Schneider Electric
Leadership Series

DIGITAL
Grid Unleashed

Life Is On | Schneider Electric

Contents

Foreword

Increased attention to improving the efficiency of buildings and industrial operations will help temper growth trends worldwide.

By the year 2040, annual global electricity consumption will be 70% higher than in 2015, according to International Energy Agency (IEA) estimates.[1] This staggering increase has left electric utilities around the globe seeking answers to some very difficult power questions. How can almost twice as much electricity be consumed while still reducing fossil fuel emissions? And how must today's power distribution systems evolve to meet this growing demand? This report sets out to offer recommendations for addressing the needs of a growing worldwide population while simultaneously tackling today's priority of decarbonizing global energy markets.

According to Bloomberg New Energy Finance, global electricity generation is on a path to hit a fossil-fuel peak sometime between 2025 and 2030. Solar and wind generation combined will out-produce natural gas by 2030 — and coal by 2035. And, in some regions, much of the added renewables, particularly solar, will be connected at the distribution level. By 2040, around 5% of the world's electricity will be generated by small-scale photovoltaics (PV) but that numerical average masks an extraordinary range. Organization for Economic Cooperation and Development (OECD) countries, for example, are pegged at 8% of generation, Europe at 9% and the United States at about 15%.[2] In Australia, however, distributed solar is anticipated to soar to close to half of total installed capacity and a quarter of total generation. Rapidly improving energy efficiency will play its own role in decarbonizing the grid, while also having an impact on electricity sales.

The mix of market participants and their specific challenges differ across global regions. Electricity demand is set to soar in developing nations over the next two decades, while developed markets will experience little, or even negative growth. Further, a variety or regulatory environments implies that no one-size-fits-all approach exists for decarbonizing electricity supply. The common denominator that emerges is a more digitized grid.

A combination of factors will be driving the enormous growth in global electricity consumption over the next two decades, including:

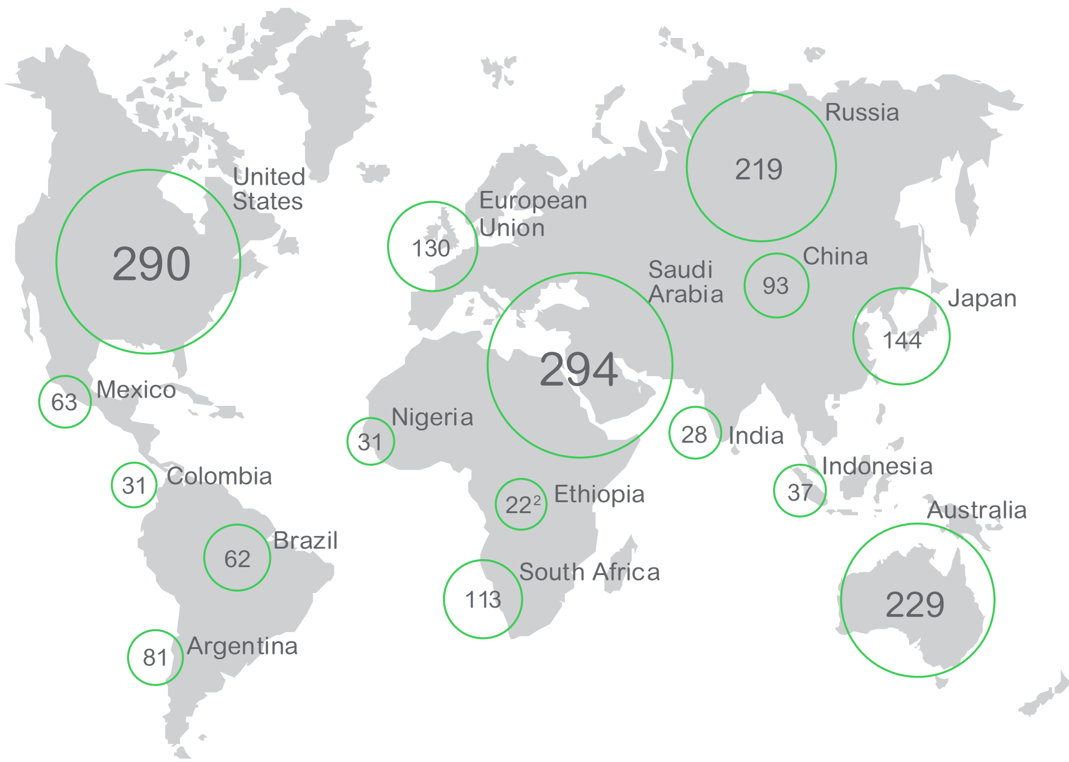
Population growth — The planet will be home to 8.5 billion people by 2030, up from 7 billion in 2010.[3]

Urbanization and rising standards of living — Electricity production will grow by more than 70% in the next 20 years, driven by the improvement of living standards in new economies.[4] Indeed, it is increased urbanization and consumption of electrical goods which primarily drive the surge in energy consumption. The impact of economic and industrial growth in developing economies will result in significant electricity production output increases. Production growth will primarily take place in Asia; the economic growth of China in particular should advance global growth. Beyond 2035, electricity consumption should continue to increase, driven this time by other regions of the world such as India, the rest of Asia and Africa as they achieve their own economic transition.

Energy per capita varies significantly across the world

These numbers represent energy use per person, measured in gigajoules, in 2014:

Non-OECD[1]	56[2]
World	79
Average required for good standard of living today	100
OECD	177



1 Countries that are not members of the Organization for Economic Co-operation and Development.

2 2013 due to limited data

SOURCE: Enerdata (2015), Historic actuals; UN Population Division (2015), World Population Prospects: The 2015 Revision

Figure 1- Current energy per capital varies significantly across the world. (Source: Better Energy, Greater Prosperity report Energy Transitions Commission, April 2017 www.energy-transitions.org)

Access to energy — Off-grid photovoltaic (PV)-plus-storage systems and other technologies are bringing electric lighting to areas of rural Africa. Rising incomes are fueling a rapid uptake of window air-conditioning units in India. Inexpensive mobile devices, including smartphones and laptops, now are being charged by small kiosks throughout the developing world.

Fuel shifting — Fossil fuels and rural biomass (especially wood) are being replaced in many areas of the globe by electricity and natural gas for heat, light, cooking and other purposes.

Energy efficiency — Increased attention to improving the efficiency of buildings and industrial operations will help temper growth trends worldwide. Massive efficiency potential could ensure up to 25% savings in the industry sector, 20% in the buildings sector, and up to 31% savings in the transportation sector. Regions with a high mix of buildings versus transportation or industry have an even higher potential overall. North America, Europe, China and Asia / Pacific present the highest opportunities for energy savings.[5]

Low-carbon transportation — Forecasts show that substantially more electricity could be consumed as a result of increased deployment of electric vehicles. Thanks to growing automotive industry investment and policy support — including recent decisions by UK and French governments to phase out sales of conventional vehicles by 2040 — electric vehicles could top 25% – 30% of the worldwide fleet of cars by 2040.[6] However, the share of light vehicle transportation strongly varies from one country to another. It typically reaches 79% in North America (60% in Europe), but barely tops 7% in India. This ratio will evolve in the coming years, and is estimated to reach up to 40% in all new economies. A potential of up to 1,970Mtoe of oil could be shifted to electricity, or 23,000TWh, with significant impacts on consumption in mature economies, as well as China, India and Africa.

Population growth is a deceptive factor, due to the vast discrepancy in per capita energy use between developed and developing nations. Populations will rise much more quickly in the developing world, but developed nations use significantly more electricity per person.

North America uses four times the global average of electricity, per capita, for example, so even though U.S. population growth will only increase by 4% between 2015 and 2035, the region will be responsible for 38% of the growth of electricity consumption globally over that same period.[7]

Rising living standards and fuel shifting, however, will be much more important growth factors for developing countries, and both could be seen as driving positive outcomes. In much of the developing world, this shift will occur as a result of new connections to electricity resources that simply did not exist before. As of 2016, 1.2 billion of the world's population lacked any access to electricity and burned kerosene and firewood for light and heat, a figure that should fall to 780 million by 2030.[8]

Further compounding the challenge of addressing this growth in electricity consumption, is the dangerous threat that comes with it. The introduction of reliable and affordable electric lighting and cooling in developing regions will change millions of lives for the better, but if such advances are powered by fossil fuels, the impacts of climate change will only become more severe. Business as usual simply isn't acceptable anymore, a fact emphasized by the Energy Transitions Commission in its April 2017 report, "Better Energy, Greater Prosperity." At the high end, in a business-as-usual scenario, global energy use could grow 80% by 2050, the report states. Considering the nature of today's fossil-fuel reliant energy mix, by the year 2100, such growth could lead to the possibility of a devastating 4 °C rise in global temperature (over pre-industrial times).[9]

Balancing these consumption-related factors, though, will be an increasingly significant emphasis on energy efficiency. Already, economies around the globe have begun decoupling the longstanding relationship between energy consumption and gross domestic product (GDP). Energy demand no longer runs in lockstep with economic growth. Even more heartening, the trend is most significant in developing nations, where economies are experiencing rapid growth.

The challenge of growing consumption while simultaneously reducing emissions — is one that the global community shares. We must therefore transition to a global energy system aiming to:

Decarbonize power while extending electrification.

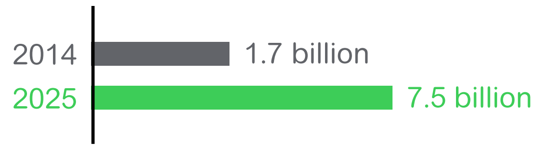
Digitize energy and associated business processes, by leveraging digital technologies such as the Internet of Things (IoT) and requiring the convergence of the world of information and the world of operation.

Decentralize existing power generation models, by embracing distributed, smarter energy and information flows throughout all levels of the grid.

> Fossil fuels and rural biomass (especially wood) are being replaced in many areas of the globe.

Digitization of data

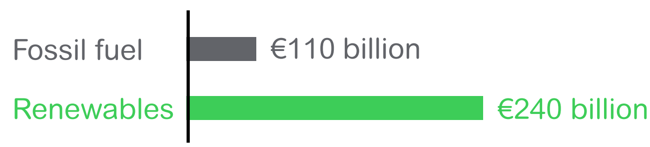
Number of connected devices in buildings



Source: IHS IoT Platforms: Enabling the Internet of Things 2016

Decarbonization of grid

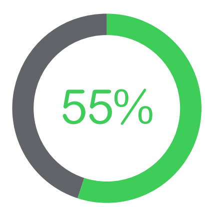
Global investment



UNEP FS / ENEFGlobal Trends in Renewable Energy Investment 2016

Decentralization of assets

Corporate investment



Over 55% of U.S. companies now have on-site generation

Bloomberg New Energy Finance

Energy intensity decreased by approximately 20% between 1990 and 2014, with large regional variations

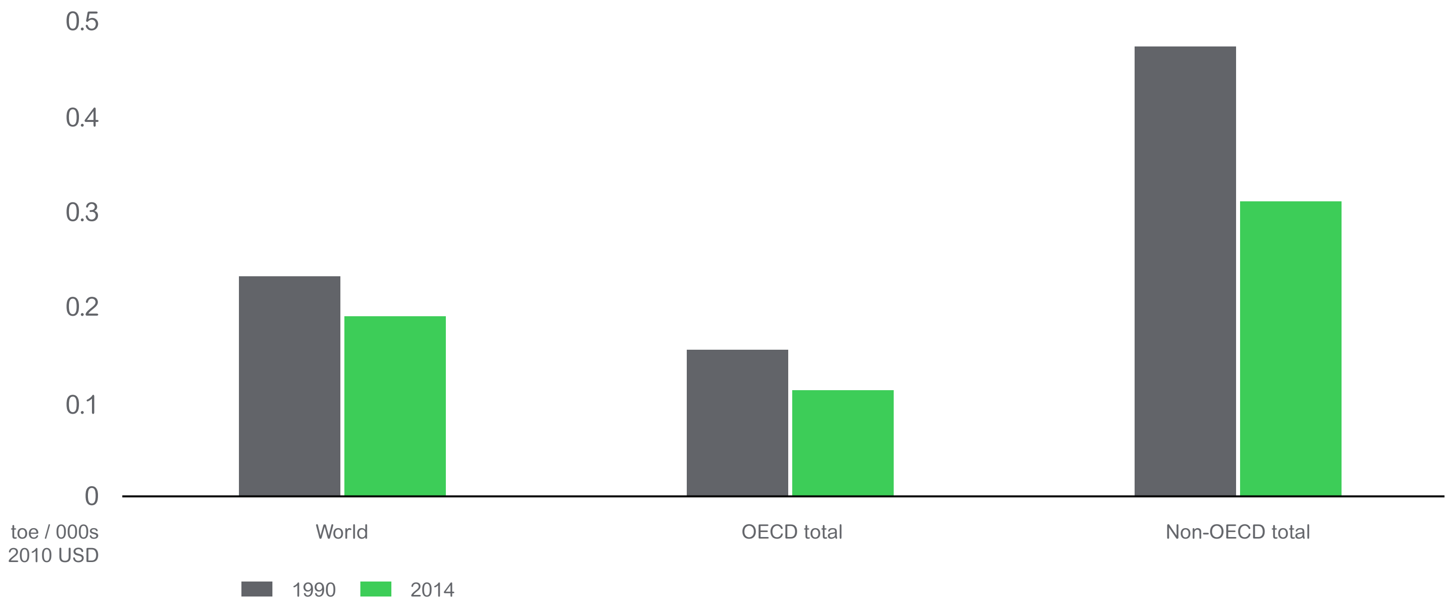


Figure 2: Energy intensity (toe / 000s 2010 USD) decreased by approximately 20% between 1990 and 2014, with large regional variations (Source: IEA World energy balances, 2017; TPES: total primary energy supply; GDP based on 2010 USD PPP © OECD / IEA 2017 World Energy Balances, www.iea.org / statistics. Licence: www.iea.org / t&c.)

Success story

South Australia

In recent years, Australia has been experiencing an increase in the number of extreme weather events, with the state of South Australia being particularly hard hit. The region is seeing heatwaves and storms increase in both frequency and intensity, resulting in new demand spikes and raising the risk of network disruption.

South Australia Power Networks (SAPN), the state's sole distribution network service provider, has responded by establishing a Network Innovation Centre, with the aim of deploying advanced network technologies. Schneider Electric has partnered with SAPN on a number of these deployments, including:

- An advanced distribution management system.
- Fault location, isolation and supply restoration.
- A smart-connected kiosk substation.

Schneider Electric's work with SAPN is ongoing, and the organization remains committed to assisting SAPN as it works to deliver on its long-term network strategy.[10]

Success story

Italy

Utilities' medium-voltage / low-voltage (MV / LV) distribution systems face some inherent inefficiencies due to line losses and switching activities. However, some utilities are realizing new opportunities for reducing those inefficiencies with advanced distribution management systems (ADMS). As Italy's largest electricity distributor Enel has discovered, even small improvements can add up to meaningful fuel-cost reductions and a corresponding drop in carbon emissions.

Enel was able to use an ADMS from Schneider Electric to optimize its Milan operations to better address real operating conditions. Using data gathered from sensors installed in its own substations and transformers, along with customer meter data, the utility was able to better understand seasonal variations in its network operations. It developed a plan to recalculate system connections at the launch of each new season, reducing energy losses by 4% in the process. While this might seem like a small improvement, at utility scale it adds up to a worthwhile reduction in fuel costs and emissions. Enel has since extended the system to its 28 control centers across Italy.[11]

01

The inevitable disruption of utilities

The challenge of change

New technologies, changing regulatory policy, and favorable economics are all pushing the accelerated development of clean, low carbon renewable power sources.

The centrally managed, fossil-fuel-dominated approach of the past is being challenged. New technologies, the rising influence of regulatory agencies, and favorable economics are all pushing the accelerated development of clean, low carbon renewable power sources. That same drive for change is being reflected in the way power networks are being designed and upgraded. But as executives and regulators alike are finding, these new priorities have wide-ranging implications. Greater adoption of renewables, especially solar and wind generation, pose challenges that are as significant as their benefits. For example:

- Once constructed, wind turbines and solar panels are "free" to fuel from an energy generation perspective (i.e., no coal needs to be procured and burned to drive the turbines), which is likely the most significant productivity improvement of this century. In the meantime, however, this advance could raise havoc with traditional wholesale power market structures.

- Major potential for improving the operational efficiency of the utility business models can be found in how electricity is now being supplied. The more distributed nature of renewables is forcing a redesign of the architecture of the transmission and distribution grid first implemented 100 years ago. Today's market and grid organizations are simply not structured to sustain such a transition efficiently. Meeting the challenge of a more distributed future will require distribution utilities to rethink technology investment strategies and engage with their customers as partners.

The energy market is still figuring out how to manage pricing in this new environment. In Europe, for example, the popularity of feed-in tariffs fostered an increase in renewables, placing traditional fossil-fuel generation at a pricing disadvantage. An unintended consequence has been a tendency to slow down the phasing out of coal-burning plants as an option for mitigating the variability of solar and wind resources.

