



## The Smart Grid Primer

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[What is the Smart Grid](#)

[The Evolving Architecture of a Rural Electric Provider](#)

[Building the Smart Grid Broadband Network](#)

[Standards Development](#)

[Resources](#)

### Part 1: What is the Smart Grid

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*NTCA presents this series of articles on the smart grid. The series explores the nature and components of a smart grid system; the benefits and drivers of an intelligent grid; the evolving architecture of a rural electric provider who implements a smart grid; the telecommunications requirements for developing a smart grid broadband network; and the development of standards for a viable network architecture.*

*NTCA has been working with key rural organizations, including the National Information Solutions Cooperative (NISC), the National Rural Electric Cooperative Association (NRECA), and the National Rural Telecommunications Cooperative (NRTC), who, like NTCA, seek to inform rural cooperatives and commercial companies about the smart grid and its technical needs.*

An intelligent electrical grid, commonly known as the smart grid, unites broadband and IP networking with the existing electrical grid. The smart grid was first introduced more than 10 years ago but, thanks to recent federal interest and investment, the concept has now moved from pilot projects to full-scale deployments.

Congress allocated \$4.5 billion in the American Recovery and Reinvestment Act of 2009 (ARRA) for smart grid activities. Of this, \$3.5 billion is set aside for a [Smart Grid Investment Grant Program](#) administered by the U.S. Department of Energy (DoE). As of June 2010, more than 100 [projects](#) in 49 states have received smart grid investment grants. Additionally, Congress set aside \$620 million in ARRA funding for [Smart Grid Demonstration and Energy Storage Projects](#). The DoE is coordinating these 32 projects. Finally, the U.S. Department of Agriculture Rural Utilities Service (RUS) [Broadband Initiatives Program \(BIP\)](#) has awarded grants for broadband infrastructure which may support smart grid activities.

Vern Dosch, CEO of the National Information Solutions Cooperative ([NISC](#)), is in a unique position to observe the marketplace as NISC develops and supports software and hardware solutions for both utility cooperatives and telecommunications companies. Dosch described the factors driving the development and deployment of the smart grid as the "perfect storm" uniting technology, investment, utility needs and consumer interest.

"The economy is in a downturn; business and consumers are more conscious of their consumption and ways to save money," Dosch said. "At the same time, energy prices across the board have increased. There are also environmental consequences to bringing new, traditional power plants online. Oftentimes these are thought of as conflicting forces; however what the smart grid promises is the next -gen technology and the data to utilize the electrical grid more efficiently and effectively."

Ed Drew, vice president of utility services for the National Rural Telecommunications Cooperative ([NRTC](#)), added another driver for the development of the smart grid: reliability. "Much of our nation's electric grid was built more than 75 years ago, and the aging infrastructure needs to be upgraded to meet today's demands."

Drew also explained that the smart grid will utilize alternative forms of energy generation, like wind and solar power. "Federal regulators, industry observers and consumers are also interested in expanding our nation's portfolio of renewable energy alternatives and, in turn, reducing greenhouse gas emissions," he said. "Although this is something that most electric cooperatives fully support, the [non-intelligent] grid isn't designed for wide-scale deployment of renewable energy sources."

The total smart grid market is estimated at approximately \$200 billion spread over the next 10-15 years, according to the [Electric Power Research Institute](#) and the [Pacific Northwest National Laboratory](#). The burgeoning market has attracted the attention of electrical utility providers, major networking vendors, tier-one broadband providers and smaller telcos.

### **Defining the Smart Grid**

The modern power grid incorporates communications and information technology into the generation, transmission, distribution and consumption of power. The smart grid will utilize digital technology to create a more efficient, reliable, resilient and responsive network. It aspires to intelligently detect and solve problems within the electrical system. The smart grid also promises to lessen the impact on our environment by reducing overall peak demand for power, successfully integrating renewable energy into the network, and supporting the widespread adoption of electric vehicles.

With such an extensive mission and a diverse set of benefits, there are a wide variety of stakeholders invested in the smart grid concept. As such, there are many definitions of the smart grid concept based upon function, benefits or even technology.

