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Presents

CleanTX Analysis on the Smart Grid

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***Special Thanks to*:**

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I. Executive Summary

The utility industry in the United States has an opportunity to revolutionize its electric grid system by utilizing emerging software, hardware and wireless technologies and renewable energy sources. As electricity generation in the U.S. increases by over 30% from today's generation of 4,100 Terawatt hours per year to a production of 5,400 Terawatt hours per year by 2030, a new type of grid is necessary to ensure reliable and quality power. The projected U.S. population increase and economic growth will require a grid that can transmit and distribute significantly more power than it does today. Known as a Smart Grid, this system enables two-way transmission of electrons and information to create a demand-response system that will optimize electricity delivery to consumers.

This paper:
- Outlines the issues with the current grid infrastructure
- Discusses the economic advantages of the Smart Grid for both consumers and utilities
- Examines the emerging technologies that will enable cleaner, more efficient and cost-effective power transmission and consumption

The existing electric grid (see Figure 1) is a massive infrastructure that enables the transmission and distribution of electrons in one direction. It is valued at more than $800 billion and comprised of transmission lines, transformers and circuit breakers. The grid moves electricity as power pulses at nearly the speed of light. However, this equipment is comprised of 25- to 40-year-old legacy technology, which is in desperate need of replacement. Consequently, the electric grid is ill-prepared to deal with the impact of extreme weather, heat waves and unforeseen security threats. The North American grid also loses a significant amount of its transmitted and distributed energy and lacks two-way intelligence. The grid also must accommodate additional power from huge, remote solar and wind farms, which are often erratic and unpredictable in their generation capacity.

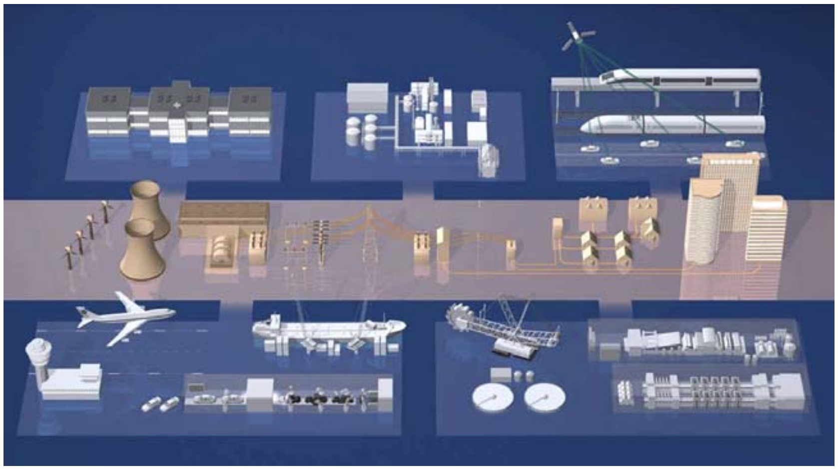


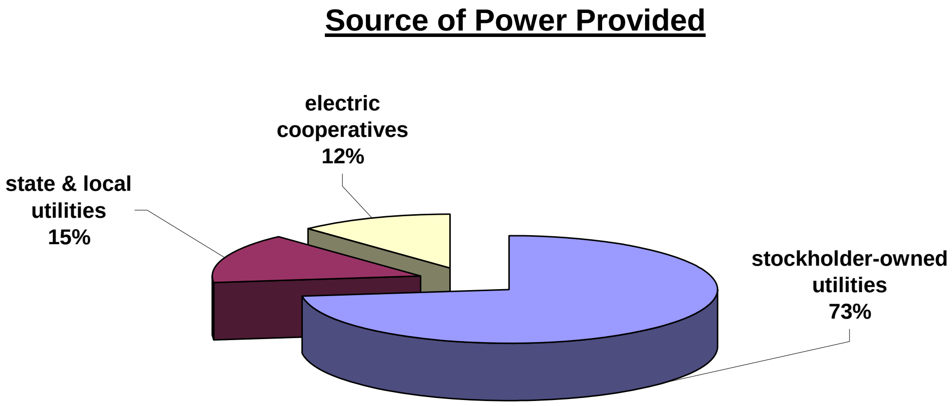
Image courtesy of Siemens AG

Figure 1: The current electric grid is the backbone of our power distribution society.

Creation and implementation of a Smart Grid will require innovation across the utility system in generation, transmission and distribution of devices in the home, including widespread wireless computing with business intelligence delivery on every critical node, and the development of smart meters that can help users and utilities more efficiently track and manage the use of energy and water. The resulting Smart Grid will be comprised of a new generation of demand-side management products and services that reduce the need for fossil fuel-based energy-generation allowing alternative sources of energy to work seamlessly with existing generation while improving reliability and enabling two-way data transfer. This demand-managed power will result in a grid that is more integrated, optimized, interactive, self-healing, secure and customer-focused than the current grid, providing several benefits for both consumers and utilities. The Smart Grid will enable consumers to monitor electricity usage, reduce costs and sell locally-generated power back to the grid. The utilities will not only optimize electricity distribution, but will be better able to respond to power outages and failures and manage peak usage periods. While deployment the Smart Grid faces several challenges, successful implementation will enable clean, more efficient and cost-effective generation, distribution and consumption of energy.

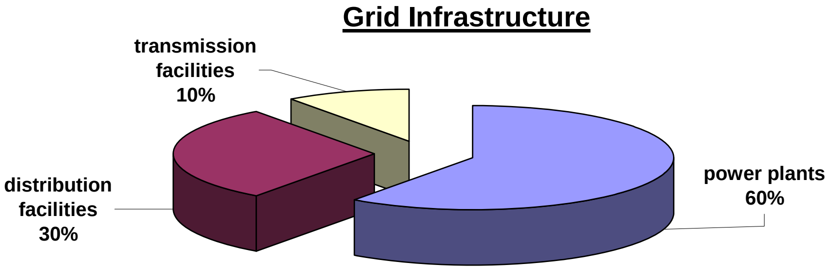
II. What is the Electric Grid?

Electricity is one of the largest and most capital-intensive sectors of the economy. Serving 140 million electricity customers, the grid has annual electric revenues (the U.S. “electric bill”) of about $247 billion and total asset value of approximately $800 billion. More than 3,100 utilities provide power through three main sources (see Figure 2) and the grid’s infrastructure is divided into three main categories (see Figure 3):


Source of Power Provided

Data courtesy of U.S. DOE Electricity Delivery & Energy Reliability

Figure 2: The three main sources of electrical power in the U.S.


Grid Infrastructure

Data courtesy of U.S. DOE Electricity Delivery & Energy Reliability

Figure 3: The $800 billion infrastructure is composed of three main equipment types.

The transmission grid is the network of equipment that supplies, controls, delivers and consumes power. Grid operations are fundamental to balancing load and supply, ensuring reliability and delivery of quality power, and reducing the impact of adverse power conditions. The bulk power system consists of three independent networks (see Figure 4): Eastern Interconnection, Western Interconnection and the ERCOT (Electric Reliability Council of Texas) Interconnection, which includes most of the state of Texas. These networks incorporate international connections with Canada and Mexico. Each grid is composed of transmission lines operated by numerous owners, including federal power authorities, regulated utilities and conglomerates. State, regional and federal regulators govern the grid and decide how much power can enter the grid and flow through each set of lines.

