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WHITE PAPER

Communications in the Energy Cloud

The Energy Superhighway and the Future of Grid Connectivity

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Section 1
EXECUTIVE SUMMARY

1.1 Introducing the Energy Superhighway

Navigant Research introduced the Energy Cloud paradigm in its April 2015 white paper, *The Energy Cloud*. According to that report, "the Energy Cloud represents a transition from one-way power flow to a dynamic network of networks supporting two-way energy flows at the periphery of the grid."[1]

In this white paper, Navigant Research takes that concept a step further, noting that the networks referenced include not only the power grid infrastructure, but also the underlying communications networks. These communications networks are fundamentally critical to Energy Cloud enablement. They will provide transport for grid intelligence and enable the management and automation of two-way power flows, transactive energy markets, and other energy services—and even non-energy-related services. In the Energy Cloud, the function of a utility will not be limited solely to the generation, transmission, and distribution of electric power. Rather, it will be about empowering end users through ubiquitous, robust connectivity to community resources and the provision of related services.

Indeed, as Navigant Consulting, Inc. (Navigant) wrote in an article for *Public Utilities Fortnightly* in October 2015, "network orchestrators" will emerge from the developing Energy Cloud—and utilities must consider their position in relation to that role. As stated in the article:

> *"Where networks of networks exist, the business model that the Wharton School dubbed the network orchestrator has been found to achieve faster growth, larger profit margins, and higher valuations relative to revenue, compared to three other types of business models (asset builder, service provider, and technology creator). The network orchestrator role will capture value by tailoring electricity supply and demand services for a customer, utility, or grid operator."*[2]

This role cannot be fulfilled without robust utility communications networks.

1.2 In the Beginning …

Electric utilities have long used communications to inform their operations centers and enable protective systems such as supervisory control and data acquisition (SCADA) to make the grid safer and more reliable. Many of these connections focused on high-voltage

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[1] For more information, see: www.navigantresearch.com/research/the-energy-cloud.
[2] For more information, see: www.navigant.com/insights/library/energy/2015/grid-to-cloud-fortnightly.

(HV) transmission networks and substations. Over the last decade, with the advent of smart grid technology, utilities have been prompted to invest in a wide array of networking technologies for a variety of purposes in both HV and distribution voltage systems: advanced metering infrastructure (AMI), distribution substation and feeder automation, and other monitoring and IT functions. Importantly, these networks have frequently been built and managed within operational silos. Even more importantly, they have been built only to handle the application for which they were conceived. Navigant Research thinks of this stage as Smart Grid Communications v1.0.

1.3 In the Future …

In the Energy Cloud future, utilities will need to reconsider this silo-based, application-centric approach. The importance of a network-centric strategy for utility communications must now be considered. This strategy assumes that a robust, ubiquitous communications network deployed across a service territory will represent the backbone upon which the utility of the future will develop and thrive within a highly networked grid. And in this grid, the line between generation and demand is increasingly blurred.

Navigant Research has dubbed this backbone the Energy Superhighway. This Energy Superhighway will be a crucial element of the larger Internet of Things (IoT). The importance of interoperability and coordination with entities and infrastructure like smart cities, smart buildings, distributed energy resources (DER), and electric transportation cannot be understated.

This paper offers a look at how the Energy Superhighway will be foundational to utilities wishing to embrace the opportunities presented by the emerging Energy Cloud paradigm. It suggests that, much as the Interstate Highway System built across America in the 1950s led to a surge in economic growth from a vast array of new product and service providers, the Energy Superhighway will support untold emerging energy services and business models. These changes will be driven not only by the efforts of traditional electric utilities, but also by third-party providers. As part of the broader Energy Cloud concept, the underlying communications infrastructure will be foundational to the successful delivery and management of both energy and energy services.

Navigant Research points out the fundamental differences between the current state of utility networking efforts—Smart Grid Communications v1.0—and the Energy Superhighway. It points to differences in how the Energy Superhighway will be conceived, planned, procured, and managed and highlights differences in the economics and funding mechanisms critical to utilities and their regulatory stakeholders. This paper also explores whether the Energy Superhighway should be internally built or outsourced and provides insight on how underlying communications technologies must be robust and cost-effective enough to support the Energy Cloud industry for the long term. Ultimately, this paper attempts to describe how new products and services built around the Energy Superhighway can re-energize economic growth and viability for utilities in the Energy Cloud era.

Section 2

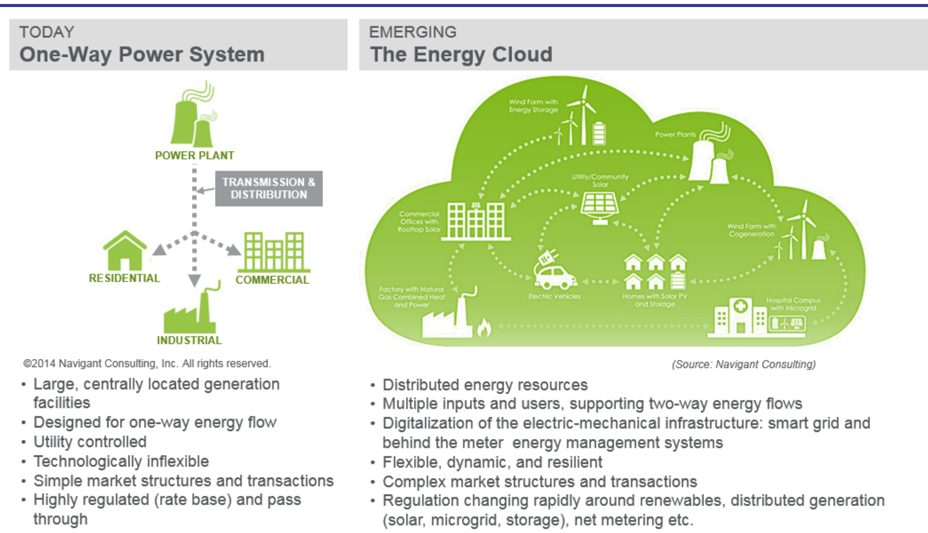
THE ENERGY CLOUD AND THE ENERGY SUPERHIGHWAY

2.1 The Energy Cloud: A Framework

The Energy Cloud concept was originally introduced as the framework for the changing energy paradigm in Navigant Research's white paper, *The Energy Cloud*,[3] in April 2015. Navigant Research also explored this concept in the *Smart Cities and the Energy Cloud*[4] report in October 2014. In *The Energy Cloud*, Navigant Research wrote:

> *"The Energy Cloud is both the result of a fundamental shift in the way electricity is generated and distributed as well as an evolution of the traditional relationship among stakeholders across the electrical grid, particularly between utilities and their customers. As a concept, the Energy Cloud represents a wide range of strategic, operational, technological, commercial, environmental, and regulatory changes that are transforming the traditional utility model for energy provision. More practically, the Energy Cloud is an emerging platform on which advanced technologies and solutions may be integrated and compete for market share in a dynamic marketplace."*

Figure 2.1 The Energy Cloud: Today and Tomorrow



(Source: Navigant Consulting)

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[3] For more information, see: www.navigantresearch.com/research/the-energy-cloud.
[4] For more information, see: www.navigantresearch.com/research/smart-cities-and-the-energy-cloud.

As noted in Section 1, "Executive Summary," that platform can be described as a network of networks. In fact, the existing communications that underlie smart grid deployments at utilities today may already be aptly described as "networks of networks." But these networks have been created over time—and in an ad hoc manner, as described in Section 2.2. They have too often not been created based on holistic, long-term, and enterprise- and territory-wide strategies, nor with adaptive, multipurpose capabilities in mind. In other words, these networks of networks are not future-proof. This is the fundamental difference between Smart Grid Communications v1.0 and the Energy Superhighway.

