# THE SMART GRID

## THE FUTURE OF POWER IN THE UNITED STATES

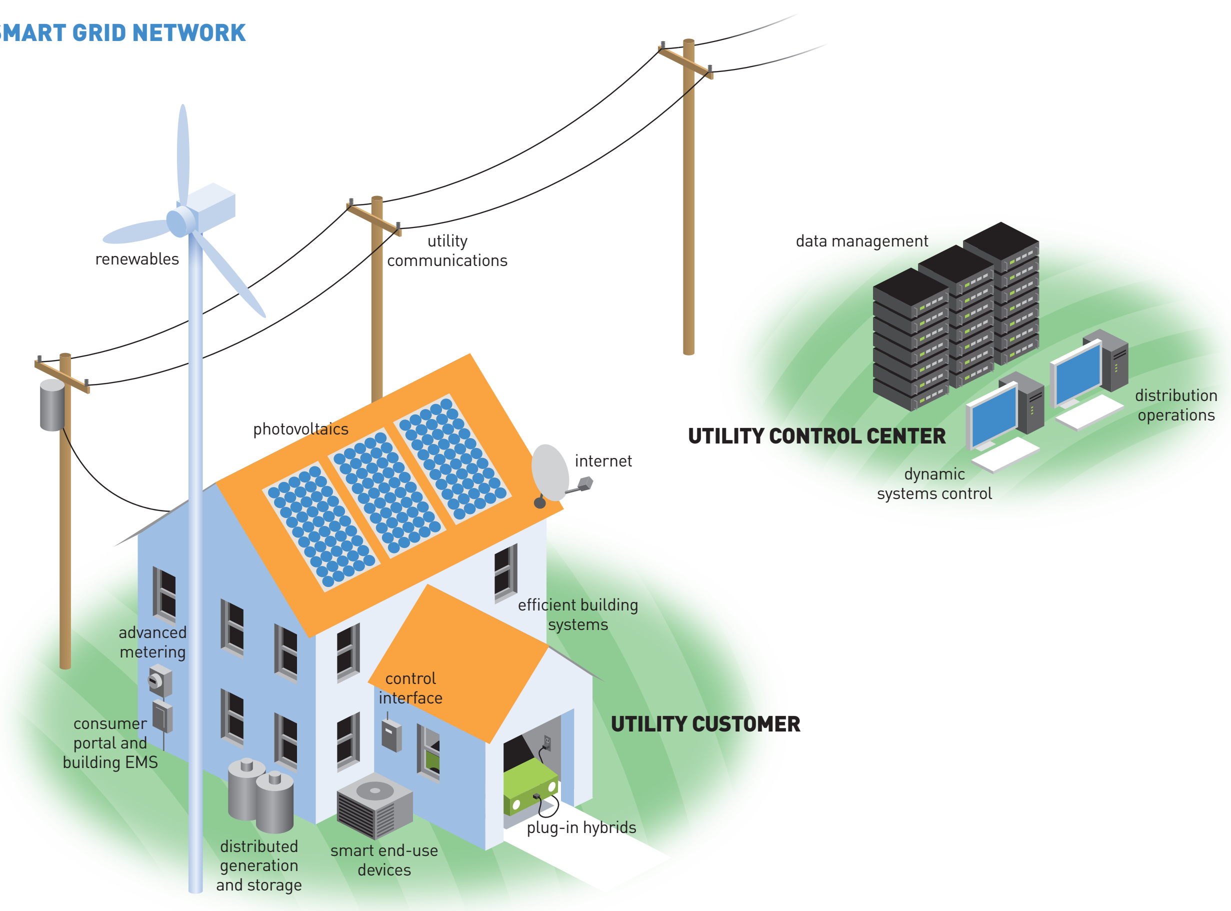
According to the U.S. Department of Energy (DOE), the nation's current electric grid is the largest interconnected machine in the world, consisting of over 9,200 electric generating units with over 1,000,000 megawatts of generating capacity, connected to more than 300,000 miles of transmission lines. Growing demand on the grid is stretching it to its limits, and there is no end in sight. The DOE estimates that nationwide demand for electricity is expected to grow 30 percent by 2030, and electricity prices are forecast to increase 50 percent over the next seven years.

Left alone as it is, the grid is simply incapable of sustaining this level of demand. However, the costs associated with "building out" the grid in traditional ways are simply prohibitive.

A solution? Enter the "smart grid." DOE defines smart grid as: "the electricity delivery network from electrical generation to end-use customers, integrated with the latest advances in digital and information technology to improve electric system reliability, security and efficiency."