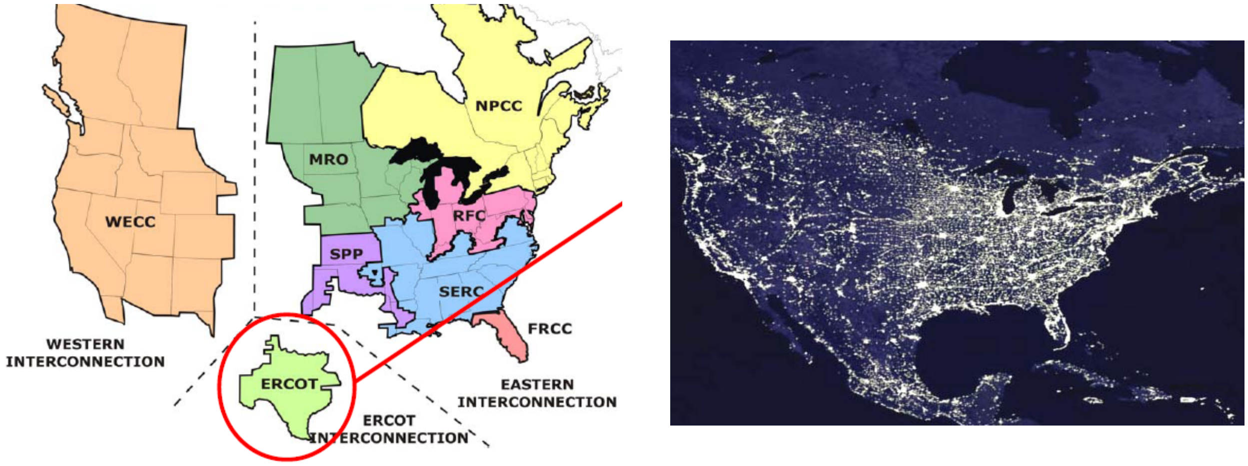


Image courtesy of U.S. DOE *Image courtesy of NASA*

Figure 4: The three main interconnections (left), and illuminated backbone of the grid (right).

The main components of the grid include power stations, transformers, distribution switches, transmission lines, converters, monitoring systems and surge protection devices. With such complexity, it is no surprise that there is a need for significant technological improvements to address problems such as blackouts.

An electric power system is a group of generation, transmission, distribution and communication facilities, which are physically connected and maintained by an electric utility (see Figure 5). The flow of electricity within the system is maintained and controlled by dispatch centers, which match the supply of electricity with the demand. In order to carry out its responsibilities, the dispatch center is authorized to buy and sell electricity based on system requirements. The interconnected utilities within each power grid coordinate operations and may buy and sell power among them.

Most of the U.S. energy today comes from large, centralized generation facilities, such as power plants. Generation is achieved through a fleet of about 10,000 power plants and 5,600 distributed energy facilities that combine heat and power generation. The profile of the electric power generation industry is changing rapidly, because ownership is shifting from regulated utilities to competitive suppliers. For utility use, cleaner and more fuel-efficient power generation technologies are becoming available.

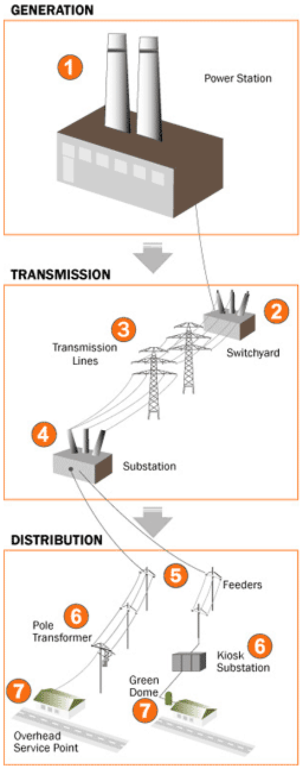
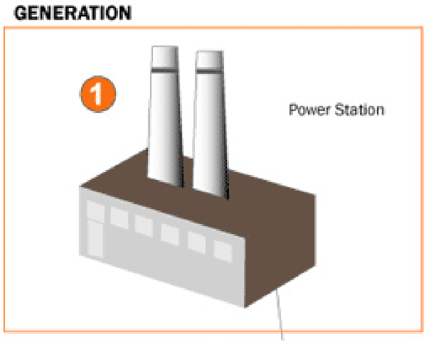


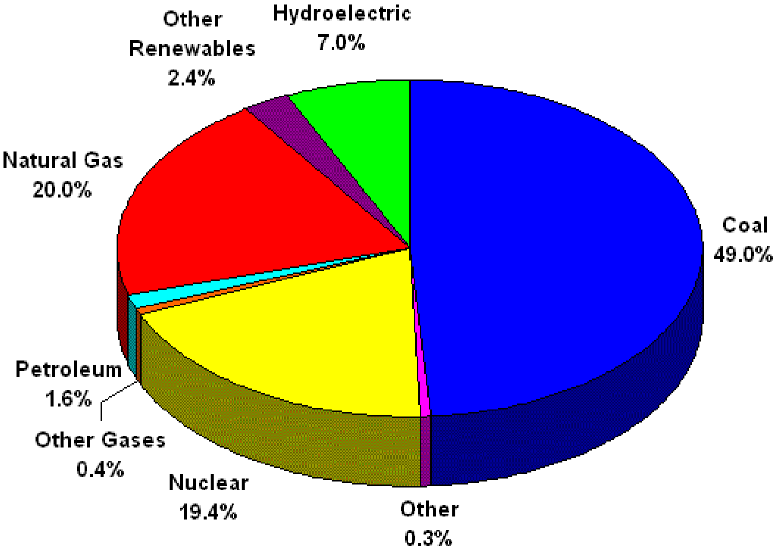
Image courtesy of Western Power

Figure 5: The flow of electricity via generation, transmission and distribution.

A. Generation



Electricity generation is the process of converting some form of energy into electricity, by a variety of different means (see Figure 6). Primarily, electricity generation is achieved by rotating turbines that are attached to electrical generators and are driven by a fluid (see Figure 7):



Data courtesy of U.S. DOE Energy Information Administration's Annual Energy Outlook

Figure 6: The sources of energy consumption in the U.S. in 2006.

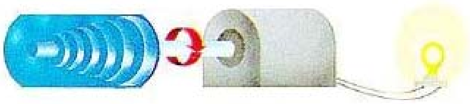


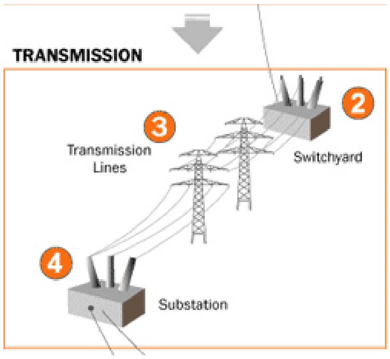
Image Courtesy of Slovenské Elektrárne, a.s.

Figure 7: Electricity generation is achieved from turning a turbine, which drives a generator to produce electricity.

The turbine motion can be produced by:

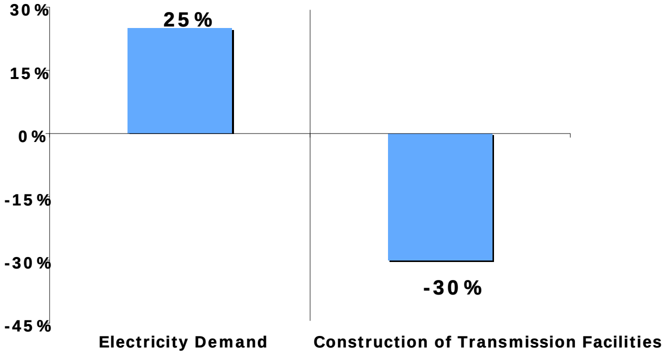
- Steam that is produced from the burning of fossil fuels, such as coal, natural gas or petroleum
- Steam that is produced when water is boiled by nuclear fission
- Solar power towers that concentrate sunlight to heat a fluid, which is used to produce steam
- Geothermal power from steam under pressure from the ground
- Hydroelectric power produced from flowing water produced by dams or tidal forces
- Wind with the use of wind turbines, mounted on land
- Hot gas that is produced by combustion of natural gas or oil

B. Transmission



Power transmission is the delivery of electricity between the power plant and a substation, which allows distant energy sources to be connected to consumers in population centers. Due to the large amount of power involved, transmission normally takes place at high voltages of 110kV or above and is transmitted over long distances through overhead power transmission lines.

