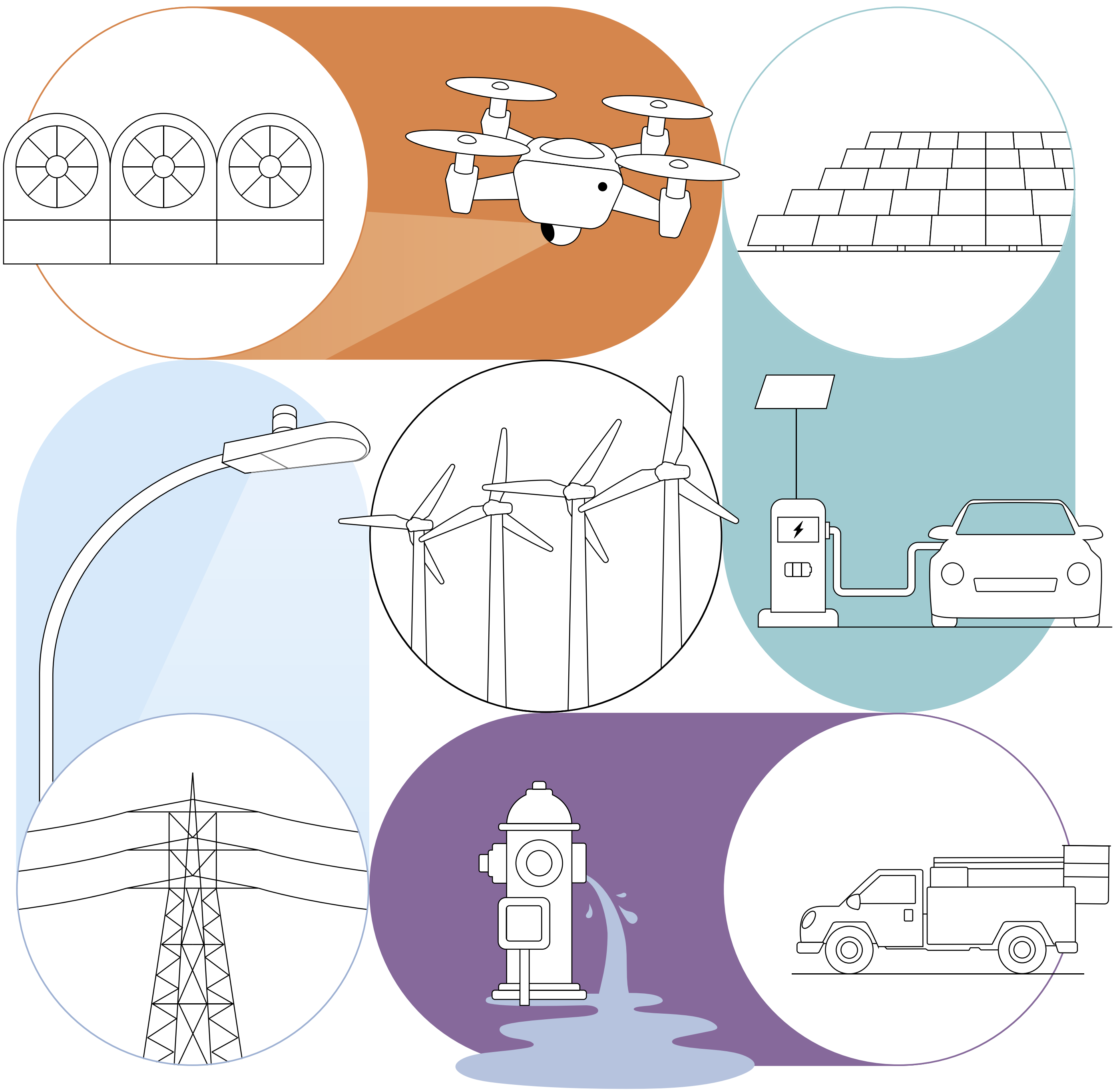
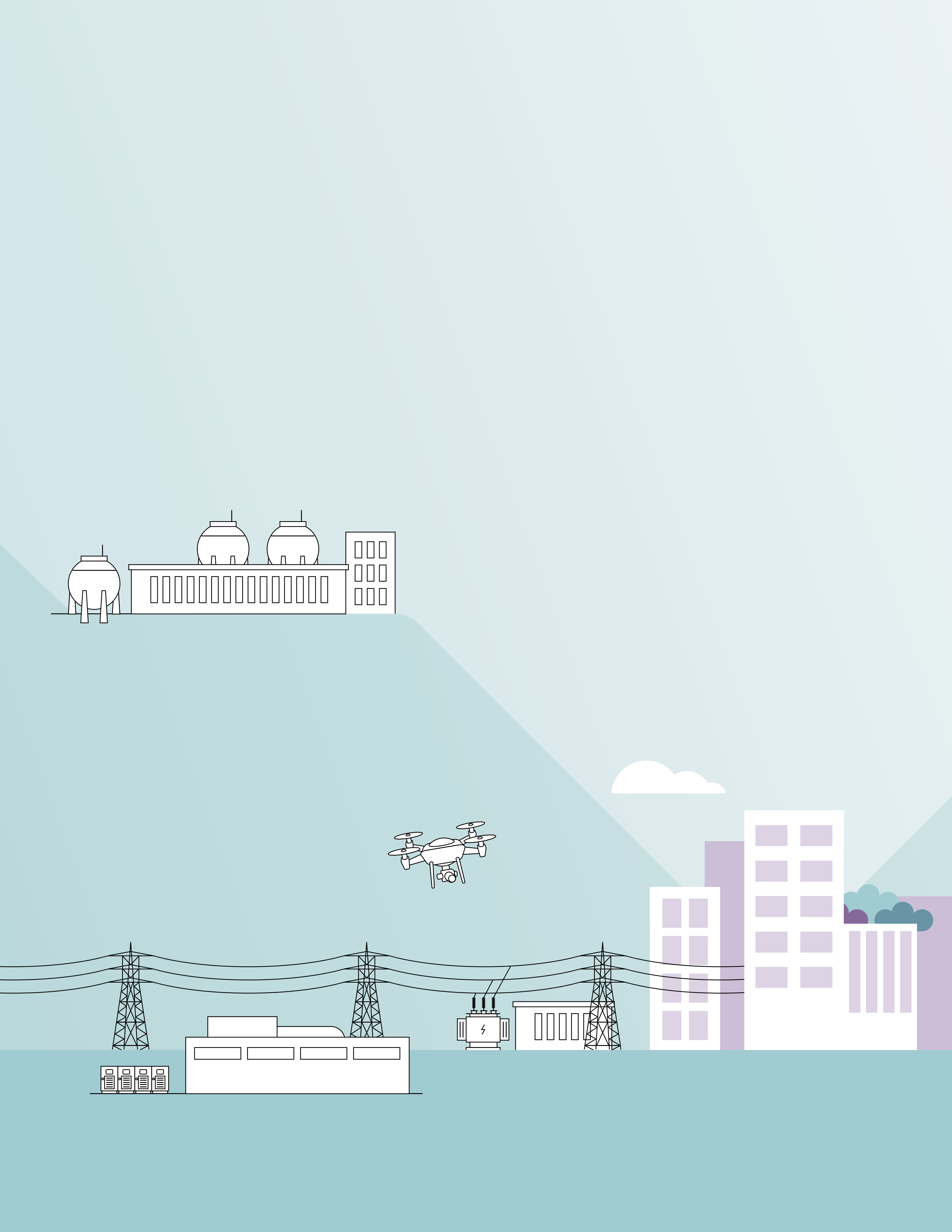
Procuring, Connecting, and Securing Smart Utilities

An Implementation Guide with Use Cases





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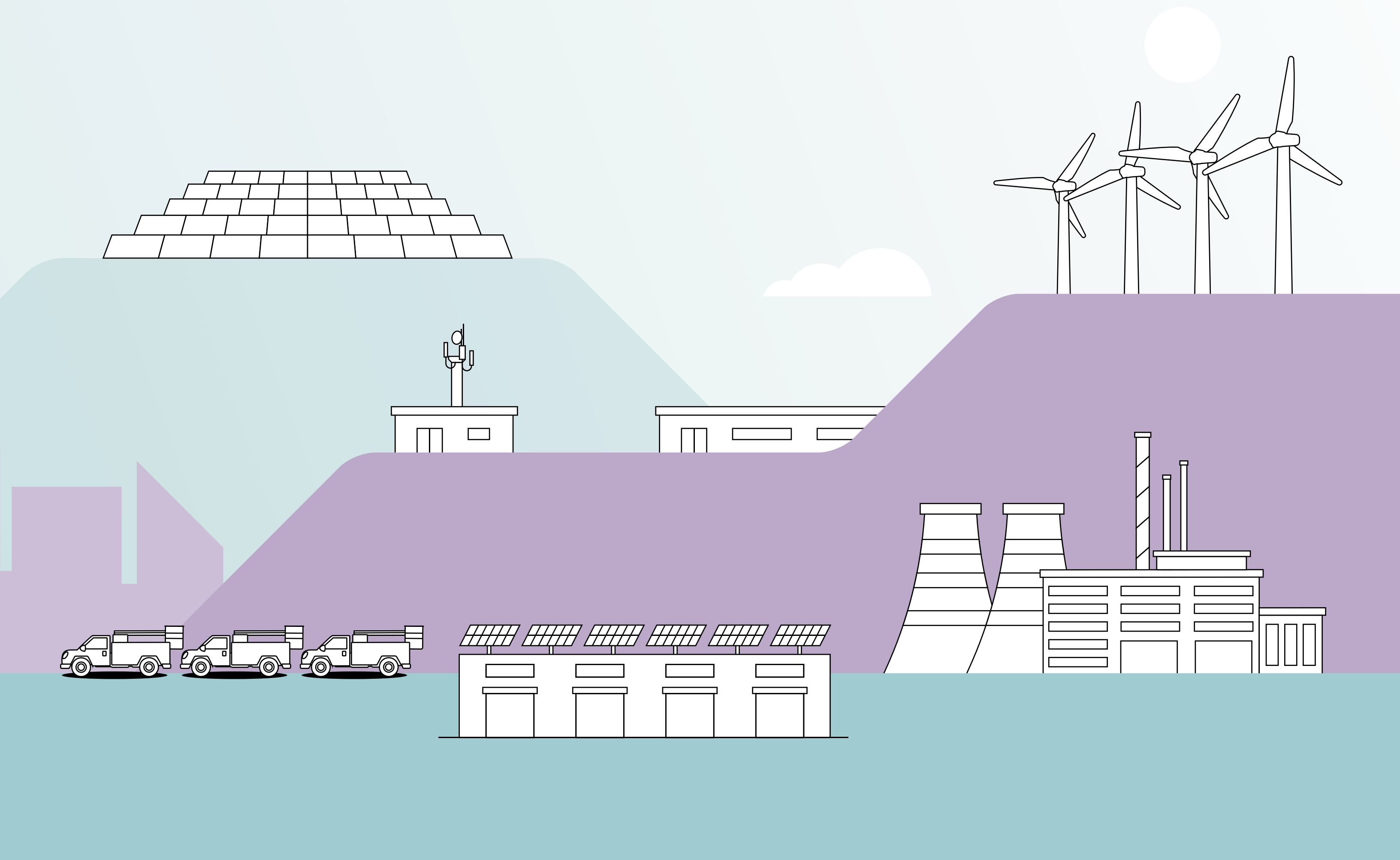