The U.S. Department of Commerce National Institute of Standards and Technology ([NIST](#)) defines the smart grid as the "two-way flow of electricity and information to create an automated, widely distributed energy delivery network."

For broadband service providers, the smart grid concept can be simplified as a robust, two-way communications network which is dynamic, interactive, provides real-time data and relies on an open-architecture. This network will link smart devices, which will reside in homes and businesses, with utility or third-party information processing companies. Smart infrastructure will provide the electric provider with far greater insight into the grid, and the consumer with more information and control over his energy use and bill.

### **The Smart Meter**

The smart meter is often thought of as the poster child for the smart grid concept and the first step toward achieving an interconnected grid. The smart meter, which will reside at the customer's home or business, will transmit information to the utility provider regarding historical energy consumption and real-time measurements of current usage. When combined with home energy-monitoring tools, the smart meter will provide the end user with detailed information on current energy consumption, which appliances consume the most power, the month's billing estimate and how his home compares to others. Providing the consumer with this basic information will offer ideas for how to reduce his energy bill by 5%-15%.

Taking this one step further, the smart meter can be used in conjunction with a gateway and a home area network. If appliances are connected to a home-area network, the consumer will be able to program major appliances on a schedule via one convenient tool.

Consumers also will be able to make on-the-spot decisions based upon current energy conditions and the resultant prices. Traditionally, customers have been charged one flat rate for power. Time-based or dynamic-pricing schemes attempt to more closely match the cost of production with what the retail customer pays for the service. Under this new pricing platform, utility companies will charge a premium for peak energy usage. This will likely encourage consumers to reduce their energy consumption, allowing utility providers to shed loads placed on the power grid.

In order to fully understand these new efficiencies, let's examine the following example. Under the current electrical and flat-rate pricing system, consumers return home from work and turn on devices such as air conditioners, TVs, computers and kitchen appliances. Without being able to precisely determine when demand will peak or how high it will reach, utility providers must bring peaker plants online to meet customers' needs. Peaker plants provide backup power once a generation site has reached its capacity, and run for a short or variable amount of time until demand is reduced. Peaker plants are often more expensive and not as efficient and environmental friendly as a base-load power plant.

But with a networked smart meter combined with time-of-day pricing, the consumer will understand how much it is costing him, in real time, to set his thermostat at 75 compared to 78 degrees, or to dry his clothes and charge his electric car during peak-load versus low-demand times. The possibilities are endless. If the customer turns on his oven to cook a meal when electricity rates are high, the stove might tell the refrigerator to delay defrosting or adjust its temperature until dinner is served. Likewise, the washing machine will

be able to communicate with the dishwasher, ensuring that it will switch on only after the clothes are cleaned. Through the use of a home network and Web applications, the end user might also be able to set up rules for appliances, such as specifying a monthly electricity budget and instructing his appliances to operate within that defined budget.

Customer education and buy-in is vitally important to the success of the smart grid. "At the heart of the smart grid is customer education," Dosch said. "When consumers understand their consumption patterns and the real-time rates for such usage, the information may influence them to change their behavior."

Dosch reminds us that the electric industry can learn from the telecom industry. "What utilities are going through today is reminiscent of the evolution telecommunications providers experienced 10 or 15 years ago," he said. "Telcos have employed time-of-day pricing for many years which allowed providers to influence customer behavior and constrain demand when the telco did not have enough network capacity. This is very similar to the scenario utilities are experiencing today as they don't have enough power production to meet these high demand times."

Installing smart meters and utilizing time-of-day pricing will allow the utility to reduce customer needs, and balance energy supply and demand throughout the day. This is the first step to achieving the smart grid and the efficiencies promised by an interconnected system.

## Part 2: The Evolving Architecture of a Rural Electric Provider

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Traditionally, the nation's electric system is built on a centralized architecture, where power is generated by high-voltage units.