In other parts of the world, legacy equipment and aging infrastructure work to slow down the evolution to a hybrid environment that includes both centralized and decentralized power structures. Utilities are recognizing that a migration to smarter grids is not a start-from-scratch process. It requires a reconfiguration — a reimagining — of existing networks, which, in many cases, works reliably and in which capital investment has not been fully depreciated.

> Today's market and grid organizations are simply not structured to sustain such a transition efficiently.

Meeting the challenge of a more distributed future will require distribution utilities to rethink technology investment strategies and engage with their customers as partners.

Shifting needs, evolving solutions

A revolutionary shift in energy economics is now underway. Wind and solar are often the lowest bidders into today's energy markets, thanks to a combination of incentives and dramatically falling prices. As a result, coal generation is shutting down in many regions around the globe. This trend began a decade or so ago in Europe and North America, and in 2017 the UK's National Grid confirmed its first coal-free day since the birth of the Industrial Revolution. Even in China and India, ambitious coal plant development plans are seeing a significant slowdown. Nuclear plants, once promoted as the emissions-free solution in a CO_2-sensitive world, also are being priced out of purchasing decisions. Even natural gas plants — especially combined-cycle versions that lack rapid ramp-up capabilities — are coming under threat.

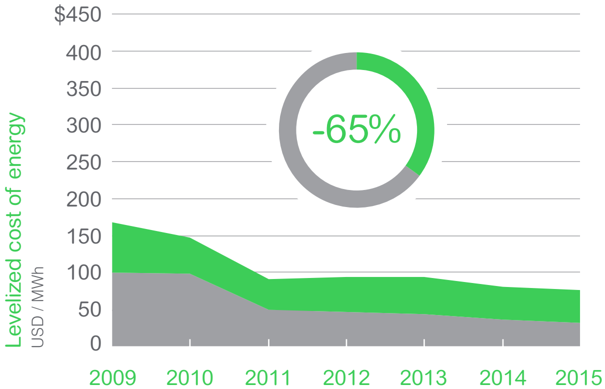
These cost shifts are forcing grid operators and power purchasers around the globe to rethink the old definition of baseload generation. No longer are fossil fuel and nuclear plants the go-to resource for the world's future electricity needs, when wind and solar generation can be installed for a fraction of the cost. Instead, in many cases, system operators are loading cheaper renewables into the baseload slot, and counting on a set of more flexible, dispatchable resources — and, increasingly, energy storage — to pick up the slack in both electricity production and ancillary grid-support services.

The results of this shift haven't always been positive for the environment. Germany, with its ambitious renewables program, saw its CO_2 emissions tick slightly upward in 2014 and 2015, as increasing dependence on intermittent wind and solar have forced coal and gas plants into operation as backup resources. South Australia has recently seen unprecedented low grid demand due to moderate temperatures, less air-conditioning and excellent solar output. However, the impact of this shift to rooftop solar and high wind production, reaching more than 100% of local demand at certain times, is being felt in energy prices.[1]

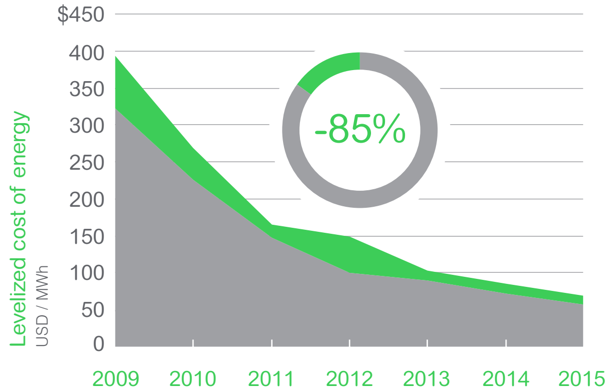
> No longer are fossil fuel and nuclear plants the go-to resource for the world's future electricity needs.

Wind and solar costs have declined significantly in recent years.

Levelized cost of wind energy
USD / MWh, unsubsidized



Levelized cost of utility-scale Photovoltaic (PV) energy
USD / MWh, unsubsidized



Recent bid priced for wind energy

$30 USD / MWh Onshore - USA, 2015
$35 USD / MWh Onshore - Morocco, January 2016
$50 EUR / MWh Offshore - Denmark, November 2016
$55 EUR / MWh Offshore - Netherlands, December 2016

Recent bid priced for utility-scale Photovoltaic (PV) energy

$24 USD / MWh - Abu Dhabi, September 2016
$29 USD / MWh - Chile, August 2016
$30 USD / MWh - Dubai, May 2016
$27 USD / MWh - Mexico, February 2017

Figure 1 - Wind and solar costs have declined significantly in recent years.
(Source: Better Energy, Greater Prosperity Report Energy Transitions Commission, April 2017 www.energy-transitions.org)

NOTE: USA 2015 wind bid price adjusted for Production Tax Credit. According to LBNL's 2015 Wind Technologies Market Report, 2015 USA PPA prices are as low as ~20 USD / MWh after PTC, plus an adjustment of 15 USD / MWh levelized value of the PTC.

SOURCE: Lazard Levelized Cost of Energy 9.0 (2015), Greentech Media, Lawrence Berkeley National Lab

Utilities: adapting with the times ...

Smarter electricity grids will be vital to success, because they support tomorrow's electricity-dependent world.

In light of such disruption, distribution utilities are trying to adapt. They are still responsible for linking transmission grids to their customers' meters. Now, they also must accommodate increasing quantities of distributed generation into systems never designed for two-way power flows. This means transforming their previous role of wire manager into a more complex role of resource planner and dispatcher, and market enabler — all duties that are much closer to those of a present-day system operator. And such transformation will require an exponential increase in the use of data, for a better understanding of real-time grid conditions. As a result, today's utilities are evolving from managers of large, long-lived physical infrastructure into managers of data-point digitized infrastructures.

Smarter electricity grids will be vital to success, because they support tomorrow's electricity-dependent world. While centralized power generation will remain critical to grid stability for decades to come, distributed energy resources (DERs), such as residential rooftop and community-scale solar arrays and storage, will become important for energy suppliers and supporters of system stability. The digitization of distribution systems will enable the greater connectivity required for a more flexible and efficient control and transfer of electricity between:

- Residential and commercial buildings' switchboards and automated home devices.
- Distributed energy resources (DERs).
- Energy communities (such as microgrids), their members and stakeholders.
- Utilities operating distribution grids, regional and connecting systems and participating in energy markets.

Distributed generation provides consumers with an option to buy their electricity from a retailer or to produce it for themselves.

Defining a new class of resources

DERs are smaller-scale sources of electricity generation. Unlike bulk-energy baseload and peaking power plants, which ship the electricity they produce to local distribution systems over high-voltage transmission lines, DERs are installed locally, within those distribution networks. Today's most common DERs include:

- Disparate, small-scale rooftop PV panels and microturbines.
- Electrical vehicles that consume and charge back energy on the move.
- The growing realm of energy storage, demand response and controllable loads.

Distributed generation provides consumers with an option to buy their electricity from a retailer or to produce it for themselves. However, connecting generation resources within distribution systems creates new complexity for grid operators and requires increased flexibility and control capabilities. As a result, utilities are now looking for digital solutions that can help them optimize existing grid assets and push the technical limits of these growing sources of distributed power. In fact, as these resources produce power closer to the load, they deliver broader value beyond just generating revenue to the owner, through distribution services, reduced losses, risk mitigation, environmental benefits and economic development through local infrastructure projects.

Intelligent network operations also hold the promise of greater customer satisfaction, which is becoming a more important bottom-line contributor in today's social media-driven environment. Distribution utilities are at the front lines of the larger transmission and distribution network, and they bear the brunt of outage complaints. Avoiding — or at least minimizing — outages and providing accurate, real-time information on projected repair times and customers' energy use can help utilities gain a reputation for responsiveness.

Currently, the market research firm IDC sees customer satisfaction as a challenge for many distribution utilities, predicting that by 2018 only one in five utilities will be capable of raising customer satisfaction scores by 10%.[2] To better serve customers, many utilities are starting to invest in technology that delivers a consistent experience across multiple platforms, from laptops to smartphones to call centers.

> Utilities are now looking for digital solutions that can help them optimize existing grid assets and push the technical limits.

To better serve customers, many utilities are starting to invest in technology that delivers a consistent experience across multiple platforms, from laptops to smartphones to call centers.

The rise of microgrids

Microgrids are created for improved reliability in places where main grid reliability is not adequate, or when the utility is providing attractive price incentives for load sharing.

Today's electricity grids are getting larger and smaller at the same time. The U.S. Plains & Eastern Clean Line, now in planning, will carry wind-generated electricity more than 700 miles, from Oklahoma to Memphis, Tennessee, when it starts operating in 2020. High-voltage direct current (HVDC) transmission technology is enabling its astounding 4,000-megawatt capacity. At the same time, microgrids are now coming online to link on-site DERs to local facilities on campuses, military bases and in housing and apartment developments. At certain times, these systems can be "islanded" from the main grid and supply themselves with their own energy. In the event of main grid supply failure, for example, they can maintain supply internally by carrying out load shedding of specific resources to maintain their balance.

Seamlessly disconnecting and reconnecting to the main grid without supply interruption of loads is a key microgrid attribute. In addition to these independent operations, such systems can run in parallel with the main grid to reinforce it. As a result, local power generation can be managed in line with local demand, minimizing exchanges at the point of connection between the system and grid, thereby freeing grid resources.

Microgrids can be classified by their connection mode to the main grid and their type of ownership. In general, they fall into one of the four major categories described below:

01 Grid-connected facility microgrids

Connected to the main grid, these microgrids are created for improved reliability in places where main grid reliability is not adequate, or when the utility is providing attractive price incentives for load shedding. Some examples are high-availability, single commercial buildings, corporate research or business campuses, hospitals and data centers. Benefits of these installations include lower energy bills, an ability to integrate more renewable sources, and improved resiliency.

The energy policy decision maker for grid-connected facilities is usually the site's energy manager. Supported by analysis tools, this individual typically makes choices that optimize the site's energy usage for improved:

- Energy procurement, including energy purchases and negotiating of delivery contracts.

- Energy consumption, with the ability to set priorities for the curtailable non-critical facility loads such as heating, ventilation and air-conditioning (HVAC) systems (with notable exceptions such as hospitals and data centers), fleet management of electric vehicle chargers, facility lighting control, etc.

The energy manager aims to optimize microgrid assets with assistance from the microgrid provider and a commercial aggregator to:

- Utilize all practical and cost-effective means of local production (DERs) and optimize self-consumption.
- Improve energy flexibility of the facility using a battery energy storage system.
- Monetize energy flexibility through a commercial aggregator.
- Benefit from advanced microgrid control that manages DER flexibility and reduces energy bills through tariff management optimization.

The energy manager prioritizes investments and optimizes energy efficiency (minimizing kWh consumed) and the kWh price. The site reaches new levels of optimization by self-consuming low-carbon, low-cost energy when it's available.

02 Grid-connected community microgrids

These microgrids serve multiple consumers and producers, are connected to the main grid, or managed as dispatchable units — or, with optimized power exchanges, with the utility's main grid. They serve districts that range in size from business campuses in cities to green villages to eco-districts or even small municipalities. They offer multiple benefits, including the ability to optimize the cost of energy, ensure resiliency, and integrate more renewable sources.

To run grid-connected communities, a new position is necessary: the district administrator aims to maximize self-consumption with locally produced energy, while purchasing energy from the grid, if necessary. Alternatively, when surplus energy is available, the district administrator can sell, store, or distribute it to the sites. The district administrator also typically determines energy flexibility for the district and selects participation in attractive curtailment events through a commercial aggregator. This economic optimization at the district level benefits all the district's sites, the community, and the campus owners.

03 Off-grid, facility microgrids

For off-grid microgrids, more public utilities and private entities call for tenders from private independent power producers (IPPs). The IPP is an entity that is not a public utility, but which owns facilities to generate electric power for sale to utilities and end users. These agreements typically include:

- Engineering, Procurement and Construction (EPC), which includes all the activities required to bring systems online, from design, procurement, construction, to commissioning.
- Solution connections, including the microgrid system, decentralized energy resources, energy management system, and electrical distribution.
- Business model / funding, which could take the form of direct ownership as a capital expenditure, microgrid as a service model, which would mean an operational expenditure, pay-as-you-go arrangement for small, remote systems, community ownership through municipal bonds, or spark spread, which compensates customers based on the difference between the cost of fuel and generation vs. the cost to buy electricity.

These are the most common type of microgrids today globally, and they are typically found in remote areas not reached by the traditional grid. Examples include remote military bases, remote mines or industrial sites, and isolated buildings such as resorts. The main benefits of these microgrids include high-reliability energy, so customers avoid downtime, and integration of low carbon renewable energy to optimize both cost and environment.

04 Off-grid, community microgrids

These microgrids serve multiple consumers and producers and are also found where the main grid is out of reach — for example on islands or in remote villages and communities. However, unlike facility microgrids, these initiatives encompass various community assets to guarantee resilient power for vital community services. The main benefits of these microgrids include a high percentage of renewable generation such as biomass, solar PV, and wind power to minimize fuel dependency with the added benefits of minimizing pollution and energy cost. Once they approach a certain size, off-grid, community-led microgrids experience constraints that can be alleviated by microgrid optimization and management technologies.

In parallel with microgrids, a broader and more disruptive idea of “energy communities” also is emerging. This term can refer to a physically connected neighborhood or campus, or a more metaphorical aggregation of distributed solar and storage resources that can be digitally networked to create its own energy market. Enabled by peer-to-peer trading capabilities, some of these communities could have consumers buying their kilowatt-hours from each other, rather than from their utilities. Recent examples include:

- In Brooklyn, N.Y., startup LO3 Energy has developed a pilot system combining a microgrid with an energy community that allows owners of rooftop solar panels to sell excess output to their neighbors. This transactive energy model is enabled by blockchain-based software, similar to that used to develop the Bitcoin digital currency.[3] Across the U.S., community solar arrays are expected to drive 20% to 25% of the non-residential solar market for the foreseeable future. Business models differ for these arrays that generally top out at 5 MW or less. But participants generally are home owners and small businesses who aren’t able to own their own solar systems. Buying into the projects can garner the same financial advantages as net-metering arrangements offer those with panels on their roofs.[4]

- Utility-led programs will emerge as a primary driver in the U.S. In Maryland, Duke Energy Renewables and Schneider Electric will partner with Montgomery County to construct two microgrids for public safety facilities. The two systems, which will be owned by Duke Energy, will include solar and combined heat and power, which saves energy by using waste heat from on-site generation to heat and cool buildings.[5]

- In Germany, battery manufacturer Sonnen has developed a virtual utility with its SonnenCommunity offering. Anyone can join for a fee of €19.99 / month, and owners of solar-plus-storage systems can sell their stored electricity into the pool. Just how potentially threatening is this approach to utilities? Consider this value proposition from the SonnenCommunity website: “Since you are exclusively using energy from the community, there is no need for a conventional energy supplier anymore.”[6]

However, these new energy communities may still depend on utility wires, transformers and substations as the infrastructure required to move kilowatts around their physical or virtual boundaries. Distribution utilities have an important role to play as an enabler and balancer of power transfers from one community member to another. In addition, community-based DERs can become a resource for active network management, reducing capital and operating expenses for utilities. Digitization will be the differentiator between distribution utilities who thrive in this changing environment and those who don’t at a time when new competitors are entering the market. IDC predicts that by 2020, 20% of global Fortune 500 companies will be in the electricity market, producing 2.5GW of electricity that they will be selling into the wholesale market through utility-independent subsidiaries.[7]

Community microgrids offer multiple benefits, including the ability to optimize the cost of energy, ensure resiliency, and integrate more renewable sources.

Europe’s first technology and educational microgrid testbed

Grenoble’s LearningGrid

The LearningGrid project at Institut des Métiers et des Techniques (IMT), aims to create a local microgrid across campus buildings to optimize energy performance, reduce consumption, train energy specialists and empower apprentices to understand energy issues as part of their professional training. IMT serves more than 2,400 students and the campus consists of 6 buildings, some of which date back to the 1960s, and others built as recently as 2015. It’s like a little city combining all typical businesses: a hotel, garage, bakery, hair salon, restaurant, etc. IMT currently has an overall picture of its energy consumption, but it now wants to control costs and measure when, where and how it consumes energy, in order to reduce its total costs by 30%, relying on 15% renewable sources and 30% from local production.

Schneider Electric is implementing the microgrid. A pooled management system of solar and cogeneration production, storage and the buildings’ loads will interconnect the electricity grid and the district heating network. At its heart will be a newly constructed 400 m^2 building — an “energy cockpit” to centralize all local facilities.

The growing role of
electric vehicles

Electric vehicles (EV) may have the potential to reduce our dependence on oil imports for road transport, cut national energy bills, reduce greenhouse gas emissions, improve urban air quality and noise pollution. However, the impressive growth trajectories forecasted for electric vehicles, battery technology and digitization presents unprecedented challenges on network topologies and supervision, in terms of how EV charging infrastructures are deployed and the significant impact placed on energy systems. For example, smart charging can provide services to utility grids to improve power quality and reliability. Even deeper flexibility can also be unlocked through vehicle-to-grid (V2G) technologies for bidirectional charging.