2.2 Smart Grid Communications v1.0

Smart grid is a blanket term that includes all manners of automation, control, and data collection efforts. Utility goals related to the smart grid generally include improving power system reliability, lowering operational costs, reducing outage impacts, and improving outage response, as well as informing asset management. Importantly, these data collection efforts are intended to enable powerful new analytics solutions—which in turn enable a utility to do all of these things more cost-effectively, better, and faster.

Fundamentally, Smart Grid Communications v1.0 is about connecting grid devices with each other and with operational and financial systems at utility operations centers, line centers, and other business facilities. Several broad categories of smart grid applications—and the most common corresponding communications infrastructure technologies—are briefly described in the following sections.

2.2.1 Substation Automation

Supervisory control and data acquisition (SCADA) systems came into use by industrial verticals, including electric utilities, 50 or more years ago. Since then, SCADA systems have been deployed worldwide, spanning transmission- and (some) distribution-level networks and substations for protection functions and monitoring. A SCADA system allows network operations center (NOC) personnel to react swiftly to grid disturbances, hazardous conditions, and other system events requiring operator intervention or resource management.

More recently, utilities have begun deploying programmable automation and control assets within their distribution grid—or at least within those portions of their service territory where there is the likelihood of service disruption at the distribution level. Historically, utilities often relied upon leased lines from the local telephone company for their substation connectivity. Today, as major telephone companies slowly retire those analog services, a great deal of fiber is being deployed (or leased) by utilities for substation automation purposes. Fiber offers very low latency communications and high bandwidth—but it comes at a high price. As a result, less expensive wireless communications networks have also been deployed, including microwave radio technology, Worldwide Interoperability for Microwave Access

(WiMAX) technology, public cellular communications, and private Wi-Fi-based technologies. In very remote areas, utilities may employ satellite service to achieve substation connectivity. Each of these various communications technologies has its own advantages and challenges in terms of cost versus functionality, as well as longevity—or the ability to be future-proof.

2.2.2 Distribution Grid Automation and Optimization

Once a distribution substation has been connected to an operations center, a utility may leverage that connectivity for increased visibility into distribution circuits, transformers, and other D-level devices, including distributed energy resources (DER). Alternatively, devices that communicate with the NOC directly (e.g., over a cellular network) may be deployed for distribution automation (DA) or optimization functions. For example, consider the concept of the self-healing grid, which is thought of by some as smart grid nirvana. A self-healing grid relies upon intelligence from and automated control of the distribution network to switch out or reroute service in response to a service interruption on a feeder or section of feeders. This is commonly referred to as fault location, isolation and restoration, or FLISR. Unless the intelligence, decision-making, and control all reside within grid-edge devices (a growing phenomenon), FLISR is dependent upon high-speed communications to bring the information back to a control room system such as a distribution management system (DMS). A DMS may then analyze the available data and make a rapid decision for what actions to take, where to take them, and then act to restore service to the largest number of customers most rapidly through control of grid resources. A multitude of connectivity solutions can be used for FLISR applications, including public cellular, Wi-Fi, power line carrier (PLC), and others—and all of these and more have been piloted and deployed.

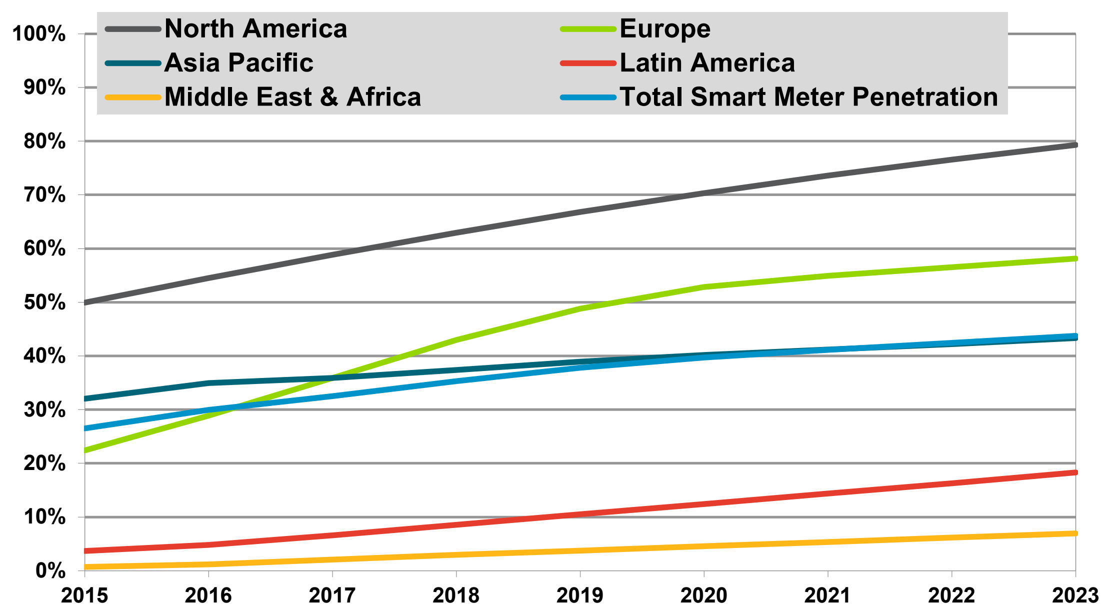
In addition to automation functions, optimization applications like conservation voltage reduction (CVR) allow utilities to reduce the amount of energy sent through the grid without breaching regulatory minimums by using distribution transformer data on real-time voltage levels. CVR applications may leverage communications modules placed at the transformer (which may then send the data directly to the NOC via a cellular or other network) or a nearby advanced metering infrastructure (AMI) network connection. Notably, many utilities separate the protective automation network from the meter data network due to bandwidth and potential latency issues.

2.2.3 AMI

Smart metering technology, or AMI, has existed for many years, but the pace of deployment was kick-started in the United States by the American Recovery and Reinvestment Act (ARRA) in 2009. ARRA provided utilities with matching funds for smart grid technology deployments. In Europe, smart meters have been widely deployed in Italy, Spain, and several Nordic nations. The European Union’s 20-20-20 initiative, which calls for a 20% reduction in greenhouse gas emissions (from 1990 levels), 20% of generation from renewables, and 20% efficiency gains by 2020, has led many nations to put plans in place for AMI deployments over the next several years.

Navigant Research estimates that the penetration of smart meters in the United States stood at nearly 50% at the end of 2015. Worldwide, penetration is expected to climb from 26% in 2015 to 44% by the end of 2023.

Chart 2.1 Smart Meter Penetration Rate of All Electric Meters by Region, World Markets: 2015-2023



(Source: Navigant Research)

Numerous communications technologies have been used to create the near-area networks that send meter data back to the NOC. These commonly include cellular, radio frequency (RF) mesh technologies, licensed wireless technologies, Wi-Fi-based technologies, and PLC. With the spread of AMI comes the ability for the utility to see what is happening at the edge of the grid for the first time, although often not in real-time.

2.2.4 Behind the Meter

In the Energy Cloud future, energy services and solutions providers move behind the meter and enable both residential and commercial and industrial customers to benefit from various options. These options include time-of-use (TOU) rates, demand response (DR) programs, energy storage, integrated distributed generation assets like solar or wind, home energy management and in-home devices, smart electric vehicle (EV) charging, and more.