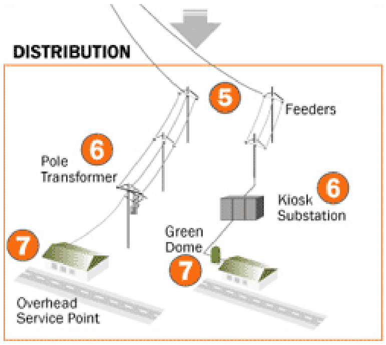
Even with adequate electricity generation, bottlenecks in the transmission system interfere with the reliable, efficient and affordable delivery of electric power. While electricity demand has increased by 25% since 1990, construction of transmission facilities decreased 30% (see Figure 8). Furthermore, annual investment in new transmission facilities has declined over the past 25 years. The result is grid congestion, which can mean higher electricity costs because customers cannot get access to lower-cost electricity supplies.



Data courtesy of U.S. DOE Office of Electric Transmission and Distribution

Figure 8: Electricity demand has grown 25% since 1990, but transmission facilities construction has declined 30%.

C. Distribution



The “handoff” from electric transmission to electricity distribution usually occurs at a substation. The United States’ fleet of substations takes power from transmission-level voltages and distributes it to several hundred-thousand miles of lower voltage distribution lines. The distribution system generally is considered to begin at the substation and end at the customer's meter. Beyond the meter lies the customer’s electric system, which consists of wires, equipment and appliances — an increased number of which involve computerized controls and electronics, which operate on direct current. The greatest challenge facing electricity distribution is responding to rapidly changing customer needs for electricity.

Transmission and distribution losses are related to how heavily the system is loaded (see Figure 9). U.S.-wide transmission and distribution losses were about 5% in 1970, and grew to 9.5% in 2001, due to heavier utilization and more frequent congestion. Congested transmission paths, or “bottlenecks,” now affect many parts of the grid across the country. In addition, it is estimated that power outages and power quality disturbances cost the economy from $25 to $180 billion annually. These costs could soar if outages or disturbances become more frequent or longer in duration.

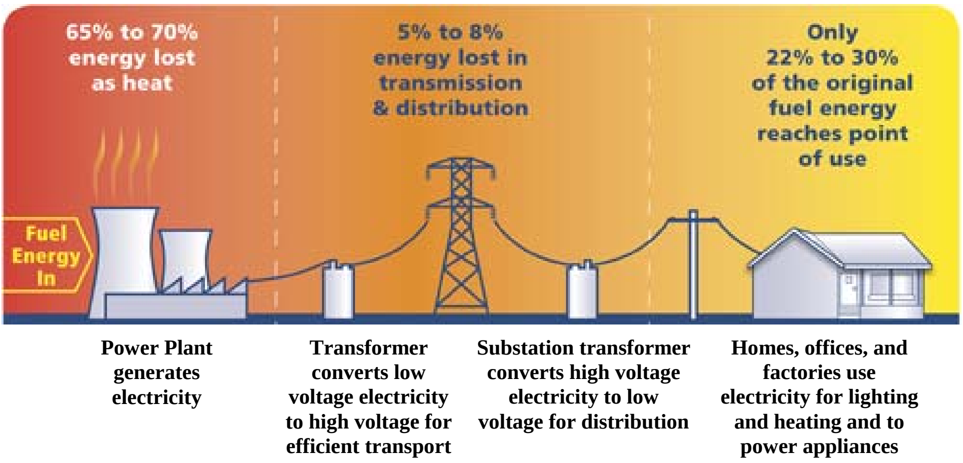


Image courtesy of Ceramic Fuel Cells Limited

Figure 9: There are inefficiencies in generation, transmission and distribution.

III. What is the Smart Grid?

The definition of the Smart Grid is an amorphous term with different interpretations to different entities. The goal of this paper and the Clean TX Forum discussion is to foster collaboration between different industries involved in this space to help unify the current definitions:

- An energy internet of downloads and uploads with two-way flows of data and energy
- The combination of flow of electrons with communication technologies
- The intelligent interaction of buildings and vehicles with the electric grid
- The connection of and remote switching of energy infrastructure and billing systems

A Smart Grid would give the existing electric grid the flexibility of supply and demand of electric power and benefit customers by allowing them to bring in what they need, when they need it. The Smart Grid also benefits the utilities since they have the ability to distribute supply when needed and reduce demand for conventional electricity through the distribution of renewable energy technologies. The potential to promote adoption of local renewable energy is a key characteristic of the distribution load management characteristics of the Smart Grid.

The Smart Grid is expected to cost $160 billion in the U.S. by 2025, but costs will be offset by reducing annual losses from outages and wasted electricity and will provide customers with value-added, information-rich services. Utilities in North America are spending about $10 billion annually on smart technologies to transform the grid into a digital, self-monitoring and adaptive system. These technologies include the implementation of communication networks to the existing grid (see Figure 10), that will interconnect generation, transmission and distribution.

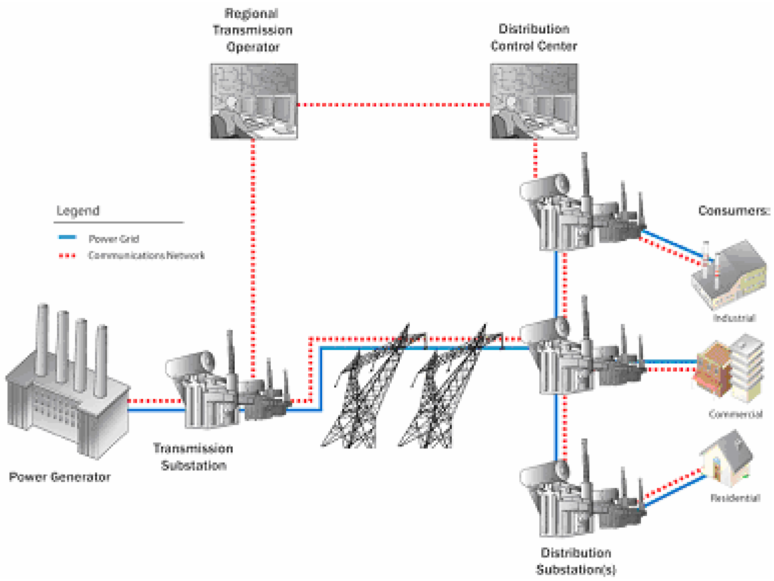


Image courtesy of RuggedCom Inc.

Figure 10: The "smartness" in the future grid is achieved through interconnected communication networks.

A. Distribution automation

The Smart Grid is able to attain operational efficiencies through distribution automation, a capability that results in improved reliability and power quality through the implementation of sensors and switches on existing electric grid lines.

1. Reliability is important to every electricity consumer because it will:
    - Enable power to remain on continuously
    - Prevent unforeseen outages
    - Enable automation restoration

2. Power quality is particularly important to high-tech industries, semiconductor facilities and IT-centers because it aids in:
    - Enabling demand response from customer and industrial usage
    - Providing customers management of their usage patterns and their pricing options
    - Preventing surges and extreme overload conditions
    - Enabling critical business functions
    - Controlling edge devices to avoid high-cost peak usage

B. Advanced Metering Infrastructure (AMI)

The backbone of the Smart Grid, Advanced Metering Infrastructure (AMI), is comprised of systems that measure, collect and analyze energy usage, which include hardware, software and communications technologies and systems. This network connects the measurement devices with business systems and allows collection and distribution of information to customers, suppliers, utility companies and service providers.

AMI responds to changes in energy usage, price and incentives designed to encourage lower energy usage use at times of peak-demand periods or periods of low operational systems reliability. For example, residential areas may be underutilized during the work day when customers have left their houses; subsequently factories may be underutilized during the evenings when workers have returned home. AMI allows for up-to-date data to be presented to consumers, rather than monthly meter readings, which are characteristic of the antiquated metering systems. In order for the AMI to be used successfully, it must communicate across three levels to enable its operation:

1. At the Substation:
    - Provides two-way communication between the data collection network and the grid.
    - Enables creation of an event to reduce peak load.