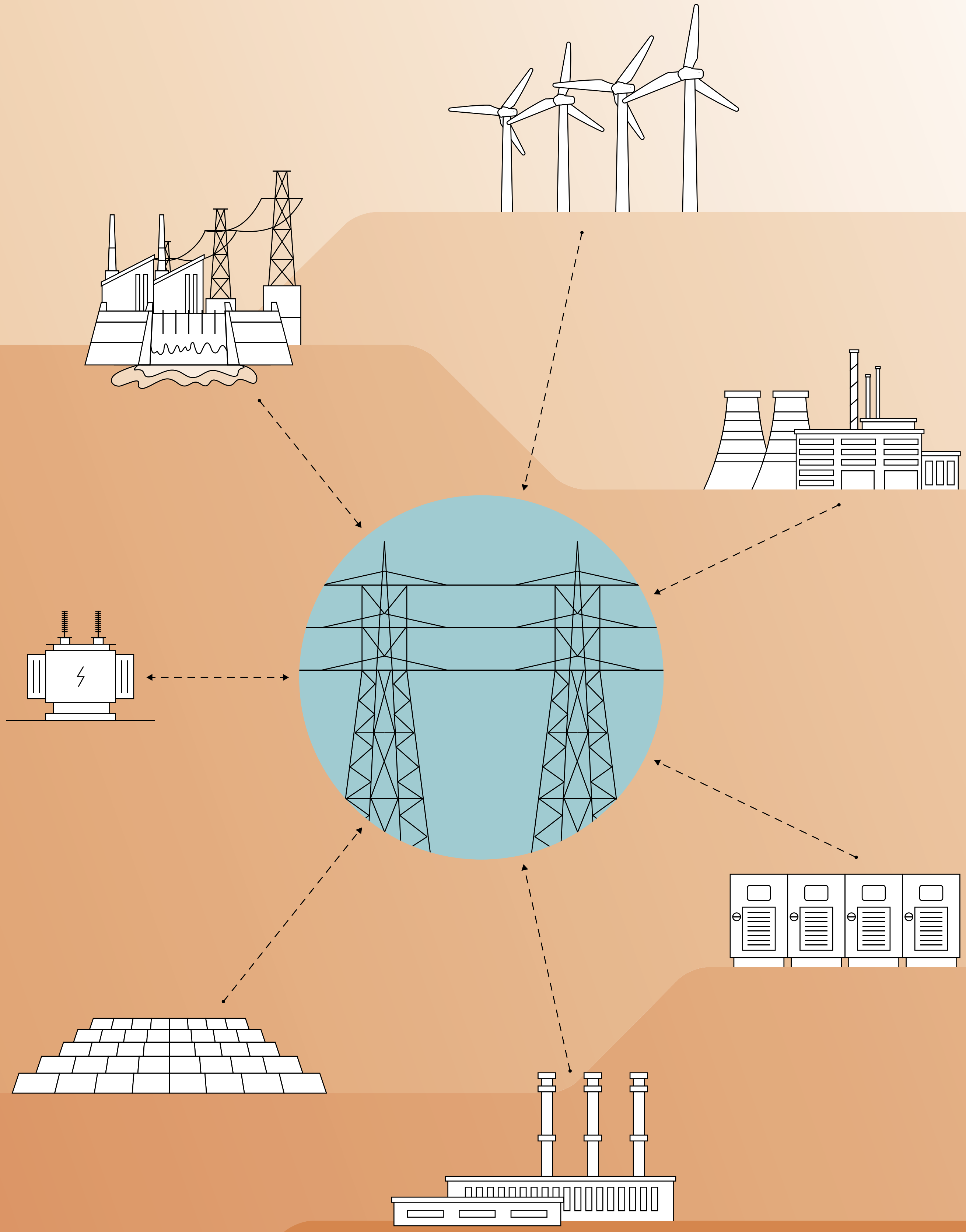
Grids for the delivery of electricity, water, and gas are part of every community's critical infrastructure. When you use advanced technology and connectivity to increase efficiency, resiliency, and responsiveness, these grids become smart grids.

Here's an example. Powered by cellular networks, sensors, meters, and connected infrastructure, a smart electrical grid can diversify the ways utilities provide power, integrating solar, microgrids, and other types of distributed energy resources.

Using advanced metering infrastructure, smart distribution boards and circuit breakers, and other innovative technologies, a smart electrical grid can help utilities restore power faster after disruptions. This smart grid efficiently transmits electricity throughout to streamline costs and deliver a better experience.

Seeing such innovations in action spurs many questions: What devices and networks are they using? How are their creators putting the pieces together? What challenges did they face, and what tips do they have for other cities and utilities?

Read on to explore the technologies and solutions transforming today's smart grids, with real-world examples and practical guidance.



The Electrical Grid:

Transmission

The transmission network represents half of the electrical grid, and its power stations, transmission lines, substations, and other infrastructure are vulnerable to disruptions, from inclement weather to downed trees. Advanced wireless technologies offer utilities innovative ways to keep transmission resilient and interruptions at a minimum.

Wireless solutions, which can be delivered over wireless networks, have the potential to make our central power plants more effective, safe, and reliable. When modernizing existing facilities and building new ones, utilities can work more efficiently and safely with low-cost, easy-to-deploy Internet of Things (IoT) sensors that monitor hardware and processes. They can strengthen security with drones and video surveillance. Finally, they can increase productivity and lay the foundation for future innovation with wireless-powered solutions for data and critical communications.

Substations are another area where smart utilities solutions using wireless networks can optimize transmission. Upgrading this infrastructure has typically been unwieldy given analog systems and copper-driven dedicated lines that can only run a single use case at a time. Expanding a substation's capabilities by traditional means typically involves adding new wiring and upgrading the cable trenches that connect the switchyard to the control room.

Wireless networks ease the path to modernization. Instead of laying trenches, utilities can upgrade their communication infrastructure from analog to digital and move switchyard control rooms to the right combination of fiber and wireless connectivity. This approach also enables utilities to collect more, and more granular, data on a continuous basis, so they can proactively manage disruptions.

Monitoring is an essential part of maintaining substation performance, and wireless-enabled solutions can help here as well. With intelligent line sensors and International Electrotechnical Commission (IEC) 61850-certified networks, utilities can detect real-time fault information and communicate this data directly back to control centers, to quickly resolve interruptions and quality issues.

A New Communication Path for Digital Fault Recorder Data

Virginia | *Deployed on 4G LTE Wireless Network*

SCENARIO

Utilities need data to know if electrical faults and other events threaten their power systems and when and where to send field crews for diagnosis and repairs. Dominion Energy Virginia uses high-resolution voltage and current measurements from digital fault recorders (DFRs) and traveling wave systems (TWS) to collect this information.

Data flows over optical fiber networks at substation sites where possible. But last-mile optical fiber isn't always available—and can't be economically justified—through some areas of Dominion's territory, like the mountainous terrain in the west.

SOLUTION

Dominion's solution: Use cellular 4G LTE modems to connect with DFRs, TWS, power relays, and substation clocks, for real-time responses to emergency events and data analysis afterwards.

For continuously streaming data and large data sets, Dominion recommends a faster 5G wireless network. This captures data and achieves the low latency needed for testing synchrophasor systems.

To maximize bandwidth requirements for telecom utility circuits at substations, the team explored vendor upgrades to 100 MB and integrated its control center to a Software-Defined Wide Area Network (SDWAN).

> "With smart grids and smart buildings, an estimated 67.9 MMtCO2e of emissions can be abated cumulatively in the United States by 2025, equivalent to CO2 emissions from electricity generated to power 12 million homes in a year."
>
> *("5G Connectivity A Key Enabling Technology to Meet America's Climate Change Goals" – an Accenture report commissioned by CTIA)*

RESULTS

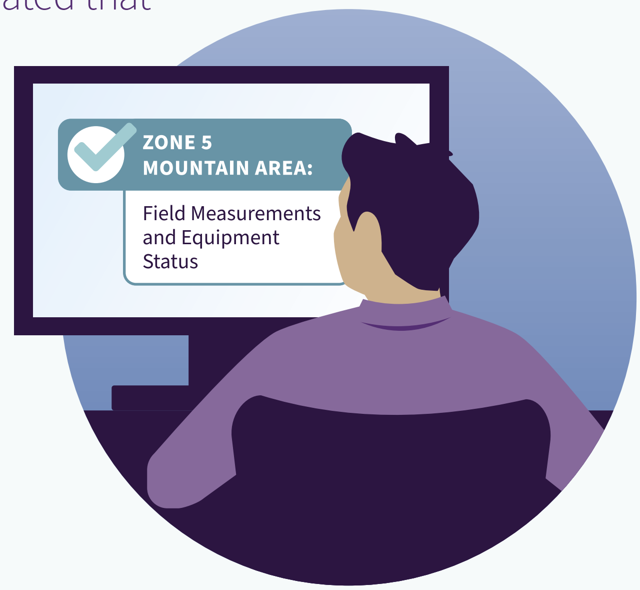
With the new solution, Dominion is now able to access field measurements and verify equipment status without sending technicians on site.

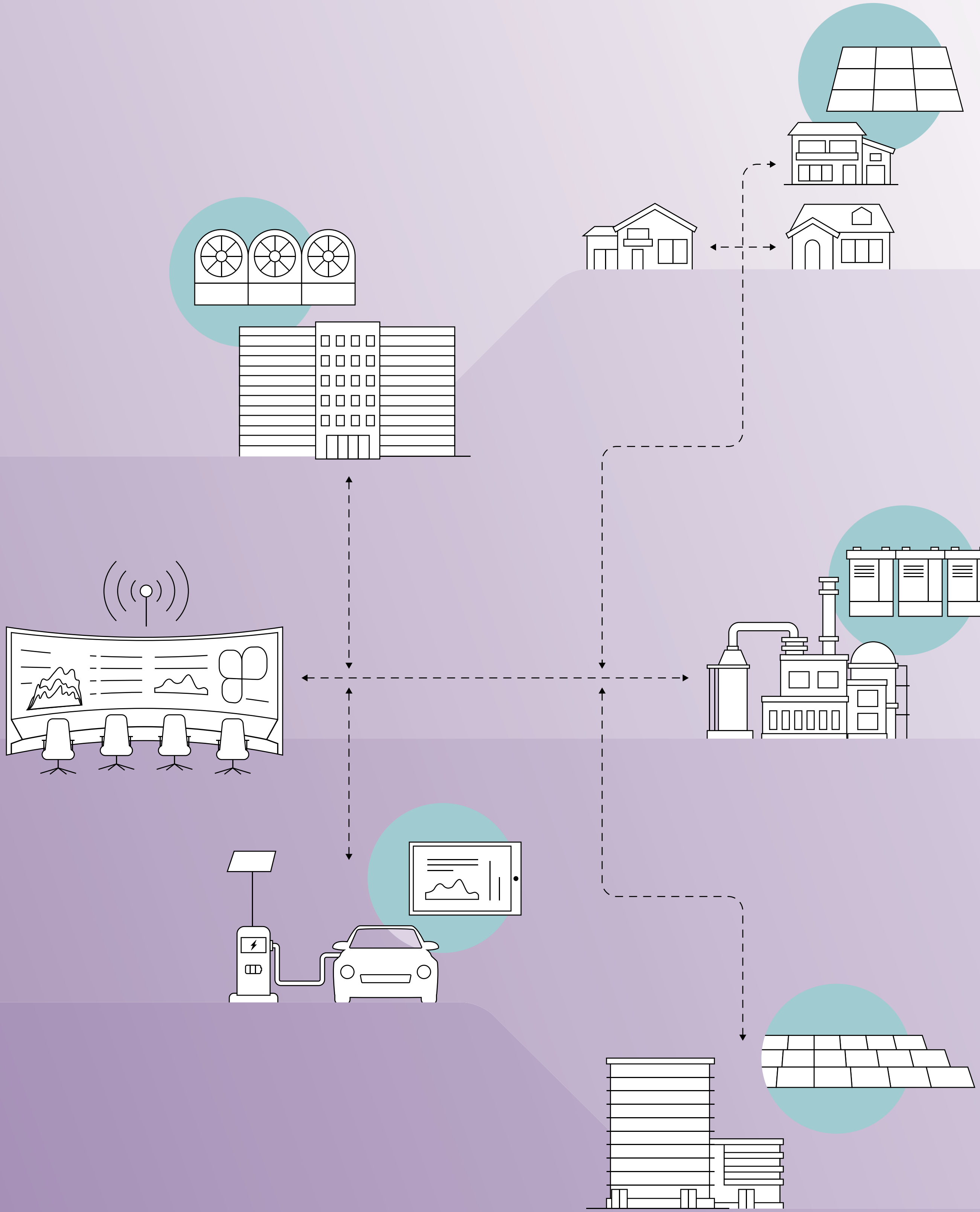
Dominion discovered that cellular modems are often a cheaper solution than installing new fiber for smaller-bandwidth, low-data applications. What's more, the low-cost model of cellular modems enables multiple modems and networks within the same site—effectively making bandwidth extensible and giving multiple groups the ability to independently manage their own traffic.

HOW CAN SMART ENERGY DELIVER HUGE ENVIRONMENTAL BENEFITS?

With IoT integrated into generation, transmission and distribution equipment, energy companies and utilities can monitor and manage their operations remotely. Such smart grid technologies are bringing distributed energy resources to the grid and accelerating the transition to an economy that's sustainable and renewable-powered. It's estimated that these technologies can save 6.3 billion megawatt-hours (MWh) by 2030.

(AT&T)





The Electrical Grid:

Distribution

The distribution network makes up the other half of the electrical grid, sending power from the substation to the end users or customers. In recent years, this area of an electric utility's operations has seen both advancements in technology and connectivity solutions that offer new ways of managing electricity delivery to homes and community members.

Increased responsiveness and remote operation with distributed automation

With conventional electrical distribution, current flows in one direction from centralized generation nodes to loads at the edge of the network. It's a primarily passive method with limited capabilities for real-time monitoring and control—and it fails to accommodate the solar cells, electric vehicle (EV) charging equipment, and other distributed energy resources changing the contour of today's electric grids.

