

Smart Grid Implementation

Strategies for Success

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May 2010

Executive Summary

The United States is well underway with the modernization of its energy grid, driven by \$4.5 billion in American Recovery and Reinvestment Act grants and other Congressional legislation. Smart Grid needs to be implemented quickly enough to provide optimal value improving delivery and reliability, and also contribute to the nation's energy security by tapping more domestic and renewable providers. But its success realizing the full benefits of a Smart Grid will rely on numerous implementation factors, including the ability of utilities and consumers to utilize information technology advances, adopt interoperability standards and increase transmission efficiency.

This report identifies and analyzes four immediate challenges for Smart Grid implementation: smart consumers, Smart Grid cybersecurity, Smart Grid interoperability, and smart transmission. Incorporating a wide range of observations by leading industry and government decisionmakers and academic experts, it highlights numerous technological and policy solutions that can play significant roles addressing these challenges. Specific policy recommendations for federal action to advance Smart Grid are proposed.

Introduction

The power grid...it's that portion of the electricity transmission between the generating source and you, the consumer.

Your grid is in the process of getting a lot smarter. “Over 58 million smart meters will be deployed to mass market customers over the next 5 to 7 years,” predicted Lisa Wood, Executive Director of the Institute for Electric Efficiency. “That’s almost half of every U.S. household,” she said.¹ Those figures were calculated before the Obama Administration awarded \$4.5 billion in stimulus dollars for an array of Smart Grid modernization projects.

But realizing the full benefits of Smart Grid goes beyond near-term steps like installing meters and improving delivery efficiency. It also depends on a series of long-term moves such as increasing the ability to transmit electricity across states and regions in order to tap renewable energy sources. Technologies are coming into the marketplace at different rates, too. Some elements of the Smart Grid, like smart meters, are moving fast. Other essential components, like grid-level energy storage, are advancing much more slowly.

Moving forward requires change across many elements of the grid. “This is a once-in-a-lifetime opportunity to rewire America and rejuvenate one of our most critical infrastructures,” said George W. Arnold, coordinator for Smart Grid Interoperability at the National Institute of Standards and Technology (NIST).²

What is Smart Grid?

The GridWise Alliance defined the Smart Grid as “a dynamic, ubiquitous two-way communication system involving the entire grid that allows for greater choice by every stakeholder on the grid.”

Katherine Hamilton, President,
The GridWise Alliance

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Why Success in Smart Grid Matters

By the early 2000s, concerns about grid congestion and reliability spurred the first major initiatives toward Smart Grid. Electricity delivery was seen first as an economic imperative. In 2008, the most recent year for which data is available, the value of electricity sales in the U.S. was a staggering \$363.7 billion.³ Electricity feeds economic growth. Rising demand for electricity often tracks closely with increasing gross domestic product, a fundamental component of a healthy economy.

In 2009, the Smart Grid grew into a full-fledged national commitment. President Barack Obama featured it prominently in his roll-out of the \$787 billion stimulus package, including \$4.4 billion earmarked for Smart Grid seed money.

Progress is a matter of aligning federal and state powers with market incentives and crucially, with consumer enthusiasm.

“Today, the electricity we use is carried along a grid of lines and wires that dates back to Thomas Edison – a grid that can’t support the demands of clean energy,” said Obama. “This means we’re using 19th and 20th century technologies to battle 21st century problems like climate change and energy security. It also means that places like North Dakota can produce a lot of wind energy, but can’t deliver it to communities that want it, leading to a gap between how much clean energy we are using and how much we could be using. The investment we are making today will create a newer, smarter electric grid that will allow for the broader use of alternative energy,” Obama explained.

Given increasing demands on power generation, the Smart Grid offers the only gateway to increased use of renewable energy and decreased reliance on fossil fuels. Hydroelectric, wind and solar power offer tremendous potential, but unlike coal-fired plants, these energy sources are often located far from areas of bulk power demand. Tapping into renewables requires more advanced and flexible transmission.

That said, implementing Smart Grid is a multi-faceted challenge. Investment, regulation, business models, consumer education, cybersecurity and even weather in space are leading factors. The current American power grid evolved over more than half a century to take its present form. Yet with Smart Grid, the imperative is to push for greater adoption within a decade.

To date, technology breakthroughs and policy imperatives have both played their roles in pushing for Smart Grid. For all the White House attention, Smart Grid is not purely a matter of federal policy. Regulation sets standards and several federal entities from the Federal Energy Regulatory Commission (FERC) to NIST have been assigned responsibilities in Smart Grid implementation. It’s important to keep in mind that there is no single “Smart Grid czar” who can design and implement the grid of the future. The main engines behind Smart Grid at the national level have been federal American Recovery and Reinvestment Act grants and other Congressional legislation. Progress is a matter of aligning federal and state powers with market incentives, and crucially, with consumer enthusiasm and willingness to modify its energy consumption.