EVs and digital innovations may also participate in energy efficiency improvements by coordinating charging systems to grid capacities and limiting the needs for new lines and transformer stations.

Indeed, EV batteries offer the possibility of regulating the grid or smoothing out peak demand when used as energy storage. This network “service” could be given economic value. Electric vehicles are thus a significant source of flexibility in electricity demand.

Smart charging can provide services to utility grids to improve power quality and reliability.

The impressive growth of electric vehicles, battery technology, and digitization will challenge network topologies and supervision, and have a significant impact on energy systems.

Digitization impact on utilities and consumers

As digitalization of the energy world progresses, the amount and granularity of available data will make it possible to develop a range of new commercial services. These include demand response, energy audits, and home management programs, among other offerings, all of which are expected to generate sources of new revenue for market players. The development of new services is dependent on consumers giving consent to access their meter data and / or to install additional meters or other devices.

Data security and privacy are critical issues in this consent. Consumers will only be comfortable providing access to — and use of — their data if they are confident that their data is secure and that their privacy is safeguarded. As smart meters are generally “imposed” and not always perceived as useful, suppliers and distribution system operators (DSOs) must explain carefully why smart meters are needed. They must also prove the added-value of the smart meter, explain how they will benefit consumers and, crucially, explain how the data generated will be used.

However, while utilities have considerable experience in meter readings, reporting financial data to regulators, and using data to make investment decisions, dealing with more granular data generated by smart grids and meters will carry a higher level of complexity. Mastering big data analytics will be crucial to make sense of the growing volume of data and additional layers of information about customer demographics and individual / household behavior.

In addition, energy suppliers are not alone in this race and consumers are not waiting for them. Competition is intensifying from all sides. Internet / telecommunications companies and security firms are offering home energy monitoring and home automation solutions. Start-ups are exploring the market with home energy management services and consumers are becoming market players, either individually (as prosumers) or collectively (via community schemes).

Suppliers will have to proactively find their place in this new ecosystem. They will need to improve operational coordination of activities, invest in data analytics and new IT platforms, recruit data experts and develop partnerships with service provider companies.

The challenges of microgrids

Microgrids are forcing utilities to consider moving beyond their existing responsibilities in order to become operators or owners of generation, storage, and load controls on the demand side.

Utilities must decide whether they will be early adopters of microgrid approaches, and in the process, transform their business models more toward new customer-oriented services, or whether they will remain on the sidelines of the microgrid movement.

Microgrids are forcing utilities to consider moving beyond their existing responsibilities in order to become operators or owners of generation, storage, and load controls on the demand side of the meter.

Today's active consumers seek to be citizens of this new electric world as well. Whether it's through tracking the output of their rooftop solar panels, following repair progress after an outage event or even setting up their own neighborhood-level energy community, they are demanding clear, real-time communications through multiple social and digital commerce platforms to support new customer engagement initiatives to effectively cross-sell new products.

IDC suggests that the most effective utility responses to such customer demands will be based on the "three-I" approach, which includes:

Individualized — Meaningful, relevant communication to the customer that addresses each as an individual.

Instant — Power made available when it matters.

Interconnected — Power that is delivered through the most convenient channel for the customer in a seamless manner.

In summary, all these elements will profoundly impact the value chain by shifting where both consumers, producers and prosumers will concentrate their resources in their attempts to maximize efficiency, reliability, and resiliency, and reduce costs.

Today's consumers seek to be citizens of this new electric world as well. They are demanding clear, real-time communications through multiple social and digital commerce platforms.

02

The evolving energy landscape

Different geographies, different priorities

Trends toward decarbonization, digitization and decentralization are playing out differently for distribution utilities around the globe.

While distribution utilities around the globe are facing the challenge of moving to a smarter grid, their motivations and requirements can differ widely, thanks to broad national and regional variations in load and generation profiles, as well as in their respective market structures. Consider how renewables profiles affect distribution utilities in these three different markets:

Germany — A strong regulatory drive to renewables means solar and wind now comprise approximately 40% of total grid-connected generation capacity (and 53% of installed net power). Most of the nation's solar capacity is produced by photovoltaic (PV) installations smaller than 1 MW in capacity. By 2030, continued renewables growth could change how German distribution utilities acquire their electricity, with conventional generation dropping out entirely during portions of the day in both summer and winter.[1]

Germany also now allows distribution utilities to implement non-firm distributed energy resource (DER) connections. For example, the German utility E.ON has launched a new residential storage product (called Aura) for easy pairing with rooftop PV arrays. By using the Aura storage system and an associated app, consumers can optimize their own usage and sell excess electricity back to the grid, essentially using the distribution system as virtual energy storage. According to a press release on Aura's market launch, "The system can increase a home's energy self-sufficiency rate — that is, the proportion of self-produced electricity the home consumes — from about one third to around 70 percent."[2]

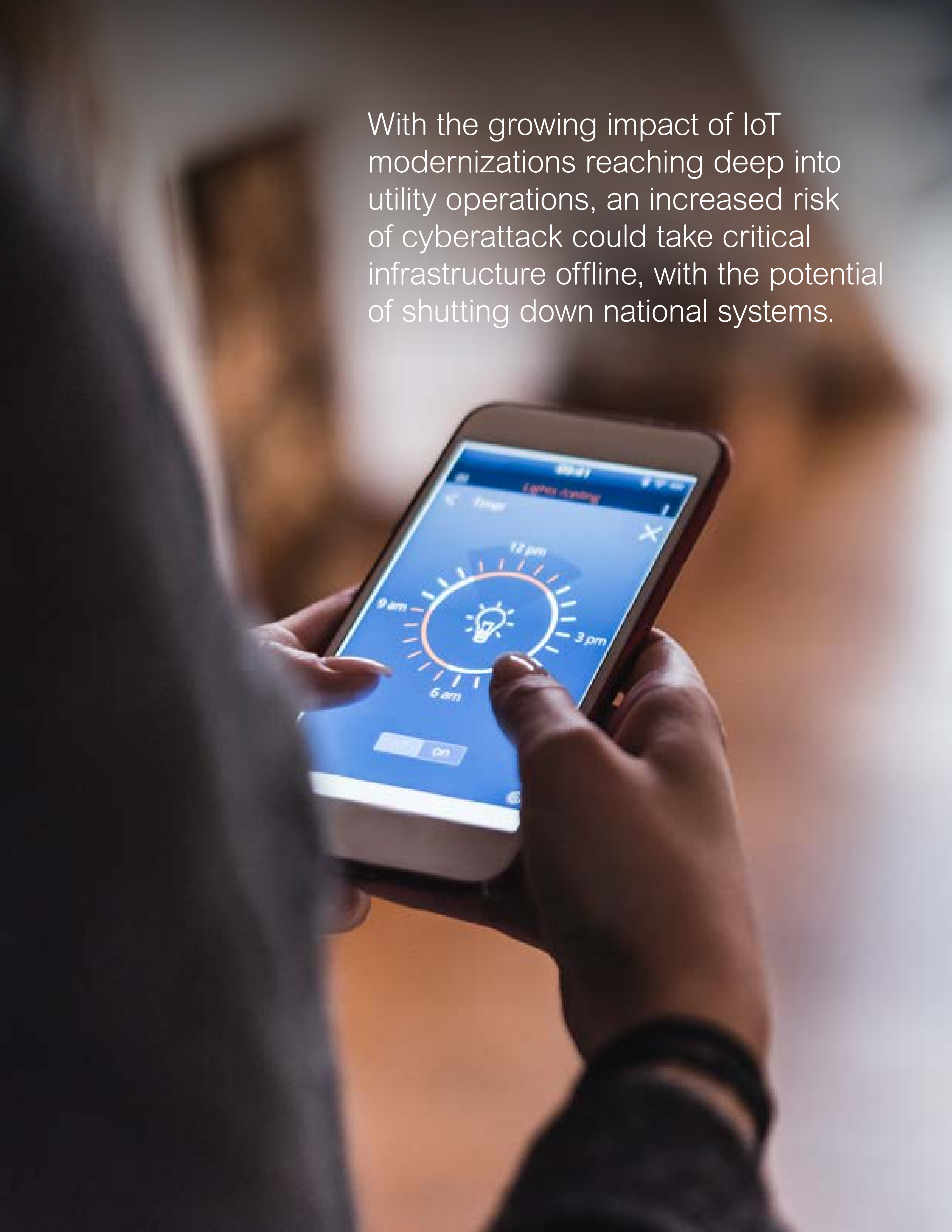
California — Home to more distributed solar than any other U.S. state, California is at the forefront of efforts to understand how DERs can add value to the distribution grid. In 2015, the California Public Utility Commission and the state's three investor-owned utilities began demonstration programs to test a tool designed to help identify the best grid locations for new DERs, recognizing the economic value of deferred distribution investments. As of spring 2017, this tool remained a work in progress.

South Australia — This Australian state has embarked on a rapid decarbonization plan that has shuttered coal plants in favor of renewables. Between June 2016 and May 2017, South Australia counted on renewables — primarily wind — for 53% of its supply.[3] Their remaining supply needs are supported by natural gas and an interconnection with the neighboring state of Victoria. As the result of a series of severe weather events and a lack of fast-responding peaking support, the state's electrical networks have suffered from a series of blackouts and load-shedding events over the course of the last year. This has prompted calls for de-privatizing the investor-owned power system.

These trends toward decarbonization, digitization and decentralization are playing out differently for distribution utilities around the globe.

By using the Aura storage system and an associated app, consumers can optimize their own usage and sell excess electricity back to the grid.

With the growing impact of IoT modernizations reaching deep into utility operations, an increased risk of cyberattack could take critical infrastructure offline, with the potential of shutting down national systems.



Understanding utility stressors

Recent history has proven the need for large organizations to plan for the unexpected. In this time of rapid change for electricity markets, risk mitigation strategies specific to electric utilities are highly recommended.

Utilities seeking to better understand how unexpected events could impact their financial stability should consider the following possible scenarios.

Energy for free — With tech companies finding new ways to monetize data, a leader in that field — Amazon, for example — could find opportunity in offering "energy for free" in exchange for personal data. In this scenario, utilities could lose the customer relationship and become pure commodity power suppliers.

Decentralized energy landscape — New direct-to-consumer DER suppliers are beginning to bundle rooftop PV systems with batteries, electric vehicles and power-to-heat technologies. Such an integrated approach, paired with a compelling brand, could mean reduced demand for traditional grid-based power. In this scenario utilities again lose the customer relationship, and generation assets quickly lose value.

Emissions fraud — This scenario considers the impact of an information leak that discloses a cover-up (in this case of a utility's emissions data). Energy companies and their executives could find themselves under public and political scrutiny, with a loss of trust.

Cyberattack on critical infrastructure — With the growing impact of Internet of Things (IoT) modernizations reaching deep into utility operations, an increased risk of cyberattack could take critical infrastructure offline, with the potential of shutting down national systems. This scenario also could provoke a loss of public trust and spur new operational regulations.

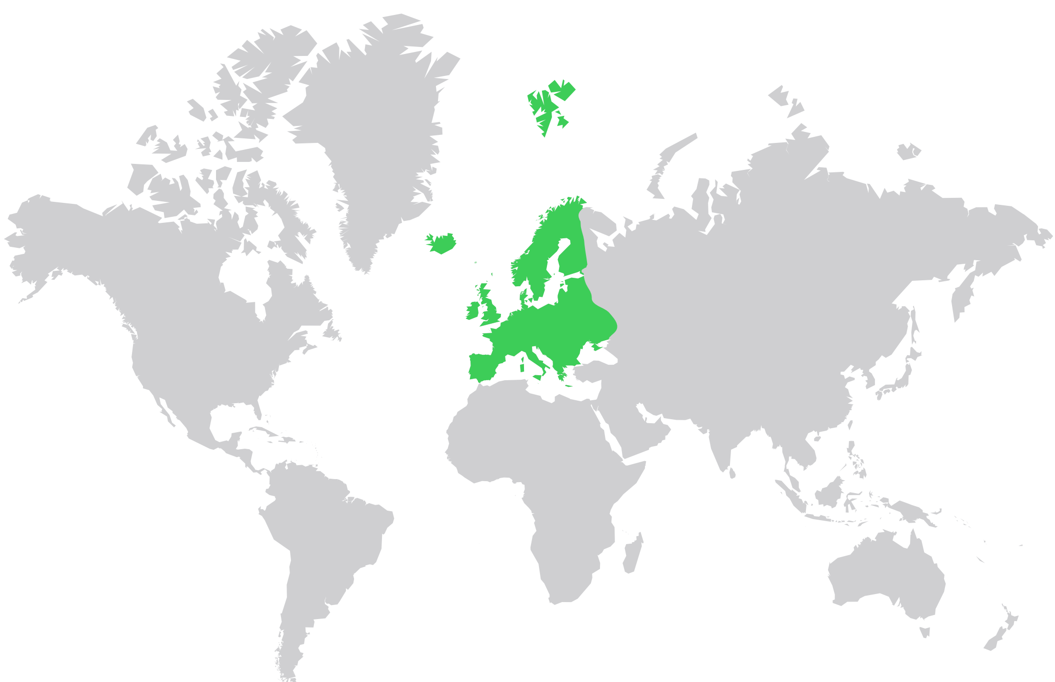
Radical price transparency — European retail power, gas and other markets have seen a rise in price-comparison websites. Taken to an extreme scenario, such portals could encourage frequent switching of energy suppliers that quickly erode profit margins.[4]

Europe

Renewables are targeted to meet 50% of demand by 2030, 65% 2040 and at least 80% by 2050.

The European Union is currently working actively on issues critical to distribution utilities and the distributed energy resources (DER) they support. In November 2016, the European Commission announced a package of measures designed to promote what it called a “clean energy transition.” This “Clean Energy Package for all Europeans” focuses on ways to empower consumers as central players in the energy markets of the future. The goal is to aid the EU in its quest to reduce region-wide greenhouse gas emissions 40% by 2030, over 2005 levels. Set to take effect in 2021, the 1,000-page package, at this point, is a proposal still under debate. The introduction of a new market design across 28 national markets (27 if the UK does not participate) is an ambitious and complex enterprise which will ensure that energy policy issues are shared across all EU member states.[5]

The package has four main axes. One axis addresses renewable generation, and the remaining three relate to distribution utilities. Of those, the first proposes new energy efficiency targets for 2030 and defines energy supplier obligation schemes and metering functionalities, as well as standards for the active management of energy efficiency in buildings. The second concerns energy flexibility, in the



context of decentralization support, freedom for end-users to access demand response, self-generation dynamic pricing, and more empowerment for distribution utilities to enable more flexibility in their century-old business model. The third axis addresses governance, so that the organization of energy markets can be strengthened at the European level.

Among the document's more contentious elements are provisions encouraging energy self-consumption via on-site resources, such as solar, combined heat and power (CHP), storage and demand-side management.

Distribution utilities in EU member states haven't held back, waiting for this new package of legislation to be finalized, however. Their varied paths are reflective of the political and economic gaps EU politicians will likely address during their negotiations.

Germany — One word — "Energiewende" — defines the reason for the massive realignment now underway in Germany. Energiewende ("energy transition" in English) is the national program to move from fossil fuels to renewable resources. Renewables are targeted to meet 50% of demand by 2030, 65% by 2040 and at least 80% by 2050.[6] As the German energy think tank Agora Energiewende puts it: "Decentralization will become a permanent characteristic of the power market, because the Energiewende core technologies — wind, solar, storage, e-mobility, heat pumps — all imply a more distributed structure."

To help address the variability caused by the rapid acceleration of rooftop PV and wind installations encouraged by Energiewende policies, the German government is dialing back generous feed-in tariffs and, instead, encouraging self-consumption. The country's KfW 275 incentive program has created one of the world's largest energy storage markets. The German solar energy association BSW-Solar estimates some 52,000 storage systems now serve solar installations in the country, with 20,000 installed in 2016 alone.[7] The association anticipates this number will double by the end of 2018. Load defection — the loss of customers now capable of supplying 100% of their own electricity — is real for German distribution utilities.

One important driver for the expected rapid growth in storage adoption will be the fact that the first solar systems are aging out of the old incentive program. Under these agreements, solar owners have been compensated for self-generated power at up to ~ 0,5€ per kWh. In future, this payment will drop to almost nothing, but with rates around 0,3€ per kWh for energy they use from the utility. This policy change could well encourage customers to disconnect from grid-connected supplies entirely.

France — France is unique in Europe as its power sector is still dominated by nuclear, which accounted for three quarters of total electricity production in 2015, along with hydropower. France's landmark energy sector reform program was initiated in July 2015. The country is currently focused on implementing and meeting ambitious targets for renewables, energy efficiency and the advanced transport sector. Among the main changes are a transition toward auctions and feed-in premiums for renewables, the launch of a net metering policy, and a cap on nuclear capacity. In 2012, 13.4% of France's final energy consumption came from renewable sources (including large hydro). This figure is short of the country's 2012 interim target of 14% and must rise to 23% by 2020 under the European Renewable Energy Directive (2009 / 28 / EC).