2. On the Grid
    - Permits command and control to the meter.
    - Can create a reduction in peak load.
    - Stores capacitance across the network.
    - Communicates between the collector node and the data collection network.

3. At the Premise:
    - Displays real-time information about energy usage.
    - Enables active control of electric usage.
    - Permits remote connect/disconnect and price signals via two-way communication meters.
    - Provides energy conservation and energy management.

C. “Smart” devices

The capability of the AMI moves the current metering systems from a simple measuring service system to a network capable of orchestrating service offerings. Monitoring, measurement and control at the Premise Level allows an internet-driven modernization and automation of electric power via the use of tools that affect demand response and load shaping activities.

Enabling communication over the power line or wirelessly will provide pricing information and offer service management functions, such as demand response signaling. In addition, the current meters become smart electric meters by enabling customers to have a range of pricing services and performance features. The Smart Grid should have the following functions to achieve these results:

- Provide real-time rate data
- Organize usage data and accounting
- Calculate time of use rates
- Provide outage detection
- Support net metering capability for solar panels
- Enable reliability load control with smart thermostats
- Send price signals to smart appliances
- Automate service turn-on/off for customers
- Communicate with the home PC
- Allow remote programmability

IV. How does the Smart Grid work?

The Smart Grid integrates information with energy and wireless capabilities through the use of new sensors and new electric/gas/water meters. The Smart Grid works by linking the current electric grid with new a communications network, software, hardware, and energy generation systems. The Smart Grid integrates new infrastructure architecture with application integration architecture and business process architecture, by enabling the following:

A. Addition of local power generation

The Smart Grid can enable the addition of renewable power supplies, such as solar photovoltaic systems, to remove stress from the electric grid (see Figure 11). This capability eliminates the need for expanded transmission capacity in local areas. For example, the addition of solar photovoltaic modules on homes and businesses can handle peak loads or days when extreme hot or cold days place high demands on the grid. Customers will have a mini-power plant in their control, which will allow them to bank renewable energy to be used at a later time.

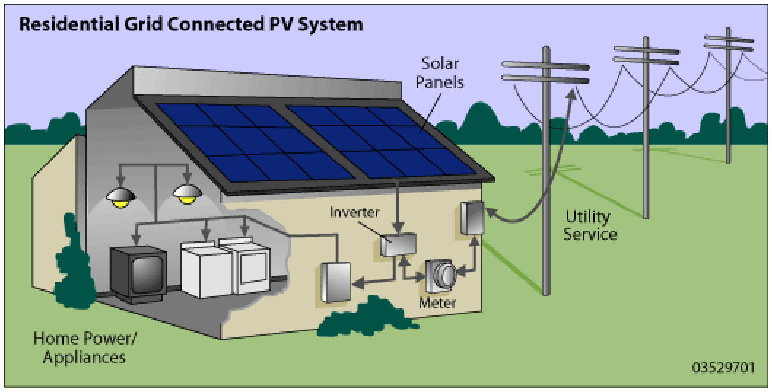


Image Courtesy of U.S. DOE Efficiency and Renewable Energy

Figure 11: Solar systems add local power to the grid.

Several innovations are necessary to enable the addition of local power to the grid, including the ability to carry electrons over long distances from distant resources and a networked system that can store energy for use during times of outages or high demand. Additionally, although asset optimization might be an issue, the promise of customer-enabled, energy-controlled systems increases the appeal of the Smart Grid.

B. Customers paid to help the grid

Customers will be equipped with smart meters which can report real-time power use to the utility. Thus, residential customers might have the opportunity to earn rebates for buying smart appliances that can cycle up and down in response to grid needs and signals. These technologies will enable customers to participate in a voluntary demand response program which will give them credits on their bills for limiting power use in a peak demand period or when the grid is stressed.

In some cases, if distributed generation capabilities were available in a home, the resident could be compensated for the power generated at or above the market rate. This is known as a "feed-in tariff". The combination of these feed-in tariffs and demand side management programs could enable a customer to be:

- Paid to turn their appliances or heating / cooling off
- Paid to turn their distributed generation resources on
- Paid to store electricity and thus help utilities load-level their generation

C. Power distribution

Local substations and other power infrastructure will be fitted with electronic controls and sensors, thereby allowing tasks to be ordered from remote sites instead of being manually controlled. For example, automation could shift capacity to the factory during the day and switch to the residences in the evening. In addition, automation will help restore service faster in the event of a blackout and better control of voltages.

D. Information / communication technologies

Wireless communication technologies are one of the innovations / complementary assets that enable the Smart Grid's real time data flow to and from customer applications. Wireless technologies, such as WiMAX, interlink the distribution and transmission network with the power source. New wireless technologies will allow customers to use handheld software-controlled applications for real-time, flexible control of power to and from their houses. This can be achieved through the building of infrastructure, such as data centers, which will establish internet connections.

There are three main wireless approaches to transmitting data on the Smart Grid (see Figures 12, 13, and 14). All of these technologies connect data from a customer to the utility and allow for a two-way network.

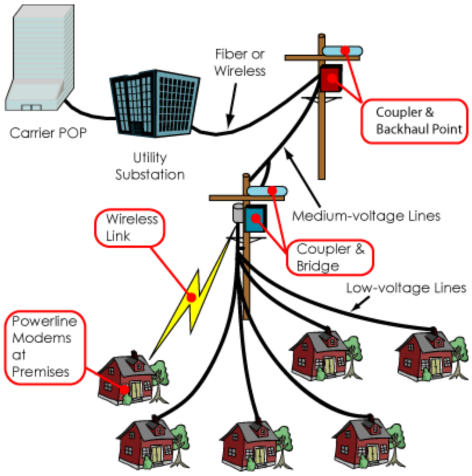


Image courtesy of http://www.howstuffworks.com

Figure 12: The Cellnet approach provides a wireless link from the house meter to the power line to utilities.

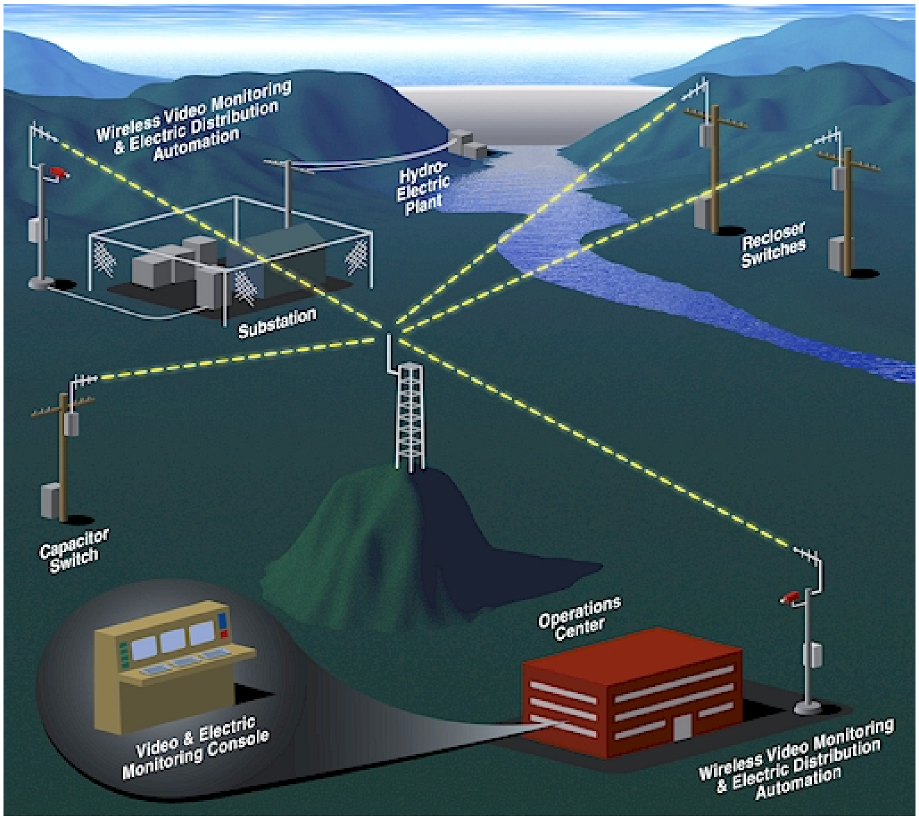


Image courtesy of General Electric Microwave Data Systems

Figure 13: The WiMAX / Zigbee local area networks wirelessly connect the house meter to the cellular cloud to utilities.