The National Rural Electric Cooperative Association ([NRECA](#)) represents 900 member cooperatives, which serve 42 million people in 47 states. Only a handful of the NRECA's members own and operate generation units. The majority of rural electric providers, approximately 95%, manage substations and the infrastructure which distributes electricity directly to end users. This is analogous to rural telcos which distribute connectivity directly to their customers, and then connect upstream with the IP backbone or long-distance network.

The central office or substation of the electric provider is connected to remote locations, analogous to telco remote terminals or hubs. These remote locations are connected via powerline to utility meters on the side of the consumer's home or business.

NRECA Principal Engineer Bob Saint noted that this conventional architecture is changing as utility providers install intelligent technology to interconnect their operations. "The smart grid will provide the ability to obtain data about the system, automate processes and operate more efficiently," Saint said. "Rural electrics have implemented a smart grid network when it has made business sense, and where it has been cost-effective."

The smart grid will not be implemented all at once but rather as an evolutionary process. The first phase involves the downstream deployment of smart meters connected to a central network, often referred to as advanced metering infrastructure (AMI). Technology that interconnects and improves the distribution system including the utility's sensors, switches, voltage controls and its monitoring system control and data acquisition (SCADA) at substations will be implemented at a slower pace. The last phase will involve the remote storage of energy in a decentralized fashion.

National Rural Telecommunications Cooperative ([NRTC](#)) Vice President of Utility Solutions Ed Drew said that rural electric co-ops are often ahead of the curve when it comes to launching smart grid technologies such as AMI. The two-way communication allows a utility to gather information about outages, and remotely connect and re-connect customers, eliminating an expensive truck roll, particularly in rural areas where customers are geographically separated. "Because rural utilities serve an average of about seven customers per mile, versus investor-owned utilities who serve about 47 customers per mile, they have led the way in adopting technologies that provide greater efficiencies," Drew said.

Saint added, "NRECA's members save time and money via AMI technology and this often justifies the initial expense to install smart meters."

National Information Solutions Cooperative ([NISC](#)) CEO Vern Dosch said, "Most utility providers are scurrying to get AMI in place and the broadband network to handle the data before it is mandated by federal or state policymakers." He added, "Where a utility is in the AMI deployment process is a direct result of its local supply and customer demand situation."

"In the Midwest, rural electrics have an ample supply of power and there is less urgency to move to a smart grid network and dynamic-based pricing scheme," Dosch said. "In the South and East, however, demand for power is outpacing supply. Some states have declared that they will not build any additional power plans but instead utilize existing power plants more efficiently." Dosch juxtaposed this with Indiana, where a few of NISC's customers will move to time-of-day pricing in 2010.

AMI is an outgrowth of advanced meter reading (AMR) technology, which was deployed in the 1990s. AMR technology enabled one-way communication, allowing utility providers to remotely read meters. It utilized power line to carry readings back to the substation and the central office. "The first-generation of AMR required very low bandwidth, well below 60 kilobits per second. In some instances it took 24 hours to read the meter, but the technology was inexpensive to deploy and it fulfilled the utility's needs," Saint said.

Dosch recognizes the chief disadvantage of this limited infrastructure. "Power lines simply do not have adequate capacity for the two-way communication enabled by a smart meter. Also, there's too much latency in the transmission."

Dosch explained that today's smart meters transmit engineering information, voltage data and meter readings. They also communicate blink data when the system blinks or changes dramatically in voltage. This allows a utility to engage in preventative maintenance before the system fails. "Right now the Achilles' heel for the smart grid and for utility providers is the connection from the smart meter to the utility," Dosch said.

### Part 3: Building the Smart Grid Broadband Network

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To operate a smart grid, rural utility providers will need last-mile broadband infrastructure connecting smart meters with remote locations and central offices. As utilities evolve and interconnect their networks, they will also need large-scale connectivity between their aggregation points.

Utilities looking to develop a smart grid have several options. They can build their own last-mile and core broadband network, partner with an existing network operator to provide the infrastructure or meet somewhere in the middle, deploying last-mile connectivity while working with a backhaul aggregator. The decision is based upon a variety of factors including the utility's unique needs and the local regulatory environment as defined by each state public utility commission.