Several communications protocols have been developed specifically for services in this domain, including ZigBee and HomePlug. These services may work in conjunction with AMI networks or leverage existing broadband/Wi-Fi networks for connectivity with the service provider—which may or may not be the local electric utility.

2.2.5 Many Solutions = Complications and Costs

Large utilities today must employ large teams of networking professionals—engineers, IT experts, and security experts—to design, procure, manage, and maintain these many, often incompatible networks of networks for each of the smart grid functions summarized above. Alternatively, some utilities (particularly smaller ones) may outsource their communications needs to a vendor/manager or employ a public entity such as a public cellular service provider—although even such outsourcing is generally done in a silo-based, application-centric manner. However, the majority of utilities still prefer to build and manage their systems internally.

Table 2.1 summarizes the characteristics of several leading smart grid communications technologies. The relative importance of each of these considerations will differ depending upon the primary application being deployed as well as upon the unique circumstances of the utility in question.

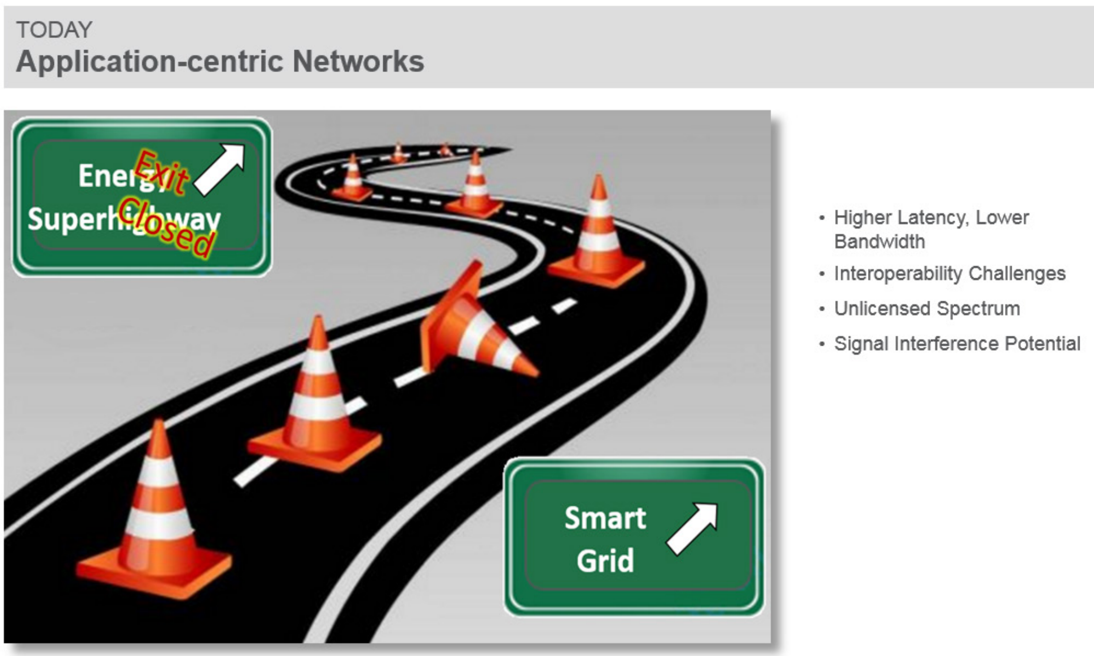
Table 2.1 Smart Grid Communications Network Considerations

Communication Technology	Upfront Costs	Monthly Service	Scalability	Latency	Licensed/ Unlicensed	Reliability	Compatibility
Satellite	Low to High	Medium to High	High	Low to Medium	Licensed	High	High
Private RF Mesh	Medium	Low	Low to Medium	Low to Medium	Unlicensed	Medium to High	Low to Medium
Public Wireless (2G/3G/4G)	Low to High	Medium	Low to High	Very Low to High	Licensed	Medium	Medium
Point-to-Point Microwave	Low to Medium	Low	Medium	Low to Medium	Licensed or Unlicensed	Medium	Medium to High
Point-to-Multipoint	Low to Medium	Low	Medium	Low	Licensed	Medium	Medium to High
WiMAX	Medium	Low	Medium	Low	Unlicensed/ Quasi-licensed	Medium	Medium
Private Fiber	Very High	Low	Low	Very Low	N/A	High	High
T1	Low	Medium to High	Low	Low	N/A	Medium	Medium
Leased Line	Low	Medium	Low	Low	N/A	Medium	Low
PLC	Low	Low	Medium	Low to Medium	N/A	Medium to High	Medium

(Source: Navigant Research)

A large number of possible connectivity solutions is combined with a number of competing teams (i.e., silos) within the utility that are vying for project funding. This means that while the possibilities are many, the actual network connectivity between devices throughout a utility's territory is built upon a multitude of older and newer (but potentially incompatible) technologies. As shown in Figure 2.2, the Smart Grid Communications v1.0 paradigm presents some challenges.

Figure 2.2 Smart Grid Communications v1.0



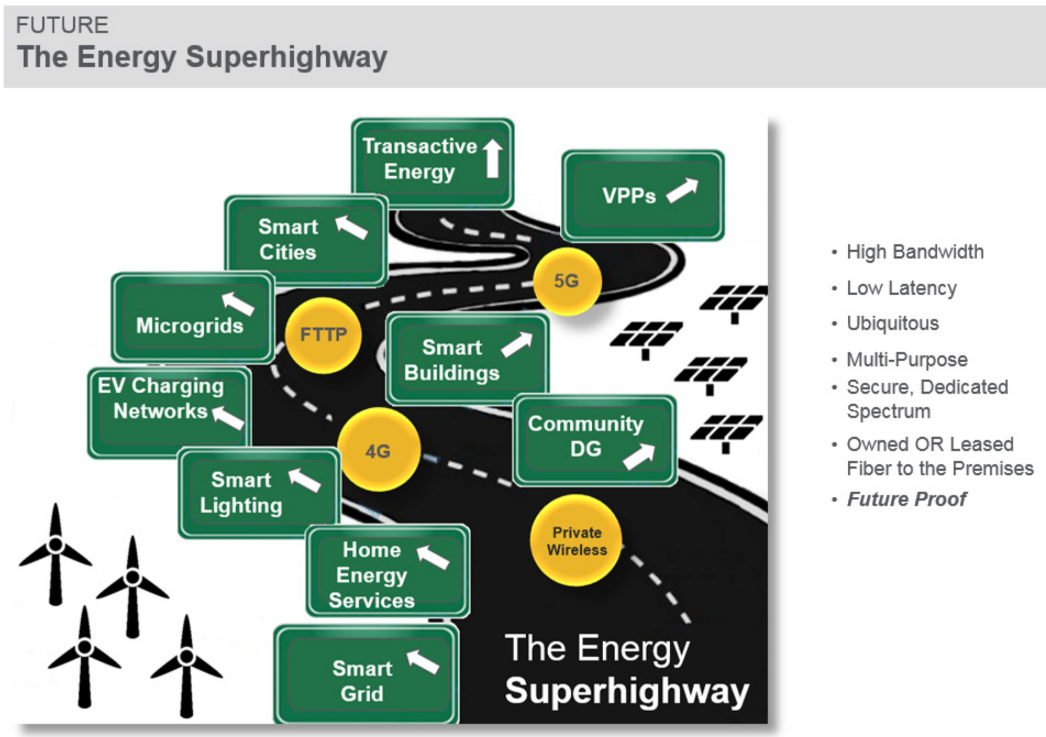
(Source: Navigant Research)

2.3 The Energy Superhighway as the Backbone for Energy Services Providers

If the Smart Grid Communications v1.0 paradigm represents an incremental, application- and silo-driven strategy where competing interests within a utility must await management or rate-case approval for each project, the Energy Superhighway represents a 180° turnabout. Ideally, a utility's Energy Superhighway will be conceived of, planned for, procured, and managed over the course of a longer-term, companywide planning and funding process. It will be built to be future-proof and support not only the smart grid applications described above, but also many, many more—including those that have not yet been conceived.