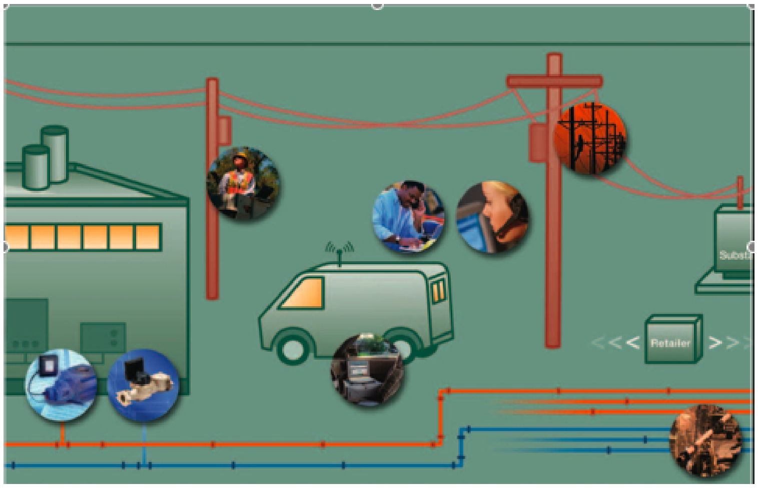


Image courtesy of Itron Inc.

Figure 14: Itron wirelessly reads house meters to a nearby car' databases that batch-loads info to a data center.

An alternate to wireless technology is Broadband over Power Line (BPL), which uses power line communication technology to provide internet access through ordinary power lines (see Figure 15). BPL enables a customer to plug a BPL modem into any electrical outlet in his/her home and instantly have access to high-speed Internet. The advantage of BPL over wireless technologies is that extensive infrastructure already exists to give people in remote locations access to the Internet with relatively little equipment investment by the electric utility.

Additionally, BPL bypasses the current problem associated with between 155,000 to 765,000 volts flowing down high-voltage power lines. At times, this amount of volts is unsuitable for data transmission, since it could be too noisy and cause interference. However, BPL bypasses this problem by avoiding high-voltage power lines. The BPL system transfers the data from traditional fiber-optic lines downstream, to the more manageable 7,200 volts of medium-voltage power lines. Then BPL carries internet into the subscriber's home or office, where the signal is received by a powerline modem that plugs into the wall, as shown below.

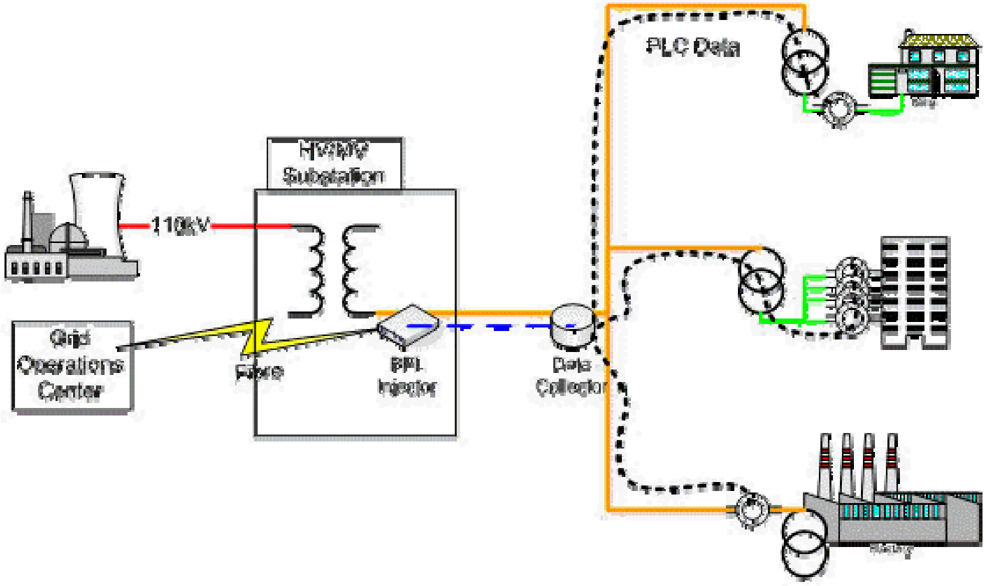


Image Courtesy of www.novastars.com

Figure 15: BPL, an alternative to wireless technologies, through carrying of internet.

E. How do wireless technologies improve the grid?

The added interconnections with the Smart Grid also mean that the grid can transmit disturbances, making the whole system harder to control. An electric disturbance becomes more pronounced at higher power levels and with increased power transfers. Because high-power transmission is so unstable, operators must often limit a line’s load to as little as 60 percent of its ultimate thermal capacity, which is the point at which the wire overheats, sags into trees or onto the ground, and shorts out. Therefore, wireless technologies are critical since they will help reduce the number of electric disturbances with a decrease in wires. Wireless technologies also can be used to increase the redundancy of information transfer in a system, thus increasing the overall reliability of the Smart Grid.

V. Who is working on the Smart Grid?

A. Utilities

Utilities are responsible for the generation, transmission and distribution of electricity to customers. The utilities are taking steps to build the Smart Grid and are driven by the need to:

- Simplify infrastructure
- Improve decision making
- Adapt to faster changing business needs
- Improve disaster recovery and business continuity planning
- Improve regulatory compliance
- Increase quality standards
- Reduce operational costs
- Increase reliability
- Increase customer satisfaction

One of the leading utilities for providing low-cost, reliable power in the United States is Austin Energy — the 10th largest public power utility and with more than $1.2 billion in annual revenues. Austin Energy currently serves about 1 million customers and 41,000 businesses. Austin Energy's strategic plan for the Smart Grid calls for a service-oriented architecture, which will use the best IT solutions to deliver a fully-integrated and self-healing utility.

Duke Energy provides the utility industry with the leading data communications network and currently has more than 37,000 Megawatts (MW) of generating capacity. Although Duke Energy already has high generating capacity, it currently is undergoing a "Utility of the Future" program with plans for full-scale rollout of its pilot advanced metering and distribution automation technologies in the second half of 2008. Pacific Gas and Electric (PG&E) Company is one of the largest combination natural gas and electric utilities in the United States, and plans to spend $1.7 billion to upgrade and install new Smart Electric Meters by 2011. Xcel Energy is a major U.S. electricity and natural gas company with regulated operations in eight Western and Midwestern states. Xcel Energy plans to spend $100 million to build a "Smart Grid City" that will become a test bed for emerging power technologies.

B. Integrators

The integrators to the Smart Grid will provide software and services to increase networking capabilities for entities involved with the Smart Grid. They hope to provide tracking and real-time data to customers through networking capabilities.

BPL Global, Ltd. is a leading international provider of Smart Grid applications to utilities and broadband services to consumers via power lines. The company forms joint ventures with national and regional electric utilities and internet service providers (ISPs), and provides Power Line Communications (PLC) and BPL technology-based products and services. March 2007 brought in investments of $26 million, including $5 million from Morgan Stanley, which the company will use to accelerate development of its technology, establish strategic partnerships, and market its offerings to utilities and ISPs that would benefit from Smart Grid and BPL solutions.