The French government aims to meet more than half of the target through renewable heat, which is the sector where progress has been the slowest (16.9% vs 19% 2012 target). Renewables are also progressing slowly, with 6.6% of electricity generated by solar, wind and bioenergy combined in 2015. However, France is closing its high-emissions power plants (-1.5GW of coal in 2015) further reducing the carbon intensity of the power system.

France's renewable energy policy support is transitioning toward more competitive mechanisms. The solar sector (more than 6GW installed in 2015) was granted considerable visibility, with the government announcing a quarterly auction schedule up to 2019 targeting 9GW of new projects larger than 100kW. The onshore wind sector (more than 10GW installed in 2015) is still in transition and is adding around a 1GW a year under the current feed-tariff. From 2017 the government will introduce an auction covering three years with annual bidding windows for the sector.

Overall, the power market in France will be affected by two other important policy changes. First, the introduction of a capacity market in the winter 2016-17, which the government hopes will help address the country's increasingly peaky consumption. Second, the decision to bring the share of nuclear in the energy mix down from around 75% to 50% by 2025. France also has an ambitious energy efficiency and electrified transport deployment strategy combining preferential loans and large direct subsidies.[8]

United Kingdom — National Grid, the nation's transmission-system operator, reported in its 2017 Future Energy Scenarios (FES) document that, by the end of 2016, 27% of the nation's installed generation capacity was connected at the distribution level. Under the most ambitious FES forecast, this figure could rise to 50%, which would be 93GW, by 2050.[9]

For example, the rapid uptick of DER has UK Power Networks, with 18 million electricity customers in London, as well as the country's East and South-East regions, rethinking their role in the larger grid. In July 2017, the company announced its intention to redefine its responsibilities from network operator to system operator. "We are on the verge of a change as significant for electricity as the advent of broadband was for telecommunications," is how the company's chief executive, Basil Scarsella, framed the shift to distribution-level generation.[10] To jumpstart their transition, the company installed a £18.4 million grid-scale battery system for distribution system support.

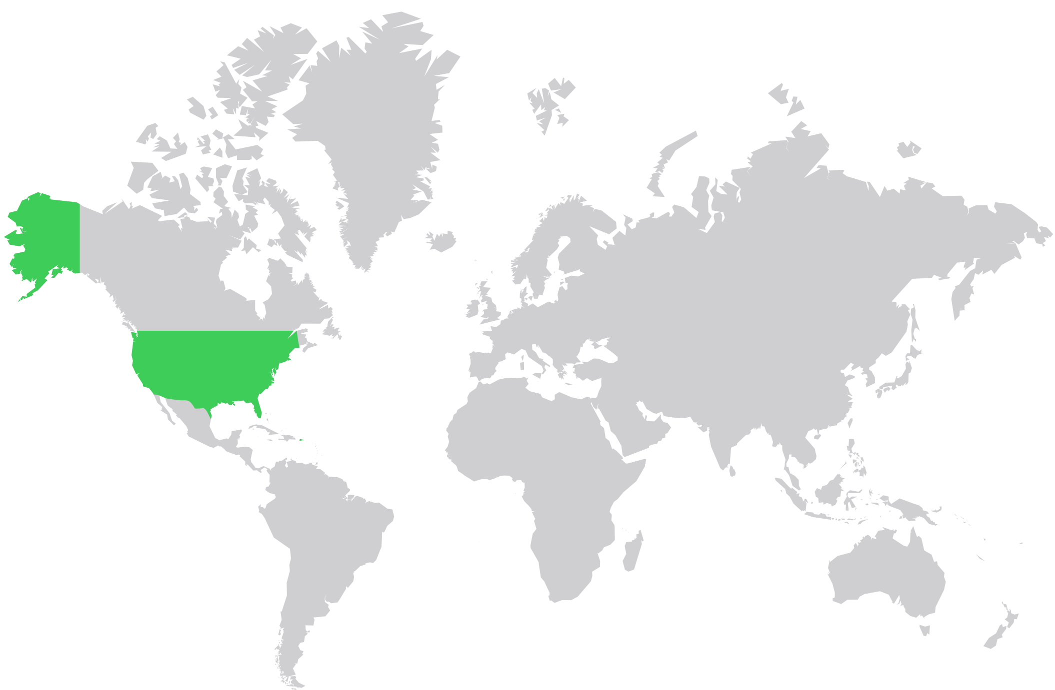
> One important driver for the expected rapid growth in storage adoption will be the fact that the first solar systems are aging out.

United States

Several states have "deregulated" their markets, meaning their distribution utilities are no longer allowed to own generation assets.

Transmission and distribution utilities in the U.S. are even more varied than their European counterparts, because electric utilities are often managed at a state or federal level. Until the early 1990s, all states had implemented a vertical, regulated monopoly model, in which utilities owned their own generation, transmission and distribution assets. Today, however, several states have "deregulated" their markets, meaning their distribution utilities are no longer allowed to own generation assets. Instead, they now serve as delivery service providers connecting independent power producers to commercial, industrial and residential customers.

In the U.S., net energy metering (NEM) programs pose a special challenge for deregulated utilities, whose revenues are based on a regulated rate of return on their distribution system assets, represented as a per-kWh service charge on a retail customer's monthly bill. In most states with NEM programs, customers are reimbursed for generation in excess of their own consumption at the full retail rate — the combination of energy and delivery charges — not simply for the cost of avoided energy purchases. As DER penetration grows, such arrangements could force customers without their own on-site generation to pick up a bigger share of distribution system maintenance costs.



Three states now are looking at new ways to encourage utilities to rethink their roles in the electricity marketplace:

New York — The state's "Reforming the Energy Vision" (REV) initiative sets a goal to rebuild, strengthen and modernize New York's energy system. The guiding New York State Energy Plan sets year 2030 targets that include a 40% reduction in energy-sector greenhouse gas emissions (versus 1990 levels), an increase in generation from renewables to 50%, and a reduction of building energy consumption by 23% (versus 2012 levels).[11]

Under the plan, New York utilities will be transformed into distribution system platform (DSP) providers responsible for facilitating third-party DER integration into the network. In fact, this task becomes the primary concern for utilities, which will be motivated through incentives to look to DERs as viable traditional grid investment alternatives.

California — The California Public Utilities Commission (CPUC) is also reconsidering the state's regulator and business models. It sees traditional models as contradictory to the state's energy-conservation goals.

As new technologies and financial innovation blur the boundaries that have, up until now, defined the limits of a natural monopoly, the CPUC has directed the state's three investor-owned utilities to draft distribution resource plans. These roadmaps will define how DERs will be integrated into gird operations, investments and planning regimes.

Texas — Texas leads the country in market deregulation, with most residents choosing from a statewide roster of energy providers, rather than a default local utility. This arrangement gives those providers more freedom to innovate — such as TXU Energy's Free Nights and Solar Days residential plan. Thanks to the state's significant wind-energy resources — always more plentiful (and less expensive) at night — customers actually pay nothing for electricity used between 9 p.m. and 6 a.m. During the day, TXU buys electricity from solar producers, along with sufficient renewable energy credits to meet participants' demand.

The solar portion of the plan is new, but the free nights offering has been available since 2015. The company claims participating customers received nearly 40% of their electricity for free in 2016.

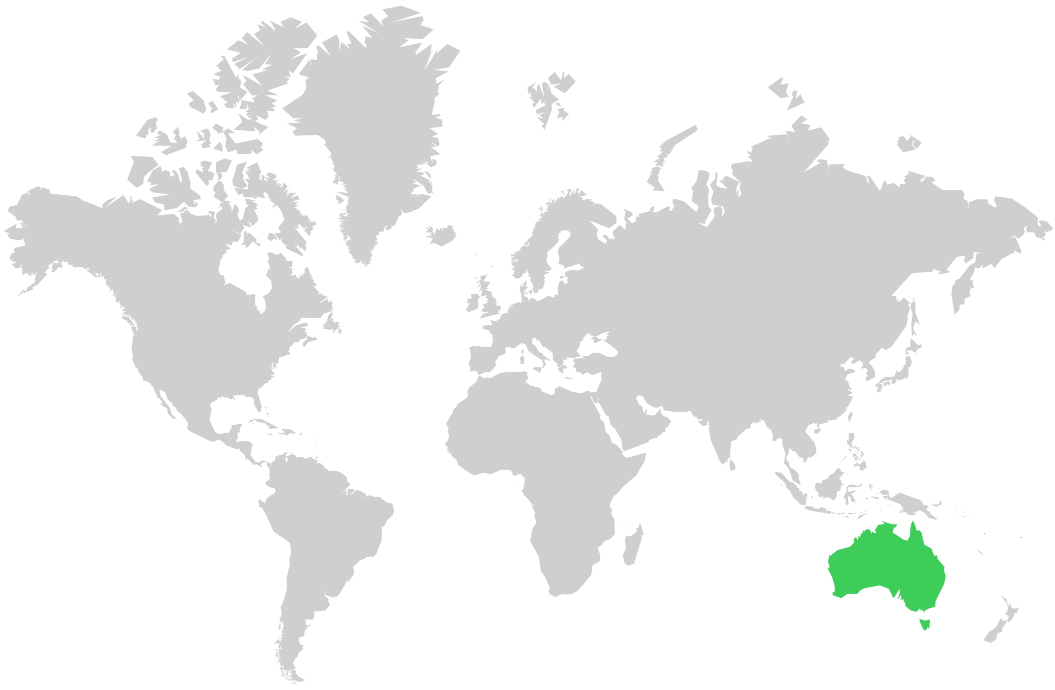
> Several states have "deregulated" their markets, meaning their distribution utilities are no longer allowed to own generation assets.

Australia

Perhaps no place better illustrates the challenges today's more digitized, decarbonized and decentralized market poses for distribution utilities than the Australian state of South Australia (SA). Between 2014 and 2016, generation capacity available to SA's sole distribution operator, South Australia Power Network (SAPN) dropped by more than a third, thanks to the retirement of several coal and natural gas generating stations. Substantial incentives have encouraged expansive wind-energy development which, in turn, has driven down wholesale electricity prices and reduced the utilization and profitability of thermal power plants.[12]

The decline in firm, thermal-power capacity has led to a heavy dependence on variable renewables. Large-scale wind, residential rooftop PV systems, along with a small degree of hydro, now account for 46% of SA's generating capacity, according to GTM Research.[13] When those resources fall short, SAPN now must rely on its two interconnection points to the country's National Energy Market (NEM), which can be inadequate to meeting actual demand.

Two recent severe-weather events have illustrated the precariousness of this situation:



- In September 2016, two tornadoes tore through SA, initiating a series of events that resulted in a significant quantity of wind generation dropping offline. The increased dependence on one of the two power interconnections then triggered protection devices that tripped the interconnection out of service. When generation then available within the now-islanded SAPN network proved insufficient to support network frequency, the entire state was plunged into darkness.

- In February 2017, at the height of the Australian summer, an extended heatwave drove up demand just as wind resources began falling short of forecasts. The remaining gas and coal plant capacity proved insufficient to meet climbing demand, leading to load shedding of 90,000 customers.

While Australia has moved to address some equipment issues specific to these two events, the lack of sufficient backup capacity remains a long-term issue.

> The decline in firm, thermal-power capacity has led to a heavy dependence on variable renewables.

India and Africa

While Europe and the U.S. are spearheading the energy transition, other global giants like India and Africa are also preparing for the same magnitude of energy distribution changes. These two geographical regions, however, are approaching the energy transition from two different sets of circumstances.

India currently has a power surplus. Electricity consumption is meeting, at best, only 60% of the installed capacity of 360GW, including periods of peak demand. Despite the power surplus, though, the country's distribution sector is challenged with chronic issues, including unhealthy distribution companies, power outages, and commercial losses, including theft and unmetered connections. These factors are limiting social and industrial growth and, as a whole, the country is unable to sustain the pace for economic growth. According to the World Bank, "…many factors that constrain performance are under the control of the utilities themselves — underpricing, physical losses, and inefficiencies in bill collection — underlining the importance of limiting the government's role, strengthening regulatory governance, and bolstering competition so that utilities are both pushed to be efficient and permitted to run on commercial lines."[14]

In view of this, the reduction of techno-commercial losses (<15%), the improvement of the System Average Interruption Duration Index (SAIDI), the enhancement of economic and financial viability, and the improvement of operational efficiency of more than fifty state-owned distribution utilities are the key growth drivers of India's Ministry of Power. Additionally, the government has set a target of 100+ GW of renewables by 2022.

The African continent, on the other hand, generally has little to no strong electric grid infrastructure. Africa ultimately needs a continental transmission grid that supports renewable integration, but the first step toward that will also focus on local energy systems. Much in the same fashion as cellular telephony developed on the African continent, modern distribution networks can avoid many of the complex problems associated with overhauling any existing models. This leap-frogging offers unique opportunities and benefits for modern electrical distribution systems to take shape.

> "… many factors that constrain performance are under the control of the utilities themselves."
>
> — Philippe H. Le Houerou
> Vice President, South Asia Region
> The World Bank

03

Distribution utilities: At the center of change

Moving beyond traditional models

The three trends of decarbonization, digitization, and decentralization are each presenting new challenges for distribution companies.

Some of the most significant changes to the way electricity is being generated and consumed are appearing at the grid's edge with distributed energy resources (DERs).

As the grid gateway closest to the edge, distribution utilities are experiencing the brunt of these changes, with energy efficiency slowing load growth and DER turning consumers into "prosumers" capable of producing — and selling — electricity on their own. Examples of prosumers include city districts, university campuses, military bases, hospitals, commercial buildings, factories, and even residential home owners that both produce and consume energy. Such dramatic shifts in roles raises questions in all regions of the globe regarding the role of distribution utilities in the larger electricity market.

The three trends of decarbonization, digitization and decentralization are each presenting new challenges for distribution companies, whose revenue plans have long been based on simply selling more kilowatt-hours. In some cases, this new electric world is forcing utility distribution system operators (DSOs) to act more like transmission system operators (TSOs). They are required to balance the output of multiple DERs against transmission-supplied baseloads using new grid technologies that support a two-way flow of both electricity and data.

Today's customers seek to be citizens of this new electric world, as well. Whether it's through tracking the output of their rooftop solar panels, following repair progress after an outage event, or even setting up their own neighborhood-level energy community, they are demanding clear, real-time communications through multiple social and device platforms.

Decarbonization

The analysis carried out by Climate Policy Initiative (CPI) for the International Energy Transitions Commission's recent report, "Better Energy, Greater Prosperity,"[1] suggests that the challenges created by the intermittent nature of renewables can be overcome at a reasonable cost given already available and rapidly evolving technologies. There is no technical barrier to the deployment of variable renewables in the power sector and flexibility options will become available at increasingly lower cost in most geographies. By 2035, a near-total variable, renewable power system could be competitive with a system based on gas-fired power generation in many geographies, provided an adequate policy framework drives the development and use of low-cost flexibility solutions.

This rapid penetration of DERs will be driven by economics and improving technology, not governmental policy. Solar panel prices fell 30% in 2016, with an additional 20% drop expected in 2017[2] and, in the U.S., wind is now cheaper than natural gas during certain times of day. In India, solar power has become more affordable than coal, marking the possible beginning of a tipping point in a nation that's seen a recent buildup in coal-generation capacity.

Distribution utilities will have to be nimble to respond to this rapid infiltration of variable generation into their systems. Balancing, which today is predominantly a transmission system issue, will become a critical element in day-to-day distribution operations.

As a result, flexibility, the ability to ramp supply — and, potentially demand — up and down as needed, will become a key performance criterion for successful energy providers.

Flexibility will require large technology investments, at a time when distribution utility sales in many regions are either flat or shrinking. In the United States, for example, residential electricity sales have fallen 3% since 2010[3], with population growth appearing to be the only reason for avoiding an even steeper slump. European nations have seen little to no growth over this decade.

On the global scale, economic development is becoming less energy intensive. As a result of improving energy efficiency, growth is becoming more decoupled from energy. In fact, energy intensity is falling most rapidly in developing countries. This means income and quality-of-life improvements don't need to be accompanied by a corresponding increase in global carbon emissions.

However, this good news comes as a challenge for electric utilities. Their revenues are generally based on an established physical asset investment rate of return. Therefore, falling demand hits utilities bottom lines in two ways:

Reduced sales — With returns based on per-kWh sales, reduced demand means either lower revenues or a need for approval to hike their customers' monthly delivery service charges.

Reduced recovery opportunities — Fewer kilowatt-hours sold means less need for power plants and related infrastructure, meaning utilities have fewer opportunities for earning a rate of return that attracts investors and helps fund other operations.

Energy intensity is falling rapidly in developing countries. This means income and quality-of-life improvements don't need to be accompanied by a corresponding increase in global carbon emissions.