In Figure 2.3, the Energy Superhighway is depicted, along with the applications it will come to support in the Energy Cloud era.

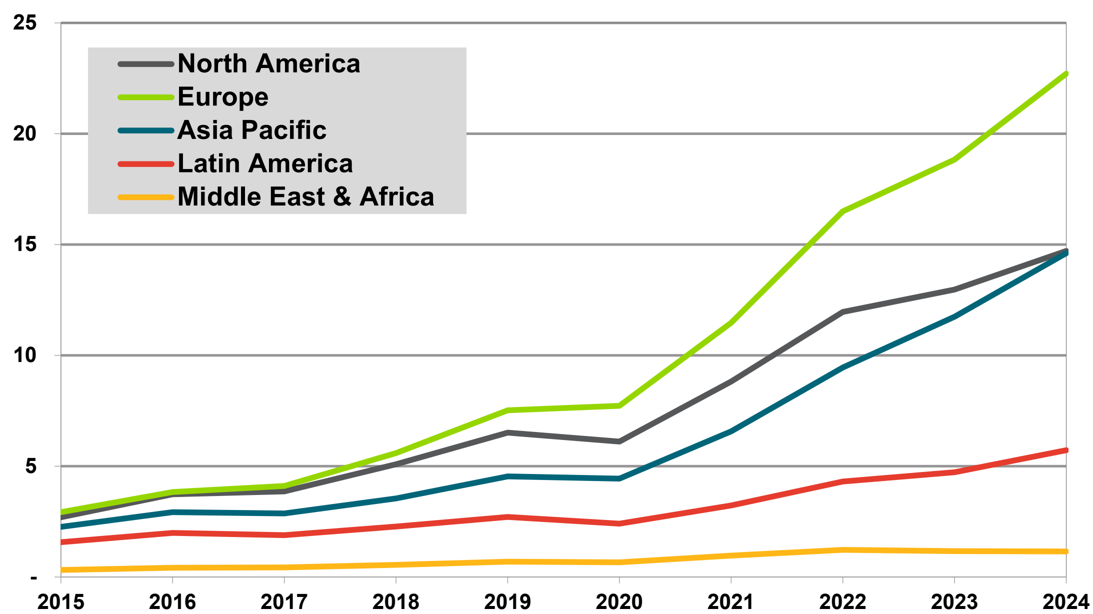
Figure 2.3 The Energy Superhighway



(Source: Navigant Research)

Utilities that proactively plan their Energy Superhighway infrastructure will be positioned to support traditional smart grid applications for reliability, efficiency, and safety. They will also be able to fully engage in smart city and smart building integration as these pursuits emerge within their service areas. Utilities will be equipped to deploy wide-area EV charging networks and manage the integration of DER projects. As shown in Chart 2.2, Navigant Research expects the tipping point for DER deployments to occur around the end of this decade.

Chart 2.2 Ratio of DER Power Capacity Additions to Centralized Generation Capacity Additions, World Markets: 2015-2024



(Source: Navigant Research)

As DER clusters emerge in densely populated areas, robust communications infrastructure will be required. Ultimately, utilities that build (or lease) an Energy Superhighway across their territory will be better prepared for transactive energy markets, microgrid management and control services, and virtual power plant integration. They will be able to effectively develop and manage fast acting DR and TOU programs and move behind the meter to offer in-home energy services ranging from the management of smart appliances and thermal management to smart lighting.

In short, the utility that creates an Energy Superhighway throughout its territory will be prepared to succeed—and thrive—in the Energy Cloud future.

Section 3
A NETWORK-BASED STRATEGY

3.1 A Holistic, Long-Term View

At its core, the Energy Superhighway concept plays off the “build it and they will come” mentality. If a utility makes the upfront investment in a robust, ubiquitous, wide-area network (or network of networks)—whether through internal capital investment or external long-term leasing—it will be able to consolidate its existing grid-tied applications. It will also be free to plan for future applications without a repeat of the network planning, funding, procurement, and management functions every time a new application is desired. This is expected to shorten implementation time and reduce project capital costs. Moreover, the utility will be more nimble and ready to act upon new opportunities that leverage its now strong communications backbone. The economic upside may only be limited by the imagination (or public utilities commissions, or PUCs—more on that in Section 3.1.2).

3.1.1 The Interstate Highway System Analogy

Consider the network of Interstate highways constructed across America under the Federal Aid Highway Act of 1956. Formally known as the Dwight D. Eisenhower National System of Interstate and Defense Highways, the Interstate Highway System has a total length of nearly 50,000 miles and carries one-quarter of all vehicle miles driven in the United States. Its cost has been estimated at more than $400 billion, and it took more than 3 decades for the network to be completed. This was a long-term, very large investment, and the effort must be acknowledged as visionary.

Now consider the economic impact of the Interstate Highway System. According to a report published by The American Highway Users Alliance on the 40th anniversary of the system—now 20 years ago—the Interstate Highway System had delivered $6 in economic productivity for every $1 in cost to build as of 1996. Employment in dining establishments increased at more than 7 times the rate of population growth between 1956 and 1996, while employment in lodging establishments grew at twice that rate. New businesses were spawned, such as long-haul trucking, while others, such as gas stations and convenience stores, enjoyed massive growth. The Interstate Highway System and its economic contribution have been frequently credited as a key underpinning to the healthy gross domestic product per capita in the United States.

Similarly, in order for utilities to tap the full potential of the Energy Superhighway backbone described herein, utilities will be required to make large, upfront investments or commit to long-term capacity leasing plans. But without this commitment—or without regulatory support for investor-owned utilities (IOUs) and their counterparts outside of the United States—the long-term economic growth and even viability of the electric utility business model may eventually be at risk.

Figure 3.1 The Energy Superhighway Supports Economic Development in the Energy Cloud

Smart Grid Communications v1.0 vs. The Energy Superhighway

- Smart grid communications today are about connecting grid infrastructure: meters, feeders, transformers, substations … to the NOC, with a spaghetti bowl of tangled up wired and wireless technologies. Utilities traditionally want to own and operate the spaghetti factory.
- **The Energy Superhighway** represents a robust, ubiquitous network controlled by utilities (though not necessarily built or owned by utilities) that will enable a multitude of new energy services offered by both traditional utilities and third-party vendors.
- Or, Google or Verizon may build it. Either way, a new economy will emerge around the coming Energy Superhighway.

(Source: Navigant Research)

It is notable that the economic growth fostered by the Interstate Highway System was spurred by multiple industries leveraging shared infrastructure. This is an important point for utilities contemplating their role in the broader context of an Internet of Things (IoT) world. In a similar fashion, the Energy Superhighway will be expected to support more than the traditional smart grid applications described in Section 2.2 in order for the economics to work. Another key difference between the Interstate Highway System example and the proposed Energy Superhighway concept lies in the source of capital funding and the oversight of the investment. The Interstate Highway System was a federally sponsored, nationwide initiative. In contrast, utilities today are regulated, are operated at the state level within different regulatory frameworks, and are subject to different levels of investment oversight depending on the type of investment, the usable life of the assets, expected return on investment, and other criteria. This is a regulatory system construct that could impede the power industry's development of an Energy Superhighway program in the

United States and similarly regulated markets worldwide. Support at the national level—and regulatory change—may be required for the Energy Superhighway's full potential to be achieved.