Vital momentum for Smart Grid implementation also comes from individual states. States such as California, Texas, Colorado, Massachusetts and West Virginia have all adopted distinctive approaches to encouraging Smart Grid implementation. Many are part of larger state-mandated energy goals. For example, *Empower Maryland*, a state mandated program, aims for a 14% efficiency improvement and peak power reduction by the year 2015. Beyond this, groups of states such as the Western Governors’ Association have formulated transmission siting initiatives critical to Smart Grid.

Conceptually, the Smart Grid consists of discrete but overlapping elements. To illustrate, one recent Smart Grid interoperability report from NIST divided the Smart Grid challenge into seven separate domains.⁴

Table 1. Domains in the Smart Grid Conceptual Model

Smart Grid Domain	Description
Customers	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: home, commercial/building, and industrial.
Markets	The operators and participants in electricity markets.
Service Providers	The organizations providing services to electrical customers and utilities.
Operations	The managers of the movement of electricity.
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

As this categorization implies, the ultimate implementation of a Smart Grid requires many steps in each domain area. The requirements for implementation range from consumer acceptance to commercial investment to separate state and federal government roles in devising long-range plans and creating the right regulatory environment.

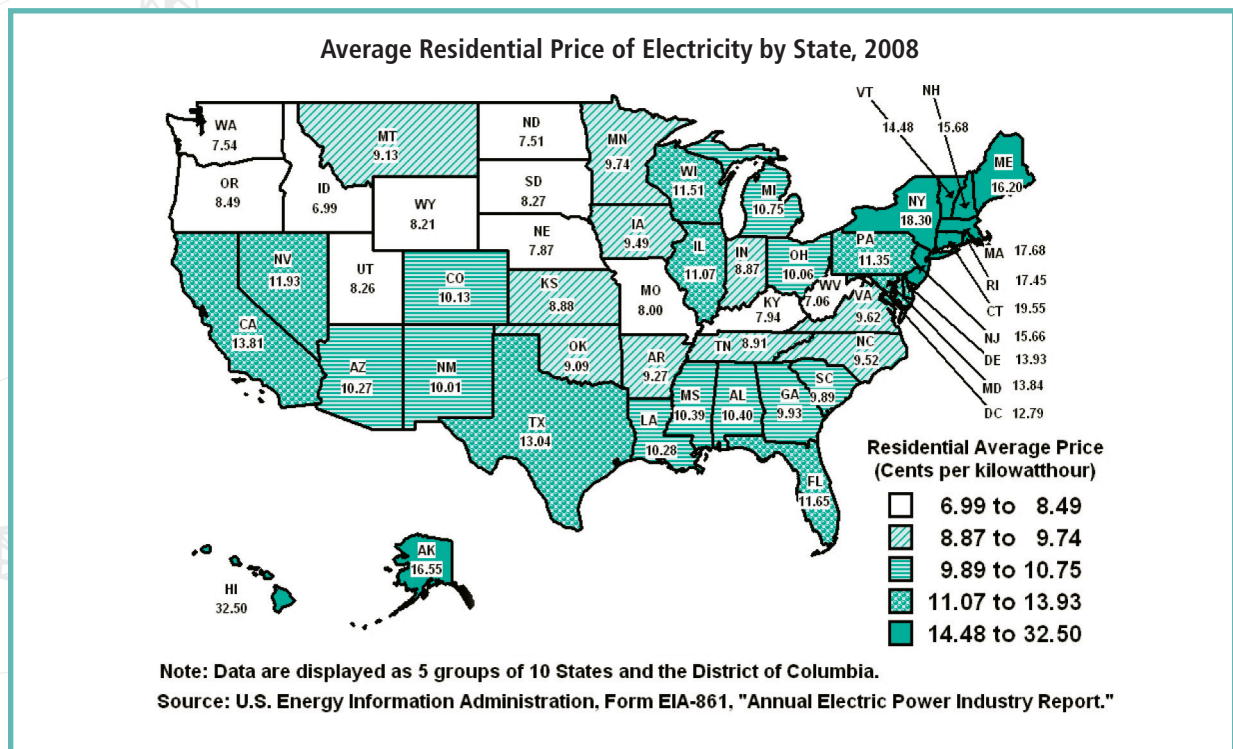
Four Challenges for Smart Grid Implementation

Smart Consumers

Most plans for the Smart Grid center on significant changes in residential power. “The customer is ultimately the stakeholder that the entire grid was created to support,” noted a recent NIST report.⁵

Pricing disparities by state also play a role. In 2008, the Energy Information Administration found the average residential price per kilowatt hour (kwh) was 11.26 cents. However, the high was Hawaii at 32.5 and the low was Idaho at 7 cents per residential kwh, with New York and California at 18 and 14 cents, respectively.