Digitization

Utilities know they need to invest in digitizing their systems. Many are unsure, however, of what's needed, what to do with all that new data, and where the money is going to come from to pay for related upgrades. Their most recent investments have been in improving capabilities like outage management, where they can most easily visualize resulting financial benefits. The majority of such projects are self-funded. Having been focused on improving operational efficiency, technologies like distributed energy storage and virtual power plants have been deemed a secondary priority with business cases that are difficult to build and longer-term in nature.

New digital technologies will be at the heart of helping to address the utilities' business challenges.

> "The grid ecosystem is moving rapidly away from a displacement and replacement paradigm to ubiquitous connectivity and technology recombination. Transactions will increasingly be digitized, new data will be generated and analyzed, and discrete objects, people, and activities will be more connected to the grid ecosystem than ever before."

— Marco Lansiti and Karim R. Lakhani in "Digital Ubiquity: How Connections, Sensors, and Data Are Revolutionizing Business"

The top three digital-grid capabilities companies are investing in:

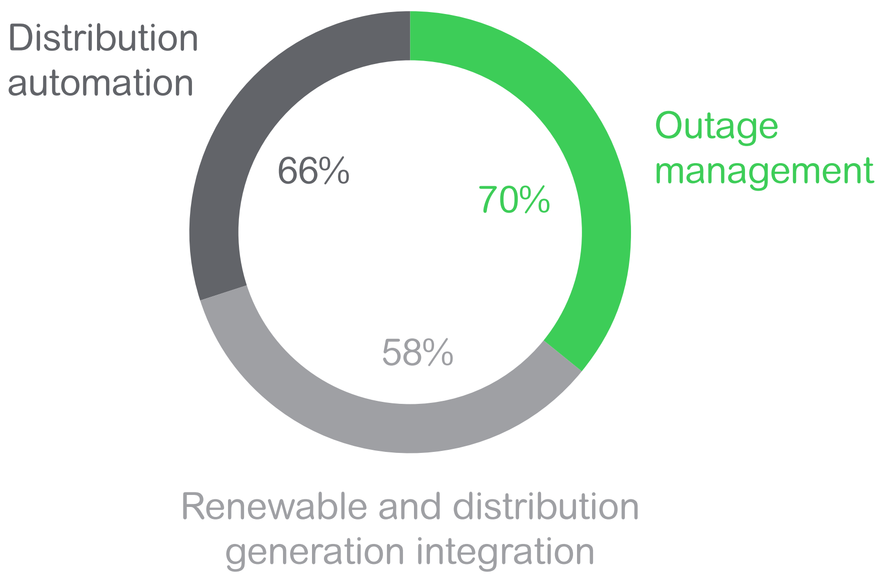


Figure 1: Top three digital grid capabilities invested in (Source: EY, “Digital Grid: Powering the Future of Utilities,” 2016)

The path to advanced metering infrastructure

Smart meters are a primary enabler of any grid digitization effort, and these devices are now being delivered and installed in a massive cross-industry rollout. But the hundreds of millions of smart meters installed over the last decade represent a worldwide penetration rate of only 30%.[4] Therefore, upgrading customer meters still represents a significant utility revenue opportunity.

However, the opportunity differs across regions. About half of North American meters feature “smart” capabilities and a few European nations, such as Italy, have reached 100% penetration. Latin America, the Middle East and Africa, and parts of Eastern Europe are much further behind.[5]

In a number of countries, regulators and other governmental branches have been the primary drivers of massive rollout plans. That was the case in the United States, where $4.5 billion in American Recovery and Restoration Act funding has helped spur the installation of approximately 15.5 million meters. In China, the State Grid Corporation of China (SGCC) has pushed initiatives that have established that nation as a global leader in smart-meter installations.[6]

Any utility planning a smart-meter transition quickly learns that the meters themselves are just an enabler of a much broader advanced metering infrastructure (AMI). Digitization benefits do not accrue by simply swapping a new device for an old one at a customer service entrance.

AMI isn’t a single technology — it’s the integration of several technologies that control and process data from smart meters across multiple stakeholders.

Managing an AMI system is complex and demanding and requires technical expertise, resources and time. Oftentimes distribution utilities seek outside support to help deploy, monitor and optimize these systems. The information technology / operations technology (IT / OT) silos present across many utility organizations can lead some companies to opt for separate providers for meters, communications and data-collection systems. But this approach can be inefficient. In a digitized world, working with a single managed-services provider can help speed up deployment and can improve overall performance in the following ways:

- More clearly define the goals and objectives for an installed AMI system.
- Develop a deeper knowledge of existing operational processes, with a commitment to create new processes that best meet the utility’s needs.
- More deeply integrate IT and OT capabilities, including tools and professional talent, to make optimal use of the information the AMI system collects.

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A proactive approach to reliability

Over the next several decades, utilities around the globe can anticipate continued adoption of distributed solar, along with a rapid uptick in electric vehicle charging equipment and on-site battery storage.

Simply keeping electrical systems up and running is becoming an ever-larger challenge for utilities in this era when many regions are experiencing flat-to-falling sales. Electricity grids are infrastructure, every bit as much as roads and bridges, and that infrastructure is aging quickly in many regions. In the United States alone, outages cost customers between $79 billion and $115 billion per year.[7]

Growing DER integration adds to a distribution utilities' reliability challenge. Over the next several decades, utilities around the globe can anticipate continued adoption of distributed solar, along with a rapid uptick in electric vehicle charging equipment and on-site battery storage.

Today's distribution utilities are too often forced into a reactive — rather than proactive — response, because they lack insight into current grid conditions and must depend heavily on manual equipment operation. These companies are now driven to digitize their networks with the latest developments in distribution automation in order to stay ahead of network reliability problems, instead of incurring the expense of simply deploying more maintenance crews to the field. Distribution automation enables advanced monitoring and control functions and employs the latest communication technologies for remote and local operation, enabling utilities to minimize supply interruptions, optimize network performance, and reduce operational costs. Distribution substations are a critical target for such digitization efforts. These facilities house the switches, capacitors, transformers and other assets used to keep grid power flowing, balanced, and routed appropriately. They're also the grid element located closest to the majority of consumers, so they offer an optimal sentinel post for system-oversight operations. Increased automation capabilities support faster network reconfiguration to reduce outage times with centralized and decentralized network architectures. Accurate voltage and power measurement ensures smoother integration of MV and LV distributed energy resources and provides real-time Volt-VAR management to stabilize any fluctuations, even when integrating intermittent distributed generation.

Utilities are recognizing the potential benefits of smarter substations and other assets, with many already making such investments to improve network operations. IDC predicts that, by 2020, one in four utilities will be integrating new sensor data and cognitive capabilities to boost their assets' efficiency and reduce maintenance costs. By bringing today's available intelligence upgrades to existing substations, distribution utilities can recognize a number of immediate benefits, including:

Better feeder-load balancing — Energy meters at LV feeder connections can calculate imbalances on those feeders in real time, locating customers by network, feeder, and phase. Repartition units installed along the feeder can then rebalance loads by switching targeted customers from one phase to another.

Greater voltage control — New sensors and voltage-regulating actuators, along with either centralized or distributed intelligence, can help distribution utilities handle the kinds of unexpected voltage shifts possible with increasing DER penetration.

Improved asset optimization and reduced field-site visits — Smart sensors and actuators increase the utility's ability to manage assets remotely. This added intelligence reduces required on-site inspection visits, while providing proactive alerts about equipment that needs attention and extend the operational lifetime of assets through modernization and the latest maintenance strategies.

Higher returns on smart-meter investments — Power-line carrier technology can add another layer of value to a utility's smart meter rollout by communicating a range of load, voltage and DER production data, in addition to basic billing information.

Reduced islanding risks — Digitized grids enable rapid communications between MV / LV substations and customer-sited DER. Ensuring DER are disconnected during any grid outage event is essential to line worker safety and reduces the risk of connected-equipment damage.

Improved quality of service — Smart reclosers on exposed lines across much of U.S. and Australia can clear electrical faults closest to where they happen and communicate their activity to an outage management center. This isolates the outage and provides accurate location information to repair crews.

Distribution utilities are too often forced into a reactive — rather than proactive — response, because they lack insight into current grid conditions.

IDC predicts that, by 2020, one in four utilities will be integrating new sensor data and cognitive capabilities to boost their assets' efficiency and reduce maintenance costs.

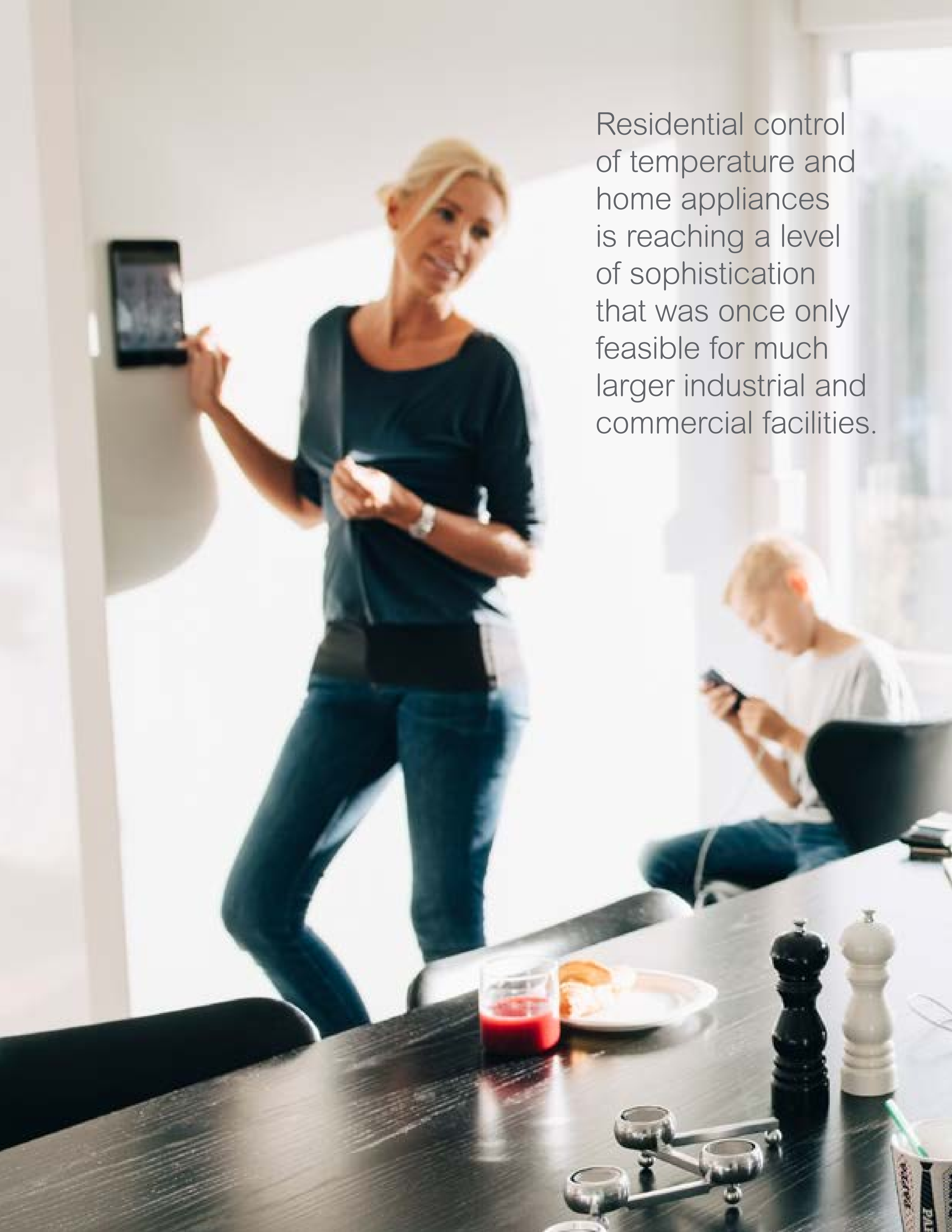
Decentralization

Increased connectivity enabled by the IoT trend, is fueling the development of new business models for aggregating residential demand.

Decentralization — the movement of power generation from the hub to the spokes of the distribution network — is at the heart of the challenges distribution utilities now face. What was once a one-way flow of electricity has become a much more networked operation. In this rapidly shifting market, prosumers find themselves producing more electricity than they need for much of the day and selling that excess back to the grid. Now, more than ever, customers view utilities as just another retailer, and they anticipate the same level of multi-platform responsiveness they receive from other favorite mainstream retail brands.

Increased connectivity enabled by the Internet of Things (IoT) trend, is fueling the development of new business models for aggregating residential demand. In addition, residential control of temperature and home appliances is reaching a level of sophistication that was once only feasible for much larger industrial and commercial facilities. Smart thermostats, internet-connected water heaters and even window air-conditioning units all can be controlled during peak events, limiting the need for new generation. Of course, throttling back demand means fewer kilowatt-hours sold, which only adds to the pressure on utility revenues.

Distribution utilities are also faced with new competition — not from other utilities, but from technology companies seeking to grow new lines of business. Consider Tesla's combined solar roof and storage offering, IKEA debuting residential solar-plus-storage distribution, tech giant Apple's move into energy trading and battery-maker Sonnen's efforts to create energy communities in which members buy and sell electricity from each other. In this context, "regulated monopoly" can begin to seem a business model under threat.



Residential control of temperature and home appliances is reaching a level of sophistication that was once only feasible for much larger industrial and commercial facilities.

Rise of the prosumer

Utilities that are already successfully transforming their businesses started by having a vision, brand image, and product and service portfolio that is in tune with "energy's new normal" and resonates with the digital consumer.

Home owners now are paying less than ever for rooftop solar panels — so much less that suppliers are also adjusting their business models. Where high costs once led buyers to a preference for leasing their solar systems, many customers now prefer to own their installations outright. With cost reductions expected to continue, distribution utilities will be seeing increasing numbers of their customers selling electricity back to the grid.

- In Germany, 98% of all solar is attached to medium- and low-voltage grids, with 85% of solar capacity in arrays less than 1 MW.
- In Hawaii, 20% of all single-family homes now feature rooftop solar, and 10% of California homes now have panels.
- By 2040, Bloomberg New Energy Finance expects rooftop solar to support 24% of total generation in Australia, 20% in Brazil, 15% in Germany and 12% in Japan.
- Also by 2040, 57% of global storage capacity will come from on-site batteries linked to PV panels.[8]

But the prosumer category is broader than simply rooftop-solar owners. Internet-connected thermostats, water heaters and other devices now are being considered as DER. As Internet of Things (IoT) technology spreads into everyday devices and appliances, more of today's utility customers will want to engage in electricity markets. When their demand becomes a commodity that can be aggregated, traded and monetized, consumers will want to participate in their own small-scale trading operations.

This transformation is happening very quickly — almost five times faster than new central generation between 2017 and 2023, according to Navigant Research. DER present distribution utilities with levels of nuance and variability they've never dealt with before, and DER / DSO interconnections could represent, in the words of Navigant's *Navigating the Energy Transformation*, "ground zero for the disruption of the global energy landscape caused by DER."[9]

IDC also predicts that fundamental shifts in the traditional energy utility model mean that current revenue streams won't be viable for long. The mix of decreasing demand, increasing efficiency, and emergence of distributed generation are decentralizing value creation and pushing it down the value chain. The uptake of renewable sources means the price of energy is gradually approaching its marginal cost so that the value is no longer with the commodity itself, but in the associated services.

This comes as no surprise to utilities. In fact, most believe the ongoing shift in value creation will be sizable and relatively quick. European utility executives recently polled by IDC Energy Insights think new business and services supporting the existing commodity business will account for about 40% of utilities' revenues by 2020.[10]

Utilities are betting that consumers will progressively seek more advanced energy-related products and services to reduce their consumption and carbon footprint, generate their own power, spend less, and possibly make some earnings on the side. Whether it is through new business models (e.g., home automation services, PV leasing systems) or value-added services supporting the core business (e.g., e-mobility charging services, distributed generation management, demand aggregation), utilities must become "convenient lifestyle" providers of the new energy consumer.

Utilities that are already successfully transforming their businesses started by having a vision, brand image, and product and service portfolio that is in tune with "energy's new normal" and resonates with the digital consumer. Italy's Enel is a champion of this brand reinvention, a utility company in the midst of profound transformation ready to lead a new era of growth by tackling some of the world's energy challenges.

> This transformation is happening very quickly — almost five times faster than new central generation between 2017 and 2023.

With solar cost reductions expected to continue, distribution utilities will be seeing increasing numbers of their customers selling electricity back to the grid.

04

Bringing IT and OT together

The future of grid technology

The effects of decarbonization, digitization and decentralization are forcing distribution utilities around the globe to rethink business models along with their own roles in the processes that generate, transmit and distribute electricity to their customers' homes and businesses. This new electric world is having the biggest impact on distribution utilities — the utility players most responsible for incorporating burgeoning distributed energy resources (DERs) into day-to-day operations.

The big-picture challenge is figuring out how utilities can accomplish these three main objectives:

- Adjust traditional business models to maintain competitiveness.
- Integrate DER, both behind and above-the-meter controlled energy assets such as rooftop solar, behind-the-meter batteries, electric vehicles, microgrids, and flexible demand-side resources.
- Address changing energy demand and volatile supply patterns while reducing losses, and ensuring security and reliability.