Enter distributed automation. Here, sensors and control devices are spread along an expansive, ubiquitous utility distribution grid, enabling the monitoring, control, and optimization of grid infrastructure in real time. Wireless networks help monitor the distribution of power over these grids, improving the reliability of power delivery along with customer satisfaction.

For mission-critical networks, 3rd Generation Partnership Project (3GPP) standardized 4G and 5G cellular technologies are a practical way of providing connectivity for sensor and control devices.

Distributed automation creates active, self-healing networks that can automatically analyze and respond to changes and disturbances. The many applications—and benefits—include:

+ **Remote monitoring and control:** Automated systems give utilities the ability to remotely operate and reconfigure devices across the distribution networks, such as switches, transformers, and capacitors. This ensures optimal power flow, load balancing, and voltage regulation, improving network efficiency and reducing the need for manual intervention.
+ **Power quality management:** Through continuously monitoring parameters of power quality such as voltage levels, frequency, and harmonics, utilities can detect issues and take corrective action. This minimizes disruptions and helps utilities maintain a stable supply of electricity. By analyzing data from these systems, utilities can identify patterns and trends, to further prevent potential problems and optimize power quality.
+ **Fault detection and restoration:** By using sensors and monitoring devices throughout the grid, utilities can quickly identify issues such as power outages, line faults, or equipment failures and promptly dispatch repair crews—reducing downtime and improving service reliability.
+ **Integration of distributed energy resources (DERs):** Distribution automation systems that monitor and control DERs help utilities optimize DER use, reduce curtailment, and maintain grid stability, for better overall management of power generation and distribution.

DECENTRALIZING POWER TO REDUCE CARBON EMISSIONS AND PROMOTE CLEAN ENERGY

Smart DER systems connected by wireless networks benefit both utilities and the customers they serve.

By integrating diverse energy sources such as solar panels, wind turbines, and energy storage systems like batteries, smart DER systems help utilities optimize available resources. Utilities can store energy when there's a surplus, supply it during times of peak demand, localize power during outages and emergencies, and shift loads throughout to mitigate peaks and avoid overload.

For customers, smart DER systems provide an incentive for generating electricity through rooftop solar panels or small wind turbines and adjusting energy usage based on price incentives or grid conditions.

The next generation of AMI

By bringing utility meters together with digital electronics and wireless connectivity, advanced metering infrastructure (AMI) delivers many benefits.

First, utilities can remotely connect and disconnect services, monitor energy usage, and view the health of the distribution grid. Furthermore, smart meters collect data more frequently and accurately than traditional manual readings, enabling faster outage response, more precise outage mapping, and improved restoration efforts. Finally, the software platforms and algorithms of advanced AMI solutions give utilities the ability to analyze this data. Utilities then can identify consumption patterns, detect anomalies, and develop targeted energy efficiency programs.

As AMI technology from the early 2000s approaches the end of its expected life, "AMI 2.0" with its more sophisticated electronics and higher-capacity wireless presents an opportunity to improve monitoring, accommodate distributed energy resources, and more.

> These next-generation meters will offer new functions and capabilities, like edge AI analytics and high-resolution waveform measurement. By deploying these smart meters over public or private 4G or 5G networks, utilities can enable direct communications between smart meters and central management and analysis systems.

Things to consider in an AMI 2.0 solution include:

Interoperability between AMI systems: Smart meters can be connected to collectors or gateways over secure cellular networks.

Distributed network protocol (DNP): Enabling communication between smart grid devices, this protocol is pivotal to migrating devices and rolling out a private 4G network. DNP makes sure devices cut over to the private 4G network can communicate with distribution automation equipment. DNP3 is required for the traffic between data center systems and the devices on a field area network.

Fault indications: By establishing end-to-end connectivity between a MM3 line sensor and the sensor gateway, fault indications flag and communicate disturbances in current.

Capacitor (cap) banks: These help utilities reduce reactive power and improve electrical efficiency. Utilities can use DNP over Low Power Wide Area (LPWA) 4G such as NB-IoT and LTE-M to monitor cap banks, and it's one of the most common use cases for a private LTE solution. Establish end-to-end connectivity between a cap bank controller and the data center's energy management system (EMS), with Internet Protocol Security (IPSec) tunnel endpoints for the cap bank controller and as an EMS firewall.

Voltage regulators: Utilities can use DNP over Low Power Wide Area (LPWA) 4G such as NB-IoT and LTE-M to monitor these devices as well. Connect regulators to an LTE modem and establish end-to-end connectivity with the energy management system.

Circuit reclosers: These minimize outages and improve system reliability by isolating the number of customers impacted by a fault. Establish end-to-end connectivity between a cellular modem-connected device and the energy management system, as done with cap banks and voltage regulators.

Starting a Smart Cities Journey with the Zhaga-D4i Industry Standard

New York | *Deployed on 4G & 5G Networks*

SCENARIO

With smart sensors and connected lighting infrastructure, cities and utilities can improve services, safety, and security while benefiting from more efficient planning and operations, significant energy savings, cost reductions, and enhanced potential for sustainability.

Yet engaging with this digital revolution and using IoT data is easier said than done. When and how can utilities and cities opt in, especially smaller ones with fewer resources, like Mount Vernon, New York?

SOLUTION

The Zhaga Consortium created an industry standard to help.

Zhaga D4i enables streetlights to become the backbone of a smart city, for safety, maintenance, public services, sustainability, and data collection. Sensor Ready streetlights leverage the Zhaga D4i standard for a plug-and play-way to extend streetlight infrastructure over cellular networks.

Mount Vernon began its smart cities journey by upgrading its streetlights to 4000 Sensor Ready LED streetlights and connected lighting controls. The city's streetlights were already sensor-ready, which allowed Mount Vernon to install the sensors easily and securely on the luminaires with a simple twist-lock mechanism. The city then added Signify's Zhaga D4i-certified Outdoor Multisensors—which deliver data on motion detection, ambient noise, and temperature—to a subset of the streetlights.

Mount Vernon's solution uses LTE-M technology and a standardized smart interface with industry-recognized LED drivers and outdoor luminaries, cellular controllers and communication nodes, and sensors. In addition:

+ Smart street light control nodes, certified to D4i Type A for multi-master control capability, work with Type B-certified sensors.
+ Control nodes plug into the NEMA socket, and sensors plug into the Zhaga socket Book 18 interface.
+ When certified nodes and sensors are attached to a luminaire, Mount Vernon can transport the sensor data into the cloud and remotely configure sensing functions.

WHY CELLULAR IS KEY

+ No need for proprietary networks and gateways
+ IT technicians/specialists aren't required for installation, set-up, and maintenance
+ Superior and scalable data backhaul
+ Data transfer requirements are accommodated for evolving applications
+ Cellular reliably and securely enables low-latency, high-bandwidth smart cities applications

RESULTS

Smarter street lighting with sensors has helped Mount Vernon "go above and beyond to make our city the best it can be," according to Mayor Shawyn Patterson Howard. The solution delivers:

+ Noise detection for reinforcing city ordinances
+ Environmental data for city planning and communications related to extreme heat and cold
+ Motion detection to trigger the optimal street lighting for pedestrians and drivers
+ The ability to easily set lighting schedules for different neighborhoods
+ Data for quick response to outages or other lighting issues

Spotting Line Disruptions Without Disrupting Power

Eastern Kansas/Western Missouri | *Deployed on 4G LTE*

SCENARIO

Evergy's service territory includes many rural areas where trees grow into power lines and cause problems. To indicate where tree growth needs a maintenance crew to trim it, the utility has installed thousands of TripSaver reclosers.

But often when these reclosers operate, there is no communications link back to the utility letting them know the event occurred. Repeated operation of the recloser signals that there is a vegetation management issue on that circuit that the utility is unaware of, exposing the utility to more frequent power outages in these areas and leaving Evergy in the dark about where and when issues needed attention.

SOLUTION

Evergy partnered with Ubicquia for a solution. The utility deployed the company's Ubicell lighting control nodes onto lighting fixtures near TripSaver reclosers, leveraging existing LTE networks for the essential connectivity piece.

The Ubicells, equipped with onboard GPS for location awareness and high-accuracy functionality, proved a cost-effective way of detecting and reporting brief power disturbances. Ubicells placed behind non-communicating reclosers improved circuit visibility, allowing Evergy to become aware of voltage and power fluctuations in real time.

RESULTS

This solution has proven promising for future deployments. Because the system uses existing LTE networks, Ubicells can be placed on streetlights or local area/security fixtures such as barn lights on customer properties, anywhere in the service territory. Ubicells can also be programmed to differentiate between momentary and full power outages.

Evergy is using the data these nodes collect to optimize the deployment of its field crews. This further increases grid resiliency while lowering operation and maintenance costs.

Getting Ahead of Distribution Transformer Damage and Repairs

South Florida | *Deployed on 4G LTE*

SCENARIO

With high lightning and storm activity putting equipment like circuits and transformers at risk, Florida Power & Light (FP&L) operates in one of the most challenging environments in the country. How could the utility more effectively spot problems, conduct repairs, and make its grid more resilient—without spending more on operations and maintenance?

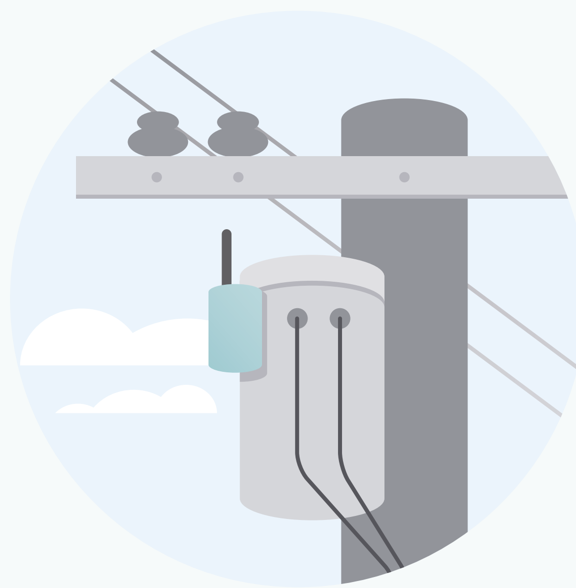
SOLUTION

The answer: retrofitting transformers with new technology to monitor their condition in real time. This gives FP&L the ability to proactively address circuit-level electrical issues driving many maintenance and repair tickets.

FP&L partnered with Ubicquia to develop GPS-equipped wireless sensors. Mounted onto existing pole and pad-mounted distribution transformers, these sensors report location, electrical and mechanical information, and oil pressure and temperature readings every few minutes via an LTE network, providing immediate alerts when a threshold is breached.

RESULTS

Data from the 5,000-plus sensors FP&L has installed to date has provided much insight into both distressed transformers and the root causes of transformer failure. The sensors show true transformer utilization and load on specific parts of the grid. They also notify the utility of actual voltages and the current delivered to customers, to verify that both are within proper limits.



Looking ahead, FP&L plans to deploy sensors that measure primary circuit currents and sensors for larger three-phase transformers that serve critical customer loads. The utility is also working with Ubicquia to create alarms for early signs of dielectric breakdown within the transformer in order to identify damaged transformers needing replacement before they fall and cause customer outages.

Itron: Improving Services with a Multipurpose Network

Chicago, IL | *Deployed on 4G LTE and Itron Gen5 Industrial IoT (IIoT) Network*

SCENARIO

Commonwealth Edison (ComEd) had a mandate to improve overall system reliability and several other goals: improve energy efficiency and asset management, give city managers more control over streetlight operations, and deliver new and better services to its customers.

To accomplish all the above, the utility needed multiple smart grid and smart cities services, partnerships across Chicago area municipalities, and a common network that would support it all.

SOLUTION

The Itron multi-purpose IPv6 IIoT network platform offered such intelligent connectivity.

Comprised of RF mesh, cellular, programmable logic controller (PLC), Wi-Fi, and distributed computing intelligence, it would be able to support an open ecosystem of smart utilities solutions.

For ComEd, this included:

+ Centralized streetlight management
+ AMI for delivering customers more choices and lower energy costs
+ Distributed automation for faster fault detection and power restoration

> The ComEd/Itron implementation involved more than 3.7 million smart meters, 6,100 smart reclosers and switches, a comprehensive suite of Information Technology/Operations Technology (IT/OT) back-office application software, and more.

Through this shared network, ComEd has been able to implement a range of smart utilities solutions, from using smart controls to upgrade 140,000 streetlights to LEDs to bringing in a neighboring utility to support gas AMI.

RESULTS

For streetlights alone, increased efficiencies in operations and maintenance and decreased energy costs reduced management costs by 65%, savings ComEd intends to return to customers each year.

Smarter utility services have resulted in less uncollectable debt . Here ComEd was able to reduce these costs by $30 million—126% of its target.