Table 2.



Implementing Smart Grid depends on resolving two critical factors that will redefine consumer interaction with their electric utility:

- The consumer's embrace of the two-way monitoring technology which can help control peak power requirements.
- Implementing dynamic pricing that provides incentives for consumers to change their energy-use patterns.

One early vision for the Smart Grid pictured a full customer gateway. The gateway concept consists of smart meters creating a two-way transaction between the home and the utility. Under this concept, every home appliance would have a smart chip capable of performing brief shut-off and restart on command so a utility could temporarily reduce peak power demands.

Energy efficiency is the goal. It sounds simple enough, but in fact, at the consumer level there is a real challenge in gaining acceptance of the Smart Grid concept.

Take the installation of advanced meter infrastructure (AMI). One survey found that approximately 13.6 million homes in the U.S. had installed the AMI devices as of December 2009. Major utilities such as Baltimore Gas & Electric (BGE) are now actively marketing the meters with radio advertisements and public information across Maryland.

However, utilities also have work to do to improve their information resources. “Remember most utilities’ networks aren’t exactly robust given cost constraints and the fact that information technology hasn’t traditionally been their strong point (though hopefully that will change in the coming months and years),” observed one frequent commentator on Smart Grid progress.⁶

Then there is the public relations angle. In some regions, electric utilities are coming off a decade where their public images suffered from seemingly arbitrary price rises. Californians recall rolling black-outs that darkened traffic lights, stranded people in elevators and forced hospitals onto emergency generators. Not all consumers are interested in “Smart Grids” to begin with and many have voiced objections when electricity utility bills have increased to offset the costs of the investment. State Public Utility Commissions have registered concern when utilities, many of which are publicly-traded companies responsible to stockholders, have filed rate increase requests, and in some cases have taken steps to increase the scope of their regulatory scrutiny.

Smart meters will allow you to actually monitor how much energy your family is using by the month, by the week, by the day, or even by the hour.

President Barack Obama
October 27, 2009

Consider these findings from a national survey conducted by Parks Associates as part of its Residential Energy Management service to determine consumer mindset regarding energy management solutions:

- Over 80% of consumers are very interested in learning how to cut their energy costs, but less than one-half want to learn more about Smart Grid.
- 80-85% of households are willing to pay \$80-\$100 for cost-saving equipment if they are guaranteed to save 10-30% off their monthly electricity bills.
- Only 15-20% of consumers are likely to sign up for time-of-use or demand-response programs; 35% do not want utilities to control systems in their home regardless of the savings potential.⁷

A crucial goal for Smart Grid implementation will be honest public information campaigns that explain the benefits and put it in terms consumers appreciate and can use. “What does it cost to run a load of dishes? Bake a turkey? Watch *I’m a Celebrity, Get Me Out of Here*? Unless you’re a power geek, you don’t know,” wrote one *Baltimore Sun* reporter covering BGE’s foray into smart meters.⁸

The 2009 stimulus from the U.S. Department of Energy includes projects that could help build consumer acceptance. For example, San Diego Gas and Electric will install wireless systems supporting 1.4 million smart meters and provide dynamic pricing.

Although widespread metering and conservation is the ideal, it will take several steps to reach that end-state. After meter installation come steps like dynamic pricing. Dynamic pricing includes offering customers cheaper rates per kilowatt hour at off peak times, for example. With price incentives, consumers may choose to run their energy-intensive applications at different times of the day.

The fact is that consumer reaction will be critical to the implementation of Smart Grid. Accordingly, consumer attitudes have now attracted federal attention. NIST launched an initiative in February 2010 to ensure that the consumer interface to the Smart Grid enables households to optimize their energy use “and encourage widespread consumer adoption.”⁹

If we continue just offering blended, flat-rates that charge the same rate 24/7, we’re never going to get all the benefits of the Smart Grid because so many of those benefits have to do with sending the right signal to customers about the value of their loads and the value of modifying those loads.