The traditional utility business model succeeded despite maintaining a separation between enterprise-serving information technology (IT) computing and the operational technology (OT) of wires, substations, transformers and other field equipment. In the new electric world IT and OT will be forced to converge.

This need to bring IT and OT together isn't news for distribution utilities. More than three-quarters of distribution utility executives that participated in Accenture's 2016 IT / OT survey saw this integration as highly important to meeting future business requirements. However, an even more significant 80% of respondents said they hadn't begun such an effort themselves, or were only in the early stages of the process.[1]

By bringing IT and OT together, utilities will capture the value of the enormous quantity of data generated by their rapidly digitizing grids. This digitalization offers a series of solutions to address new electric world challenges. It also unleashes new possibilities for improving performance in areas of strategic importance to both utilities and their customers, including:

- Asset management, for smarter investment planning and more efficient maintenance operations.
- DER integration, with big data and analytics enabling much needed flexibility to keep systems in balance with greater penetration of solar, storage and electric vehicles.
- Demand side management and other customer engagement efforts, for higher participation rates and increased loyalty in today's brand-centric consumer environment.

Each of these areas will require the development of best practices in order to enable a smoother convergence of both IT and OT technologies. The millions of new data points available in substations, transformers and customer meters will also offer distribution operators new opportunities for improving the safety, reliability and efficiency of their networks and workforce, including:

- Outage management systems to pinpoint failure locations and re-route around them, drastically limiting the numbers of customers affected by any outage.
- Distribution management systems to provide real-time, network-wide insight into grid operations — including load conditions, fault locations and voltages — from a single interface.

Variable resource management systems to identify and manage the growing presence of DERs with outputs that can quickly swing from positive to negative, such as distributed solar, wind, storage, and even electric vehicle charging stations. As DER adoption grows, the complexity of grid management also increases, requiring intelligent software to optimize network operations efficiently and respond to changing grid-edge conditions in real-time, capturing the full value of available distributed energy resources.

Asset management systems to enable real-time monitoring of equipment performance and improve end-of-life replacement planning.

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By bringing IT and OT together, utilities will capture the value of the enormous quantity of data generated by their rapidly digitizing grids.

Business drivers for
IT / OT integration

- Growth of the digitally enabled grid is resulting in the deployment of potentially millions of new intelligent grid devices into a distribution network — including smart meters, line sensors and on-load tap changers — all generating valuable information across all parts of the business.
- The increasing complexity of managing distribution networks is driving utilities to look for improved approaches to optimize their systems, such as incorporating real-time weather information into distributed generation management and automated rule-based control of assets.
- New business models are yielding services that can only be delivered when business data and operational decisions are brought together, such as the purchase of network services from third-party storage operators.
- Regulators are pushing utilities to do more with less. At the same time, in many mature countries, overall energy consumption is flat or declining while peak demand remains constant or is increasing. This situation strains distribution assets while undercutting traditional energy consumption-based cost recovery methods.
- New distribution assets delivered with significant embedded sensor technologies, combined with communications and analytic technologies, can yield faster, more accurate insights that optimize and prolong asset life.[2]

Using IT to maximize OT

Digital services become the link between engineering efforts, operational activities and infrastructure planning teams.

Asset management is one of the most complex tasks distribution utilities face, and one of the most in need of modernization. Aging utility infrastructures and workforces are impacting operational efficiencies; it is estimated today that 45% of U.S. distribution infrastructures are near the end of their useful life. Also 38% of utility employees will be eligible to retire in the next decade. Current regulatory and revenue-related challenges make it more important than ever to do more with less. This means operating existing assets as closely as possible to their physical limits — but that approach implies knowing just what those physical limits might be at any given time. In addition, asset-management functionality is often spread across several software applications and databases — and across multiple enterprise and operational boundaries.

In most utilities, IT and OT have evolved into the following silos:

- Traditional IT, which manages information for humans, such as customer databases, billing systems, call-center software and workforce management tools.
- Traditional OT, coordinated through supervisory control and data acquisition (SCADA) systems, which manages data for machines, such as metering data, transformer and switch status and relay position.

In recent years, however, OT systems have become connected to the same networks as IT resources through addressable Internet Protocol addresses. As a result, the new field of asset performance management (APM) has emerged which allows for much more useful analysis of centralized asset data. APM can help build bridges between existing enterprise asset management systems, workforce management systems and other relevant data. Analytics can be used to mine this information for insights that both cut costs and improve safety and reliability.

Modern digitized systems also enable predictive maintenance to minimize field-crew visits and inspection-related shutdowns. Achieving this level of performance requires technology investment across the following operational layers:

Equipment layer — IoT-enabled equipment and devices with integrated sensor capabilities provide connectivity and generate data. In some cases, existing components can be retrofitted with communication modules, sensors and high-end control units to achieve similar functionality. Retrofitting circuit breakers, contactors and protection relays also reduces environmental impact, with less production downtime and fewer risks during installation. This resource circularity protects operators' health and safety, and the environment.

Advanced analytics — Cloud-supported analytics can also create digital replicas of physical assets ("digital twins") to optimize more efficient operation and maintenance procedures.

Edge layer — Edge computing at the equipment level can provide more intuitive interfaces for monitoring and controlling operations, using the latest communication and feeder automation technologies and as a cornerstone of IoT-enabled power distribution architectures to detect and manage faults within MV / LV substations and across public power distribution networks. This can include web-based access to operating parameters and interfaces with other systems.

Analytics and services layer — This layer is increasingly cloud-based, and merges and correlates data to assess current equipment status and potential problems. By emulating equipment behavior, these analytics can establish alarms when a predefined level of wear has been reached.

IDC also predicts that by 2020, 25% of utilities will integrate Asset Performance Management investments using sensor data to achieve a well-balanced system based on extensive knowledge of how equipment fulfills its function.[3] For example, operators need to understand what data constitutes a warning alert that indicates a need for proactive replacement. Utilities often don't possess the workforce resources to take on this task by themselves. Like many other cloud-based analytics offerings, APM systems are sold as a service (APMaaS). As such, these digital services become the link between engineering efforts, operational activities and infrastructure planning teams. The next-generation asset management platform concept is known as "Digital Twin," which is a virtual image of an asset, maintained throughout the lifecycle and easily accessible at any time. This one platform brings all the experts together, providing powerful analysis, insight and diagnostics and enabling collaboration along the entire asset lifecycle of all related stakeholders, including suppliers and customers.

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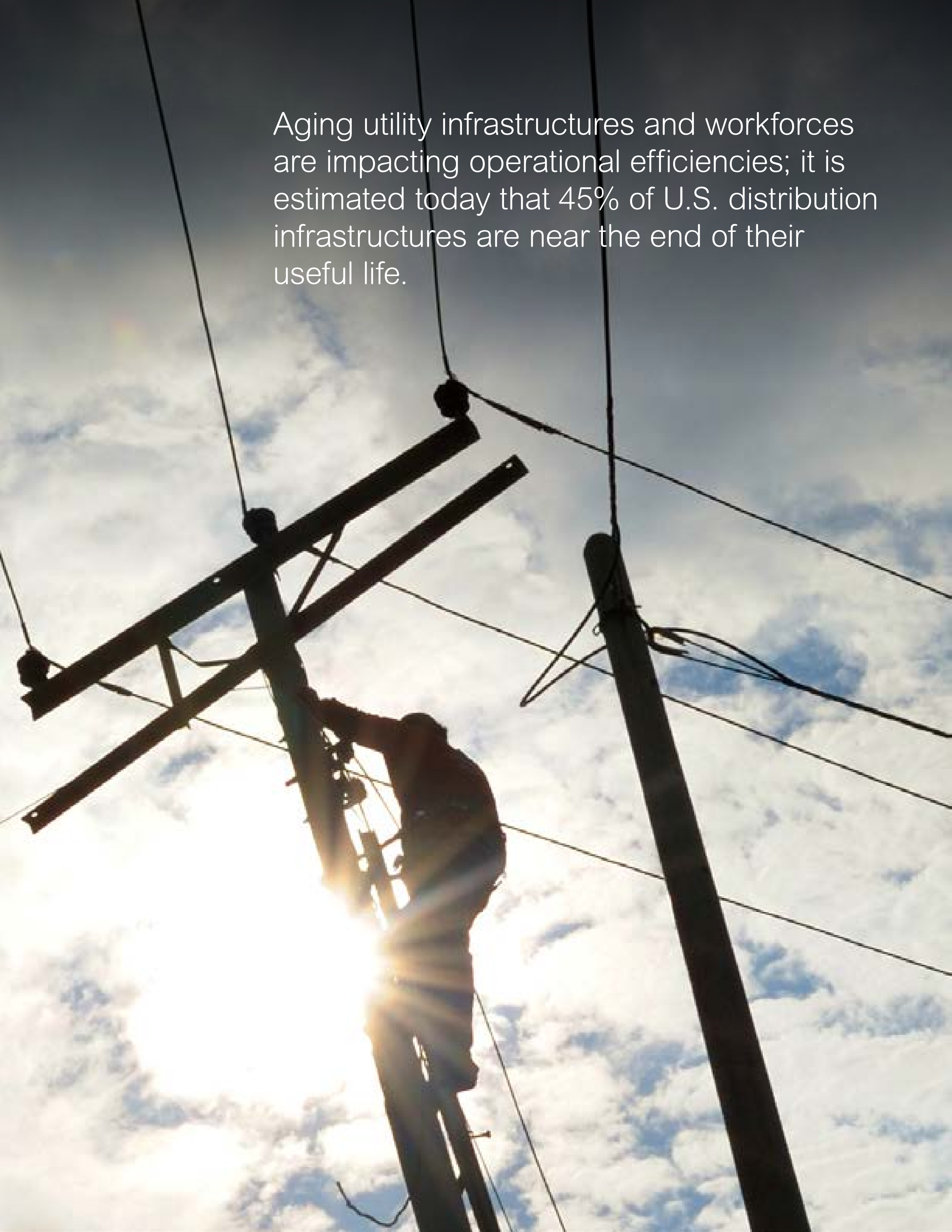


The need for flexible grid management

How can a distribution utility maintain network reliability in the face of multi-directional power flows and intermittent DERs? Today's grid must handle a range of customer equipment — including photovoltaics (PV) panels, batteries and electric vehicles — that can produce or absorb electricity connected at the distribution level or below — behind a customer's meter. Meeting this challenge will require a phased approach over time. As distribution utilities are now experiencing, DERs connected to a distribution network at different voltage levels might not be well aligned with local demand. At any given time, net power flows can occur from the distribution network out to the bulk power system, or vice versa.

Voltage control can present a significant challenge as DER penetration increases. Utilities around the world face contractual and regulatory requirements to maintain specific voltage limits — for example, within + / - 10% of an agreed-upon target. Historically, voltage control has been performed at the high-voltage / medium-voltage substation level, but with heavier DER penetration, voltage-control issues have dropped down to the distribution level. Distribution utilities now have to manage situations where voltage is rising on one part of their grid and falling somewhere else. To address this situation, utilities are deploying sensors to monitor voltage all along their feeders, along with new actuators that are able to regulate the voltage at different levels.

For now, the early first wave of DERs is made up of mostly rooftop solar panels. Moving forward, distribution utilities could be hosting a range of other resources, including energy storage and demand side management, that also could be called on to maintain balance.

Advanced distribution management systems (ADMS) are among the tools that distribution utilities are now turning to for help in managing the enormous volume of data characteristic of digitized grids. These systems present several advantages:

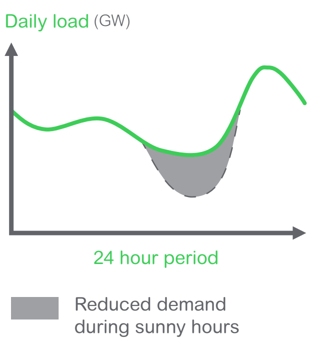
- Optimization and grid-improvement functions for demand and efficiency management.
- Analysis and management of distributed energy resources.
- Support of automated switching for a self-healing grid.

At their most sophisticated, ADMS can support operator simulations of forecasted grid conditions, with weather forecast information supplied by advanced weather systems. The ADMS develops and proposes a set of potential optimization solutions from which the operator can select. The ADMS then executes this program, monitoring and readjusting volt / VAR (volt-ampere reactive) settings as grid parameters change.

The future of energy

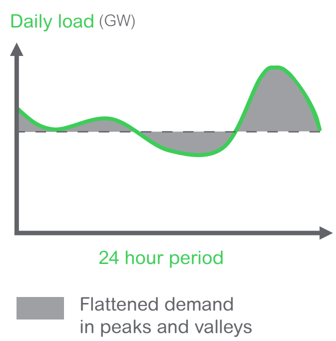
Distributed Generation

Distributed generation from renewable sources — primarily Photovoltaic (PV)



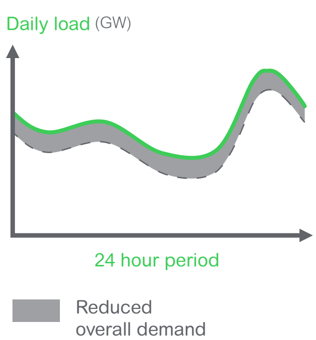
Distributed Storage

Devices that store electrical energy locally for use during peak periods or as backup



Energy Efficiency

Any service or device that allows for reduced energy use while providing the same service



Demand Response

Technology that enables control of energy usage during peak demand and high pricing periods

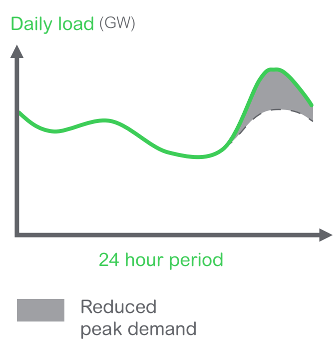


Figure 1 - The Future of Electricity: New Technologies Transforming the Grid Edge. (Source: World Economic Forum in collaboration with Bain & Company, March 2017, page 9)

Customer engagement: Turning prosumers into partners

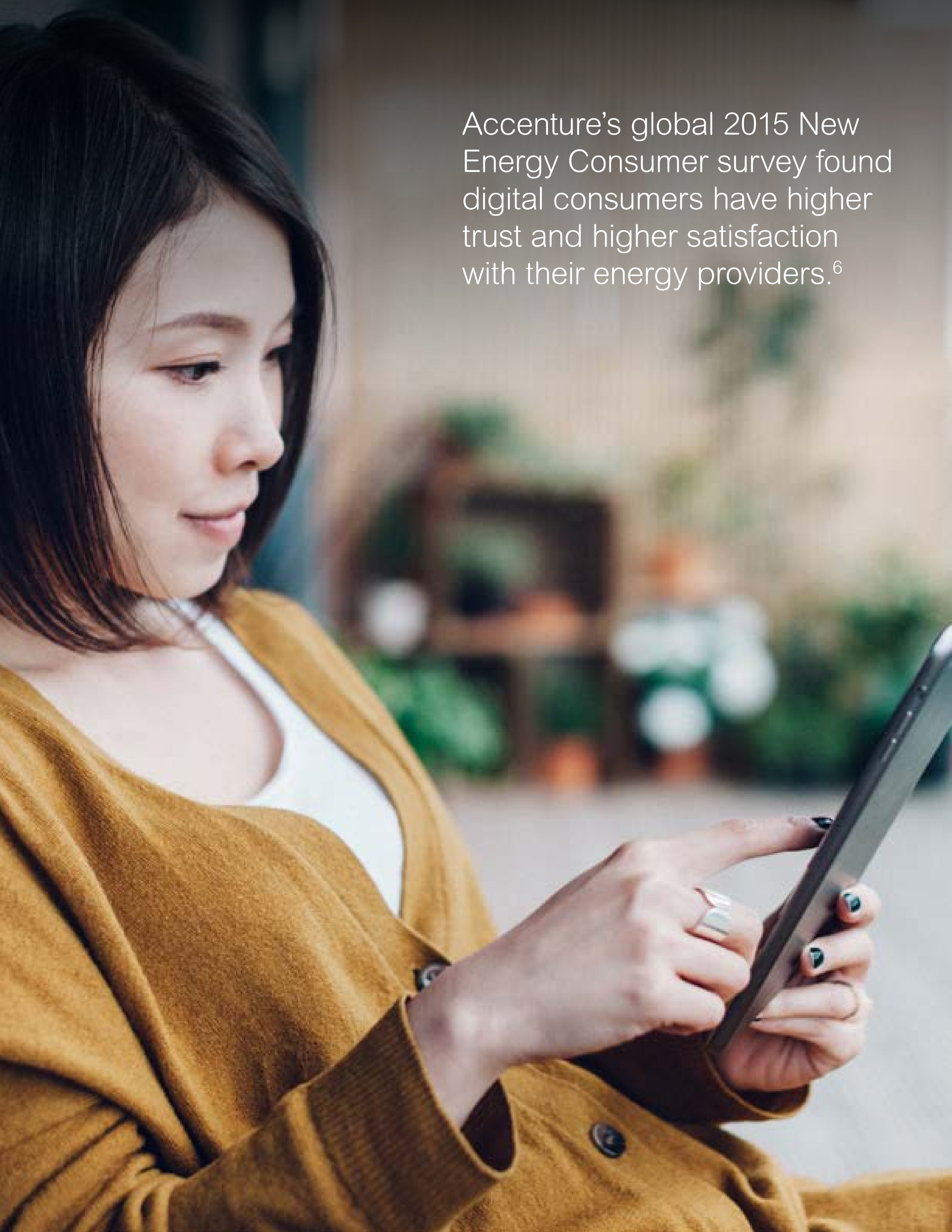
As the new electric world emerges with new challenges and opportunities, electric utilities hold on to one major advantage: their customers. A J.D. Power 2017 customer satisfaction survey of U.S. residential utility customers continued a six-year run of increasing scores.[4] That survey revealed that those satisfied customers are increasingly interacting with their utilities in digital ways:

- More customers are paying their bills electronically — Though the numbers are small, 20% of those surveyed now pay their bills online, an increase of three percentage points over the 2016 results.
- Communications are becoming less paper-based — More customers are accessing utility websites for information, and more have accepted email communications from their utilities.
- Mobile device usage is on the rise — More than one-third (35%) of customers now access utility websites using a mobile phone or tablet, a 15% increase over 2016.