In the critical area of outage management, ComEd was able to avoid millions of customer interruptions and reduce the frequency of these interruptions, lifting its J.D. Power scores for customer satisfaction.

Further, since ComEd began deploying smart grid and advanced metering infrastructure technology in 2012, overall reliability has improved by more than 80%, with customers avoiding more than 19 million interruptions and saving more than $3.3 billion in outage-related costs through YE 2022.

In 2022, ComEd was named the most reliable electric utility in America.

+ **140,000** upgraded streetlights
+ **65%** reduction in management costs
+ **Most reliable** utility in the country

Using Synchrophasors to Estimate Distribution Energy Resources

Germany | *Deployed on Commercial 4G LTE*

SCENARIO

Communities are installing more distributed energy resources (DERs), from solar panels to electric vehicle (EV) charging stations. Yet today's power distribution infrastructure wasn't designed for such intermittent generation and loads.

In Germany, a nation at the forefront of the energy transition, utilities are investing in cost-effective, minimally disruptive ways to achieve DER visibility and therefore safe, efficient network operations. For one major utility, this investment involved distributed system state estimation (DSSE) by Zaphiro Technologies.

The DSSE solution uses phasor measurement units (PMUs) installed in strategic locations to collect synchrophasors, time-synchronized numbers that represent the magnitude and phase angle of sine waves found in electricity. It creates an accurate digital twin model of the network that estimates the status of network voltage, current, and power flows in real time.

SOLUTION

PMU-based DSSE typically sends synchrophasor measurements to a central software platform via fiber communication. Because fiber was not available for this utility's selected site, the utility used a public 4G LTE network from a local provider.

To bring the solution to life, the utility:

+ Installed seven PMU devices in two medium-voltage feeders to collect synchronized and high-speed measurements of voltage and current synchrophasors
+ Installed a 4G LTE router in every PMU device and established separate virtual private network (VPN) tunnels between each device and the cloud-based software platform. This enabled real-time data communication.
+ Logged measurement and state estimation data in a long-term database for offline analysis

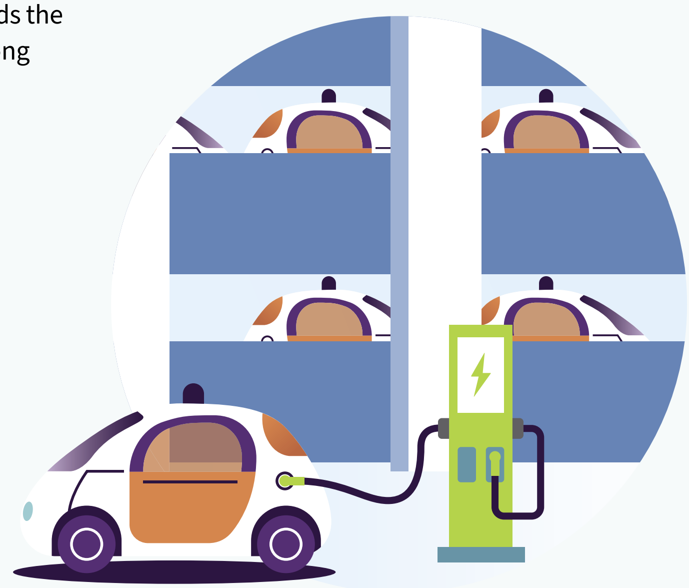
RESULTS

The utility met its accuracy threshold of 1% error for voltage estimations and 10% error for estimating the network's current state. In addition, overall process latency showed that the solution could be used for both real-time operations and offline applications such as grid analytics, root cause analysis, advanced planning, and predictive maintenance.

> Overall, the utility found public LTE to be a cost-effective and ready-to-use alternative to traditional fiber network for PMU-based DSSE.

For others pursuing this path, the utility noted that a lack of specific service level agreements (SLAs) with network providers might cause sporadic periods of increased packet losses and latencies.

The utility also noted that private networks have been deployed to offer more robust security controls. Not only does this increase protection and control, it offers utility grids the increased coverage they need in remote areas along with benefits such as increased data capacity, reliability, and resiliency, and lower latency.



Mobile-Ready Shutoff Solutions

King City, CA | *Deployed on a 5G Fixed Wireless Network*

SCENARIO

Shutting off the power grid during dangerous weather conditions prevents power lines from becoming ignition points for falling or windblown debris. This mitigates the risk of wildfires.

When King City discovered that its shutoff solutions had inadequate backup power, city officials sought a rapidly deployable uninterruptable power source (UPS) to keep critical public safety cameras and networks online.

SOLUTION

King City's solution was a real-time citywide monitoring system with an outdoor UPS by Solis Energy and hardened surveillance cameras by Axis Communications. High-bandwidth, 5G millimeter-wavelength backhaul radios by Siklu provide communications. The solution is readily deployable by a two-person crew and effective for power blackouts lasting up to a week.

While King City's specific solution was a semi-custom design, the municipality noted the value of a standardized mobile unit like a pallet-mounted system with battery backup, surveillance, and 5G backhaul capabilities. Such equipment could be shipped to a site via conventional freight channels to quickly strengthen infrastructure resilience without heavy investments into transportation or site preparation.

RESULTS

After a complication-free installation, King City now has cameras that stay online during public safety power shutoffs and a 5G backhaul radio keeps information flowing even when other local networks go down. Because of the deployment's success, the city is looking into integrating other critical applications, including water utility management, onto the network.

Spotting Damaged Utility Poles with Greater Speed and Precision

South Florida | *Deployed on 4G LTE*

SCENARIO

The faster and more accurately utilities can assess storm and wind damage to utility poles, the sooner they can restore power and either replace or reinforce these assets. To this end, Florida Power & Light (FP&L) implemented a new family of sensors for cost-effective, real-time monitoring.

SOLUTION

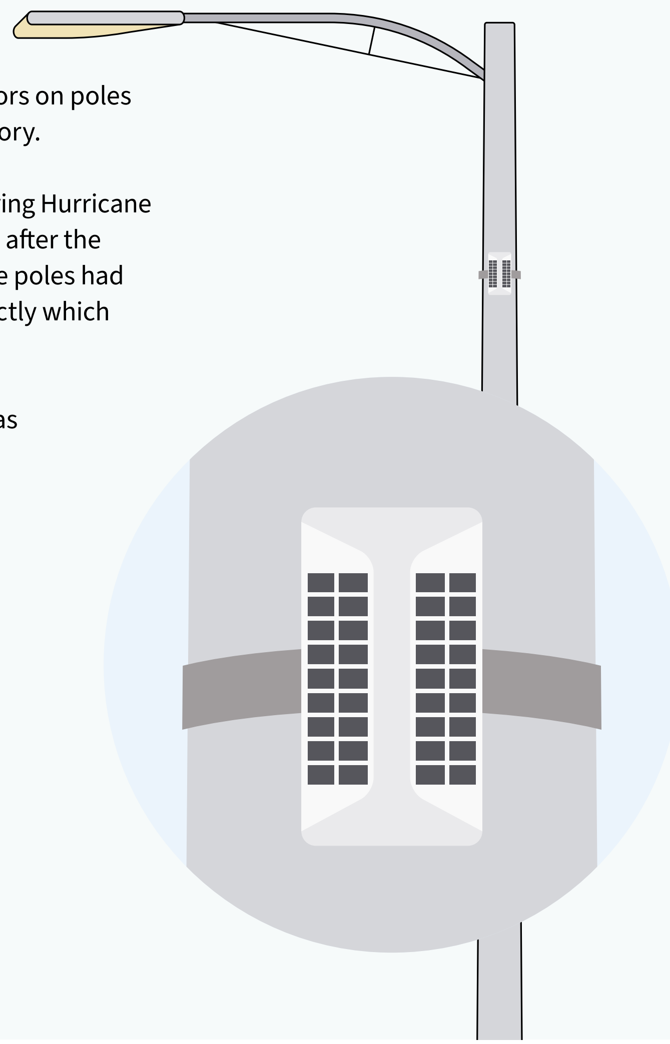
FP&L partnered with Ubicquia to develop solar-powered tilt/vibration (TVM) wireless sensors equipped with dual rechargeable batteries and capable of self-powering for 10 years. Onboard GPS enables the sensors to report their exact location and provide daily information on pole tilt, vibration, and solar panel and battery status. FP&L receives immediate alerts for any reading that exceeds the utility's threshold.

RESULTS

FP&L installed approximately 4,000 TVM sensors on poles in the western coastal area of its service territory.

All nodes maintained LTE communications during Hurricane Ian in late 2022. Data from before, during, and after the storm revealed that approximately 2.6% of the poles had a significant tilt. GPS coordinates showed exactly which poles were affected.

This sensor data enabled FP&L to identify areas where pole restoration was most needed and validated the capabilities of the TVM sensors and LTE communications, laying the groundwork for future deployments.



Turning an EV Charger into a Grid Powerhouse

New York | *Deployed on 4G LTE & 5G networks*

SCENARIO

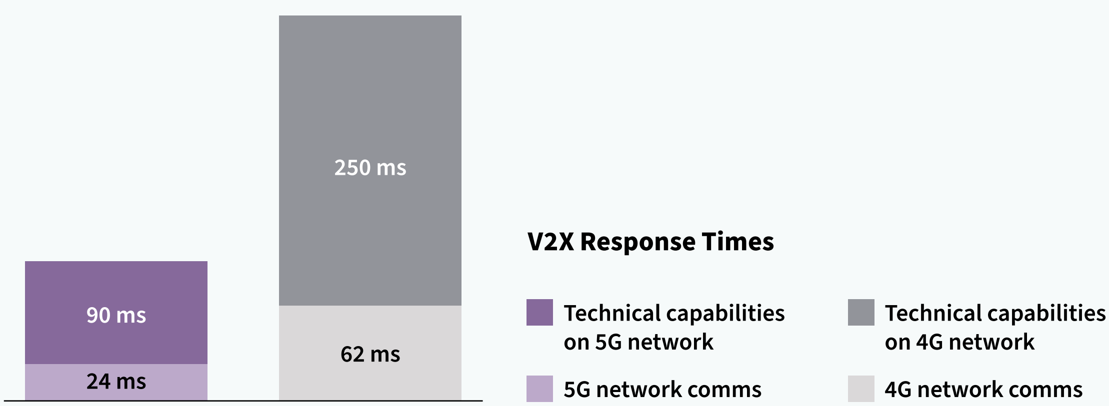
Fermata Energy's Vehicle-to-Everything (V2X) technology turns electric vehicles (EVs) into battery storage assets, enabling EVs to send energy to a building or the grid and support grid resilience. Brooklyn-based technology accelerator Newlab discovered its power during Hurricane Ida.

At the beginning of the storm, Newlab and Verizon were demoing a Nissan LEAF plugged into Fermata Energy's FE-15 bidirectional charger and managed by the Fermata Energy V2X cloud software. Throughout the rest of the meeting and that night, the Fermata Energy V2X platform managed the energy load of the Newlab building.

This demo spurred further thinking. Utility substations need to be able to respond swiftly to changing grid conditions, especially given the growing density of distributed energy systems and the fleets of EVs connected to them. Applications that involve photovoltaic (PV) smoothing and frequency response require low latency and high reliability between the controls that process decisions and the chargers that execute them.

How would different communications networks affect these functions, including a utility's ability to deliver data in near real time and quickly load-balance and optimize the grid?

> No other systems right now work as quickly as 5G and edge computing, a distributed computing paradigm which brings computation and data storage closer to where it is needed, improving response times and saving bandwidth.



SOLUTION

To answer this question, Verizon compared 4G LTE and 5G technology performance on V2X's vehicle-to-building system.

Using one Nissan Leaf EV paired with Fermata Energy's bidirectional charger, the team linked the software with a wavelength Amazon and Verizon product called the EDGE. The goal: see how fast it would communicate with the EV. Instead of using 4G LTE, the team enabled the system with the latest Verizon 5G network.

The team used the Fermata Energy cloud control system to monitor the state of vehicle chargers and the energy load of the building. VPN tunnels over cellular connections link the system to the remote networks containing the chargers and building load meters.