The smart grid is designed to provide a two-way flow of electricity and information, and will be capable of monitoring everything from power plants to individual customer preferences for home appliances. It incorporates the benefits of distributed computing and communications to deliver real-time information and to enable the near-instantaneous balance of supply and demand at the device level. The technology interacts with the grid in a "soup to nuts" fashion, including electricity transmission, electricity storage, wide-area situational awareness, demand-response, advanced metering infrastructure (AMI), distribution and overall grid management.

### SMART GRID NETWORK



## SMART GRID APPLICATIONS AND FUNCTIONALITY

Overall, the smart grid is designed to improve reliability, security, the environment and global competitiveness. It does so in a number of ways. However, five areas of particular interest to stakeholders these days are:

**1 - Reduced Peak Demand:** Smart grid technology helps to reduce peak demand by actively managing consumer demand. The ability to manage power in both directions (by the consumer and by the utility) will reduce the need for power, especially during high-use periods. Already, the percentage of available appliances and equipment that can respond to consumer and utility operator priorities is growing.

**2 - Improved Operational Efficiency:** As the grid becomes more automated, smart sensors and controls will be integral to its design and operation. Utility operators will be able to easily identify, diagnose and correct problems, and will even have the ability to anticipate problems before they happen.

**3 - More Access to Renewables:** The smart grid offers the only gateway to increased use of renewable energy and decreased reliance on fossil fuels. The reason is that certain alternative energy sources are often located far from areas of bulk power demand. The smart grid can seamlessly integrate these clean energy technologies. That is, electric vehicles, roof-top solar systems, wind farms and storage devices are becoming a fundamental part of the grid, and the smart grid can link them up to the grid to run power in both directions.

**4 - Reduced Carbon Footprint:** While the transportation sector emits 20 percent of all carbon dioxide, electricity generation emits 40 percent. By reducing energy demand through the first three improvements (reduced peak demand, greater efficiency and more access to renewables), the smart grid can significantly reduce the carbon footprint of the electric industry.

**Potential reductions in electricity sector energy and $CO_2$ emissions in 2030 attributable to smart grid technologies***

| Mechanism | Direct (%) | Indirect (%) |
|---|---|---|
| Conservation effect of consumer information and feedback systems | 3.0 | - |
| Joint marketing of energy efficiency and demand-response programs | - | 0.0 |
| Deployment of diagnostics in residential and small/medium commercial buildings | 3.0 | - |
| Measurement and verification for energy efficiency programs | 1.0 | 0.5 |
| Shifting load to more efficient generation | < 0.1 | - |
| Support additional electric and plug-in hybrid vehicles | 3.0 | - |
| Conservation voltage reduction and advanced voltage control | 2.0 | - |
| Support penetration of renewable wind and solar generation** | < 0.1 | 5.0 |
| **TOTAL** | **12.0** | **5.5** |

* assumes 100% penetration of smart grid technologies
** 25% renewable portfolio standard

**5 - Improved Reliability and Power Quality:** Since the smart grid can anticipate, detect and respond to problems rapidly, it reduces the potential for wide-area blackouts to almost zero. In addition, these days, more and more applications require almost perfect reliability and quality. The smart grid will be able to provide these levels and requirements.

Stakeholders and the private and public sectors are becoming more aware of the benefits (some say necessity) of the smart grid, and significant steps are being taken to create it.

For example:

- The Energy Independence and Security Act of 2007 (EISA) made the smart grid a national priority. The legislation created a number of new programs and guidelines, including support for research and investment, as well as establishing a smart grid advisory committee and the Smart Grid Task Force to oversee and guide smart grid activities.
- In early 2009, the president signed a $787 billion economic stimulus package (American Recovery and Reinvestment Act) that allocated $4.4 billion in grants for modernizing the electric grid.

## THE ROLE OF SMART GRID IN HOME ENERGY MANAGEMENT

The advanced metering infrastructure (AMI) component of the smart grid provides consumers with information and technology to manage their energy usage more intelligently. AMI technology can send price signals to "smart" home controllers or end-use devices such as thermostats, washers/dryers and refrigerators. The devices process information based on consumer wishes, and then power up or down accordingly. For example, if the price of electricity rises above a certain level that the consumer has identified, the technology will shut down certain appliances.

An important goal of the smart grid rollout is to ensure that every home has a smart meter, and that every high-energy-using appliance will have a smart chip capable of performing shutoffs and restarts, so that a utility can temporarily reduce peak power demands. According to the Institute for Electric Efficiency, over 58 million smart meters will be deployed to mass-market customers over the next five to seven years.