In fact, digitally-engaged consumers are among their most satisfied consumers. Accenture's global 2015 New Energy Consumer survey found digital consumers have higher trust and higher satisfaction with their energy providers and are more likely to recommend those companies and share their personal information with them.[5] Survey results also show that these consumers offer utilities an assortment of new business opportunities.

Thus, utilities are entering into digital customer relationships with an incumbent's advantage. However, that relationship could be at risk without a thoughtful approach for enhancing services. A foundational first step, such as the installation of smart meters and a supporting advanced metering infrastructure (AMI), can help to begin the process. However, that ability to gather raw data will need to be supplemented with enhanced connectivity. This implies integration of the gathered meter data into existing customer relationship management databases, grid-forecasting functions, billing systems and other legacy operations.

> For now, the early first wave of DERs is made up of mostly rooftop solar panels. Moving forward, distribution utilities could be hosting a range of other resources.



Accenture's global 2015 New Energy Consumer survey found digital consumers have higher trust and higher satisfaction with their energy providers.[6]

05

Data: The new lifeblood of utility success

Converting data into business success

The lifeblood of the new digitized utility will be data. Data will describe operational status, equipment performance, customer loads and distribution-level production. Data also will describe current and forecasted weather conditions, availability of connected transmission-level power supplies and the locations of field crews throughout a utility's service territory. In short, data now is transforming how utilities do business.

Success or failure during this transformation depends on capturing the full worth of what is becoming a flood of data.[1] IDC reports that less than 10% of data is used effectively — so simply collecting more of it will not increase its value. Instead, utilities should focus on those digital assets that are most central to understanding and improving customer experience and system operations. The growing importance of data and the software from which it is derived is also raising new questions regarding current business models, as these intangible assets are becoming as central to utility operations as the physical infrastructure on which many utilities' earnings are based.

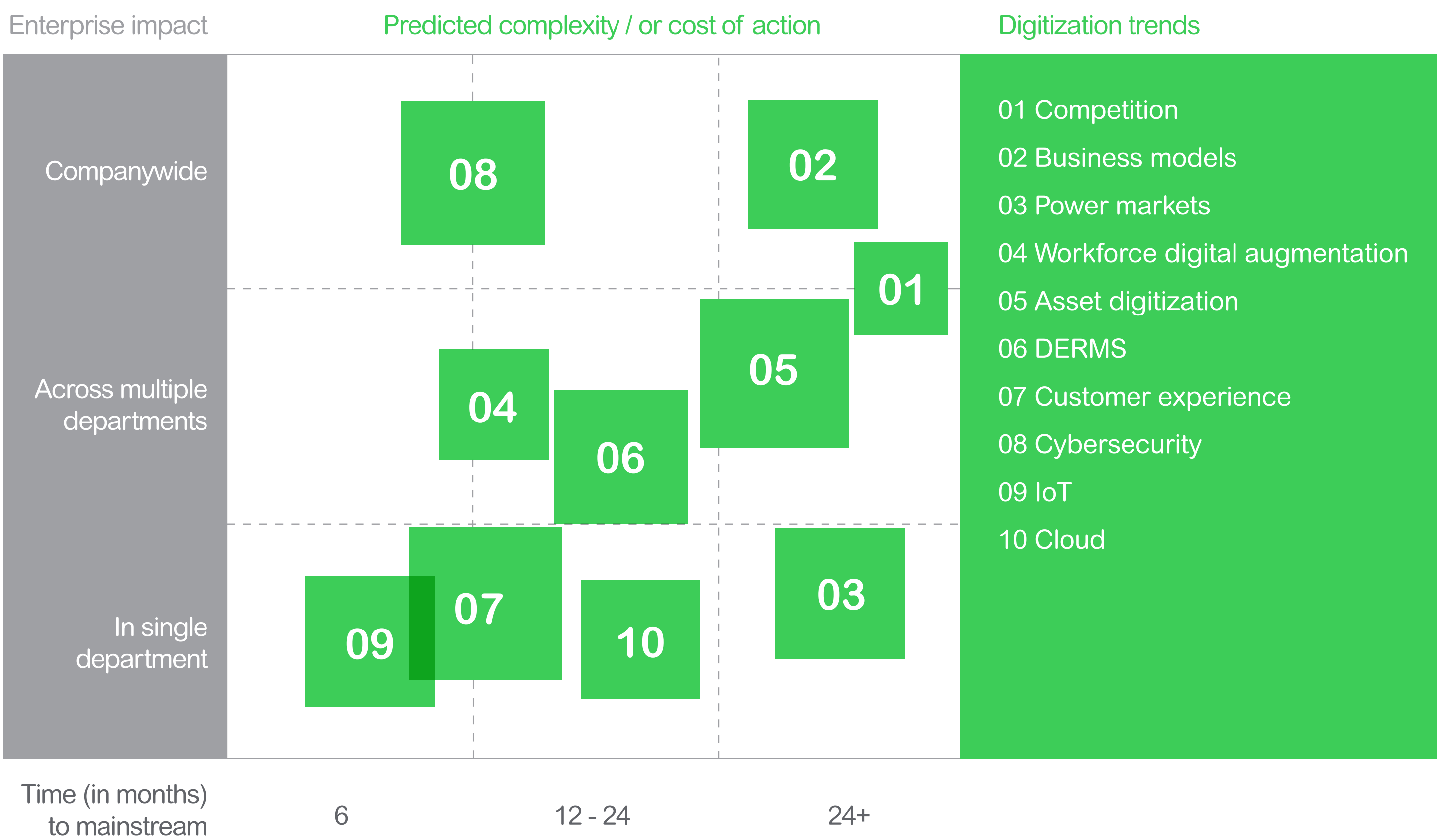
There are three broad categories of digitization that utilities can leverage to better address their transition to a new, and more successful business model:

The Internet of Things (IoT) — This universe of internet-connected devices is quickly evolving into the distribution utility network's eyes and hands.

Data modeling and management — These methodologies can be used by utilities to describe and convert raw data into useful information.

Security and privacy — These represent mechanisms that utilities can leverage to ensure data and its related delivery systems remain safe and secure.

Worldwide utility market top 10 digitization trend predictions



Source: IDC 2016

Figure 1-IDC FutureScape: Worldwide Utilities 20017 Top 10 Predictions. Utility market researchers at IDC have identified 10 digitization trends now underway in utilities around the globe. IDC also forecasts the likely impact of these trends across the enterprise and the time it will take for the predictions to reach mainstream. Each bubble's size provides a rough indicator of the complexity and / or cost an enterprise will incur in acting on the prediction.[30]

Internet of Things (IoT)

According to Navigant Research, more than 1.3 billion IoT devices are anticipated to be installed in the world's commercial and residential buildings by 2021.[2] That year, Navigant analysts believe, will prove to be a tipping point for IoT technology — though it might seem that point already has been crossed. Driving this phenomenal growth are steady increases in computing power and decreases in hardware prices, factors that are combining to connect virtually anything to the internet. Navigant quantifies the amount of data points generated by IoT devices in terabytes — and potential revenues are almost as large. Cumulative total revenues in the commercial and residential building sectors, 2016 through 2025, are expected to reach $750 billion dollars.[3]

IBM defines IoT as "the concept of connecting any device (so long as it has an on / off switch) to the Internet and to other connected devices. IoT is a giant network of connected things and people — all of which collect and share data about the way they are used and about the environment around them."[4] For distribution utilities, those connected things and people could include customers (via smart meters and mobile phone apps), equipment located at customer sites (such as distributed energy resources, thermostats, water heaters and lighting controls) and their own networks of substations, switches, breakers and line workers.

Electric utilities, in particular, are just beginning to realize the opportunities IoT technologies could offer to their bottom lines. As a first step, many of these companies are investigating new ways IoT data can help them understand current operations and, potentially, identify opportunities to automate processes that now might require hands-on oversight and control. Even under current business models, IoT capabilities offer promise across multiple use cases, including outage management, customer experience and real-time pricing. Utilities are evaluating IoT at two levels — at one level for their field workers, in the form of wearable devices, and at the hard asset level, including plants, substations and transformers.

A handful of utilities the market research firm IDC labels "digital transformers"[5] are actively piloting — and in a few cases deploying — augmented reality capabilities and wearable technologies to aid workers' efforts in the field. In the United States, the Electric Power Research Institute is leading a 15-utility research effort investigating how connected safety glasses, helmets and other equipment could improve safety and performance.[6]

IoT efforts have progressed more quickly in distribution utility initiatives to digitize their assets. Equipment-mounted sensors collect operational data to monitor performance, optimize maintenance schedules and better understand performance shortfalls. In order to execute these projects correctly, utilities need to encourage cooperation between information technology (IT) and operational technology (OT) teams to better understand the best IoT opportunities for the organization and implement new solutions at scale.

Utilities' vendors are becoming increasingly important as utilities move forward with IoT projects. These third-party solution providers are developing cloud-based software-as-service (SaaS) offerings developed around specific use cases. Partnering with such a packaged solution provider can result in faster implementation and a more rapid return on investment.

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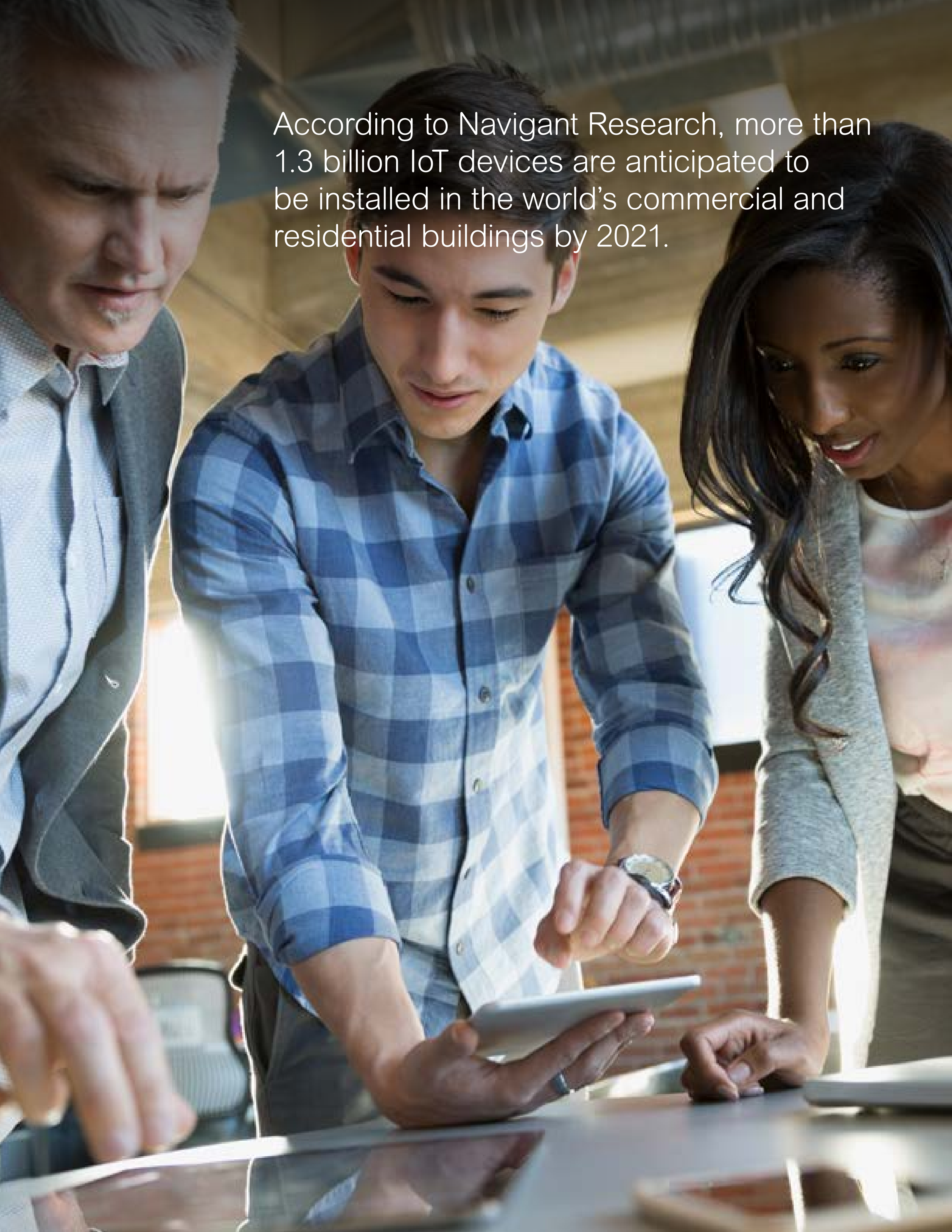

From a grid and marketing perspective:

Understanding data

For a device to be classified as “smart,” a number of criteria need to be fulfilled; it needs to be connected or have the ability to connect, it needs to capture useful data and produce some sort of insight, which requires effective data management.

Increasingly, home devices will be connected, and will generate and exchange massive sets of data yielding new insights into consumer habits and preferences. Data will be more granular and new tools will become available to better tailor communication, increase transparency and, most importantly, develop more personalized offers and services.

In Europe, there is an agreement to distinguish between meter data, grid data and market data and to divide data uses into regulated obligations and commercial services. The difference between smart grid and smart market data can be defined in the following manner:

- Smart Grid Data includes all technical data (e.g., voltage, power quality, frequency, etc.) collected by sensors in the network — including smart meters — allowing system operators to plan, operate and manage their networks. Smart grid data is needed for network monitoring and management (to predict or identify congestion) and planning. Such data becomes more and more important in a decentralized energy system as it provides the foundations for a more flexible market.
- Smart Market Data is driven by market players seeking to create innovative services by enriching smart meter and smart grid data with data from other sources, such as from commercial energy contracts (price information, first day of supply, payment method, etc.), from smart appliances (devices such as smart thermostats or electric vehicle charging set offered to consumers) or from external sources (weather data, social media).[7]

Data modeling and management

The massive quantities of data generated by IoT devices represents only the “raw material” layer of the digitized utility. Understanding the significance of a response from any single data point is rarely possible without knowledge of physical and logical context and historical performance, among other factors. Value can only be harvested from data through a clear understanding, beforehand, of why it is being gathered, as well as how it is to be modeled and managed.

For distribution utilities, the modeling and management processes can become especially complicated because new IoT data is being introduced into decades-old, and siloed, IT and OT systems. Obviously, the desire to access IoT data across enterprise and operational environments becomes another business case for IT / OT convergence.

The gathered data must also be formatted in such a way that exchange with other actors in the power ecosystem is possible, including transmission system operators, distributed energy resource (DER) operators, aggregators and prosumers. As a result, standardized data models and interfaces should be at the core of a utility’s business. Stronger, more efficient, and better automated distribution grids will rely on internationally recognized standards. These will provide a framework in terms of data models, data integration, and open data and communication for smart grids and grid-edge technology. This helps to ease integration efforts and boosts efficiency in a more open yet secure operating environment.

The global International Electrotechnical Commission (IEC) 61850 standard addresses this need for communications within substations, enabling vendor-agnostic specification of Ethernet-enabled communications and control. The Common Information Model, originally developed by the Electric Power Research Institute (EPRI) in North America and now maintained under a series of IEC standards, provides a similar function throughout the electrical distribution system.

An additional critical component is the development of an accurate distribution network model that reveals the location of any device or piece of equipment in the network. Most utilities today use a geographic information system (GIS) to maintain their network models. Because the physical network changes constantly, it’s important to design the architecture of the model so it can keep track of model changes as they occur. This implies a central master network model, hosted by the GIS, that can be shared and updated across all operational systems, including the SCADA, distribution management and outage management systems. Critical success factors in designing an effective model include the capability to import and export network changes as they occur and the avoidance of having to overwrite databases. In this way data discrepancy and computer network overload risk is minimized.