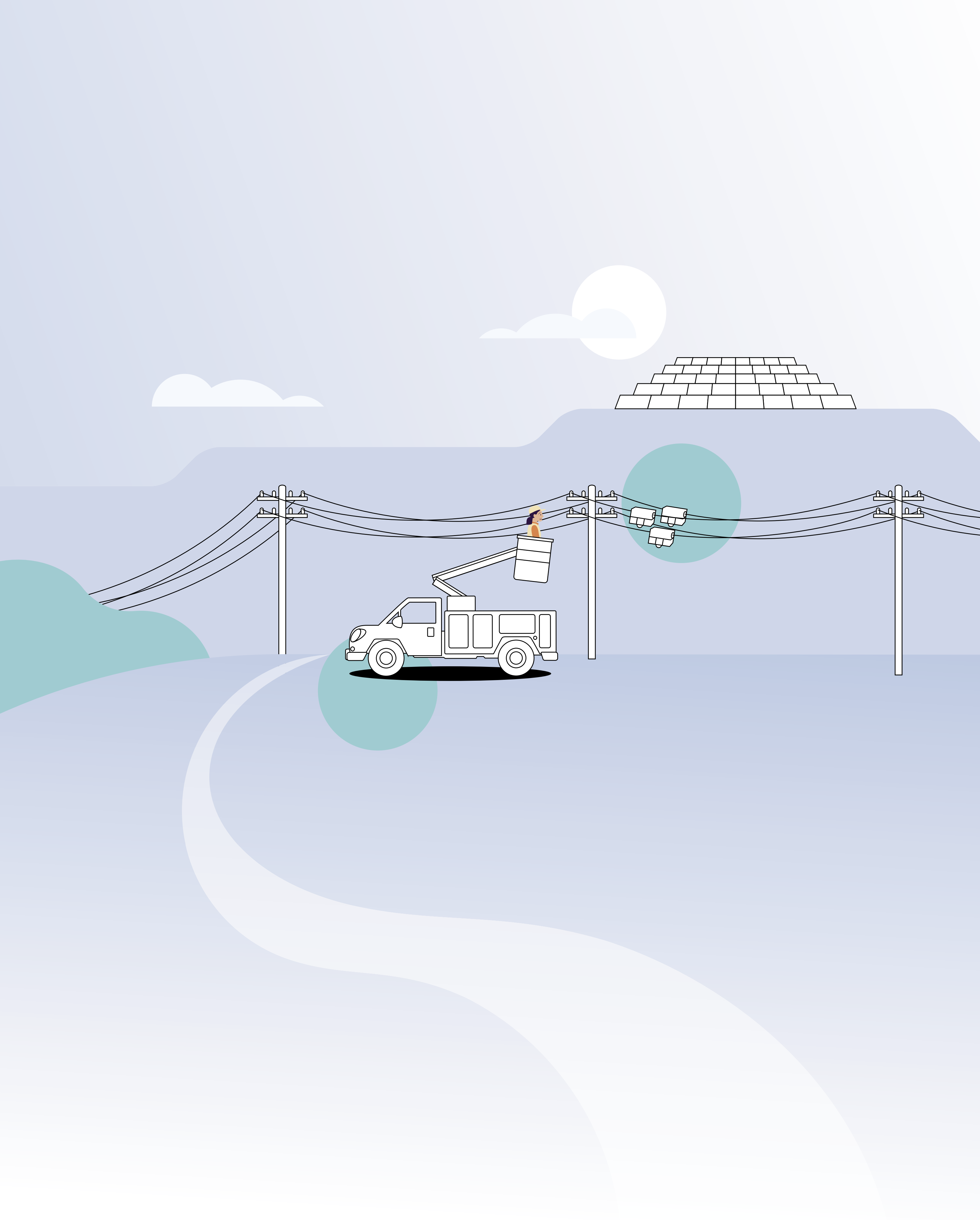
RESULTS

With a normal response time of under 100 milliseconds, the Verizon 5G/AWS Wavelength network pathway outperformed Newlab's existing 4G LTE/datacenter pathway, which reported a normal response time of over 300 milliseconds.

Today the Fermata Energy V2X charger is either charging EVs or powering the Newlab building, with the ability to power 10% of the building's electrical load.

Fermata Energy has created utility protocols for its platform and is working closely with utilities to design programs and optimize utility signals for sending energy from EV batteries to buildings.

This technology can also be used for microgrids, compressed versions of the larger electrical grid, and virtual power plants, which are anticipated to become highly valuable resources as hurricanes, wildfires, floods, and other natural disasters impact communities more frequently.



Advanced Communications and Connectivity

Advanced technologies like automation, connected by advanced communications, can help utilities work more safely, productively, and efficiently. They streamline workflows, improve communication, deliver real-time access to critical information, and more.

Mobile workforce management is one example. Specialized software enables efficient scheduling, dispatching, and work-order tracking from the central office. Meanwhile, field personnel can use smartphones, tablets, and other devices to navigate to job sites, access details about equipment condition, maintenance, and spare parts, and update the status of a job in real time.

GPS-equipped wearables protect workers in the field by enabling utilities to monitor worker conditions, detect hazards, and alert teams about emergencies. Augmented and virtual reality technologies strengthen safety even more by delivering an enhanced training and maintenance experience. Technicians are able to see digital information like equipment schematics, instructions, and diagnostic data overlayed onto a real-world environment.

Wireless-connected drones expand the view. These smart devices enable workers to inspect transmission lines, substations, wind turbines, and poles or towers remotely. For both routine maintenance and emergency response, utilities are able to act faster and keep workers safe.

Teams at the 2022 Utility Broadband Alliance Summit & Plugfest demonstrated interoperability between land mobile radio and LTE mission-critical push on live networks.

3GPP: BRINGING LAND MOBILE RADIO INTO THE FUTURE

For decades, land mobile radio (LMR) has been a proven, reliable technology for mission-critical, two-way communications. Yet much LMR infrastructure today is aging and in need of modernization.

Think, for example, how workers are increasing their use of data services over push-to-talk LMR devices—and how they are hindered by voice-centric, low-throughput legacy LMR networks.

3GPP standardized technologies address these challenges by meeting push-to-talk, video, and data requirements for both 4G and 5G networks. What's more, 3GPP supports interoperability with legacy LMR, enabling users to communicate across multiple networks until the legacy system is retired.

Here are some things to consider when implementing advanced communications and connectivity:

Fiber backup is critical for a seamless transition from existing fiber technologies. This involves configuring the private 4G LTE network to provide back-haul transport for gateway-connected mesh radios and reconfiguring the lab recloser to connect to a primary/secondary pair of narrow-band mesh radios. The goal is for the private LTE network to serve as the backhaul for the mesh radio network and provide the backhaul for mesh AMI user data.

Wireless failover is also important, as it's the bridge between today's public LTE networks and evolving private LTE networks. Here, devices need to be set up either with one SIM for the public network and one for the private network or with a single SIM that has public and private IMSIs. Ideally, utilities should be able to determine latency and transition conditions as a smart grid device moves from one network to another.

Over-the-air firmware updates—the ability to perform software updates on remotely connected devices—are among the many benefits of a private LTE network, reducing operating costs in areas such as truck rolls.

Expanding possibilities with IEC 61850/GOOSE and private LTE

The IEC 61850 standard for substation communications, widely used in Europe and outside of North America, is in the early stages of adoption in the US and Canada. This standard defines generic object-oriented substation event (GOOSE) protocols and sampled values (SV) for event-based, intra-substation communications using layer 2 ethernet to eliminate the additional latency associated with layer 3 routing.

The protocol suite includes device-to-multidevice and "publish/subscribe" communication protocols. It was extended to include Routable GOOSE, Routable SV, and R-SV (IP-based variants) for inter-substation communications. This extends its utility outside of the substation and into the distribution network.

Private LTE networks expand what's possible with GOOSE and with advanced communications and connectivity overall. By using a private LTE network, utilities can:

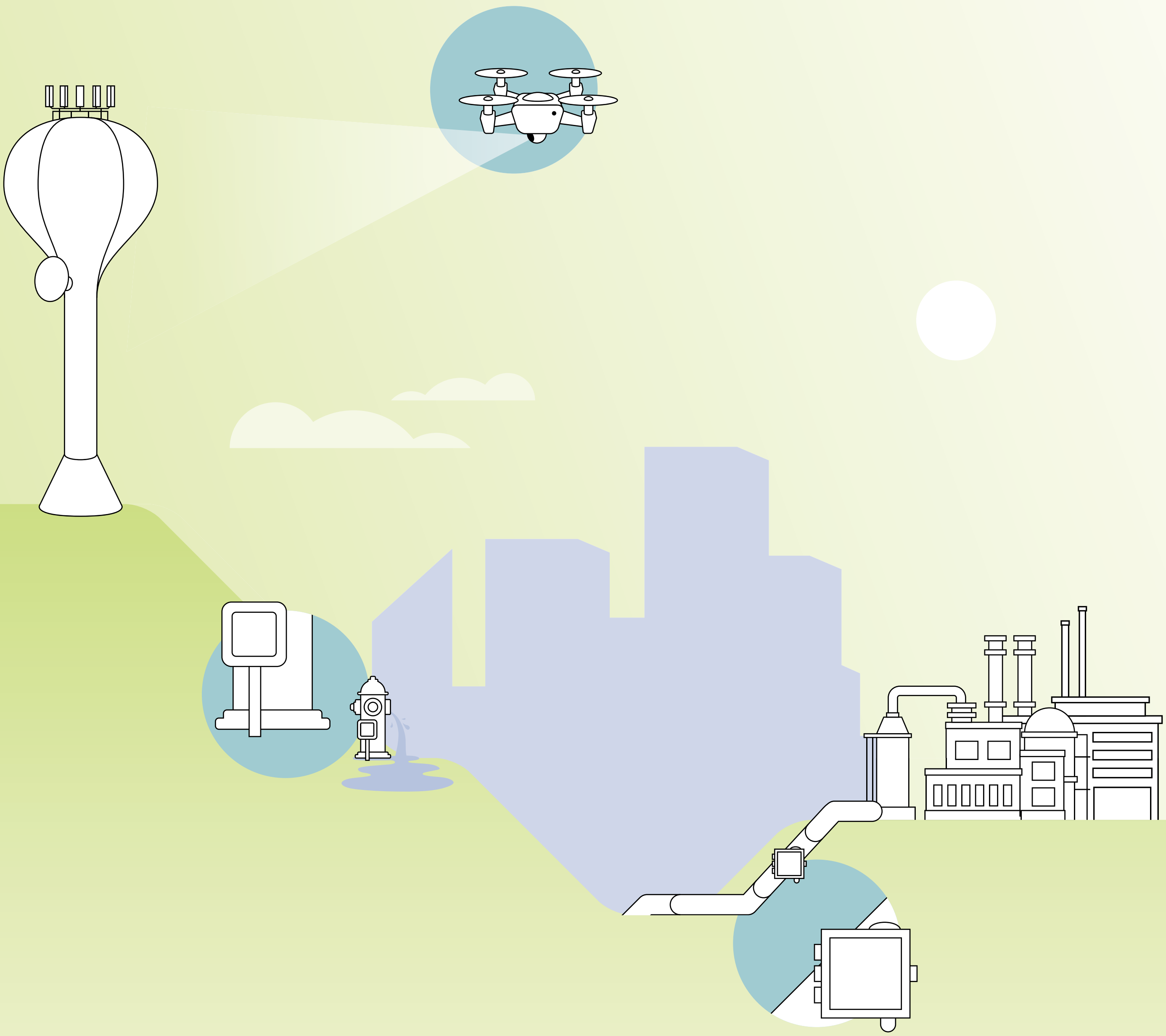
+ Implement advanced LTE features like ultra-reliable low latency communication, which can reduce latency into the single digits
+ Implement multicast and broadcast service, to extend regular GOOSE outside of the substation
+ Reduce or eliminate hard-wired Local Area Network/Wide Area Network (LAN/WAN) circuits, to substantially reduce the cost and complexity of introducing IEC 61850 into the utility environment

GOOSE AND SV PROTOCOLS TRADITIONALLY SUPPORT:

+ Protection switching/teleprotection
+ Interlocking protection schemes between substation switch gear and localized automation/control systems
+ Power quality measurements like PMUs
+ Highly precise time synchronization

OUTSIDE OF THE SUBSTATION, GOOSE SUPPORTS:

+ Direct transfer trip, to eliminate ground switching on transformers
+ Checks of remedial action and system integrity during system failure and overload
+ Detection of broken or downed wires
+ Load shedding during demand-side management



Water and Gas

While water and gas distribution systems are often less operationally complex than electric utilities, these entities can also use wireless connectivity like private LTE networks to improve visibility, efficiency, safety, and cost effectiveness.

One way is through leveraging the power of LTE-connected smart meters and low-power, reduced-capability devices that have a longer battery life. Such IoT solutions expand the possibilities for pipeline leak detection, flow control, and remote monitoring and control, from pumps, valves, and water distribution sensors to irrigation systems and other field equipment.

> When Synergistic Solutions International used drones to inspect water tanks in a time- and energy-efficient way, avoiding the need to drain and refill them, the savings added up: 1 billion gallons of water and $12 million.
>
> *(AT&T)*

CONNECTED UTILITIES IN ACTION

Meters and low-cost hardware deployed over Low-Power Wide-Area (LPWA) networks can help utilities save power, detect malfunctions, and prevent outages—even across areas of varying cellular coverage

+ **Monitoring pipelines:** Omnimetrix reduced $300,000 in fuel and labor costs and 8,500+ hours drive time while avoiding almost 200 metric tons of CO_2e.
+ **Tracking performance:** Enphase increased solar production by 735 kWh while avoiding 160,000 miles of driving and over 6,600 metric tons of emissions.