In the United States, numerous efforts have been made by the Utilities Telecom Council and others in the industry to promote Federal Communications Commission (FCC) support for a nationwide utility spectrum band upon which to construct the Energy Superhighway. To date, no such proposals have been successful in the United States, but some governments (e.g., in France, Canada, and the United Kingdom) have provided regulatory support for coordinated utility communications at the national level. As regulators worldwide consider the evolving electric utility business model, particularly in the context of IoT and smart cities, smart transportation, and transactive energy models, this type of national—if not international—cooperation and coordination will become increasingly critical.

3.1.2 More on the Regulatory Challenge

IOUs within the United States and in many other countries have a fiduciary duty to operate in such a way as to maximize shareholder return quarter after quarter. The regulatory framework is typified by a monopoly- or oligopoly-type model that allows a predetermined rate of return on invested capital in exchange for reasonable and reliable operations within a set service territory. This means that customers generally have no choice as to the utility that serves them. Such an approach has historically been effective in managing rates and guaranteeing quality service for some time, but is not without its critics. In order to ensure rates are effectively based on the cost of service, very detailed rate filings are submitted to PUCs or other regulatory oversight establishments every few years specifying the investments, planning, and operations of the utility. Once approved, these plans, commonly called Integrated Resource Plans, fix the electric rates—and essentially profits—that a utility and its investors may receive. If a utility does very well within the financial framework established, rates may be lowered, limiting profits in the next cycle. However, if a utility fails to perform well within the framework or needs new investment to guarantee quality service, rates may be raised.

These details are important in the context of a global trend toward the deregulation of electric utilities that began in the 1990s, leading to an uncoupling of generation and transmission operations from distribution or retail operations in some U.S. states and other countries. In the United States, Texas is an example of a deregulated state where competitive retailers cooperate with generation and transmission operators and at the same time compete among themselves for customers. Such unregulated utilities have the freedom to invest more aggressively in emerging technologies where they believe Energy Cloud trends will deliver longer-term financial and operations benefits. At this point, however, these investments have been more bleeding edge than leading edge. For example, in September 2015, NRG announced that it would spin out its money-losing solar and EV businesses into a new division, dubbed GreenCo. At the time, the company said "Now is neither the time to abandon GreenCo nor to transfer its full value to someone else, but it is very much the time to impose a new higher level of financial rigor on GreenCo befitting the type of capital discipline imposed on entrepreneurial startups by venture capitalists." NRG's investors, tired of the earnings drag, forced the move.

In short, in order for traditional utilities to maximize their role in the Energy Cloud and potentially to engage in developing new energy services, changes to the regulatory framework will need to occur. Progressive states like New York (with its Reforming the Energy Vision proceedings), California, and Hawaii have taken bold steps in that direction, but change happens slowly. Utilities will need to make the difficult choice between moving ahead of regulatory change, as NRG has done, and waiting until a clearer (safer and supported) path can be identified. Either choice may be fraught with investment risk; however, in order to maintain relevance, utilities must consciously consider their long-term place in the Energy Cloud market. The communications backbone underlying their efforts—and how well it has been planned for the long term—may ultimately prove to be a significant predictor of long-term relevance in the Energy Cloud future.

3.2 Early Efforts Only the Tip of the Iceberg

Thanks at least in part to the regulatory challenges described above, the majority of electric utilities remain firmly rooted in an application-centric approach to connectivity within their territories. There are several utilities, though, that have begun to broaden their thinking and plan ahead for the Energy Superhighway and IoT eventuality.

In North America, most converged network strategies to date are focused on leveraging AMI networks. For example, PECO has DA devices like reclosers operating over its AMI network. Commonwealth Edison (ComEd) is also operating a converged AMI/DA network, and Oklahoma Gas & Electric is running its DR program over its AMI network. Florida Power & Light is running not only AMI and DA over the same network, but also its smart street lighting program. Duke Energy's Coalition of the Willing is another effort designed to help utilities and vendors band together for establishment of interoperability standards for technology, including communications networks.

Another example can be found at Vancouver, Canada-based BC Hydro, which has upgraded its entire communications network (consisting of numerous communications technologies, including WiMAX, RF mesh, satellite, microwave, and fiber) to Internet Protocol version 6 (IPv6). The company says that this upgrade will support far more devices that are connected, provide enhanced security, and deliver improved quality of service (QoS) capabilities (e.g., signal prioritization and peer-to-peer communications between disparate devices). BC Hydro's network upgrade also supports lower latency packet transfer, a necessary requirement for advanced DA applications. The company notes that this strategy is not based on a meter-to-cash mentality, but rather, a meter-to-grid approach.

These utility initiatives are just the tip of the iceberg, however, in terms of defining what the Energy Superhighway may ultimately encompass. Admittedly, utilities making these major communications network investments today face measurable risk. But what is the risk of deferring? With or without federal- or state-level support, utilities increasingly operate in a complex, risk-fraught environment, and the opportunities for non-energy businesses to encroach on the traditional utility space are growing. Much as the Interstate Highway System has delivered exponential returns on the initial investment, Navigant Research believes the Energy Superhighway presents a pathway to greater economic relevance and returns for the utility of the future.

Section 4

A NETWORK OF NETWORKS

4.1 Taking the Long View

Large and small utilities are already managing complex, interconnected, multiprotocol networks, and many have substantial internal telecommunications engineering capabilities. Yet, certain strategies remain relatively shortsighted when juxtaposed with the eventual Energy Cloud paradigm. For example, RF mesh technologies are frequently used not only for AMI, but also for DA functionality—particularly by utilities in North America. Mesh technology is well-suited as a relatively inexpensive way to cover large swaths of a utility's territory, but most of these technologies leverage unlicensed spectrum. In an IoT future, the risk of those unlicensed frequency bands becoming clogged and bogged down—in other words, slow—is real in some geographies.

Another development of interest for the long term that is specific (at this time) to the United States is the growth of commercial, multi-lateral location and monitoring services (M-LMS). These services allow 911 operators and public safety organizations to receive information on the vertical location of emergency callers. The technology tells them, for example, from which floor in a high-rise a caller is calling. It may be provisioned in the 900 MHz band and has the potential to accelerate interference issues in congested markets. Notably, despite stringent utility protests, the FCC licensed a business to provide such a service in 2013. To date, such network interference has generally not been an issue for utilities—but then, IoT is still in its infancy. Eventually, the fear is that unlicensed spectrum may prove to be unsuitable for mission-critical applications for utilities as well as other verticals.

WiMAX technology also leverages unlicensed spectrum in many markets, though licensed options exist as well. For example, Canadian utilities have used WiMAX over their 1.8 GHz licensed spectrum. PLC technology—widely used across Europe for AMI and also by rural utilities in the United States—has immediate cost benefits, as it leverages the existing distribution grid infrastructure to carry communications signals over power lines. However, its throughput and latencies are often inadequate for real-time grid protection functions and even for more basic DA functionality.

All of these technologies perform their smart grid functions quite well today. But the ability of a utility to continue to layer on new applications as technology evolves may be constrained, particularly when one looks out 10 or more years.