#### Private versus Public Networks

Traditionally, electric providers have built private networks designed for crew communications and to control substations. Utility providers have justified this expenditure with the need to ensure service continuity at all times, especially during emergency scenarios.

Utilities are not only accustomed to operating private networks, they also have economic disincentives to use commercial networks. The utility industry is regulated at the state level. As rate-of-return regulated utilities, they typically earn guaranteed profits on the assets they deploy—such as private communications networks—but only receive cost recovery if they use commercial networks. In an attempt to eliminate barriers, [The National Broadband Plan \(NBP\)](#) released in March 2010 requested that state regulators carefully evaluate the current regulatory structure to reduce impediments and financial disincentives to using commercial networks for smart grid communications.

Electric providers maintain that private networks offer them control and simplicity of operations. "Utility providers want to utilize one ubiquitous broadband network for all of their customers, but in rural areas, not all of the customers are serviced via one [broadband] network," said Vern Dosch, CEO of the National Information Solutions Cooperative ([NISC](#)). "This creates complications for utilities."

Electric providers service much larger geographic areas when compared with rural telcos, and their territories are often served by Bell companies. In order to partner with local broadband providers, rural electricians will need to negotiate with various local telcos and Bell companies, as well as middle-mile providers for transport.

Despite utilities' historical preference to operate private networks, Dosch noted that the complexity and expense of managing and operating a private broadband network should not be underestimated.

Commercial networks are often suitable for many smart grid applications including metering and routine sensing applications. They also may provide a resilient and reliable network at an equal or lower total cost of ownership. The cost to build and maintain the network is an important attribute to the utility provider and its state regulatory authority.

#### Network Topology

The underlying smart grid broadband infrastructure, both within the home and within the larger grid, may utilize wired, wireless, cellular or mesh topology. "There is no one-size-fits-all solution," said Ed Drew, National Rural Telecommunications Cooperative ([NRTC](#)) vice president of utility solutions. "Every utility is different, and you really need to consider the geography of a utility's territory in order to make that decision."

Drew also reminds us that rural areas have unique electric—and smart grid—needs. "When selecting a telecommunications solution, a utility also needs to consider connectivity to areas where there are no people at all. For example, many rural areas will require connectivity at applications like irrigation pumps so the utility can remotely turn them on and off to reduce energy demand."

Utility providers often are turning to wireless technology for collecting smart meter data from homes and businesses. "Rural electricians are switching to a wireless broadband because of the relative cost, bandwidth and reliability," said Bob Saint, principal engineer at the National Rural Electric Cooperative Association ([NRECA](#)).

The electric industry has requested licensed spectrum from the FCC in order to operate a private IP network to exchange smart meter data and emergency voice communications for utility employees. The NBP proposed that utilities share or lease space on the public safety 700 MHz wireless broadband network, an idea which the [Utilities Telecom Council](#) (UTC) supports. The UTC also has asked the FCC for an additional 30 MHz of spectrum in the 1800-1830 MHz spectrum band to be set aside for smart grid applications, auction-free or without cost. The utility providers suggest that this set-aside will match with Canada's bandwidth allocation, creating a larger, attractive market which might invite more equipment manufacturers.

#### **Bandwidth Needs**

The million dollar question: How much bandwidth is necessary for smart grid operations? Experts at NISC, NRECA and NRTC characterize a smart grid broadband network as carrying bursts of data at even intervals. "Most smart meters in use today are capable of sending data at 15-minute increments, which is in excess of 2,900 meter readings per month," Dosh said. "The telco's wired broadband network—DSL or FTTH—will not notice this dribble of bits and bytes compared to other bandwidth-intensive Internet and video needs."

Drew added that historically, bandwidth needs have been modest. "Smart meters collect and transmit relatively small amounts of data, about 300 kilobits with every reading; however, the frequency of reading is increasing, and that data is being brought back to substations, aggregated and sent on to the utilities' operation centers."