(AT&T)

Remote Monitoring that Reduces Leaks and CO_2 Emissions

Nationwide | *Deployed on 4G NB-IoT and LTE-M Cellular Networks*

SCENARIO

More than 2.6 million miles of oil and gas pipelines crisscross the United States. As oil and gas companies transition to less emission-intensive energy sources, they must monitor and maintain these pipes to address safety concerns and limit leaks. In fact, the Pipeline and Hazardous Materials Safety Administration (PHMSA) requires pipeline inspections every two months.

But inspection points are typically five to 10 miles apart, and the actual driving distance between them can be much longer. Even for just a few onsite inspections a day, the hours, fuel costs, GHG emissions, and environmental impact add up.

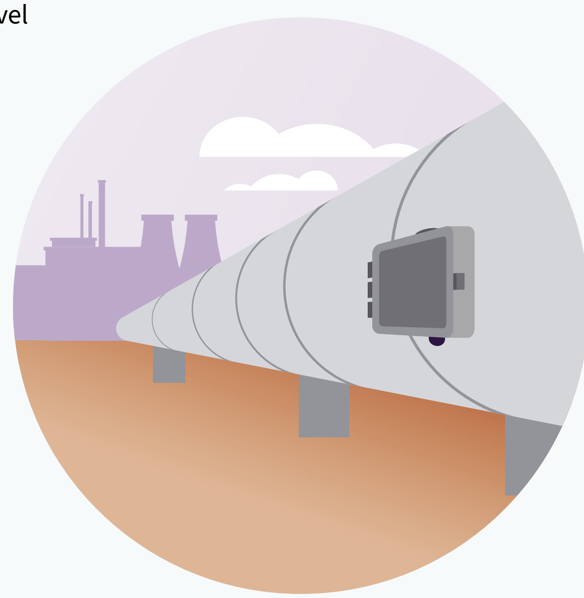
SOLUTION

OmniMetrix has found a more efficient—and energy-efficient—way. This provider of critical asset management services uses an AT&T Internet of Things (IoT) remote monitoring solution to help customers monitor the condition of their steel pipelines. This system both reduces the GHG emissions associated with inspectors driving from site to site and collects detailed, timely information about pipeline health, helping companies reduce leakages.

RESULTS

Across multiple pipeline companies and thousands of sensors, the AT&T IoT solution not only reduced inspection travel time, labor, and fuel costs, remote monitoring shrunk fuel usage by around 22,000 gallons of gas a year—equivalent to almost 200 metric tons of CO2e4.

The solution team noted that it is currently very difficult to collect data on methane emissions, as many factors impact the reduction of these emissions from pipeline infrastructure.



Smart Water Data, Delivered

Columbia, SC | *Deployed on a 4G Wireless Network with Advanced Metering Infrastructure*

SCENARIO

The City of Columbia and Columbia Water—driven by the core values of accountability, transparency, and integrity—were looking for a way to enhance the customer service experience for 400,000 water and wastewater customers.

SOLUTION

Columbia Water partnered with Badger Meter to replace touch-read meters with a cellular AMI solution across its entire 320 square mile service area.

These Recordall® Disc Series and E-Series® Ultrasonic meters, coupled with ORION® Cellular LTE-M endpoints, deliver data at 15-minute intervals to a BEACON® Advanced Metering Analytics (AMA) solution. Customized dashboards deliver system-wide information to desktops and devices. Alerts proactively monitor exceptions, and automatic software updates maintain accuracy.

Through the EyeOnWater® mobile app, consumers can monitor their water usage patterns and set consumption and leak alerts. Data from across the system, from digital water meters to utility billing centers, helps improve meter-reading efficiency and billing accuracy.

The solution leverages existing cellular networks throughout, which eliminates the city needing to maintain its own communications infrastructure. The system is easy to upgrade and expand as service demands change. Delivery over cellular networks helps ensure that water systems remain online, safe, and secure.

> "The Badger Meter technology allowed us to deliver an AMI solution quickly and responsively, as well as cost-effectively."
>
> *– Carmen Flemming, senior program analyst, program management office, Columbia Water*

RESULTS

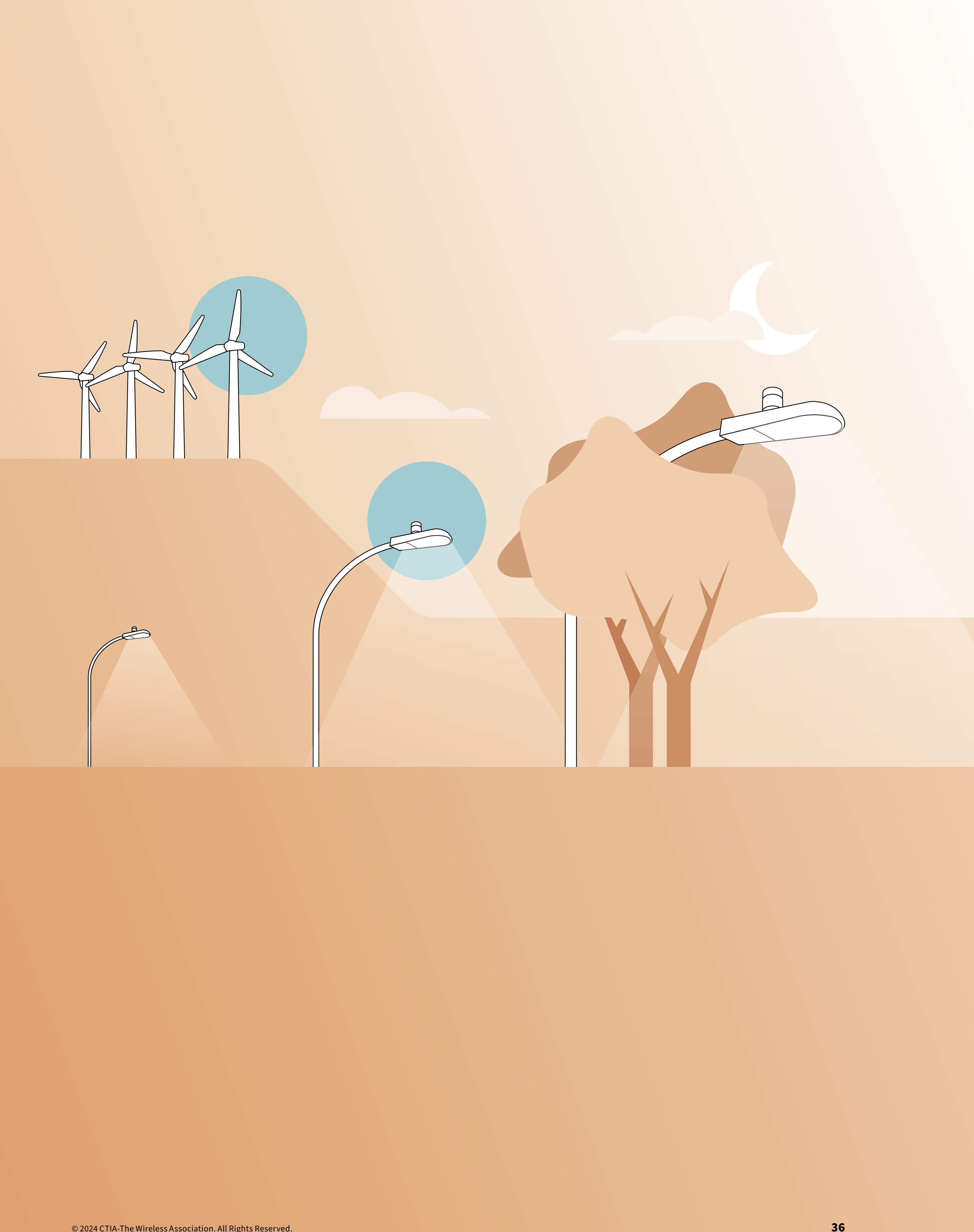
With upgrades to over 150,000 services, the changeout project is the largest deployment of cellular AMI at a North American water utility to date. It's also a powerful example of how smart water technologies give utilities access to more information for decision-making and infrastructure management. Improved meter-reading accuracy, for example, has given Columbia Water the ability to:

+ Eliminate estimated bills
+ Reduce truck rolls for meter reading re-checks by 96%
+ Reduce customer complaints regarding water bills
+ Reduce inactive water-consuming accounts by 21%

What's next? According to the solution team, smart water systems shouldn't just address current challenges. The right solution should help a city or utility meet future goals and objectives, too. Today's smart water systems enable utilities to upgrade and expand as they grow and integrate their efforts with other smart systems for efficient city management.

WHY CELLULAR FOR MISSION-CRITICAL COMMUNICATIONS?

As severe weather and natural disasters become increasingly frequent, municipalities are pressed to make their water systems more resilient. The cellular networks millions of people rely on for daily communication offer a powerful solution. These networks are managed, monitored, and maintained to 99.999% uptime to keep individuals connected, even in an emergency. In fact, cellular networks are among the first services restored after a big storm or natural disaster.



Applying Advanced Technologies to Your Utility

Across models of grid ownership—private, municipal, co-op, and Investor-Owned Utility (IOU)—utilities have a common mission: delivering resilient, high-performance services to customers while operating efficiently and sustainably. Modernized grid equipment, controls, and utility management can be a step forward in this mission: improving grid resilience, restoring services faster, and facilitating insights from data-rich connected devices and sensors.

In this section, we'll explore how different ownership models have successfully modernized utility operations and the benefits utilities are seeing today.

Accelerating Streetlight Innovation

Baltimore, MD | *Deployed on a Wireless Mesh Network*

SCENARIO

Baltimore Gas & Electric (BGE), an Exelon company, had an ambitious goal: roll out over a quarter million wireless smart lighting nodes to lower the utility's carbon footprint, reduce outage resolution time, enhance operational excellence, and improve service.

BGE aimed to leverage technology throughout: using mobile field apps for deployment and maintenance, detecting outages via wireless networks rather than customer reports, and using data analytics to reduce truck rolls. The mission also involved synchronizing and maintaining data across asset management records, GIS applications, and other back-office systems.

SOLUTION

To accomplish all of this and more, BGE deployed TerraGo's cloud-based streetlight operations platform, integrated with Itron's Streetlight.Vision central management system.

With the TerraGo platform, BGE can continuously track smart nodes as they're installed and commissioned, with full chain of custody. TerraGo inventory management identifies bottlenecks and helps eliminate delays. The utility can also track all warranty and asset records for future maintenance.

BGE crews use the TerraGo mobile app to install and commission wireless network controls on the city's streetlights. Configurable workflows guide crews through smart control installations while capturing and validating essential data related to pole attachments, stop signs, cell phone antennas, and surveillance cameras. These guided workflows enforce quality control, prevent errors, and accelerate installation.

Post-installation, TerraGo performs remote triage on system alarms, dispatches crews, and guides personnel with step-by-step workflows to resolve outages efficiently and correctly the first time.

The solution leverages the existing Itron IIOT wireless network throughout, which will also enable future smart city applications. The system is easy to upgrade and expand as service demands change.

RESULTS

With TerraGo, BGE crews are able to install nodes faster and resolve problems more quickly, accurately, and efficiently. In an optimal scenario, a BGE field crew can fully complete a smart streetlight installation in six minutes or less.

Once wireless controls are deployed, both lights and people work smarter. As just one example, BGE previously diagnosed streetlight problems by sending out a bucket truck and having a crew examine the fixture from the top down, reassigning the repair and rolling another truck as needed. Now the system can discern the nature of the problem in advance and automatically dispatch a crew with the right skills the first time.

Behind the scenes, BGE's smart lighting operations have gone completely paperless, with fully digital, automated operations from planning and installation through inventory management, maintenance, and the creation and assignment of work orders.

Wireless edge devices and mobile field operations apps can transform operations and maintenance, the team noted.

Yet it's important to remember that networked lighting involves more than just screwing dumb photocells on top of existing lights. These wireless cyber assets require a deployment strategy, process control, and cross-platform data management.

Furthermore, as wireless lighting nodes automatically collect valuable data, utilities must commit to the next steps of analyzing, integrating, and using this information.

Grid Modernization for Improved Safety and Service

United States | *Deployed on AT&T FirstNet Cellular Network*

SCENARIO

An investor-owned utility (IOU) needed to make communication upgrades for critical infrastructure devices across multiple states, including the reclosers that help clear obstructions like tree growth on power lines.

