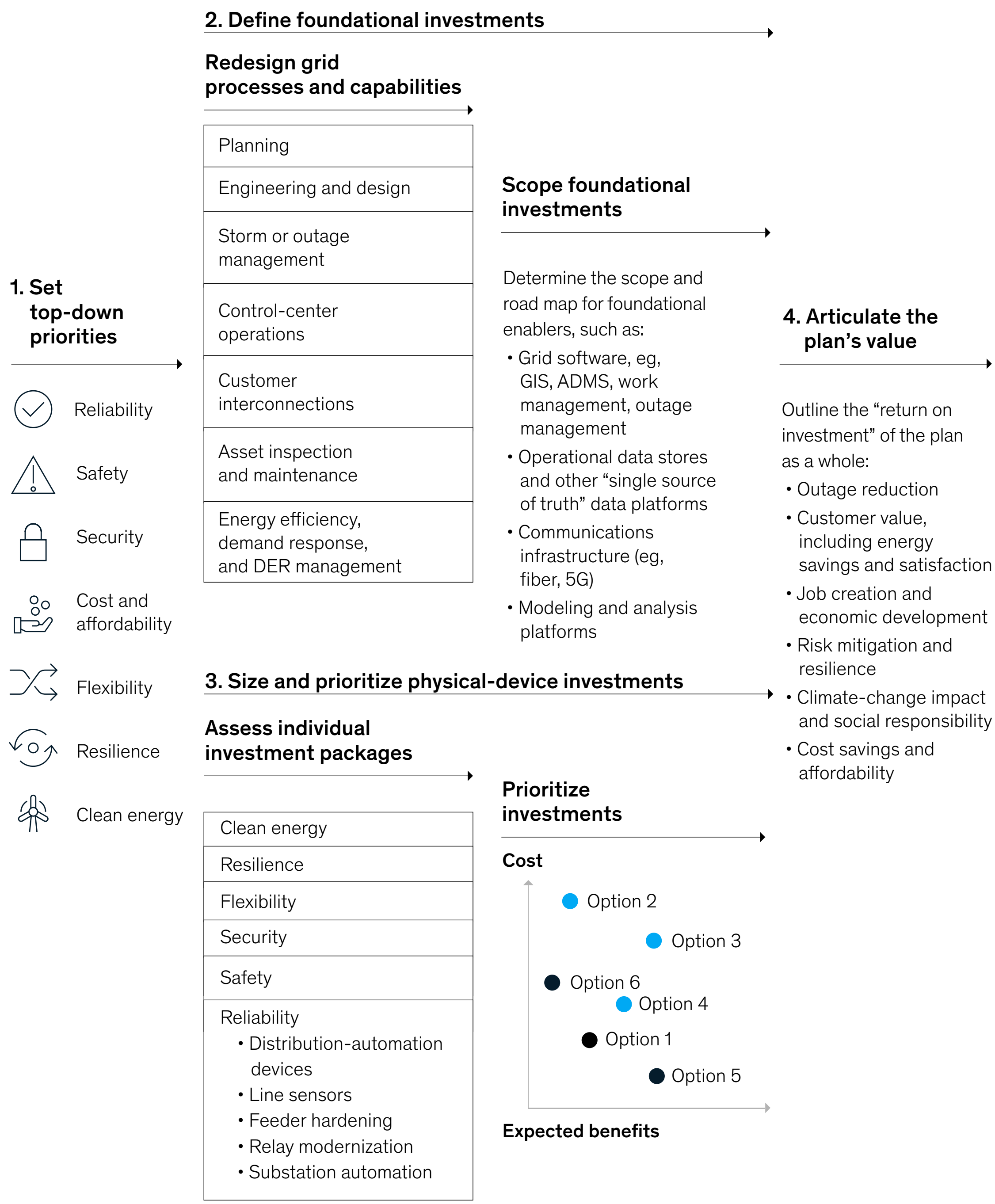
[6] Clément Alaton and Frédéric Tounquet, *Benchmarking smart metering deployment in the EU-28 report: Final report December 2019,* European Commission, April 6, 2020, ec.europa.eu.