Richard Morgan,
Commissioner, District of
Columbia Public Utilities
Commission

Two long-term issues can perturb consumer acceptance of Smart Grid. First is providing adequate assurances that electric utility consumers are not asked to shoulder an excessive burden to pay for the modernization. One set of questions that will need to be resolved is to what extent consumers in a particular state should be asked to subsidize transmission technology that provides some benefits but also crosses state boundaries. Second, while efficiencies promise savings over time, transparency will show up in pricing disparities. Power plants are amortized over 30 years. But consumers understandably look at just two or three years to see how smart meters, energy efficient appliances, and larger regulatory price changes affect their balance sheets at home.

While most agree that consumers need to be let in on the benefits of variable pricing, some point out that it comes with risks. Changes in pricing are likely to cause at least short-term turbulence and fuel some opposition to Smart Grid implementation. “Half the country’s above average

and half is below,” for pricing, as one expert noted. “And the grid flattens that out. It will have many local enemies, okay?”¹⁰

As a result, full implementation will also require a more subtle approach to marketing opt-in programs. “As utilities gain a better understanding of their consumer segments and move into their homes with smart technologies, the utility business model must shift to more of a service provider role, offering different plans for different lifestyles, much the way cell phone companies and cable and satellite providers operate,” suggested one expert.¹¹

Second is the issue of privacy. “The ability to access, analyze, and respond to a much wider range of data from all levels of the electric grid is a major benefit of the Smart Grid, but it is also a significant concern from a privacy viewpoint,” acknowledged NIST.¹³ “The Smart Grid offers great promise for fighting climate change and improving energy policy, but it can also amass vast amounts of data that reveals intimate details of consumers’ lives,” pointed out Jennifer Lynch, an attorney with the Samuelson Clinic.

The Smart Grid promises great benefits to consumers and the environment, including lowered energy costs, increased usage of environmentally friendly power sources, and enhanced security against attack and outage. At the same time, however, the Smart Grid presents new privacy threats through its enhanced collection and transmission of detailed consumption data – data that can reveal details about activities within the home and that can easily



With Smart Grid, load control switches like the one pictured here can be set to lock out loads during expensive, peak power periods.

be transmitted from one party to another.

Smart Grid implementation will generate more data, over longer periods of time, and spread it more widely. Gone are the days of once-a-month meter readings fed into the computer doing the billing. Smart Grid devices will churn out data on activities in the home, and that data in aggregate form will be coveted by those developing applications for Smart Grid, for example. Aggregated data may play a vital role in application development and monitoring of trends, much as it has done for decades. But the highly refined and personal data emanating from Smart Grid practices must be safeguarded.

“Building privacy protections into the Grid from the beginning protects both the environment and consumers from harm.”¹²



Interior Department fast-tracking on rights-of-way land it manages in Idaho, California and Nevada is expected to add more than 1,000 miles of new transmission lines.

Cybersecurity on the Grid

Safeguards are also vital in yet another challenge area for Smart Grid implementation: cybersecurity.

As with other forms of innovation, Smart Grid comes with benefits and drawbacks. Use of the internet to link data flow between utilities and customers creates a need to address cybersecurity. “Remote access to control systems poses a huge danger,” said Dr. Phyllis Schneck, McAfee’s vice president of threat intelligence. “We must either protect it appropriately or move it to more private networks and not use the open Internet,” added Schneck, a member of the Center for Strategic and International Studies’ Commission on Cybersecurity for the 44th Presidency.¹⁴

A byproduct of the transition to Smart Grid will be generation of more consumer data – with more potential vulnerabilities. Smart Grid depends on sophisticated control of supply and demand based on a vast amount of data generated by the daily energy usage of millions of consumers. It is data that determines the approach to peak power loads and when to briefly shut off power devices in Smart Grid-equipped homes. And what will carry that data? The internet, of course.



Within 60 days of smart meter installation, consumers can view their energy usage down to 15-minute intervals, without waiting for their monthly bill.

conditions to destabilize the grid in unpredictable ways,” hypothesized the experts at NIST.¹⁷

Is the power grid really a tempting target? Apparently so, say intelligence officials. In fact, several elements of the nation’s cyberspace structure come under daily attack. “The Chinese have attempted to map our infrastructure, such as the electrical grid,” said a senior intelligence official. “So have the Russians.”¹⁸ The report suggested hackers may have tried to leave behind access paths. “If we go to war with them, they will try to turn them on,” the intelligence official told *The Wall Street Journal*.¹⁹ China later denied ambitions to tap into U.S. infrastructure, but for many, *The Wall Street Journal’s* 2009 report crystallized nascent fears about the vulnerability of the Smart Grid.

In spite of introducing new vulnerabilities, Smart Grid fundamentally makes the electric system more secure.