IBM has teamed with U.S. electricity provider CenterPoint, to enable residential customers to track how much energy they're consuming in real-time prices. If IBM is successful with its grid software plans, the software will be able to manage large-scale, connected, parallel grid applications, achieve dynamic load balancing, and attain system fault tolerance and recovery capabilities. Meanwhile, ABB is growing its Power Technologies Division to have worldwide operations to focus on electric systems reliability, power systems transmission and distribution, substation automation and protection, and utility communication systems technologies. KEMA is developing its energy business consulting services, emissions verifications, transmissions and distributions studies, high- and medium-voltage certification capabilities, and IT-energy systems consulting capabilities.

C. Information technology vendors

The companies offering smart metering capabilities are providing data communication networks and advanced infrastructure. Itron is developing solid-state meters — electricity, water, gas and heat — and communication systems, including automated meter reading (AMR) and advanced metering infrastructure (AMI) technology (see Figure 16). Itron enables customers to collect more detailed, reliable and timely data, analyze it in meaningful ways and use it to make informed decisions that optimize the use of energy and water.

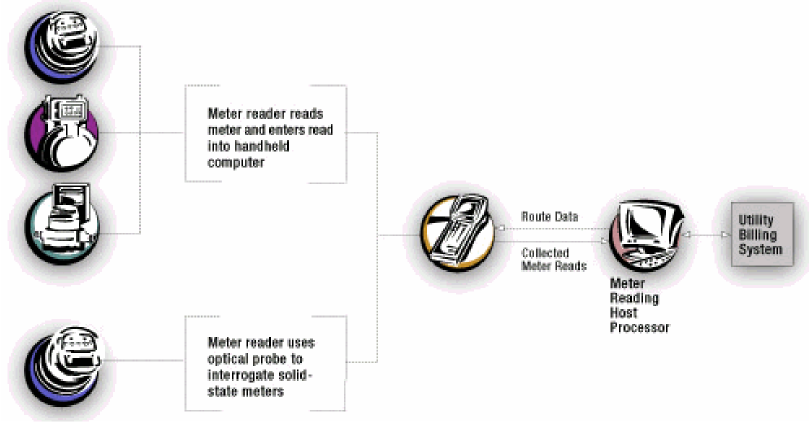


Image courtesy of United Systems & Software, Inc.

Figure 16: Itron's smart meters enable customers to collect detailed and timely data and optimize energy use.

Cellnet is creating a data communications network for the utility industry to enable advanced infrastructure. It already operates the single largest advanced metering infrastructure (AMI) network in the United States, with more than 11 million electric, gas and water endpoints deployed.

SmartSynch is a Smart Grid cleantech company whose smart meter technology uses broadband networks to connect electricity meters to utilities. In February 2007, SmartSynch began selling a residential version of one of its meters, which is being used by 10 utility customers.

D. Energy-efficient smart buildings

The companies that are building automation solutions are enabling customers to control the use of energy in their homes and offices. These companies achieve energy efficiency in their customers' buildings through different approaches.

Comverge has designed demand response, advanced metering and grid management solutions to assist end-consumers in utilizing energy "smarter" and more efficiently. Its products include smart thermostats, home energy automation systems, and advanced under-glass metering gateways. Its services include implementing demand response programs, such as marketing, customer recruitment, measurement and verification.

EnerNOC's energy management software, with its proprietary algorithms, enables customers to achieve sustainable demand reductions. Its reverse auction technology platform also increases competition in deregulated markets for energy supply. EnerNOC offers customers solutions in emissions tracking and trading, energy procurement, energy analytics and control, and demand response and advanced metering.

Gridpoint offers utilities a modular, scalable and upgradeable architecture to achieve the short- and long-term business objectives of electric utilities. For example, utilities can immediately deploy proven distributed technologies and plan for the future by adopting a wide array of emerging technologies, such as plug-in hybrid electric vehicles (PHEVs) and fuel cells. Gridpoint partners with electric utilities by providing guidance on existing and new technologies to achieve the short- and long-term goals of the smart grid. Gridpoint is the first system to offer a comprehensive plug-and-play clean solution for backup power. Gridpoint has also created the Public Power Smart Grid Taskforce to enable prioritization of energy investments and return on investment to meet current and future challenges. This comprehensive solution offers environmental benefits by reducing emissions and conserving fuel and land resources, while enabling competitiveness of local economy through creation of new jobs and robust energy infrastructure attracting new business.

Site Controls provides on-demand energy and asset management solutions that increase profitability and improve the environment through energy efficiency. The company's flagship platform, Site-Command, was specifically designed to address the unique needs of retail, restaurant, and convenience store operators. Site-Command remotely monitors, logs, and controls HVAC, lighting, outdoor signage, refrigeration, and other major in-store energy consumers, online and in real-time. By providing persistent real-time access, visibility and control over thousands of assets and sites nationwide, Site Controls helps customers create a compelling customer experience while simultaneously reducing emissions, saving money, and improving business efficiency.

E. Trade organizations & government

There are many barriers to achieving a Smart Grid. Therefore, several organizations are seeking to unite public and private sectors to help overcome the barriers. Since collecting these stakeholders is a difficult task, Smart Grid stakeholders need to make a clear case for the environmental benefits of their technologies, and appropriately identify and approach the beneficiaries. The environmental benefits for smart grid technologies do not often come out of the direct use of the technologies, but out of programs that creatively utilize technologies, or through programs and resources enabled by the availability of a modern grid.

GridWise™ Alliance is a consortium that provides a forum where members representing a broad range of interests in the electricity sector can meet, exchange ideas and work cooperatively on a common set of issues, with the goal of moving our industrial-age electric grid into the information age. IntelliGrid is creating the technical foundation for a smart power grid that links electricity with communications and computer control to achieve tremendous gains in reliability, capacity and customer services. The IntelliGrid Architecture is an open-standard, requirements-based approach for integrating data networks and equipment that enable interoperability between products and systems. Center for Commercialization of Electric Technologies (CCET) is a Texas institution that seeks to produce innovation in the transmission, distribution and the use of electric energy that will maintain the state's leadership in the industry and improve the economic well-being of all citizens. The U.S. Department of Energy has developed a roadmap called Smart Grid 2030, which is a vision and plan for a fully-automated power delivery network that monitors and controls every customer and node, ensuring a two-way flow of electricity and information between the power plant and the appliance, and all points in between.

There remain some challenges for these organizations to achieve their goals. GridWise™ Alliance needs to provide its members with opportunities to interact with senior policy makers on both the federal and state level that, together with industry, will transform the nation's electric power system. IntelliGrid intends to provide utilities with the methodology, tools and recommendations for standards and technologies when implementing systems such as advanced metering, distribution automation, demand response and wide-area measurement. CCET intends to enhance the safety, reliability, security and efficiency of the Texas electric transmission and distribution system through research, development and commercialization of emerging technologies. The Grid 2030 roadmap hopes to achieve three major milestones: 1) national electricity "backbone," 2) regional interconnections, which include Canada and Mexico, and 3) local distribution, mini- and micro-grids which provide services to customers and obtain services from power generation resources anywhere on the continent.

F. Policy advances

In December 2007, President Bush and Congress passed the Energy Independence and Security Act of 2007. This bill represents major steps forward in expanding the production of renewable fuels, reducing our dependence on oil and confronting global climate change. One important part of confronting climate change is making the United States' electric grid more efficient.
Title XIII, Sections 1301 -1309 of the bill, include the first federal building blocks for America to deploy a nationwide Smart Grid. The bill's smart grid provisions will advance the efficiency, reliability, safety and security of utility services.