4.1.1 Near-Term Challenges

Communications technology advances on a far more accelerated schedule when compared with traditional utility planning cycles. For example, one (of several) reasons utilities often avoid the use of public networks is the fact that communications chips within grid devices may expire sooner than the device itself. Utilities note that even if there were no other concerns with (for example) public cellular networks (e.g., security and QoS guarantees), the likelihood that an older generation network such as 2G would be retired before the utility is prepared to upgrade its 2G-based meters or grid devices is high. Whereas a utility may expect its equipment to last 20 years or more, the cellular carriers are continuously upgrading their networks in cycles that may endure for only 5-10 years.

This forced retirement can happen even with wired technologies. Most recently, utilities across North America were faced with the sunset of leased lines that had connected their substation SCADA and other inter-facility communications for years or even decades. Newer Ethernet options proposed by communications service providers may cost several times what those leased copper lines did; utilities understandably do not like to find themselves at the mercy of these telecom providers.

But does that mean that utilities are rightly avoiding the public carrier option? In some cases, the answer may be yes. On the other hand, telcos with robust nationwide wired and wireless networks are intent upon providing the backbone of IoT, and utilities are not the only industrial players to have these concerns. Widespread proliferation of fiber networks (by telcos or third parties such as Google Fiber) and the advent of 5G technology, currently in development and testing among numerous large telecoms concerns, might help to narrow this divide between utility needs and public offerings. Alternatively, utilities may consider making (admittedly large) private network investments in relatively future-proof technologies such as private Long-Term Evolution (LTE) or fiber to the customer premises, perhaps in a coordinated effort that cuts across service territories.

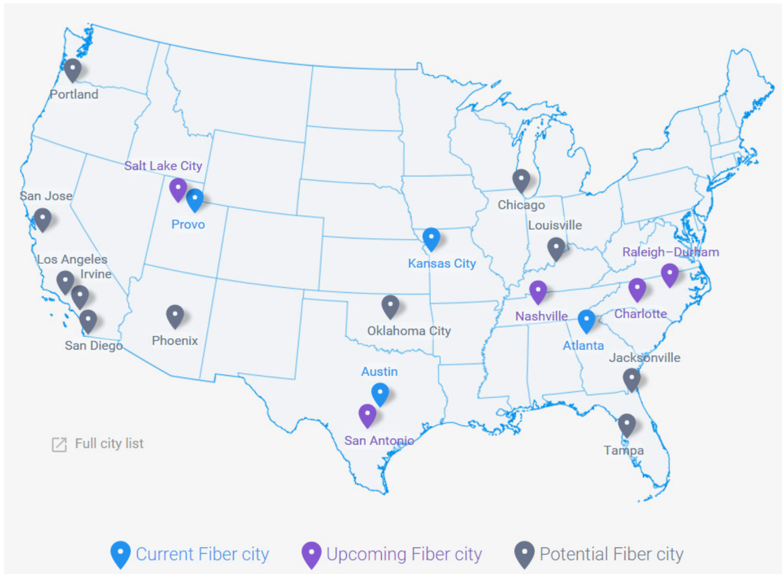
4.2 Future-Proofing the Network

In order for utilities to adapt and thrive in the Energy Cloud, access to a ubiquitous, high bandwidth, low latency network—whether built or leased—will be needed. There are numerous technological paths by which a utility might get there, including both private and public options and both wired and wireless options.

4.2.1 Fiber-to-the-Premises

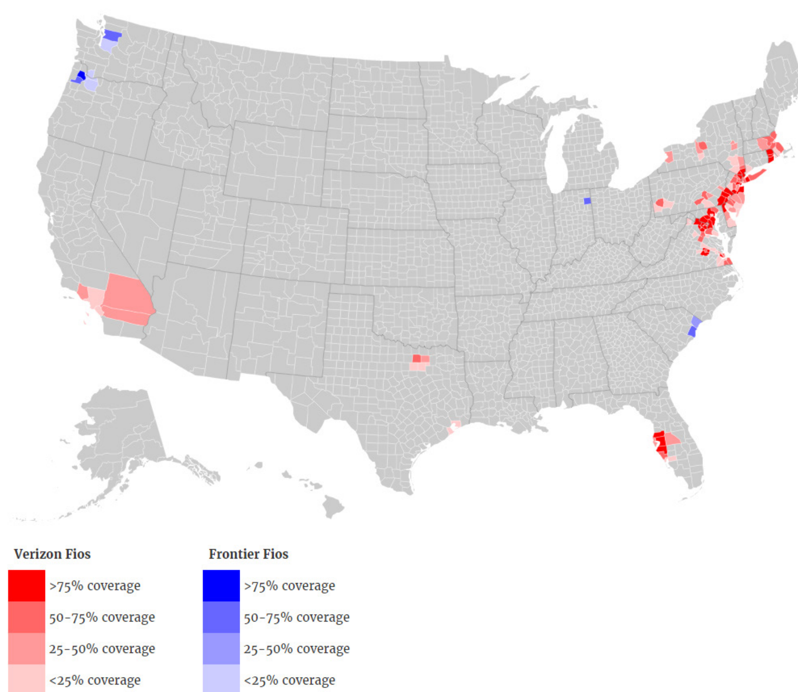
The ultimate (today at least) in connectivity for virtually any application is fiber-to-the-premises. This is the technology behind Google Fiber (now available in nine cities), Verizon's FiOS network (offered to more than 15 million end users in the United States), and Frontier Communications' FiOS network (offered to select regions in the Pacific Northwest United States). Figure 4.1 and Figure 4.2 illustrate the coverage areas for Google Fiber and FiOS.

Figure 4.1 Google Fiber Current and Planned Deployment



(Source: Google Fiber)

Figure 4.2 FiOS Network Availability



(Source: Fiber for All)

The FiOS example is useful in terms of understanding the economics of fiber for a broadband service provider. Specifically, it is important to note where FiOS is and where it is not—and why. That reason is simple: cost. Laying fiber is expensive, as much as $100,000 per mile; provisioning a home with fiber can range from $700 to $800 per home in densely populated areas to $4,000 to $5,000 per home in lower density areas. Notably, Verizon curtailed its FiOS deployment when it determined that the population density in remaining territories was not high enough to provide an attractive return on investment, given its entertainment and communications service offerings.

For utilities, the opportunity exists to create a fiber-to-the-premises network that not only provides an Energy Superhighway backbone—enabling smart grid and a plethora of new energy-related offerings—but also supports broadband, video, and voice, commercially referred to as Triple Play services within the telecommunications industry. Yet, there are legal challenges related to this opportunity today. In at least 18 U.S. states, the cable TV industry has successfully blocked efforts by utilities to provide such Triple Play services. Of note, Google Fiber announced in February 2016 that it will leverage the fiber network being built by Huntsville Alabama Utilities in order to provide its Triple Play services in the market. Such infrastructure sharing arrangements present an interesting opportunity for utilities to share costs with another party—although that party may then accrue the longer-term benefits of new services, such as Triple Play.

These types of legal challenges are not ubiquitous, however, and utilities may ultimately decide that the end goal is one worth fighting for—or they may decide that partnering with local telcos is a more viable strategy. One example of a successful utility fiber-to-the-premises deployment is provided by the Electric Power Board (EPB) of Chattanooga, Tennessee.