Appliance manufacturers are also getting on board. Whirlpool, the world's largest manufacturer and marketer of major home appliances, has announced plans to make all of its electronically controlled appliances smart grid-compatible by 2015. Whirlpool has said that this is contingent on two things happening. First is the development by the end of 2010 of an open global standard for transmission signals to and from appliances. Second are appropriate policies in place that reward consumers, manufacturers and utilities for adding and using these new peak demand reduction capabilities. And, as can be seen later in this white paper, important strides are being taken toward these two goals. General Electric is another company that manufactures several "smart" appliances, and it has been running a pilot program to determine all of the benefits of the technology.

Other efforts are under way to encourage widespread consumer adoption. That is, consumers need to embrace the two-way monitoring technology that can help control peak power requirements. One way to achieve this is for utilities to implement dynamic pricing that provides incentives for consumers to change their energy-use patterns (i.e., offering cheaper rates per kilowatt hour at off-peak times, thus encouraging consumers to run their appliances at these times).

Another important component of consumer interaction with the smart grid is that the technology will allow the use of net metering, which provides an incentive for consumers to invest in distributed energy generation.

## SMART GRID'S WEALTH OF BENEFITS FOR THE POWER INDUSTRY

The smart grid offers an almost unlimited number of benefits for those involved in electricity generation, transmission, storage and distribution.

| LEVEL | 1 Exploring and Initiating | 2 Functional investing | 3 Integrating cross-functional | 4 Optimizing enterprise-wide | 5 Innovating next wave of improvements |
|---|---|---|---|---|---|
| DESCRIPTION | Contemplating smart grid transformation. May have vision but no strategy yet. Exploring options. Evaluating business cases, technologies. Might have elements already deployed. | Making decisions, at least at a functional level. Business cases in place, investment being made. One or more functional deployments under way with value being realized. Strategy in place. | Smart grid spreads. Operational linkages established between two or more functional areas. Management ensures decisions span functional interests, resulting in cross-functional benefits. | Smart grid functionality and benefits realized. Management and operational systems rely on and take full advantage of observability and integrated control across and between enterprise functions. | New business operational, environmental and societal opportunities present themselves, and the capability exists to take advantage of them. |
| RESULT | VISION | STRATEGY | SYSTEMIZATION | TRANSFORMATION | PERPETUAL INNOVATION |

**1 - Peak Demand Management and Reduction:** First and most important among these is the ability to manage and reduce peak load requirements. While the law of supply and demand is a bedrock concept in virtually all industries, the utility industry struggles more than any other industry simply because, with the exception of a limited number of small storage devices, electricity must be consumed the moment it is generated. Without being able to determine demand precisely at any given time, having the right supply available to deal with every contingency is difficult.

This is particularly true during episodes of peak demand. During peak demand times, utilities are usually required to bring on "peaker plants" to ensure sufficient demand and reliability. Most of these peaker plants are old and expensive. In addition, according to the DOE, 10 percent of all generation assets and 25 percent of all distribution infrastructure are required less than 400 hours per year.

Reducing peak demand not only reduces the need to pull power from existing peaker plants, but can also reduce or even eliminate the need to build new peaker plants in the future.

The smart grid allows the systematic reduction of load demand, primarily through AMI technology, but also through granular-level visualization of demand that allows utilities to better control loads. In sum, both of these technologies can reduce, even eliminate, the demand for bringing peaker plants online.

In a DOE demonstration project, which took place on Washington's Olympic Peninsula, consumers saved about 10 percent on their bills. Peak load was reduced by 15 percent, providing the already-constrained regional grid with another three to five years of peak load growth.

**2 - Grid Awareness:** Decision support systems within the smart grid will "know" when there is a need to quickly reduce load and respond to adverse conditions. Communications and control technologies will be able to isolate faults and allow more rapid restoration of service.

A project being conducted by the DOE and the Oak Ridge National Laboratory, called Visualizing Energy Resources Dynamically on Earth (VERDE), will provide wide-area grid awareness, integrating real-time sensor data, weather information and grid modeling with geographical information. This will allow the exploration of the grid at all levels, from the national level to the street level. It will provide rapid information about blackouts and power quality, as well as insights into the system operations.