More specifically the bill:

- Establishes a statement of policy supporting modernization of the grid
- Authorizes a biennial status report and survey of barriers to modernization
- Authorizes R&D on smart meters, distributed generation, energy storage and demand management, and interconnection to access the energy stored in vehicles
- Establishes a public/private advisory committee to work with the Secretary of Energy on modernizing the grid and a federal employee task force to coordinate federal grid modernization activities and regulation
- Directs the National Institute of Science and Technology (NIST) and authorizes $5 million/year for 2008-2012 to develop protocols and standards to achieve interoperability of smart grid devices and systems
- Establishes a federal matching fund for 20% of qualifying smart grid investments

VI. What is the value of the Smart Grid?

A. Economic opportunity

The global expenditure for over the next ten to twenty years on energy infrastructure is estimated to be between $10 trillion and $20 trillion. Such investment will create significant economic benefits by delaying or preventing the need for creating a new power plant. Additional economic benefits from the Smart Grid for customers will occur through:

- Enabling the “Energy Internet” to allow downloads and uploads with bi-directional flows of data and energy
- Charging and uploading access at centralized parking lots of train/bus stations and malls
- Connecting anywhere with infrastructure and the billing system

The economic benefits for the utility result from interacting intelligently among buildings and vehicles within the grid by:

- Responding to real-time, dynamic pricing facilitated by Smart Meter systems
- Producing energy during peak hours
- Storing energy during off-peak times
- Managing demand and/or providing capacity to the grid during critical peak periods

Moreover, the Smart Grid creates economic savings by reducing peak-load capacity, replacing base load capacity and allowing circuit-level monitoring control for a user or utility to create capacity by calling off an event. Thus, utilities will not need to build additional plants to support necessary peak power requirements.

B. What are the advantages for the consumer?

The main advantages for the consumer are:

- Faster notification and restoration times from outages
- Higher Quality of Service levels
- Greater reliability
- The ability to better manage bills
- Greater transparency
- Participation in energy efficiency and demand response programs
- Improvements in timeliness and accuracy of billing and fewer estimated bills
- Ability to call utility for real-time meter read or ability to see real-time data in-home display

Since the utility can use sensors, instrumentation and IT added to the substations and the lines to collect massive amounts of data and then process the data, it can provide energy price information to customers. Thus customers have an opportunity to optimize usage based on data visibility, be it through manual or automated means. In the event of power or gas outages, outage information is easily available and communicated to the customer.

Thus, the distributed storage-generation characteristic of the Smart Grid will enable individual homes to have 3 to 5 days of energy storage with on-site distributed power stations to help during downtimes, peak energy usage and major disruptions. Additionally, the customer will be better able to manage utility bills, and with better management, ultimately reduce utility costs.

C. What are the advantages for the utility?

The implementation of the Advanced Metering Infrastructure (AMI) costs a utility hundreds of millions of dollars to billions of dollars. However, the investment can payback itself back in several ways, including:

- Reduced need for additional generation and transmission
- Improved distribution load management and planning
- Greater historical load and usage data
- Better asset management and maintenance
- Improved outage management due to the ability to quickly determine if power is on or off
- Reduced number of delayed and estimated bills
- Lower procurement costs
- Reduced energy theft
- Reduced operating costs

These advantages to the utility come from sharing the risk of wholesale price fluctuations which affect the utility's costs. A key step for most utilities is to closely examine the economic value of implementing a Smart Grid solution before committing to an actual deployment. Deployments are capital intensive and impact multiple departments within the organization, as well as directly impact the cost of energy and service levels for the end-use customer. Typical operational benefits for the utility include reduced meter reading costs, reduced costs associated with field visits and customer calls, improved billing accuracy and improved cash flow, improved outage information and response and more efficient asset management, and improved distribution engineering design. Calculating a return on investment for smart grid installations can be complex, as it involves multiple parts of the utility value chain including better operational management, customer relationship improvements, and generation peak load shaving. These returns will differ from utility to utility, based on their geography, grid technologies currently in place, and competitive landscape. Many experts believe that Smart Grid technologies have exciting ROIs, citing BPL examples of 2 – 3 years.

In addition, using these sensors, utilities can automatically analyze all of the data for control purposes, asset monitoring, power-quality monitoring and increased outage intelligence. The Smart Grid allows utilities to take a proactive approach to outage detection and restoration rather than relying on customers to alert utilities to power outages. The utility will know the outage location, which equipment is affected, be able to determine the root cause and automatically dispatch the repair crew. Additionally, the smart grid has the potential to isolate the fault with automatic switching and restoration of power service to as many customers as possible, by re-routing power flow around the problem.

The Federal Energy Policy Act 2005, Section 1252 (EPAct) states that energy policy supports all utilities to "provide customers with time-based rates and the ability to receive and respond to electricity price signals." The EPAct, however, does not specifically mention or require that utilities do anything directly, but instead it requires the regulators and the Boards of Directors of unregulated utilities to "consider and determine" what these utilities must do to comply with the objectives of the EPAct. This regulatory driver, in conjunction with recent developments in communication and IT, has created an opportune environment to seriously consider the Smart Grid as a practical solution to address power delivery needs in the future.

D. What are the constraints to achieving the value of the Smart Grid?

The main challenges to achieving the Smart Grid are developing and improving upon:

- Open standards availability from engineering applications
- Cultural issues
- Better integration needed with sensors
- Better real-time databases to help self-healing functions
- Distributed generation to grid controls (such as vehicle-to-grid controls)
- Tremendous amounts of data
- Consumer behavior

E. How can Austin take advantage of the Smart Grid?

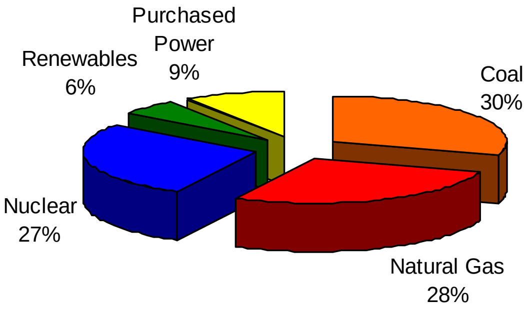
Austin has two major motivations for interest in the Smart Grid:

1. Attracting high-technology companies, which require uninterrupted power quality for precise manufacturing and product development
2. Developing new power sources or renewable energy as a viable energy source to meet the project increased demand
3. Building Smart Grid companies and technologies locally

Another reason for the City of Austin to take advantage of the Smart Grid technologies is that current IT needs already are placing significant demands to the existing grid. The sheer amount of data that Austin Energy manages will necessitate improvement in the current infrastructure of:

- 400,000 meters, 300 servers, 1500 PCs/laptops, 600 phones, 200 pagers, 65,000 thermostats
- Monitoring 195,000 devices in real-time today; plan to have 500,000 devices by mid-2009
- 500,000 billing transactions per month

Austin Energy's 2006 electricity came from approximately: 30% coal, 28% natural gas, 27% nuclear, 6% renewables, and 9% purchased power (see Figure 17).



Data courtesy of Austin Energy

Figure 17: Austin Energy's 2006 electricity generation

F. How are cities in Texas involved in the Smart Grid?

Image courtesy of Texas Renewable Energy Industries Association (TREIA)

Austin / Austin Energy

One of the nation's leading utilities is working to continue provide the city of Austin with Smart Grid technologies. Since 2004, Austin has had 130,000 wireless meters installed. Austin Energy has also completed a one year Broadband over Power Line (BPL) pilot project to evaluate the use of BPL technology for its Smart Grid strategic plan. Austin Energy conducted the BPL pilot over a twenty-block area in downtown Austin. Austin Energy learned that BPL technology is innovative and has potential, but still has reliability issues and can be expensive. Cost figures for BPL are about $2,000 per device for 75,000 total transformers. Nonetheless, BPL technology is promising for integrated communication systems on the electric grid.

Along with the implementation of new software, hardware, and new sensors, as part of its strategic plan, Austin Energy intends to have a Smart Grid in place by spring of 2009. Austin Energy initiated these efforts by beginning to upgrade a portion of the existing 400,000 electric/gas/water meters in its area. The remaining 270,000 meters will be converted into two-way networks by implementing Cellnet's 950MHz meters. This will make Austin Energy a leading utility in the nation deploying two-way network capability. Meanwhile, Austin Energy has continued to build the hardware, software, and services infrastructure to improve its distribution generation, billing systems, control center and outage response abilities. It is investigating offering rebates for home appliances that are needed to achieve the Smart Grid.