Last-mile connectivity is just part of the picture. Drew notes that utilities will need high-speed connectivity, often microwave or fiber links, between their substations. In addition, utilities may require mobile voice, data and video surveillance in the field, and high-speed data and voice access in their operations centers. "Bandwidth demands will grow but, bandwidth may not be as challenging as the need to reach 100% of the service area, ensure low latency and provide four- or five-nines network reliability," Drew said.

#### **Utilities Partner with Telcos**

In the quest to build a smart grid broadband network, rural electric and rural broadband providers can partner together to leverage each other's strengths and share resources. "Redundant systems are expensive," Saint said. "It's imperative that rural electric and rural telco providers work together for the good of our members and our customers."

Rural telcos are equipped with the network capacity and technical expertise needed to build out the network. Dosch advises telcos to be progressive and assertive. "Don't sit and wait," he said. "Knock on your local electric provider's door and ask if there is any way your telco can help—if you can collaborate to leverage the existing infrastructure the telco has in place and its technical expertise. You will provide a valuable service to the local utility provider and perhaps create a new revenue stream in the process."

Telcos will need to understand utility providers' unique needs before engaging in partnerships. Reliability, resiliency, low latency and security are fundamental to their operations.

Drew also advises telcos to talk with management at local electric utilities: "What are their communications needs? Are they installing smart meters, upgrading substations, adding mobile data to their work fleet or more? What communications technologies do they use today? Are they looking at building out communications systems? Can you provide what they need, or work together on shared resources or joint build-outs? Can the local electric co-op be an anchor tenant for your network?"

The collaboration between broadband service providers and utility operators is an evolving process that will take different forms in various communities nationwide.

### **Part 4: Standards Development**

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Crucial to the smart grid ecosystem is the development of an open architecture defined by clear, accepted standards for interconnection, interoperability, performance and monitoring. These standards will provide a necessary foundation for an intelligent network and the many devices which will interface with the grid.

The National Rural Electric Cooperative Association ([NRECA](#)) is intimately involved with the standards development process. "We need uniform ways of communicating for the smart grid network to be successful," said Bob Saint, principal engineer at NRECA. "Electric cooperatives don't have the staff or resources to customize solutions. We need a device that is plug-and-play, or as near plug-and-play as possible for a variety of network architectures."

The U.S. Department of Commerce National Institute of Standards & Technology ([NIST](#)), which started working on smart grid standards in 2007 when it was tasked to do so by the Energy Independence & Security Act, is spearheading national standards efforts. To carry out its mission, NIST received \$15 million through the American Recovery and Reinvestment Act of 2009 (ARRA).

The agency estimates that the smart grid will require hundreds of standards. NIST is facilitating the process, acting as a mediator between countless public and private organizations to unite their diverse interests and industries. Saint shared one anecdote whereby home area networking vendors, remote energy management systems and utility providers all define a time period differently. This is an important and basic input into the smart grid system and the lack of agreement speaks to the complexity and sheer size of the task.

NIST has developed a three-phase plan to tackle standards development. Phase one involved the identification of applicable standards, gaps in available standards and priorities for new standardization activities. In September 2009, the agency released the [NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0](#), a high-level reference model for the protocols and standards for managing information among smart grid devices and systems. The document identified 75 applicable existing standards and 16 high-priority gaps for which new or revised standards are needed.

In Phase 2, the agency established a formal public-private partnership to drive longer term progress. This included a more permanent governance structure called the Smart Grid Interoperability Panel. More than 1,600 individuals from 580 organizations will guide the ongoing development of standards. The Cyber Security Working Group was also convened. As of early August, the working group is preparing to issue a final draft of "Guidelines for Smart Grid Cyber Security." Phase 3 will concern testing, certification and interoperability.

Privacy and security issues are at the forefront of any smart grid discussion. Smart meters will collect real-time information concerning a consumer's energy use and relay this information over an IP network. Vendors want access to this information to market products and services directly to potential consumer and enterprise target markets. There are a lot of questions surrounding who "owns" the detailed energy usage data that smart meters will record and transmit, and under what circumstances third parties should be able to access that information. The U.S. Department of Energy (DoE) is investigating privacy issues as a direction of the National Broadband Plan (NBP). NIST also is examining the privacy and security requirements for the billing and usage data that is gathered via smart meters.