Garry Brown
Chairman, New York State
Public Service Commission,
October 2009

Concerns about Smart Grid stem from the fact that easy-to-use meters also open vulnerabilities. “Smart meters give consumers direct access to information about their power usage and the ability to manage that usage over the Web, but that two-way communication also opens up the possibility that the grid could be attacked from the outside,” noted a recent report. Many of the Smart Grid systems “require little authentication to carry out key functions, such as disconnecting customers from the power grid,” the report continued.¹⁵ Even far less insidious acts could do considerable long-term damage, such as customers hacking into data to roll back the meter on their utility bills.

“For decades, power system operations have been managing the reliability of the power grid in which power *availability* has been a major requirement, with information integrity as a secondary but increasingly critical requirement,” noted NIST.¹⁶

Compromise of customer data, however, is not the only concern. Smart Grid technologies look to govern much of the grid’s operation, too. “Vulnerabilities might allow an attacker to penetrate a network, gain access to control software, and alter load

Highly secret military systems are secured by encryption and physical access. The Smart Grid, in contrast, aims to exploit wireless technology and will have numerous participant points of access – all ripe targets for hackers.

The Chinese and Russians have attempted to map our infrastructure, such as the electric grid.

Securing the information flow could be a key determinant of success for Smart Grid, and the problem has been put in very capable hands. “We could open the door to new risks if we carelessly put together new systems that don’t have resilience and security guarantees built in from the ground up,” said Ilesanmi Adesida, dean of the college of engineering at the University of Illinois.²⁰ The university’s Information Trust Institute is home to a \$26 million Trustworthy Cyber Infrastructure for the Power Grid Center, a leading research operation for evaluating the effectiveness of defenses against attacks on the nation’s energy grid and developing new security tools.

NIST took on responsibility for cybersecurity for Smart Grid in 2007. The Energy Independence and Security Act of 2007 empowered NIST with “primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems...” The 2009 American Recovery and Reinvestment Act added money to the NIST budget for development of a comprehensive cybersecurity plan for the grid.

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Ilesanmi Adesida, Dean,
University of Illinois College of
Engineering

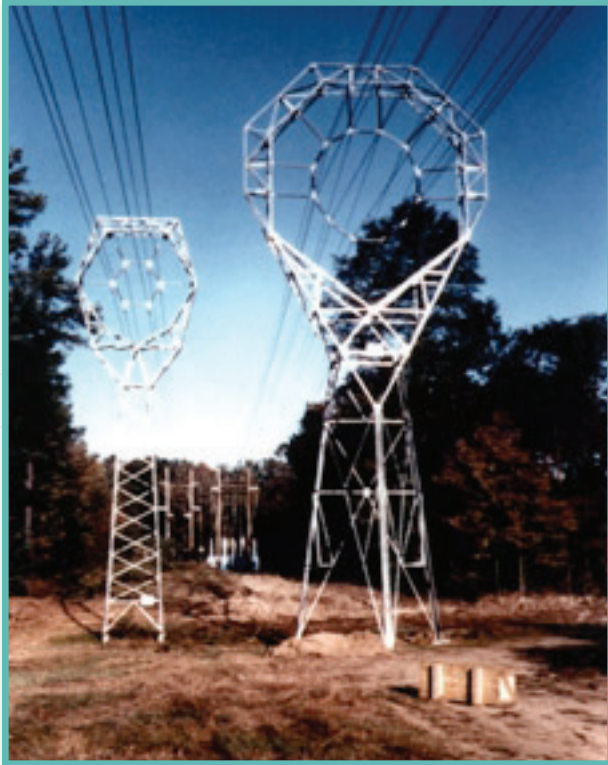
Since that time, NIST has established a Smart Grid cybersecurity operating group and drafted plans for grid security standards. The core of the approach embraces best practices in cybersecurity, such as designing in security from the start.

However, NIST is still in the process of identifying cybersecurity standards. At present, only the North American Electric Reliability Corporation Critical Infrastructure Protection standards are mandatory for the bulk electric system.²¹ Other standards are available but not fully implemented. For example, there is a document that sets out standards for cybersecurity for intelligent electronic devices at substations, but it is not yet part of the mandatory NIST-governed interoperability standards.²²

Setting standards is only part of the equation. According to an estimate by Pike Research, utility companies around the world could spend \$21 billion by 2015 to improve cybersecurity.²³ That figure would be about 10% of the estimated \$200 billion global investment in Smart Grid.

In the United States, the keys to implementing greater cybersecurity begin with NIST’s assessment of vulnerabilities and its 2010 strategy for securing the devices that enable the grid.