4.2.1.1 Case Study: EPB Chattanooga

EPB provides electric and Triple Play services to more than 175,000 homes and businesses in a 600-square-mile area, including greater Chattanooga and Hamilton County, as well as portions of surrounding southeastern Tennessee counties and areas of north Georgia. Chattanooga was the first city in the United States to offer 1 Gb broadband speeds thanks to its citywide fiber network, which it launched in 2010. To date, results have been impressive. According to an EPB-commissioned study by the University of Tennessee at Chattanooga's Department of Finance in 2015, EPB's smart grid and fiber optic network has added 2,800 jobs and injected more than $865 million into the local economy over the past 4 years. Economic benefits are quoted to come from reduced power outages, improved data connections, lower power bills, and new businesses attracted to the city.

In terms of service offerings, the utility has nearly 76,000 customers signed up for at least one of its Triple Play services, or nearly 50% of the available customers, despite fierce regional competition from cable giant Comcast. In 2015, EPB reported $671 million in operating revenue, up from just more than $500 million in 2010, with much of that growth attributable to the fiber network and Triple Play service offerings. Over that same 4-year period, kilowatt-hour sales were shown to be roughly flat at around 5.7 billion kWh. In terms of electric system benefits, EPB's fiber-centric smart grid is estimated to have avoided 125 million customer minutes of interruptions through the detection of power faults and faster service restoration.

EPB has proven itself as a role model for other municipal utilities exploring their fiber networking options and has enjoyed economic growth despite flat load demand. Thanks to its bold investment, EPB ideally positioned for future smart city or other Energy Cloud applications.

4.2.2 Private Licensed Spectrum

Historically, utilities have not made large investments in private spectrum for grid applications. As with fiber, high cost is an oft-cited reason. In its most recent major wireless spectrum auction, ended in January 2015, the FCC raised more than $41.3 billion for federal coffers by selling spectrum. The average price per megahertz population unit (MHz POP) for the Advanced Wireless Service (AWS) licenses (in the 1.7 GHz and 2.1 GHz bands) was $2.03. This was a new record for overall spectrum auction proceeds. Not surprisingly, AT&T Wireless and Verizon were the two largest winning bidders, accounting for more than half of the total proceeds, or nearly $23 billion. Utilities simply cannot compete with major wireless carriers when it comes to buying large swaths of private spectrum. And as noted previously, industry efforts to prompt the FCC to award dedicated utility spectrum have, to date, been unsuccessful in the United States.

Across the pond, the European Commission took action in 2014 to bring 48 European nations into alignment on spectrum policy across the continent. Specifically, for smart meters and smart grid applications, the European Conference of Postal and Telecommunications Administrations announced in February 2014 a framework whereby 5.6 MHz of spectrum at 870 MHz-875.6 MHz would be set aside for unlicensed machine-to-machine (M2M) uses, including smart meters and other grid applications. This alignment does not address the longer-term concerns related to unlicensed spectrum, but it sets the stage for vendors and utilities to converge around a standardized spectrum band across borders.

Generally, however, utilities tend not to own their own spectrum—although some smart grid communications vendors may. For example, Sensus' FlexNet system operates at 900 MHz in a band owned across the United States by the company. In the United Kingdom, Sensus' system is being deployed in the northern region and will leverage the 450 MHz spectrum owned by Arqiva. Tantalus' TUNet system operates at 220 MHz, also owned by the company. In California, San Diego Gas & Electric (SDGE) acquired 10 MHz of C and D Block Wireless Communication Service spectrum from NextWave in 2010 with the intent of building its smart grid applications. The company was deploying a private WiMAX solution, but then changed strategy in 2012. SDGE sold the spectrum licenses to AT&T and contracted service from the cellular carrier for some of its communications needs.

The averseness on the part of utilities to spectrum ownership may be slowly shifting, however. In 2015, several private spectrum buys were made by utilities, including one by Salt River Project (SRP). Alternatively, spectrum and infrastructure sharing arrangements such as that between Green Mountain Power (GMP) and Vermont Telephone Company (VTel) may prove instructional, especially for non-urban markets.

4.2.2.1 Case Study: SRP

In 2015, Phoenix, Arizona-based SRP acquired the Phoenix-Mesa economic area license #158, covering an estimated 4.3 million POPs in central Arizona. The license includes two 1 MHz swaths of spectrum at 757 MHz-758 MHz and 787 MHz-788 MHz. Private equity firm Access Spectrum was the seller. The company, along with Columbia Capital and Beach Point Capital, has been marketing similar licenses nationwide for $0.75/MHz POP (POPs x MHz). This implies that SRP made an investment in the $6.5 million range for the license. Relatively speaking, for a company with annual revenue of roughly $3 billion, this is a rather small investment—but one with potentially great upside.

SRP is working with vendors and standards bodies to develop a WiMAX-based protocol for this spectrum band. In particular, the company is aiming for a standardized protocol in order to avoid vendor lock-in and promote longer-term economies of scale should the band become popular with utilities. SRP intends to use the private network to fill connectivity gaps between its substations, which are all connected by fiber, and its AMI networks. It is also interested in DA applications like voltage control, FLISR, smart inverters for solar installations, distribution transformer monitoring, and dynamic line rating applications. The company admits that its slim, 2 MHz license will not allow it to do every application that it may eventually want and that high volume AMI data would overload the network's capacity. Nonetheless, it believes that it can accomplish its DA goals for the next 10 years with the new network.

SRP's acquisition of just 2 MHz of spectrum may be a mere toe in the water at this point. However, the company's recognition that unlicensed bands may well become overloaded in coming years could prove prescient—at which point even 2 MHz of private, uncluttered airwaves may appear highly attractive to utility operations managers.

4.2.2.2 Case Study: GMP

GMP, based in Colchester, Vermont, is the largest electric utility in Vermont and serves more than 250,000 customers. In addition to traditional generation and distribution, the utility is also active in the areas of wind, hydro, and solar-powered microgrids. GMP was awarded more than $69 million in U.S. Department of Energy Smart Grid Investment Grant money for projects including a meter data management system, AMI deployments, substation and distribution automation, customer web presentment, dynamic pricing, consumer studies, and a customer information system upgrade.

GMP's challenges included a mountainous terrain and sparse population density, inadequate coverage and service-level guarantees from public wireless carriers, a lack of available spectrum, and expensive wired alternatives. Additionally, when the utility began the process, there were no ruggedized customer premises equipment (CPE) for LTE networks available commercially.

Meanwhile, VTel had been awarded an ARRA grant to build an LTE network on spectrum that it already owned to meet the broadband needs of un- and under-served populations in Vermont during 2010. GMP later negotiated with VTel, Central Vermont Public Service, the Vermont governor's office, and the Vermont Public Service Board in order to create a partnership.

It was agreed that VTel would own and operate all of the 700 MHz base stations and core network equipment. GMP owns and operates its own CPE, and it colocated VTel base stations at mountaintop sites that housed GMP's two-way mobile radio base stations. GMP also offered pole-top assets that would be used to lower the build cost. The utility invested its own grant funds to support the extension of the LTE network to unfunded areas of Vermont and to cover the cost of backup batteries and generators.

The GMP model for partnership between local utilities and incumbent local exchange carriers (ILECs) may make sense for other electric utilities, especially in rural and sparsely populated areas. Particularly where the local ILEC already owns 700 MHz LTE spectrum (many ILECs acquired such spectrum licenses for low prices in FCC auctions throughout the 2000s), such partnerships may be a good way for smaller utilities to obtain access to a first-rate communications network without the onerous upfront capital costs of a solo private build.

4.2.3 5G

Fifth generation—or 5G—wireless technology is the next step in the evolution of wireless technologies. Its promise as the backbone of IoT is well marketed, but the practical reality is that it is not here yet. This is primarily because the precise specifications of the standard are still being written—and numerous global entities are each working on their own version—so a clearly defined standard is likely still a few years out.