**3 - Improved Power Quality:** According to the Electric Power Research Institute (EPRI), 16 percent of our nation's electric load will require digital-quality power by 2011, in order to reduce voltage dips that can cost banks, data centers and other facilities millions of dollars by impacting their sensitive equipment. The smart grid will help move the trend to digital-quality power along.

**4 - Improved Capacity and Storage:** The smart grid will increase the overall use and value of existing generation and transmission capacity, and improve power quality to correspond to new digital demands. DOE estimates that smart grid enhancements will ease congestion and increase utilization of full capacity, sending 50 percent to 300 percent more electricity through existing energy corridors. For example, the smart grid will allow more access to the use of distributed energy resources, such as combined heat and power (CHP) units, most of which reside at large industrial and commercial sites. These units have a substantially lower profile of $CO2$ emissions.

The smart grid will also enable utilities to locate more storage batteries and other forms of energy storage in more places. Stationed at thousands of points throughout the smart grid, these devices will be able to provide additional electricity resources throughout the system.

Overall, according to the DOE:

- Smart appliances costing $600 million can provide as much reserve capacity to the grid as power plants worth $6 billion.
- The increased energy efficiency, renewable energy and distributed generation made available by the smart grid can save an estimated $36 billion annually by 2025.
- Distributed generation alone can significantly reduce transmission congestion costs, currently estimated at $4.8 billion annually.
- Over 20 years, $46 billion to $117 billion can be saved in the avoided costs associated with the construction of new power plants, transmission lines and substations.

## COMMUNICATION NETWORK AND DATA MANAGEMENT REQUIREMENTS

As the grid becomes more automated via smart grid technologies, smart sensors and controls will be integral to its design and operation. Utility operators will be able to easily identify, diagnose and correct problems, and will even have the ability to anticipate problems before they happen. Communications and control technologies will be able to isolate faults and allow more rapid restoration of service. Decision support systems will "know" when there is a need to quickly reduce load and respond to adverse conditions.

Gone are the days of reading or "pinging" meters once a month. Smart grid devices will generate data on usage and activities in the home on a minute-by-minute basis.

OE has identified five fundamental technologies that will drive the smart grid:

**1 - Integrated Two-Way Communications:** This involves connecting components to open architecture for real-time information and control, allowing every part of the grid to both "talk" and "listen." This creates a grid with dynamic, interactive, real-time infrastructure. An open architecture creates a plug-and-play environment that securely networks grid components and operators, enabling them to talk, listen and interact.

**2 - Sensing and Measurement Technologies:** These are designed to support faster and more accurate response, such as remote monitoring, time-of-use pricing and demand-side management. The technologies enhance power system measurements and facilitate the transformation of data into information to evaluate the health of equipment, support advanced protective relaying, enable consumer choice and help relieve congestion.

**3 - Advanced Components:** These play an active role in determining the electrical behavior of the grid, applying the latest research in materials, superconductivity, energy storage, power electronics, diagnostics and microelectronics to produce higher power densities, greater reliability and better power quality.

**4 - Advanced Control Methods:** These technologies monitor power system components, enabling rapid diagnosis and timely, appropriate responses to any event. In addition, they also support market pricing, and enhance asset management and efficient operations.

**5 - Improved Interfaces and Decision Support:** These technologies are designed to amplify human decision-making, transforming grid operators and managers into "visionaries" when it comes to seeing into their systems. They enable grid operators and managers to make more accurate and timely decisions at all levels of the grid, including the consumer level, while enabling more advanced operator training.

## PUBLIC AND PRIVATE SECTOR INVOLVEMENT: ADDRESSING THE CHALLENGES AND OPPORTUNITIES

Not many things are seen as "silver bullets" in terms of offering solutions to various problems. However, most observers believe that the smart grid is the closest thing to a "silver bullet" as there is for the power industry. Still, the technology is not without its challenges.

There are many, but three are "front and center" for those who are involved with rolling out the smart grid:

**1 – Interoperability:** The smart grid requires open architecture solutions and agreed-upon standards for smart grid devices. In fact, interoperability may be the biggest challenge smart grid faces.

**2 - Cybersecurity:** While smart grid introduces technologies that are designed to improve security over what is currently available on the grid, the smart grid itself also opens up new exposures, such as remote access to control systems, as a result of increased two-way communications and the expanded collection and transmission of consumption data. For example, issues associated with consumer attempts to alter consumption data, and outside hackers breaking into the system to steal data or even sabotage the grid, are of great concern.

**3 - Consumer Adoption:** Consumers need to embrace the two-way monitoring technology that can help control peak power requirements. Without this, a significant portion of smart grid benefits will go unused.