Cybersecurity for Smart Grid is somewhat different than cybersecurity for other sectors because of the need to protect a wide array of devices connected to and enabling the grid. Encryption, limited physical access, and “white hat” techniques (barring access to all but safe users) are common to military cybersecurity, for example. Training of employees to resist social engineering threats – such as inadvertently disclosing passwords or identity clues – has been proven to be critical even in the most heavily secured organizations. Part of the Smart Grid cybersecurity challenge will be to implement standards at all levels and in all domains, from the consumer to the Supervisory Control and Data Acquisition (SCADA).



Today some 157,000 miles of high-voltage transmission lines carry electric power across the continental United States.

State Public Service Commission told a Congressional subcommittee in October 2009, “In spite of introducing new vulnerabilities, Smart Grid fundamentally makes the electric system more secure.”²⁴ Security comes just as much in the form of increased reliability as it does from cyber protection.

So far, NIST has approached the process by examining the grid as a whole and assessing risk across its different domains. Key areas identified include electric transportation, electric storage, wide area situational awareness, demand response, advanced metering infrastructure, and distribution grid management. The list underscores the diversity of the solution set for Smart Grid cybersecurity. A significant number of federal documents already outline cybersecurity standards. By the end of 2010, a NIST architecture will be in place to set standards across all domains of Smart Grid.

Then the challenges begin. Organizations may adopt recommended cybersecurity standards directly, or put in place what NIST calls “compensating” measures, which may be composed of one or more solution sets.

Either way, cybersecurity planning will become a foundation element of Smart Grid technologies under federal mandate.

Ultimately, as the Chairman of the New York

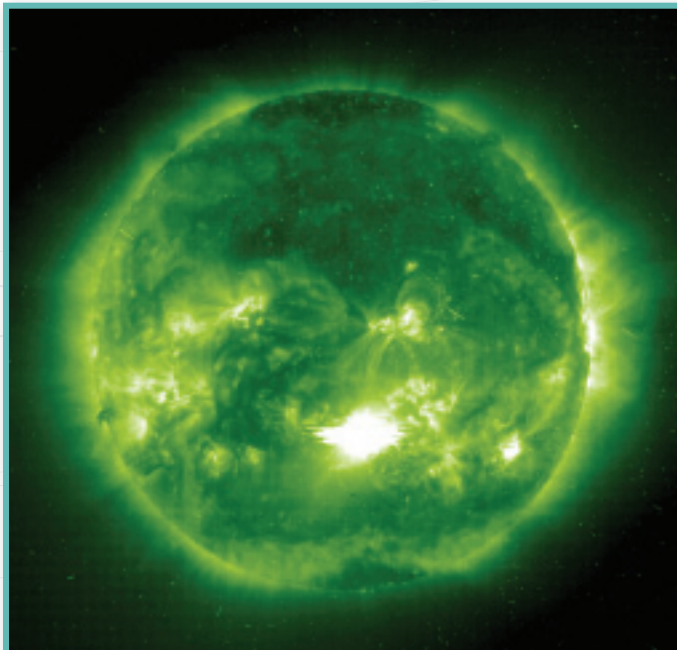
Interoperability: The Shift to Common Standards

Smart Grid implementation ultimately depends on linking numerous devices at several points of the model into a seamless flow of data. That can't be done with proprietary software or meters that don't talk to the database at the utility. Open-architecture solutions and agreed standards for Smart Grid devices represent a key step forward in implementation.

The quest for Smart Grid standards to facilitate interoperability is “the most complicated issue facing the Smart Grid industry – and it's developing amidst on-the-ground deployments of technologies both proprietary and open, all of it needing to interoperate with decades-old utility systems.”²⁵

One of the best everyday examples of interoperability standards is the USB port. Behind devices such as memory sticks and cameras lie a detailed set of standards that support physical compatibility and exchange of data and metadata. Many different companies in the U.S. and abroad create devices and write code guided by these standards. Done right, interoperability standards ensure functionality and security and lay the groundwork for a viable commercial market.

In the future, standards must include a number of interfaces such as the communication between the grid and plug-in vehicles. The quest for standards is not an easy one. Fortunately, NIST is well-placed to comb through the requirements and set action plans. Speeding up development of interoperability standards will also smooth the path for commercial manufacturers – a needed step to normalizing Smart Grid technologies.



A 1989 Canadian blackout affecting 9 million people was caused by currents produced by a large geomagnetic storm.

Interoperability standards range far and wide and include taking into account external factors such as weather in space. “Space weather can produce solar storm electromagnetic fields that induce extreme currents in wires, disrupting power lines, causing wide-spread blackouts and affecting communication cables that support the Internet,” concluded a 2009 study by the National Academy of Sciences.²⁶ The worst storms may be once-in-a-century events, but big flares have occurred in 1976, 1989 and 2003.