These upgrades would be complex to install, and the utility would need to minimize operational downtime throughout. For these reasons, the IOU explored a retrofit approach to grid modernization, with an emphasis on scalability.

SOLUTION

An IoT solution over an AT&T FirstNet cellular network transformed a communication upgrade into total grid modernization. The turnkey solution included design, customized hardware, enclosures, and software, plus maintenance and full project management for the life of project.

RESULTS

The IOU is now able to detect faults in near real time, improving power restoration after outages.

But this was just one of the solution's many benefits. With advanced circuit protection to protect and manage devices across its critical infrastructure, the IOU now had increased visibility and control across its grid.

Operations became more efficient and cost-effective, too. Remote control over the network helped the utility optimize resources, such as using more reclosers and fewer truck rolls to address tree growth.

Throughout, improved communications and control across a multi-state service area enhanced the utility's mission of customer service and public safety.

Canoochee EMC Smart Lighting

Southeast Georgia | *Deployed on 4G LTE*

SCENARIO

Canoochee EMC monitors nearly 12,000 light points for Fort Stewart and Hunter Army Airfield. The electric cooperative realized it needed a smart lighting solution.

Maintenance costs have increased significantly, and regular reporting of energy uptime and outage response has become a very manual and labor-intensive process. Legacy infrastructure lacked the flexibility and real-time alerts necessary to address the military installations' lighting issues. Finally, as the remote nature of the service territory precluded network buildouts, Canoochee EMC needed to find other ways to achieve cost-effective service.

SOLUTION

Canoochee EMC partnered with Ubicquia on a modern, real-time lighting control solution leveraging existing LTE networks. The electric utility replaced its legacy lighting solution with Ubicquia Ubicells, nodes that plug into the NEMA sockets of existing lighting fixtures for immediate commissioning once powered up.

The Ubicquia solution give the bases control and metrics for the lighting network and Canoochee EMC revenue-grade metrology for the lights to measure energy consumption. The LTE networks provide sufficient cellular coverage for real-time reporting and control of the lighting platform.

RESULTS

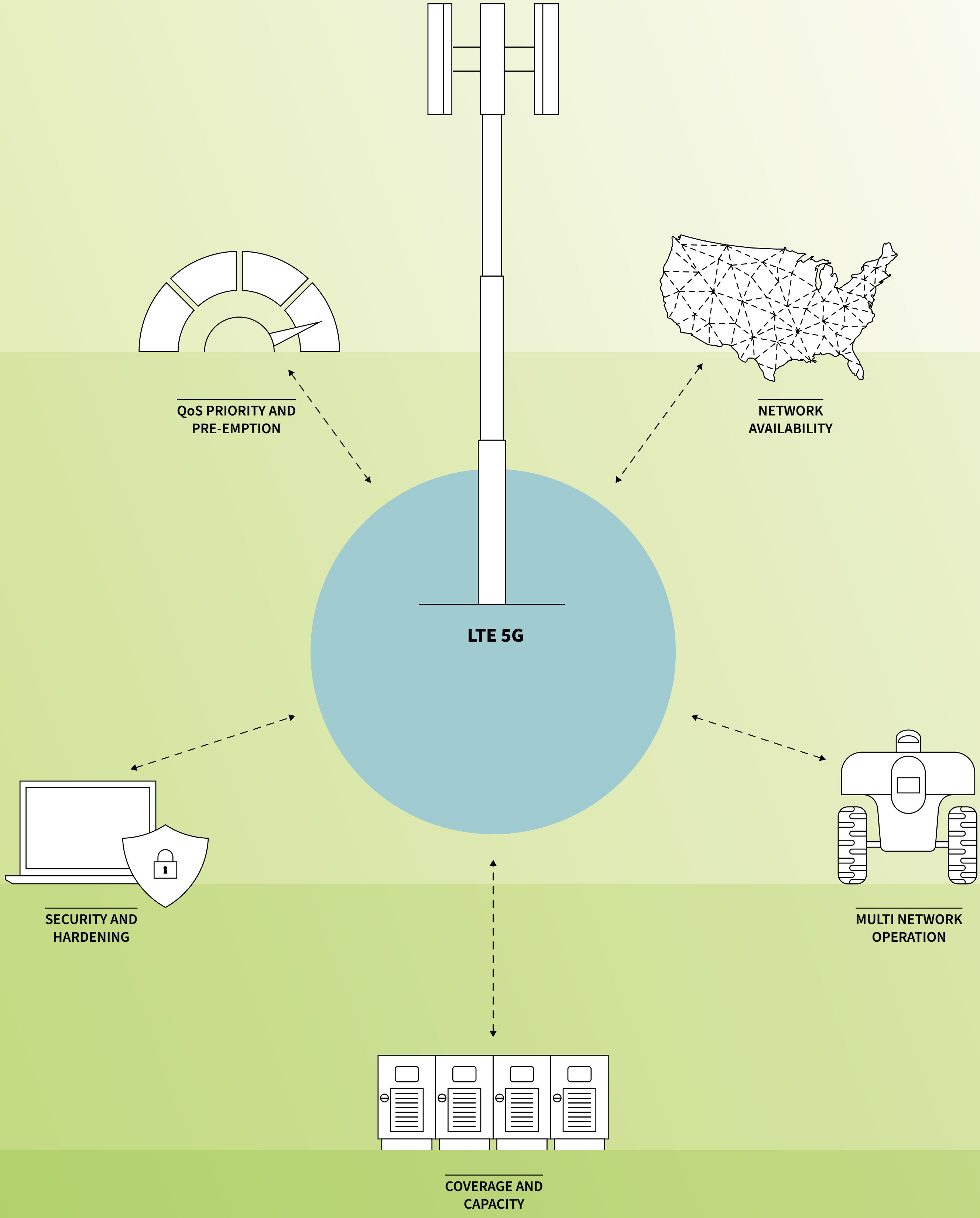
With several thousand nodes now installed, Canoochee EMC reports increases in both system uptime and annual energy savings. Notably, the electric utility has reduced its response time to outages on the military bases by 75%.

THE POWER AND POTENTIAL OF SMART LIGHTING

+ **Multiple platforms:** LED lightning retrofit, advanced lighting controls, utility-grade energy metering, tilt and vibration sensors, third-party sensor integration
+ **Wide-ranging benefits:** Reduced energy use, reduced emissions, improved public safety

(AT&T)

Mission Critical Capabilities



Special Considerations for Mission-Critical Networks

Many electric utility services are essential for business, daily life, and safety. To remain up and running and meeting expectations, the networks supporting these services have functionality, availability, capacity, and security needs beyond those of consumer-grade networks.

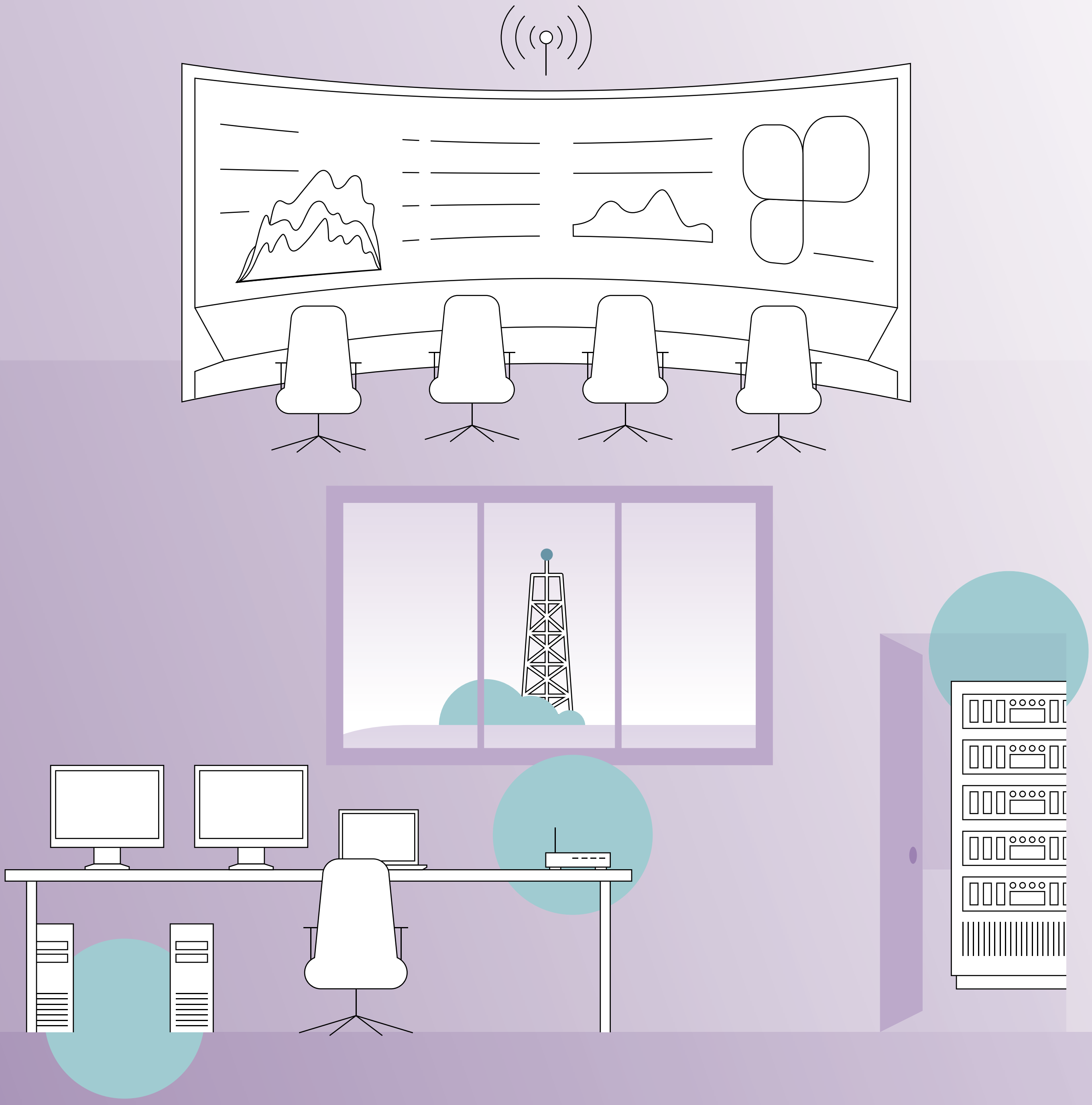
+ **Network availability** is about making sure that a multi-channel network is ready to go as planned. Make sure solutions are in place for network and site hardening and congestion control. Also look at system redundancy, redundancy in centralized network controls (check for geo-redundant cores), and transport backhaul redundancy, from cell sites to the network's dual cores.

+ **Multi-network operations** can significantly increase the availability of mission-critical services. One way to achieve this is by implementing wireless failover on endpoint LTE gateway routers. If an event disrupts coverage between the private cellular network and a router, these devices reroute traffic onto an available public cellular network.

+ **Coverage and capacity** on a multi-channel utility network often need to extend beyond what's typically available on consumer networks.

+ **Security and hardening** are a critical part of the multi-layer security that mission-critical networks require and operational and regulatory restrictions demand. Note that you'll need to secure authentication, authorization, and communication integrity to a greater degree than is necessary with consumer networks.

+ **Quality of service (QoS), priority control, and pre-emption** ensure consistent end-user performance even during high loads and congestion, measuring network performance for a particular user or application and the network's ability to prioritize and assign resources to specific traffic or applications during congestion. This is essential to make sure that data for real-time critical grid control or critical communications preempts other traffic in a congested cell.



Cybersecurity

Standards-based cybersecurity testing should be an ongoing priority for any network a utility uses: private or commercial 4G LTE, 5G, and beyond.

Also consider full end-to-end security to protect information, infrastructure, users, and devices from threats and authorization protocols for maintaining data integrity and confidentiality. Healthy cybersecurity practices leverage robust controls to avoid congestion and effectively prioritize data according to mission and needs.

A cybersecurity blueprint can help with implementing cybersecurity protocols and meeting cybersecurity goals. Elements of such a blueprint might include:

1. **Both defense in depth and Zero Trust security:** Traditional defense in depth security protects the internal network and perimeter. Zero Trust security augments and complements it by building security into all components: users, devices, applications, data, and the network itself.

2. **Traffic separation and asset isolation:** Separating different traffic types, like Operations Administration and Maintenance (OAM) and Radio Access Network (RAN), enables protection of more sensitive traffic with more stringent security policies and security levels. Security gateways and firewalls play an important role in traffic separation, as do the virtual routers in the cellular core.

3. **Encryption to protect data in transit and at rest:** Use methods such as Advanced Encryption Standard (AES), Transport Layer Security (TLS), Internet Protocol Security (IPsec), and Datagram Transport Layer Security (DTLS) to protect nodes, control plane traffic, and the user plane payload. The network's externally facing Surface Gateway interface (SGi) will require a firewall to give the user plane advanced security. Make sure mobile devices only talk with required applications.