Austin Energy is spending the first half of 2008 developing a demonstration house to serve as a public showcase of a Smart Grid enabled business and home of the future. This Smart Grid Lab will demonstrate potential pervasive energy management solutions such as an internet portal and an in-home display to allow for real-time data control.

Some challenges Austin Energy will need to address are consumer behavior issues that stem from the mass adoption of new technologies. As the new Smart Grid technology will be self-healing, issues may arise with the lack of human interaction in times of a breakdown. A cultural shift will be necessary for users to adjust to the new form of grid automation.

One of the biggest challenges to Austin Energy's Smart Grid plan is the sheer amount of data that must be managed and controlled. Austin Energy currently has 20 TBs of data per year, which doubles every 18 months; with the Smart Grid, there will be over 400 TBs of data per year. Although Austin Energy is working on solving the data problem, it will only be a small part of the solution, as Austin Energy accounts for less than 1% of the total amount of data the U.S. Smart Grid will create. The tremendous amount of data poses a challenge and Austin Energy must solve several questions prior to establishing the Smart Grid, including:

- What data is relevant?
- What data should be stored and what data should be thrown away?
- What sort of data analysis should be done?

Solving these data questions will be a critical step in implementing Smart Grid technologies.

Dallas-Fort Worth /TXU Electric Delivery

TXU Electric Delivery is the nation's sixth largest electric transmission and distribution company and is a subsidiary of TXU Corporation, which provides electricity to more than 2.3 million Texas customers and has more than 18,300 MWs of generation in Texas. TXU has teamed with CURRENT Communications Group, LLC, the nation's leading provider of BPL solutions, to transform TXU's power distribution network into the nation's first broadband-enabled Smart Grid to serve approximately two million homes and businesses in the Dallas-Fort Worth Metroplex.

Houston/CenterPoint Energy

CenterPoint is in the process of testing whether the BPL communications network can handle advanced metering, remote connect/disconnect and automated outage detection and restoration for 44K electric and 22K gas customers. The eventual rollout of this technology is seen as a key step toward an intelligent grid system for electric and gas companies.

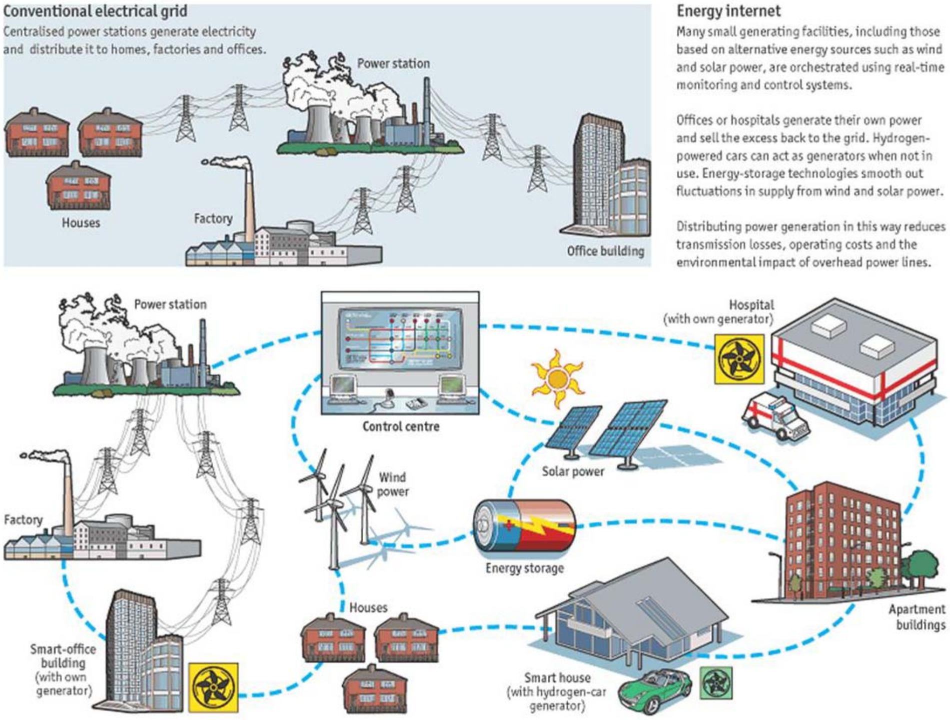
VII. What could the Smart Grid be in the future?

The future Smart Grid will require new storage and distributed hardware to be added to the existing grid (see Figure 18). High-temperature superconductors could be implemented, because they have no resistance to electricity flow at supercritical temperatures, but when heated up — for example, by an electricity spike — the wires become resistive and limit the propagation of the power surge. Thus, surges and sags in power could be handled by superconductors without shutting down the entire system. This new grid hardware could function as power controllers, and thereby allow operators to charge a higher fee for high-quality power, while no additional fees would be charged to users that don't need completely stable power. The ability to switch the flow of electrons is required for this type of dual-power system, wherein more reliable power can be delivered at an added cost only to those consumers who need it.

However, there are questions that need to be answered prior to the realization of the Smart Grid:

- How will regulatory barriers be surpassed?
- How can existing technologies be leveraged?
- How will the Smart Grid be financed?
- How will the necessary parties be financially rewarded for saving electrons?
- How can a rate case be justified?

It is conceivable that the Smart Grid can become a reality, and the following illustration displays the possible configurations and the interconnected nature of the system.



Conventional electrical grid
Centralised power stations generate electricity and distribute it to homes, factories and offices.

Energy internet
Many small generating facilities, including those based on alternative energy sources such as wind and solar power, are orchestrated using real-time monitoring and control systems.

Offices or hospitals generate their own power and sell the excess back to the grid. Hydrogen-powered cars can act as generators when not in use. Energy-storage technologies smooth out fluctuations in supply from wind and solar power.

Distributing power generation in this way reduces transmission losses, operating costs and the environmental impact of overhead power lines.

Image courtesy of Austin Energy

Figure 18: The future Smart Grid will include distributed power generation and interconnections.

VIII. Conclusion

The purpose of the Smart Grid is to transform the nation's electricity grid by integrating emerging energy and information technologies to generate, distribute and consume energy in a more efficient, clean and cost-effective manner. Integration will enable an automated, digital grid, which will pollute less through: consumer efficiency and demand response, the use of renewables, and a more efficient operation of the infrastructure.

Computer upgrades and the latest advances in digital information technology, along with new hardware, such as superconducting fault current and next-generation nanotechnology transmission lines, will require testing and development in an operational system before they can be deployed widely. This network will need interoperability in generation, delivery and consumer systems to effectively monitor and control the flow of electrons and ensure a two-way flow of electricity and information between a power-generation facility and the end-user.

The Smart Grid was proposed to address the existing problem of growing customer usage needs, driven by the increase in power-consuming home appliances, home computing and gaming, home offices and more stringent industrial requirements. A solution to the growing power demand issue, the Smart Grid also is a means to improve the reliability and power quality characteristics of the existing grid. There also will be tremendous energy and environmental benefits from implementation of the Smart Grid, including:

- Energy efficiency
- Delaying new power plants and transmission lines
- Distributed generation
- Mass-scale use of renewable energy
- Clean power market
- Consumer incentive for conservation
- Support for Plug-in Hybrid Electric Vehicles (PHEVs) and Vehicle-to-Grid (V2G)
- Support for more intelligent appliances at the demand-side
- Demand response for managing air pollution
- Advanced metering as a method of calculating environmental footprints

Ultimately, the Smart Grid will prove to be an economically advantageous and environmentally sound solution to the United States' growing power consumption demands, providing benefits to both consumers and utilities.

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