A reliable model provides a way to uniquely associate a physical component to its data, which helps to avoid ambiguity when exchanging information between applications. All IT and OT systems can share and make sense of the data if it is based on this unique network model. Utilities can also deploy the same GIS-based asset management software used for power equipment to manage additional assets, including the smart devices, communications equipment and equipment at grid edge, including meters, chargers and gateways.

The desire to access IoT data across enterprise and operational environments becomes another business case for IT / OT convergence.

Case study:

A single source of truth

Bringing together IT and OT can mean lots of data — and data sources — for a distribution utility. An advanced distribution management system (ADMS) can create a single source for customer meter and DER data, so utilities can trust they have an accurate understanding of network operations, now and in the future. Schneider Electric recently implemented such a system for the Australian utility company ActewAGL, which has helped streamline operations and help operators better understand and address the impact of solar and other DERs across its service territory.

Over a two-year period, ActewAGL's high- and low-voltage network models were consolidated into a single GIS, billing and other data was modeled to each customer connection point and paper-based work requests were replaced with electronic versions that also track to affected customer connection points. The utility is planning for further ADMS optimization that will include a new customer information portal, advanced feeder-level load forecasting and dynamic network-management capabilities.[8]

Security and privacy

Utilities need to think about how their cybersecurity strategies will adapt over time, in a planned and iterative manner, and with a recurring annual investment.

Today's utility stakeholders are applying cybersecurity processes derived from their IT peers, to better safeguard their distribution systems. Within the substation environment, for example, proprietary devices once dedicated to specialized applications are now vulnerable. If left unprotected, sensitive information available online that describes how these devices work can be accessed by anyone, including those with malicious intent. With the right skills, malicious actors can hack a utility and damage systems that control the grid. In doing so, they also risk impacting the economy and security of a country or region served by that grid.

Meter data has traditionally been exchanged between the metering operator and market parties in a bilateral way. Today, some European players are in the process of setting up centralized data hubs as a common clearing platform operated by a regulated party. The data processed in the centralized data hub undergoes consistency crosschecking before being distributed to the addressees. This approach is convenient for all market participants as it simplifies data exchange and reduces operational costs, and is increasingly relevant in smarter energy systems, which are characterized by more granular data and greater complexity. However, as a single "point of failure," there is a risk of targeted cyber-attacks. Other actors prefer to keep this task decentralized, generally in the hands of the distribution system operator (DSO), as DSOs have specific network knowledge and a long-standing experience in data handling.

This is an increasingly important concern for European utilities, as they face a specific data-security challenge with the new General Data Protection Regulation (GDPR) set to take effect in March 2018. This regulation will hold businesses accountable for the data they possess and require them to expand consumers' abilities to access and control their data. For example, GDPR's data portability requirement stipulates that data can be transferred at the request of a consumer to a new "controller." So, a consumer who switches to a new energy supplier can request that data held by the original company be transferred to the new provider and then be deleted from the original provider's system. Obviously, such provisions could reach far into a utility's IT and OT operations.[9]

To address these security and privacy challenges, regulators have anticipated the need for a new structured cybersecurity approach. In the U.S., North American Electric Reliability Corporation Critical Infrastructure Protection (NERC CIP) requirements set out what is needed to secure North America's electric system. The European Program for Critical Infrastructure Protection (EPCIP) does much the same in Europe. New and complex cyber-attacks occur every day, some of which are organized by state actors. This leads utility regulators around the globe to reconsider the industry's overall security approach.

Contributing to these new risks is a shift towards the use of more open communication platforms, such as Ethernet and

IP. As operators of critical utility infrastructure investigate how to secure their systems, they often look to more mature cybersecurity practices. However, the IT approach to cybersecurity is not always appropriate considering the operational constraints utilities are facing. Today, it becomes necessary to develop cross-functional teams to address the unique challenges of securing technology that spans both worlds. Protection against cyber threats now requires greater cross-domain activity where engineers, IT managers and security managers are required to share their expertise to identify the potential issues and attacks affecting the increased "cyber-attack surface" in energy systems.

Cybersecurity experts agree that standards, by themselves, will not create the appropriate security level, because security, today needs to be thought of as an ongoing process, not a static state of being. As a result, adequate protection from cyber threats requires a comprehensive set of measures, processes and technical means, and an adapted organization, and it must be designed for continuous improvement as security threats continue to evolve.

Therefore, utilities need to think about how their cybersecurity strategies will adapt over time, in a planned and iterative manner, and with a recurring annual investment. These companies need to deploy a complete program to take full advantage of cybersecurity protection technologies.

The following four-step approach can help to establish and maintain cyber-secure systems:[10]

1. **Performance of a risk assessment**
   This first step involves conducting a comprehensive risk assessment based on internal and external threats. During this process, OT specialists and other utility stakeholders can understand where the largest vulnerabilities lie, as well as document the creation of security policy and risk migration.

2. **Design a security policy and processes**
   A utility's cybersecurity policy provides a formal set of rules to be followed. These should be led by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC)'s family of standards (ISO27k) providing best-practice recommendations on information security management. The purpose of a utility's policy is to inform employees, contractors, and other authorized users of their obligations regarding protection of technology and information assets. It describes the list of assets that must be protected, identifies threats to those assets, the authorized users' responsibilities and associated access privileges, and the unauthorized actions and resulting accountability for violation of the security policy. One key to maintaining an effective security baseline is to conduct a review once or twice a year.

3. **Implement the risk mitigation plan**
   Select technologies that adhere to international security standards, to ensure that proper risk mitigation can be enforced. A "secure by design" approach that is based on international standards like IEC 62351 and IEEE 1686 can help further reduce risk when securing system components.

4. **Manage the security program**
   Effectively managing cybersecurity programs requires not only considering the previous three points, but also the management of information and communication asset lifecycles. Accurate and living documentation about asset firmware, operating systems and configurations should be maintained. A comprehensive understanding of technology upgrade and obsolescence schedules is also required, in conjunction with full awareness of known vulnerabilities and existing patches. Cybersecurity management should also mandate that certain events such as critical points in asset lifecycles or any detected threats trigger security assessments.

Mitigating risk and anticipating attack vulnerabilities on utility grids and systems is not just about installing technology. Utilities must also implement organizational processes to meet the challenges of a decentralized grid. This means regular assessment and continuous improvement of cybersecurity and physical security processes to safeguard the new world of energy.

By addressing the challenges digitization poses, utilities have the opportunity to create distribution systems that are more responsive to both DERs and the customers who own them. But this isn't an effort that can be implemented successfully with one-off initiatives — instead, each utility needs to develop a holistic plan that considers how these digital pillars of IoT, data modeling and data security overlap and interact with each other. Creating this transformational roadmap requires skills that aren't always on-hand within utility organizations. Looking to an outside partner who is knowledgeable about the latest digital technologies, and has the expertise required to convert theory into practice, can be one of the most important investments a utility can make to ensure success in an increasingly digitized environment.

> Cybersecurity experts agree that standards, by themselves, will not create the appropriate security level, because security today needs to be thought of as an ongoing process.

The three axes of cybersecurity

1 Organization

Patch management
Security awareness
Security training
Secure operations
Audit capability
Secure configuration

2 Process

Patch management
Incident response
Secure dev. and test
Risk assessment
Secure configuration
Access protection

3 Technical

Hardening
Access protection
User athentification
Security logs
Secure communications

Energy industry standards and guidelines

IEC 62351	IEEE 1686	NISTIR 7628	ISO / IEC 27002 / 19
IEC 62443 / ISA 99	IEEE C37 240	NIST SP800-53	

Figure 2 - The three axes of cybersecurity. (Source: IEC, "Cyber security for the modern grid," 2017).

06

Strategies for future utility success

Advancing the digital journey

The three most important components that lie at the core of a successful evolution — greater customer engagement, real-time insight into DER operations, and a move to cloud-based applications and data storage — all require buy-in and support across the enterprise.

The centrally managed, fossil-fuel-dominated approach of the past is being challenged. New technologies, the rising influence of regulatory agencies, and favorable economics are all pushing the accelerated development of clean, low carbon renewable power sources. That same drive for change is being reflected in the way power networks are being designed and upgraded. But as executives and regulators alike are finding, these new priorities have wide-ranging implications. Greater adoption of renewables, especially solar and wind generation, pose challenges that are as significant as their benefits. For example:

- Once constructed, wind turbines and solar panels are “free” to fuel from an energy generation perspective (i.e., no coal needs to be procured and burned to drive the turbines), which is likely the most significant productivity improvement of this century. In the meantime, however, this advance could raise havoc with traditional wholesale power market structures.

- Major potential for improving the operational efficiency of the utility business models can be found in how electricity is now being supplied. The more distributed nature of renewables is forcing a redesign of the architecture of the transmission and distribution grid first implemented 100 years ago. Today’s market and grid organizations are simply not structured to sustain such a transition efficiently.

Enhancing customer engagement

According to IDC, non-utility companies will seize up to 20% of the world's retail energy business by 2020.

According to IDC's Worldwide Utilities 2017 Predictions, non-utility companies will seize up to 20% of the world's retail energy business by 2020.[1] These new competitors include:

- "Digital disruptors" who are aggregating solar, storage and other resources located on customer sites to participate in energy auctions. This is exemplified by companies like Stem in the United States and Sonnen in Germany, which are both using cloud-based software applications to manage customer interactions within utility markets and between each other. In these cases, the distribution utility grid is providing the necessary platform for these transactions.

- Global Fortune 500 companies seeking to do well by doing good. Apple, Ikea, AB InBev and other such international players are setting up energy subsidiaries to purchase the entire output of utility-scale solar and wind installations, oftentimes in locations with no grid connections to their own data centers and manufacturing plants. Any related renewable energy credits are retired, so the moves represent a net gain of carbon-free electricity, and the financial arrangements with energy developers help the companies to arbitrage their total energy costs.

Similarly, at the retail level, distribution-utility customers are on their own paths to gaining more control of their energy sources and use, through the uptick in products ranging from rooftop solar panels to smart thermostats and lighting systems. As a result, and with demand flat in many developed countries, utilities will need to look beyond basic kilowatt-hour sales to maintain revenues. This is happening more quickly in Europe, where utility executives recently polled by IDC predict new business and services supporting the existing commodity business will make up 40% of their companies' revenues as soon as 2020.[2]

Some utilities are testing new customer-centric offerings in pilot and one-off projects that pose a risk of fracturing the customer experience. Distribution companies who have been successful in these efforts are now starting to develop new core values that support change. They have borrowed strategies from technology marketers to build new offerings that focus more specifically on their customers' experiences. Such a significant transition has important implications across a utility's operations, particularly in marketing and IT efforts.

Utility marketers are refocusing their strategies in the following ways:

- Realignment of their product and service portfolios with a common corporate vision to generate a customer value proposition that resonates with today's digitally savvy consumers.

- Exploration of opportunities for co-creation and collaboration so that bundled offerings with third-party product and service providers can be developed and delivered.

- Creation of customer personas that revolve around specific customer “journeys” (i.e., from utility selection to online bill payment, to moving and establishing or expanding service). This process will help define customers’ expectations and then allow an objective comparison against actual service performance. The data can then be used by designers and customer-engagement specialists to help identify and rectify gaps in service.

IT experts are also realigning their priorities in the following ways:

- Creating platforms, not products. Channel-specific systems and isolated pilots have been shown to fragment the customer experience. A platform-based approach makes it easier to integrate today’s products and simplifies the task of bringing future offerings to market.

- Partnering with cloud-based, as-a-service vendors to develop and implement new platforms. Outsourcing these efforts can also boost IT agility and speed-up time-to-market.

- Placing focus on the three “I”s of customer engagement: Individualized (meaningful to the customer as an individual), Instant (available when it matters), and Interconnected (delivered through the most convenient channel in a contiguous, consistent experience).

This new customer-focused approach will mean breaking down walls that might previously have existed through the introduction of common goals and metrics across IT, customer service and customer marketing functions.

> At the retail level, distribution-utility customers are on their own paths to gaining more control of their energy sources.

Distribution-utility customers are on their own paths, gaining more control of their energy through products ranging from rooftop solar panels to smart thermostats and lighting systems.

Automating DER management

The new customer-focused approach means breaking down walls that might previously have existed through the introduction of common goals and metrics across IT, customer services and customer marketing functions.

With the rapid proliferation of DER, today's distribution utilities are beginning to look more like much larger system operators, in terms of their responsibilities. While they once served primarily as a conduit for centrally generated kilowatts, these companies now must integrate the output of hundreds — or thousands — of individual rooftop solar panels, community-scale arrays, wind turbines and microgrids, while remaining prepared to balance their systems should skies turn cloudy or wind speeds drop. With DER penetration only set to rise, utilities clearly need help managing a number of resulting challenges.

DER management systems (DERMS) offer utilities the data, insights and control capabilities needed to efficiently operate diverse distribution grids. DERMS combine sensors, controls, hardware and software to drive the intelligence needed to harmonize distribution and transmission systems and to optimize DER input and centralized generation.

DERMS extends beyond managing grid operations through the support of billing systems, especially where net-metering tariffs are in place, and by facilitating the implementation of retail-level demand response programs connected to customers' smart thermostats and other IoT-connected devices. DERMS can also support blockchain-based community energy markets, enabling customers who participate in transactive energy models. IDC forecasts 30% of utilities will have invested in such management systems by 2019.[3]

> Some utilities are testing new customer-centric offerings in pilot and one-off projects that pose a risk of fracturing the customer experience.

Distributed energy resource management systems (DERMS) offer utilities the data, insights and control capabilities needed to efficiently operate diverse distribution grids.

Shifting to the cloud

Over the next three years, utilities could have more data on remote servers than in their own data centers, which could speed the migration of legacy systems and data to the cloud as well.

Data-management demands are set to soar for distribution utilities, potentially straining their existing IT resources. Maintaining existing systems while also working to address increased DER integration and customer-service initiatives could limit a team's ability to respond to new needs in a timely manner. Such pressures are fueling rapid growth in cloud-based applications and storage geared to the utility market.

To some extent, the decision to move away from corporate-managed data operations to cloud-based alternatives is already being made by the market. Today's latest generation of data-intensive, utility-related applications are being developed with cloud operations in mind. Over the next three years, utilities could have more data on these remote servers than in their own data centers, which could speed the migration of legacy systems and data to the cloud as well.

This big shift in how utilities are operated will require new skills to facilitate the transition to a software-as-a-service IT model. Outsourcing applications and data storage will require personnel capable of leading policy conversations with various business stakeholders, appropriately vetting cloud service providers, auditing vendor performance and ensuring compliance with data protection and security requirements. Gaining access to a talent pool that combines the needed business and IT skills is expected to be a challenge for some time to come, with IDC seeing a "war" (or at least a "grab") in today's environment to attract the skillsets needed to excel in digital transformation.[4]

Regulators could slow this transition, as they take time to determine how to treat cloud-service payments under existing compensation rules for operating expenses. The result, however, seems almost inevitable, as legacy systems are now being stretched to keep up with the demands of our increasingly decarbonized, digitized and decentralized distribution systems.

Today’s latest generation of data-intensive, utility-related applications are being developed with cloud operations in mind.

Definition of terms

DSO — "Distributed System Operators" or DSOs are grid network operators who manage multiple points of variable power supply and consumption.

DER — "Distributed Energy Resources" or DERs refer to a wide array of distributed energy-related technologies and services. Examples include distributed energy storage, distributed generation, and assorted demand flexibility and energy efficiency improvement tools. The precise definition of which technologies and programs are considered DERs varies by geography.

Feed-in tariff — A governmental policy mechanism that rewards the generation of electricity from renewable energy sources, such as solar panels and wind turbines.

Prosumers — Companies, buildings, and people that both consume and produce energy. "Prosumers" can be city districts, university campuses, military bases, hospitals, commercial buildings, factories, and even residential home owners.

Digitization —The process of converting information into a digital (i.e., computer-readable) format, in which the information is organized into bits.

Digitalization — The use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business.

Transactive energy — The utilization of economic or market-based constructs that factor in grid reliability constraints when managing the generation, consumption or flow of electric power within an electric power system.

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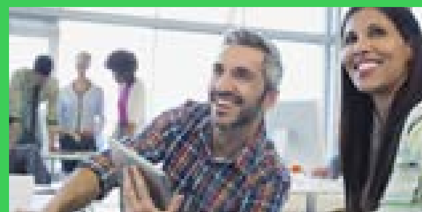

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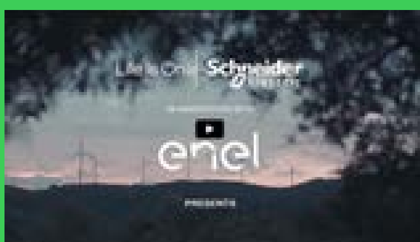

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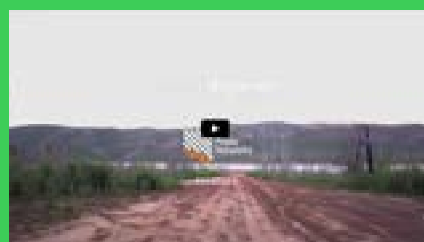

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