4. **Holistic security management:** This is essential to ensure network security and privacy from end to end, especially as smart utilities solutions increasingly involve virtualization, automation, and the Internet of Things. Be sure to encrypt all protocols.

5. **An identity and access management system:** Use access controls, identity administration, and user provisioning to authenticate and authorize network users and roles.

6. **System-verified network security:** As security threats and attacks on end-to-end networks escalate, utilities will need to strengthen the protection of critical network assets, services, and data in transit and be prepared to mitigate risk for each network area potentially under attack. Ensure quick, effective action by testing these solutions in a range of scenarios.

7. **Secure solutions and operations:** CTIA recommends that utilities align their security blueprint with the specifications of the Third-Generation Partnership Project (3GPP), which unites seven telecommunications standards development organizations, with policies and procedures in place for secure equipment, deployment, and management.

8. **Supply chain security:** Leverage best-in-class practices to comply with governmental and customer requirements and maintain trust in an evolving geopolitical landscape.

A New Standard for Smart Connected Infrastructure

Teams from Ericsson and CTIA Certification have established a first-of-its-kind, industry-recognized standards for testing the cybersecurity and cellular connectivity of IoT devices on critical infrastructure.

IoT Network Certified for Smart Connected Infrastructure™ draws on proven standards to provide best practices for advanced deployments on wireless networks with connected, secure IoT devices.

The standards cover the performance of integrated devices, like a device with an embedded module that's IoT Network-certified, a SIM card, and external antennas. At Ericsson's CTIA-authorized test lab, utilities test the SIM card interface, over-the-air radio, and antenna performance. They can also test on band-specific network simulators and check to make sure there are no radiated spurious emissions.

	LPWA 4G		
	NB-IoT	**LTE-M**	**Broadband 4G**
Battery Life	Up to 10 years	Up to 10 years	Use case dependent
Uplink Peak Throughput/UE	~151 kbps	~1,119 kbps	UE category dependent
Downlink Peak Throughput/UE	~118 kbps	~500 kbps	UE category dependent
Cell Range	Up to 120 km	Up to 100 km	Up to 200 km

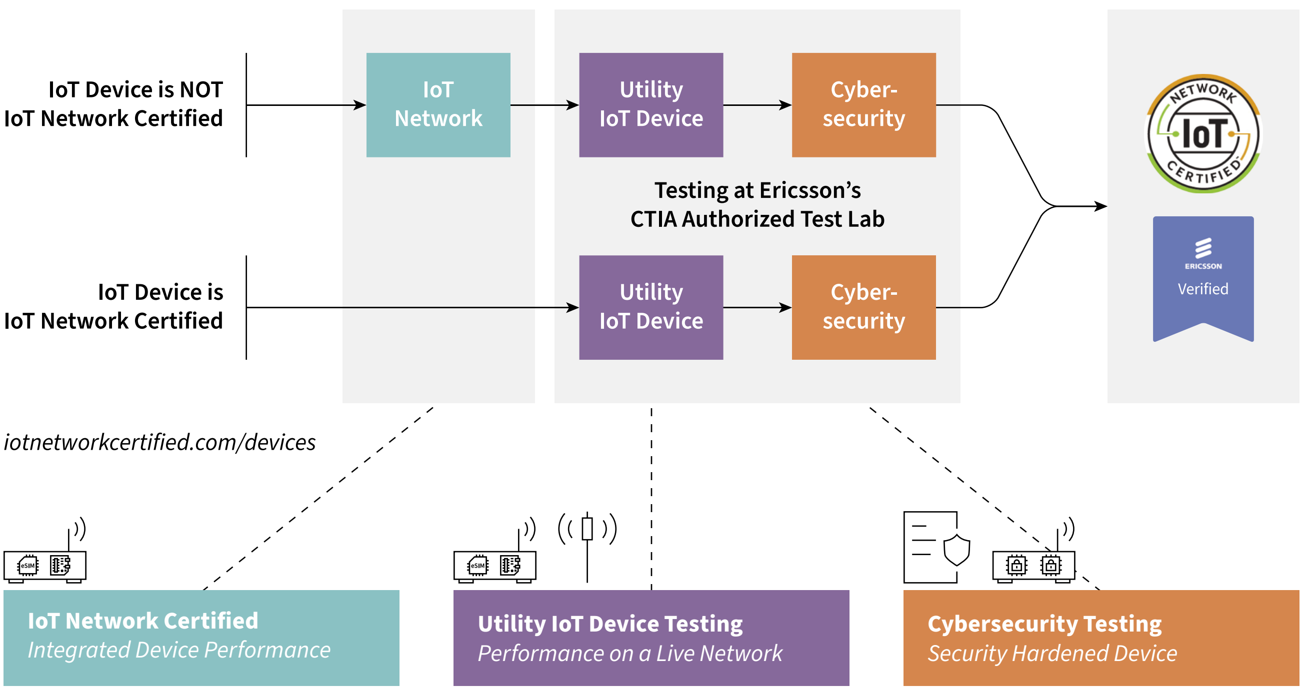
The standards also cover how a device performs over a live network, such as basic functionality on an OEM e2e network, and the cybersecurity of a security-hardened device.

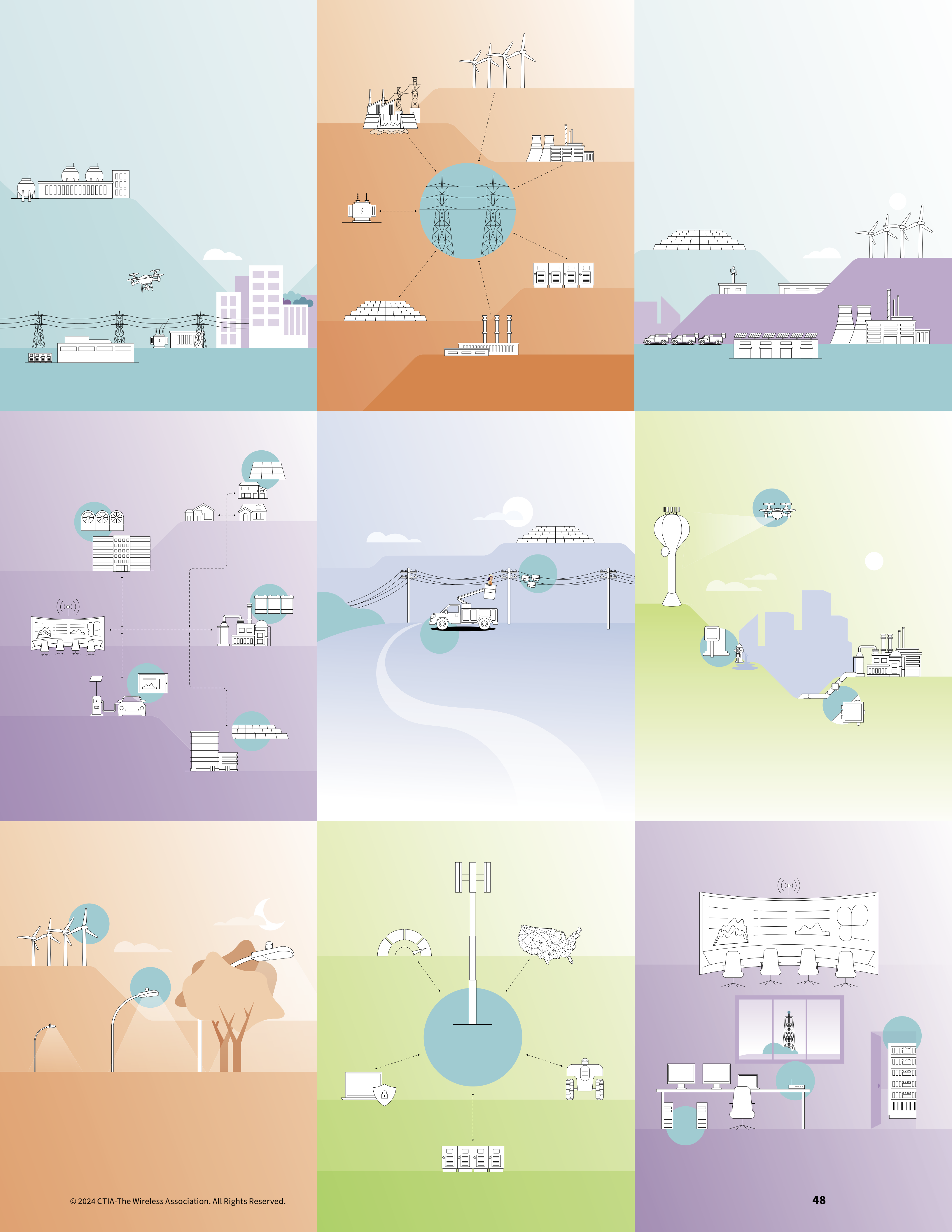
Many use cases require broadband IoT connectivity, which is typically provided by Cat 1, Cat 4, or higher-category LTE modems. These modems are either embedded directly into a utility grid device or integrated into an LTE gateway router connected via ethernet to multiple utility grid devices.

Other use cases can be served by the LPWA NB-IoT and LTE-M radio technologies. These use cases typically involve low-cost devices with long battery life, devices deployed in massive numbers, and very low data usage.

This new certification standard will streamline device screening for smart grid deployment and, by creating a common baseline, help utilities deploy connected devices more confidently and securely. By including this certification in their vendor requirements, utilities can help ensure that devices deployed on the smart grid meets industry standards.

Device-Testing Scenarios and Paths to IoT Network Certified for Smart Connected Infrastructure™





A First Step to a Smarter Future

Advanced wireless networks and devices, like IoT sensors, offer great potential for improving operations, from detecting infrastructure damage to optimizing energy and water usage.

Advances in wireless connectivity are similarly transforming the delivery of data, to help utilities make faster, smarter decisions for business, safety, and customer service. And new communications certifications and standards bring all the pieces together, ensuring interoperability as innovations and applications evolve.

We hope these use cases have been helpful for envisioning what's possible and what's next for your utility or community. And we hope that these guidelines are useful for incorporating certifications into RFPs and partnerships, so we can all work together toward a shared vision of the future.

Learn more about IoT Network Certified for Smart Connected Infrastructure™.

Join Town Square at smartcities.ctia.org

Acronym Glossary

AES	Advanced Encryption Standard
AMA	Advanced metering analytics
AMI	Advanced metering infrastructure
DER	Distributed energy resource
DFR	Digital fault recorder
DNP	Distributed Network Protocol
DSSE	Distributed system state estimation
DTLS	Datagram Transport Layer Security
EMS	Energy management system
EV	Electric vehicle
GOOSE	Generic object-oriented substation event
GPS	Global positioning system
IEC	International Electrotechnical Commission
IoT	Internet of Things
IIot	Industrial Internet of Things
IOU	Investor-owned utility
IPsec	Internet Protocol Security
IT/OT	Information technology/Operations technology
LAN/WAN	Local Area Network/Wide Area Network
LEDs	Light-emitting diodes
LMR	Land Mobile Radio
LPWA	Low-Power Wide-Area
LTE	Long Term Evolution
MWh	Megawatt hours
OAM	Operations administration and maintenance
PLC	Programmable logic controller
PMUs	Phasor measurement units
PQM	Power quality measurements
QoS	Quality of service
RAN	Radio access network
RF	Radio frequency
SDWAN	Software-Defined Wide Area Network
SGi	Surface Gateway Interface
SIM	Subscriber Identity Module
SLA	Service-level agreement
SV	Sampled values
TLS	Transport Layer Security
TVM	Tilt and vibration monitor
TWS	Traveling wave systems
UPS	Uninterruptable power source
VPN	Virtual private network
V2X	Vehicle-to-Everything
3GPP	Third Generation Partnership Project
4G	Fourth generation of broadband cellular network technology
5G	Fifth generation of broadband cellular network technology

About CTIA

CTIA represents the U.S. wireless communications industry and companies throughout the mobile ecosystem. Our members provide the wireless networks, devices, equipment, and solutions that make smart cities possible. This includes the connectivity solutions behind smart utility deployments.

CTIA members are also drivers of 5G, the next generation of wireless. As advanced networks roll out across the nation, 5G will allow up to 100 times more simultaneous connections, up to 100 times faster connectivity, and lower latency, which is key for innovations like intelligent transportation systems.

Due to the tremendous amount of private investment necessary to bring advanced networks to life, collaboration between industry and the public sector is paramount. As we look ahead to the exciting possibilities of smart cities technologies, CTIA is committed to helping communities of all sizes become the cities of the future.

Acknowledgments

This guide was created in collaboration with:

+ Ameresco
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+ Ericsson
+ Flashnet
+ Generac Power Systems
+ Itron
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+ Signify
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