Big solar flares create geomagnetic storms that can disturb electricity on the Earth's surface. A massive solar flare blacked out 6 million power customers in Canada in 1989, for example. An even larger flare in 2003 created a plasma

cloud that travelled toward earth at 5 million miles per hour. The flare created a G5 level storm – the highest on the astrophysicists' scale for these events. “It's arriving earlier than anticipated. It's a little bit surprising it got here so fast,” said John Kohl, a solar astrophysicist at the Harvard-Smithsonian Center. Satellite sensors shut down or risk frizzling in the energy of the plasma.²⁷

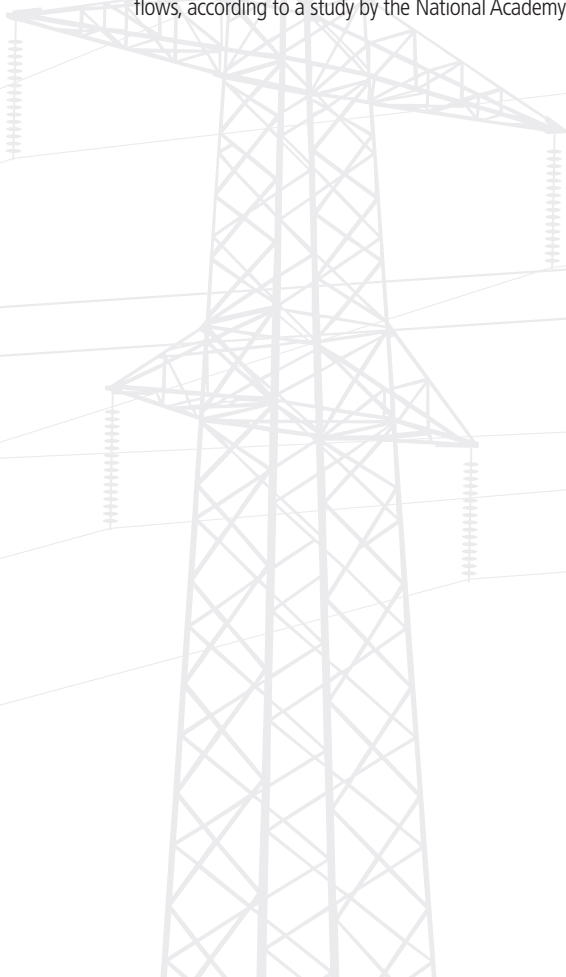
For Smart Grid, the geomagnetic currents pose two problems. First is the potential for power lines to surge, while the second is disruption of terrestrial and satellite communications embedded in Smart Grid. With more reliance on communications to ensure delivery and demand tracking, making Smart Grid elements impervious to solar weather will be among the many imperatives for implementing the grid.



One technology solution may come from the installation of supplemental transformer neutral ground resistors to reduce geomagnetically induced current (GIC) flows. The technology is relatively inexpensive, has low engineering trade-offs, and can produce 60-70% reductions of GIC levels for storms of all sizes.

Beyond this, the March 2010 launch of the latest National Polar-orbiting Operational Environmental Satellite System weather satellite included enhanced space weather capabilities.

Supplemental transformer neutral ground resistors reduce geomagnetically induced current flows, according to a study by the National Academy of Science. (Photo: Avtron, Inc.)



The Long Haul: Smart Transmission

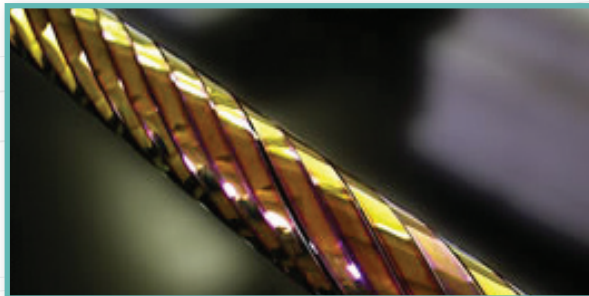
With all the focus on meters and standards, it's easy to forget that restructuring the grid for better transmission of resources is the other major component of implementing the Smart Grid.

Transmission lines expanded from local plants to local communities in the 20th century. Today about 157,000 miles of high-voltage transmission lines carry bulk power in the continental United States. The grid is organized into three major sectors: the Eastern, Western and Texas interconnections, with links to Canada and Mexico. It's a grid that covers U.S. territory, but its flexibility is limited.