### TODAY'S GRID, AND TOMORROW'S

| Characteristic | Today's grid | smart grid |
|---|---|---|
| **Enables active participation by consumers** | Consumers are uninformed and non-participative with power system | Informed, involved, and active consumers — demand response and distributed energy resources |
| **Accommodates all generation and storage options** | Dominated by central generation. Many obstacles exist for distributed energy resources interconnection | Many distributed energy resources with plug-and-play convenience focus on renewables |
| **Enables new products, services and markets** | Limited wholesale markets, not well integrated — limited opportunities for consumers | Mature, well-integrated wholesale markets, growth of new electricity markets for consumers |
| **Provides power quality for the digital economy** | Focus on outages — slow response to power quality issues | Power quality is a priority with a variety of quality/price options — rapid resolution of issues |
| **Optimizes assets and operates efficiently** | Little integration of operational data with asset management — business process silos | Greatly expanded data acquisition of grid parameters — focus on prevention, minimizing impact to consumers |
| **Anticipates and responds to system disturbances (self-heals)** | Responds to prevent further damage Focus is on protecting assets following fault | Automatically detects and responds to problems — focus on prevention, minimizing impact to consumer |
| **Operates resiliently against attack and natural disaster** | Vulnerable to malicious acts of terror and natural disasters | Resilient to attack and natural disasters with rapid restoration capabilities |

For better or worse, there is no centralized or national "smart grid czar" orchestrating the rollout of the technology. Currently, there are a number of federal and state agencies and quasi-agencies, as well as private industry groups, involved in the initiative, working both independently and cooperatively:

- The U.S. Department of Energy (DOE). While there is no "czar," the DOE has the most direct and wide-ranging responsibility for orchestrating the wholesale modernization of the nation's electric grid, including a number of elements of the smart grid. This is done through the DOE's Office of Electricity Delivery and Energy Reliability. DOE created the Electricity Advisory Committee and the Smart Grid Task Force to advise the DOE on strategies to modernize the nation's electricity delivery infrastructure, to coordinate standards development, to guide research and development projects, and to reconcile the agendas of the various stakeholders.

- The National Institute of Standards and Technology (NIST) has been charged under the Energy Independence and Security Act of 2007 (EISA) with identifying and evaluating existing standards, measurement methods, technologies and other support in service to smart grid adoption. Since 2007, NIST has been shouldering a lot of responsibility for cybersecurity issues. Since that time, it has been assessing vulnerabilities and, in 2010, adopted a strategy for securing the devices that enable the grid. This should be in place by end of 2010. NIST is also working on interoperability standards. It recently released a report titled "NIST Framework and Roadmap for Smart Grid Interoperability Standards." In addition, in early 2010, NIST launched an initiative designed to encourage widespread consumer adoption of smart grid technology. Finally, the Gridwise Architecture Council, which is part of NIST, is composed of industry experts focused on interoperability of grid devices and systems.

- The Federal Energy Regulatory Commission (FERC) and its state counterpart, the National Association of Regulatory Utility Commissioners (NARUC), are partnering to facilitate the transition to the smart grid, thus linking federal initiatives (FERC) with state initiatives (NARUC). It is called the FERC/NARUC Smart Grid Collaborative.
- The North American Electric Reliability Corporation (NERC), a utility industry group, is working directly with utilities to create the Critical Infrastructure Protection (CIP) standards, with a special focus on cybersecurity.

The Electric Power Research Institute (EPRI) is working on a variety of research, development and demonstration projects that support the smart grid, especially those that help to link electricity with communications and computer control to achieve gains in reliability, capacity and customer services.

The GridWise Alliance, which is composed primarily of stakeholders from the private sector and academia, has established work groups to address the challenges of implementing the smart grid. Current work groups are focused on federal, regional and state legislation and policy, implementation and interoperability.

- Numerous other government agencies and industry groups have formed and/or created initiatives to address smart grid adoption.

## RESOURCES

The U.S. Department of Energy (DOE) has a number of useful resources available online. These include:

| **General information on the smart grid:** | **Other useful sites include:** |
|---|---|
| www.oe.energy.gov/SmartGridIntroduction.htm | Electric Power Research Institute: www.smartgrid.epri.com |
| A 48-page introductory document on the smart grid: www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf | GridWise Alliance: www.gridwise.org |
| A 30-page document on smart grid information of specific interest to utilities: www.oe.energy.gov/DocumentsandMedia/Utilities.pdf | Smart Grid News: www.smartgridnews.com |

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