Simultaneously, cybersecurity standards are under development. The smart grid will interconnect home appliances, PCs and countless other devices to the power and information grid, offering many portals for inadvertent and direct attacks and sabotage.

NIST has developed a clear-cut framework to tackle smart grid standards development but questions and confusion remain. The process has been rife with politics and differing opinions. This is not unlike the telecom standards ecosystem where consumer electronics manufacturers and broadband service providers are at odds. "Most proposed smart-grid standards are IP-based and describe themselves as 'open,' but on both sides of the meter the issues have been political as much as technical," Saint said.

For instance, the U.S Federal Energy Regulatory Commission ([FERC](#)) has clear jurisdiction over bulk power generation plants. The 2007 Energy Independence & Security Act also tasked FERC with approving the framework adopted by NIST. However, the state regulatory bodies, which oversee electric distribution systems, might object to this interference with their authority.

Developing smart grid standards will be a multiyear effort which, in some cases, will be never-ending as the requirements and the technology evolves. Despite the technological and political obstacles, standards are vital to ensure the resulting network is reliable, robust and future-proof. It is important for utility providers and their broadband partners to stay abreast of standards development and requirements as it will affect how the network is built, operated and maintained.

#### **Now is the Time to Partner**

The federal and state landscape is complex, and it will directly influence the pace, scope and direction of smart grid deployment. The U.S. Congress, DoE, FERC, NIST, FCC and state public utility commissions have influence and jurisdiction over pieces of the smart grid marketplace.

Modernizing the electric grid is a monumental undertaking which will require creativity and coordination. Capital investment is needed to build and maintain an interconnected information and electrical grid. Standards are needed to ensure an open architecture. Utility providers must change their business models and resolve their broadband needs. These are only a few of the major hurdles which stand between utility providers and ubiquitous smart grid deployment.

National Information Solutions Cooperative ([NISC](#)) CEO Vern Dosch leaves us with this thought: "I've heard a lot of talk that the smart grid is a fad, the latest buzz term. But this is not the case. Just as the PC and the Internet forever changed the way telcos do business, the smart grid will forever change the way utilities operate. The smart grid is just too important, from an environmental and

cost efficiency perspective, not to be pursued. But the smart grid will fail if utilities do not effectively transmit the data from the home to a central access point.”

Rural utility and telecommunications providers share a commitment to providing the rural customer with top-notch service and cutting-edge technology. Despite their common goals, historically rural electric and broadband providers have been ill-inclined to work together. For the smart grid to blossom, rural electric and broadband providers need a fresh start and a new, creative approach to mutually constructing and maintaining this foundational partnership.

The broadband network is fundamental to all aspects of the smart grid and as such, rural electric providers and rural telcos are ideal partners in smart-grid ventures. There is no one-size-fits-all approach; what this partnership looks like will be different in every community. The smart grid ecosystem is still at its infancy, and now is the time to partner to develop a shared vision for the intelligent grid of the future.

## Resources

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[The American Recovery and Reinvestment Act of 2009 Broadband Initiatives Program \(BIP\)](#)

[Electric Power Research Institute](#)

[Federal Energy Regulatory Commission \(FERC\)](#)

[National Broadband Plan, Recommendations on Energy and the Environment](#)

[National Information Solutions Cooperative \(NISC\)](#)

[National Institute of Standards and Technology \(NIST\)](#)

[National Rural Electric Cooperative Association \(NRECA\)](#)

[National Rural Telecommunications Cooperative \(NRTC\)](#)

[NTCA's October 2, 2009, comments submitted to the FCC on smart grid](#)

[Pacific Northwest National Laboratory](#)

[SmartGrid.gov](#)

[U.S. Department of Energy \(DoE\) Smart Grid Overview](#)

[Utilities Telecom Council \(UTC\)](#)

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