Nonetheless, the commonly stated characteristics of 5G networks promise stunning improvements over existing technologies:

- 1–10 Gbps connections to endpoints in the field (not theoretical maximum)
- 1 ms end-to-end roundtrip delay (latency)
- 1,000 times bandwidth per unit area
- 10-100 times number of connected devices
- 99.999% availability
- 100% coverage
- 90% reduction in network energy usage
- Up to 10-year battery life for low-power, M2M devices

Despite the attractiveness, there is currently no way that all of these system characteristics can be served simultaneously (without defying the laws of physics). Rather, certain network characteristics will be needed for certain applications, while other characteristics will be required for other applications. Finally, creating a ubiquitous, less than 1 ms latency network may simply not be physically possible across very large geographies—in the near term.

That said, 5G service will happen in the near future, perhaps even before 2020. The transition will no doubt prove to be evolutionary rather than revolutionary, but the point is that the targeted goal has been established by the largest and most capable service providers, including public wireless carriers such as Verizon, AT&T Wireless, and numerous other global infrastructure vendors. They are all currently hard at work creating the 5G communications future. The 5G future may well fulfill a great many of the progressive (Energy Cloud-based) utility's needs related to its Energy Superhighway vision—if the utility is willing to partner with public carriers.

4.3 Public versus Private Networks

Utilities have long been averse to becoming too reliant upon public telecom providers for their connectivity needs for many good reasons. Going back only a few years, public wireless carriers often charged rates that equated an endpoint in the grid to a mobile voice or data subscriber—and charged $40/month or more for that connection. As a result, public carriers have often been relegated to backup network status, providing redundancy for critical, utility-owned networks.

More recently, wireless providers have embraced the IoT vision of the future and M2M communications service rates are today just a fraction of those previous, subscriber-based levels. But there remain numerous concerns within the utility community that industrial verticals and applications will always take a back seat to telecoms providers' first love—

namely, their mobile business and consumer subscribers who spend well more than the $40/month that voice-only customers were spending just a few short years ago.

Telecom providers will always prioritize their core business, but with the 4G LTE technology available today, public carriers are finally settled in a place where they can offer utilities QoS and competitive service pricing. Perhaps more importantly, security concerns can be allayed and signal prioritization will allow for the cost-effective development of territory- and enterprise-wide strategies.

As the foundation for a utility's Energy Superhighway backbone, existing LTE networks provide low latency and high throughput. Those characteristics are not only adequate for smart grid applications, but also offer a defined progression path as carriers upgrade to 5G technology. While many utilities will continue to manage and develop their own communications backbones internally, there are many for which the public carriers' commitment to providing the latest in connectivity advances—usually before those advances are economically viable on a private level—may be attractive.

In fact, in February 2016, AT&T and Nokia (formerly Alcatel-Lucent) announced they would cooperate to offer U.S. power utilities a private network option, leveraging licensed spectrum owned by AT&T. The spectrum will be made available to utilities in a lease structure, allowing for the capitalization (i.e., rate basing) of the investment. The companies will help utilities migrate existing wireless devices and AMI collectors to a private broadband wireless solution. This offer will be made available in the second half of 2016.

4.4 Conclusions

The Energy Cloud future presents challenges, but also undeniable opportunities for utilities. Progressive utilities may not only embrace but actually direct industry evolution toward a business model focused on providing energy—or non-energy—related services to end users, as opposed to the provisioning of commodity electrons. As distribution grid operators are increasingly faced with two-way energy flow and critical, real-time information needs, the traditional, silo-based, application-centric approach to communications will not suffice.

Utility vision and investment in ubiquitous, high-speed broadband networks will be a prerequisite to ensure that evolving utility and power industry goals and service offering creation are not thwarted by inadequate connectivity—and not met by other service providers in the marketplace. An enterprisewide, holistic, long-term strategy for a utility's communications backbone—the Energy Superhighway—will be foundational to companies seeking to remain nimble and opportunistic as the Energy Cloud paradigm evolves. Navigant Research believes that the potential for substantial economic growth to emerge around the Energy Superhighway is great—if difficult to quantify at present.

Regulatory, interoperability, and security challenges remain to be addressed, and they will evolve differently in different parts of the world. But utility executives and their management teams must define a flexible, long-term vision for where their company's service offerings are moving—today—in order to effectively influence those changing dynamics.

Bigger picture goals may only be achieved to the utility industry's best advantage if industry leaders think outside of the box as they consider their potential to participate in the financial opportunities presented by Triple Play, smart city, and connected community opportunities. These opportunities will no doubt leverage the most capable network available in a given market, regardless of who provides it. And at the end of the day, the best network may very well win.

Section 5
ACRONYM AND ABBREVIATION LIST

2G ..... Second Generation

3G ..... Third Generation

4G ..... Fourth Generation

5G ..... Fifth Generation

AMI ..... Advanced Metering Infrastructure

ARRA ..... American Recovery and Reinvestment Act

ComEd ..... Commonwealth Edison

CPE ..... Customer Premises Equipment

CVR ..... Conservation Voltage Reduction

DA ..... Distribution Automation

DER ..... Distributed Energy Resources

DMS ..... Distribution Management System

DR ..... Demand Response

EPB ..... Electric Power Board (Tennessee)

EV ..... Electric Vehicle

FCC ..... Federal Communications Commission

FLISR ..... Fault Location, Isolation, and Service Restoration

Gb ..... Gigabit

Gbps ..... Gigabit per Second

GHz ..... Gigahertz

GMP ..... Green Mountain Power

HV .... High Voltage

ILEC .... Incumbent Local Exchange Carrier

IoT .... Internet of Things

IOU .... Investor-Owned Utility

IPv6 .... Internet Protocol version 6

IT .... Information Technology

kWh .... Kilowatt Hours

LTE .... Long-Term Evolution

M2M .... Machine-to-Machine

MHz POP .... Megahertz Population Unit

MHz .... Megahertz

M-LMS .... Multi-Lateral Location and Monitoring Service

ms .... Millisecond

NOC .... Network Operations Center

PLC .... Power Line Carrier

POP .... Population Unit

PUC .... Public Utilities Commission

QoS .... Quality of Service

RF .... Radio Frequency

SCADA .... Supervisory Control and Data Acquisition

SDGE .... San Diego Gas & Electric

SRP .... Salt River Project

TOU .... Time-of-Use

TV .... Television

U.S. .... United States

VTel. .... Vermont Telephone Company

WiMAX .... Worldwide Interoperability for Microwave Access

Section 6

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SCOPE OF STUDY

Navigant Research has prepared this white paper to provide current and interested stakeholders at all levels of the electric industry—including utilities, regulators, technology suppliers, service providers, investors, and policymakers—with an overview of the opportunities and challenges offered by the emerging Energy Cloud. Emphasis is placed on the importance of a robust communications backbone—i.e., the Energy Superhighway—for long-term success in this evolving operating environment.

The objective of this white paper is to provide an understanding of the importance of a holistic strategy for enterprise- and territory-wide connectivity for energy applications. It also aims to provide a high-level overview of technical options that are either available today or anticipated over the next several years. Note that the report does not aim to offer an exhaustive assessment of these specific developments or technologies; much of this can be found in Navigant Research's in-depth market and technology reports.

SOURCES AND METHODOLOGY

Navigant Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Navigant Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Navigant Research's analysts and its staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Navigant Research's reports. Great care is taken in making sure that all analysis is well-supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

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