A unified approach to solving the grid-modernization puzzle

Utilities can develop an integrated, step-by-step modernization plan (Exhibit 2). First, companies must define the specific performance outcomes—with target KPIs and metrics—that the modernization programs will achieve. In meeting these objectives, they can pursue two parallel streams: one aims to determine the foundational capabilities and centralized investments required to accomplish the vision, and another aims to develop business cases for localized grid investments.

Exhibit 2

Grid modernization requires a four-step approach.



T&D operators that develop a modernization plan with the aim of providing optimal consumer benefits—and convincing regulators of its effectiveness—should include a synthesized, comprehensive description of the plan's return on investment for ratepayers.[7]

1. Set top-down priorities

Utilities have previously used simple and well-understood compacts to justify their grid investments: in exchange for building a reliable electric grid, utilities' stakeholders would approve their projects and guarantee a return on the capital invested. Utilities have specific metrics to track reliability and safety (such as Customer Average Interruption Duration Index or Occupational Safety and Health Administration recordables), and stakeholder expectations centered on a continual improvement in these metrics. In other words, more capital investment meant greater reliability for their customers and communities.

Today, a safe electric grid continues to be table stakes, but customers' expectations around resilience, security, and flexibility have changed. This evolution represents not only an opportunity for utilities to deliver expanded outcomes and benefits to their customers but also a challenge to define the relationship between investments and what customers can expect.

Utilities have struggled both to explain new value propositions and to clearly link them to community demands and needs. As a starting point, they should sharpen their articulation of what outcomes their proposed programs will provide. "Grid modernization" is an imprecise term that can mean different things to different stakeholders; the first step for utility companies to get regulators and consumers on board is to pin down exactly what utilities mean by "modernization" (Exhibit 3).

[7] For more on rate-design changes in US electric utilities, see Blake Houghton, Jackson Salovaara, and Humayun Tai, "Solving the rate puzzle: The future of electricity rate design," March 8, 2019, McKinsey.com.

Exhibit 3

Customers expect a greater set of performance outcomes from their electric grids.

Grid outcomes

■ Traditional ■ Evolving ■ Both

Reliability (Traditional)	Safety (Traditional)	Security (Evolving)	Flexibility (Evolving)	Resilience (Evolving)	Clean energy (Evolving)	Cost and affordability (Both)
Limit frequency and duration of service disruptions, momentary interruptions, and other power-quality issues	Minimize grid-related equipment failures and associated danger for employees, customers, and the general public	Make the grid robust against man-made physical and cyber threats	Improve the grid's ability and capacity to integrate distributed energy resources (eg, electric vehicles, distributed generation, and demand response)	Prevent or withstand damage from major disruptive events and improve recovery speed and survivability when damage does occur	Support achievement of renewable energy and decarbonization commitments and goals	Optimize O&M and capital efficiency to ensure an acceptable level of affordability for ratepayers

Reliability and safety have **historically been the key outcomes** for distribution utilities.

Security, flexibility, resilience, and clean energy—plus cost, to some degree—are **emerging grid outcomes**, driven by nascent technologies, customer demands, and policy priorities.

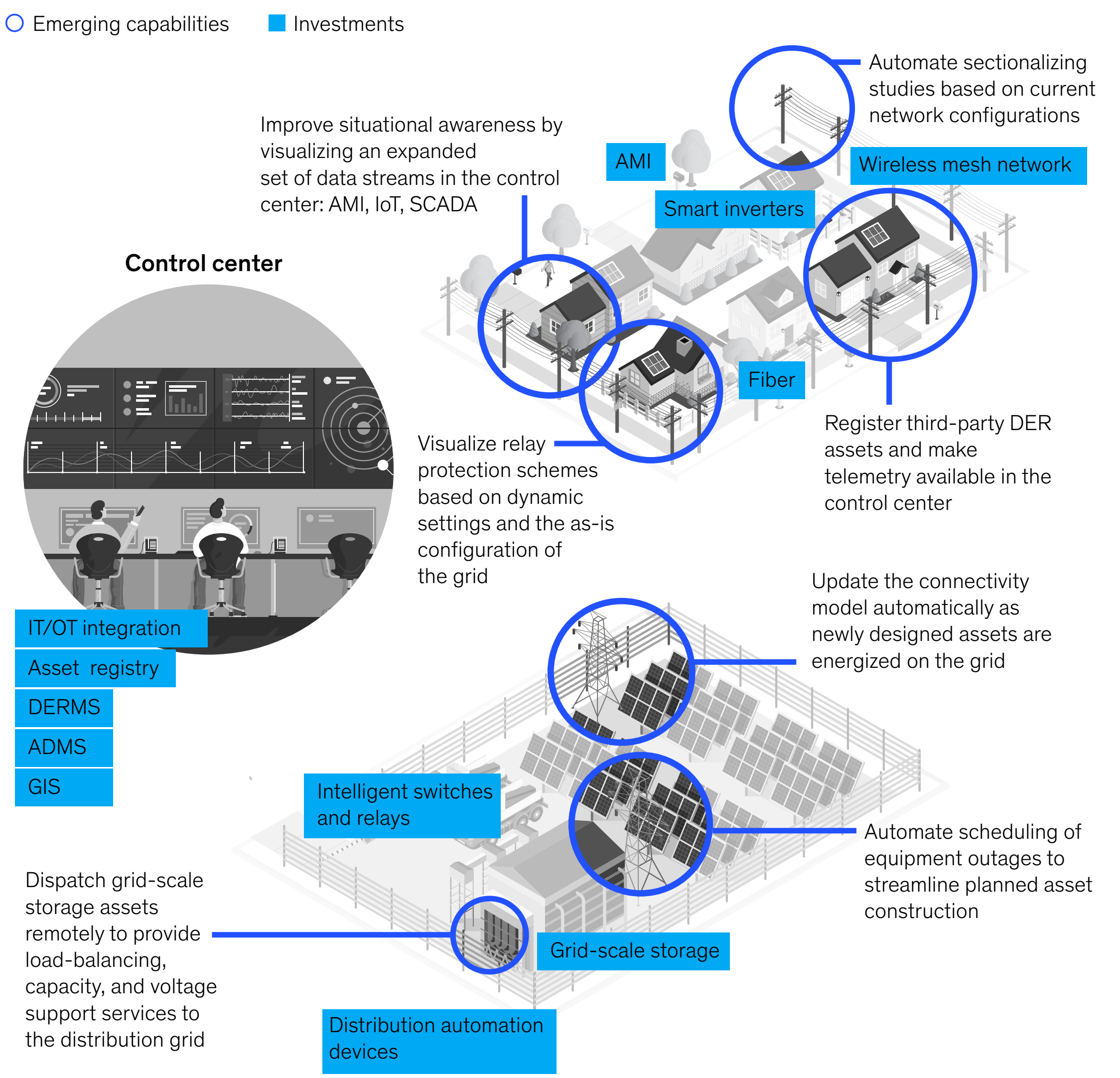
Utilities can create specific KPIs and targets for each performance outcome to clearly define what their modernization-investment programs hope to accomplish. They can also incorporate stakeholder perspectives and feedback into these targets to align the outcomes to the needs of their customers. The relative weighting of traditional and evolving outcomes will vary. In the Southeast, for example, a spate of exceptionally strong hurricanes—such as Laura (2020), Michael (2018), Harvey (2017), and Irma (2017)—has highlighted the importance of a resilient grid that can ride through extreme weather events without outages or restore power quickly. This could be measured through storm-specific metrics such as "Customer Average Interruption Duration Index" (CAIDI) and "Maximum customers interrupted" during the storm. However, areas with limited penetration of DERs, such as solar photovoltaics, and fewer natural disasters could prioritize non-storm reliability and limiting increases in electricity rates.

2. Define foundational investments

Capabilities are not binary. Some may become more mature and widespread across the grid over time. Monitoring and control, for example, are universally foundational. Thus, most utilities have basic monitoring and control capabilities already in place, but many seek to grow maturity over time (Exhibit 4).

Exhibit 4

Utilities must strengthen their capabilities over time.



Utilities must determine how advanced these capabilities need to become, but they must also consider timing. Doing so can ensure utilities invest at an appropriate pace to build their capabilities as needed. How mature each capability should be—and how comprehensively deployed across the grid—depends on the specific characteristics of the grid and the community it serves. For example, utilities with significant amounts of EVs and distributed generation might require probabilistic, scenario-based planning for each distribution circuit. For others, such a capability might not be needed in the next five to ten years.

Understanding the foundational investments required can be difficult, as they are often not tied to a specific grid circuit or asset. Companies can work with subject-matter experts and line leaders to diagnose weaknesses in existing foundational workflows—such as grid planning, asset design, control-room operations, and field and emergency operations.

3. Size and prioritize physical-device investments

News reports on grid-modernization programs tend to cover the deployment of millions of field devices. These monitoring and control devices include smart digital substations, next-generation smart meters, and distribution automation devices (reclosers or sectionalizers). What goes unmentioned, however, is that other programs focus on retrofitting obsolete designs, such as upgrading substations and feeders to higher voltage levels. Regardless of the type of investment, our research shows that the best approach is bundling investments in packages that achieve a common outcome. For example, feeder undergrounding can serve higher levels of resilience, while sectionalizing feeders achieves higher reliability. An investment package can therefore be sized based on a target level of device penetration and subsequently prioritized based on quantifiable outcomes achieved for the customer versus the cost of each package.

4. Articulate the plan's value

Most plan rejections across the country are rooted in insufficient documentation of ratepayer benefits, as compared with cost implications. This trend will likely persist—unless utilities articulate the value of all ratepayer outcomes and, if necessary, commit to targets enabled by their plans.

Such efforts are best done at the plan level, as opposed to the investment level. Grid-modernization plans are frequently more than the sum of their parts. For example, modern distribution relays work better when operating on a communications infrastructure that can handle the bandwidth of data transmission in addition to a utility-asset data platform that allows data scientists to run asset analytics. Painting the whole picture can make utilities more successful, and frequently more accountable, for regulators and stakeholders alike.

Taking action: Implications for utilities

Grid modernization cannot be a siloed effort led by engineering divisions. Given the interdependencies and sources of uncertainty, it must instead be a cross-functional effort that draws input from across the organization. For instance, regulation and policy teams can advise which assets utilities should add to the base rate, as well as what they can or cannot do with assets for building capabilities. Customer teams can clarify how changes in grid investments influence customer-facing technologies, such as interconnection portals. And finance teams can provide information on how investment will affect customers' bills and fund the projects over time.

As we have seen, creating an appropriate portfolio of required investments is not a quick or easy task. While utilities work on developing their long-term investment plans, they can make the following short-term moves with confidence:

— *Develop a lasting aspiration with quantifiable outcomes tailored to your service territory.* Utilities need goals and targets to inform redesigned business processes and investment packages. The clearer the aspirations—with metrics where possible—the more likely it is that the modernization plan will produce tangible benefits. For instance, if a utility wants to support electrification, how many heat pump installations does it want to achieve? How many EVs? How many EV charging ports? How many circuits need to be reconductored to maintain adequate capacity margins? It's also important for these aspirations to be specific and responsive to the service territory's needs. Some service territories may have extremely reliable service but community aspirations to decarbonize; others, in areas more exposed to climate risk, may be laser-focused on improving system resilience to protect against damage from severe storms or brownouts from extreme temperatures.

— *Take a system-wide lens to address local needs in the long term.* Utilities should consider the full range of solutions to meet their service territory's needs, such as cleanliness, reliability, and resiliency, as effectively and affordably as possible. These solutions may involve a combination of infrastructure investments. Take resiliency as an example: for remote or rural communities, utilities could consider investments in local supply, batteries, and demand response, rather than new and underutilized transmission lines. However, utilities in urban communities with dense gas grid networks can explore using the gas network to provide a resilient backup supply that feeds local generator sets or fuel cells in the case of an electrical outage.

— *Involve stakeholders across the utility.* Grid modernization is an organization-wide transformation. Successful delivery requires stakeholders from across the business—engineering, operations, customer, regulatory—to buy into the vision. Capturing the full benefits of AMI or automated demand response, for instance, requires utilities to bring new data sources into control centers and sign up new customers, respectively. In addition, regulatory teams can help evaluate whether the program's potential investment costs are justifiable and reasonable relative to the benefits. If stakeholders beyond the engineering team are not involved in redesigning business processes and determining localized investment needs, then execution is destined to fail.

— *Modernize workflows and ways of working, not just equipment.* For grid-modernization investments to generate real business outcomes, they need to improve core business processes across a given utility. The unfortunate truth is that these processes are often broken and filled with pain points. The promise of the "grid of the future" is rooted in an abundance of new grid-data streams that can support use cases—such as improved system planning and faster outage identification, resolution, and restoration. These use cases require more than shiny new smart devices on the grid, however. Unless data streams from those assets are integrated into core business workflows to improve how utilities get work done, they will create no tangible benefit.

  Utilities can minimize grid failures and operating costs by developing effective predictive maintenance programs. However, they also need to reimagine how work is triggered (for example, automated work-order generation); how that portfolio of work is governed and managed (such as what's reviewed versus automatically approved); and how grid failures and outcomes are tracked (for example, accurate failure codes) to validate effectiveness. Similarly, potential reliability and flexibility benefits from installing additional smart, dispatchable resources on the grid (including voltage support and firm capacity) will only be achieved if established processes are in place to take advantage of these benefits. Those resources need to be registered in operating platforms, with an updated connectivity model and precise asset parameters and operational capabilities. Having a granular vision for core workflows—including what data will be used as inputs, how it will be sourced, and how it will be analyzed—is critical for understanding the investments (especially software expenditures) needed and how they will translate to new benefits.

— *Do not discount enterprise technology investments that support new ways of working.* Investing in core technology platforms is difficult.

It involves changes to processes that, for the past 30 years, have remained largely the same and have continued to provide reliable service to ratepayers. Moreover, utilities are rewarded economically for investing in physical assets, not soft technologies with a higher operations and maintenance burden. But without investments in these capabilities, utilities will be unable to maximize the benefits from localized investment packages. Absent the underlying technology to provide real visibility into conditions in localized grid areas, for example, additional monitoring and control investments, incremental sensors and sectionalizers will provide minimal value. Effectively integrating OT and IT systems can help maintain accurate asset data while making it available for other enterprise applications (such as predictive maintenance algorithms and power flow analytics). Investing in these integrations can de-risk the overall investment program by ensuring utilities can actually operate differently and capture the value at stake.

— *Create investment headroom.* Investments that reduce costs, have quick paybacks, or both create additional investment headroom in the budget, which will only accelerate the pace of modernization and achievement of top-down aspirations. Replacing old, frequently failing conductors can reduce run-rate repair costs. Similarly, investments in work-management systems and scheduling processes can improve crew productivity (jobs per day). Utilities should also scrub existing capital investment plans for projects that neither support development of new capabilities nor tie to a discrete, localized benefit.

— *Develop a road map with milestones.* The volume of work and capital required to modernize the grid will stretch well beyond five years. To maintain buy-in and support from ratepayers and regulatory bodies, utilities need to set clear milestones and markers of success over time (metrics such as numbers of EVs enabled, CAIDI scores, or days to interconnect; or alternatively, demonstrable capabilities such as distribution circuit forecasting). Internally, utilities need to have a view into the gradual maturation of their core business workflows and localized investment plans. Externally, utilities need to be able to link these milestones to improvements in target metrics that demonstrate new benefits to their communities.

Developing an appropriate modernization plan is difficult and will inevitably be an iterative process. Utilities should start by clearly defining their goals and embedding disciplined, rigorous investment-planning processes that are aligned to those goals. Only through these processes can they mitigate the risk of misdirected investments and make real progress toward building the best possible grid of the future—for both themselves and their customers.

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