Putting electricity generated by renewables onto the grid depends on building more and different high-voltage transmission lines. Just how does wind power from Delaware arrive in upstate New York? "Transmission is ultimately the key," said Jon Wellinghoff, Chairman of the FERC. "If we cannot put the transmission in place, we cannot deliver it to loads, and so we have to somehow look at the fundamentals of what's necessary to make that transmission into a system that ultimately can provide deliverability and marketability of these renewable resources."²⁸

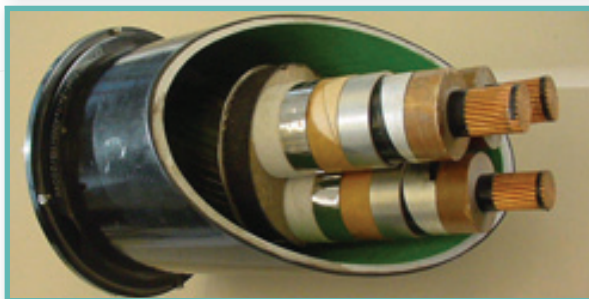
Near-term, improved efficiency is the goal. If the grid were just 5% more efficient, the energy savings would equate to permanently eliminating the fuel and greenhouse gas emissions from 53 million cars," found the Department of Energy in a 2008 report.²⁹

Several new technological developments could aid transmission efficiency. The discovery of high temperature superconductivity (HTS) materials in 1986 soon netted a Nobel prize for IBM Researchers Karl Müller and Johannes Bednorz. HTS also spawned new transmission cables and transformers. HTS technologies like the transmission line pictured below offer reduced resistance and increased efficiency of transmission. They suit applications in dense, urban environments where underground transmission exists or where building more transmission lines and substations to meet demand is difficult. According to a RAND report, HTS technology can in some situations increase voltage without installation of new lines.



However, the promise of HTS technologies will not necessarily erase the need for more transmission lines.

"New transmission requires 7-10 years or even longer to plan, permit, and construct; once built, its economic life can span multiple decades," found researchers at Ernest Orlando Lawrence Berkeley National Laboratory who were evaluating transmission alternatives for the Western Renewable Energy Zone.³⁰



HTS cables can reduce the growing costs of electricity lost in transmission and distribution.

The U.S. power grid currently operates on an amalgamation of old alternating current (AC) transmission lines. Most lose 10% of the electricity they convey, and can only move electricity across certain distances. Even these power lines are known to be inadequate for the job. Power losses due to congestion were once considered a minor factor. Before 1970, such

losses typically averaged 5%. In 2001, the combination of rising demand and an aging grid made for a 9.5% loss. That means that 9.5% of generated power was wasted before it could even be delivered – with the costs in both dollars and carbon emissions.

If the grid were just 5% more efficient, the energy savings would equate to permanently eliminating the fuel and greenhouse gas emissions from 53 million cars.

According to FERC Chairman Wellinghoff, the purpose of the transmission lines now in place “was primarily for delivering energy from fairly local centralized generation that was put in place by either municipal entities or co-ops, or vertically-integrated investor-owned utilities to serve their own modes, usually from their own generation in a very local area. Some modest exchanges took place between utilities for balancing and for economic purposes.³¹ But for the most part, these transmission lines were not designed for a national grid capable of supporting multiple power

transactions or expanding to carry electricity generated from remote wind or solar farms.

As it turns out, few new transmission lines have been built in the last 20 years even though demand for electricity has increased. According to the Department of Energy, electricity demand increased by about 25% since 1990, but construction of transmission facilities decreased about 30%.³²

Improving transmission is central to success in Smart Grid. As authors of a RAND study explained, “The central impact of transmission constraints is suboptimal dispatch of power generation. When economic generation to meet load requirements creates power flows that would overload lines, grid security coordinators are forced to order curtailment of some generation in order to reduce congestion on power lines. Surging power to meet higher demand and prevent cascading failures can result in big price differences from location to location.”³³

Transmission lines represent an implementation challenge for several reasons. First, ownership and interests are dispersed. More commercial operators entered the field in the 1990s. Decades of focus on local generation, transmission and delivery obviated the need for centralized management. Even the North American Electric Reliability Council is a voluntary body (it was established a few years after the major black-out of 1965).

Second, high voltage transmission lines often generate protest from citizen action groups. A case in point is the plan by Sempra, Inc. to install a 150-mile high voltage transmission line in Southern California. The line would pass through U.S. Forest Service-owned areas. While it would bolster a weak link in the transmission lines, citizens’ groups have complained of environmental consequences.³⁴

However, the issue of localized disputes over line placement pales in comparison to the larger problem of how to coordinate the massive investment in new transmission lines. The Sempra project, for example, carried a price-tag of \$1.9 billion. Line replacement across the United States over the next two decades could cost as little as \$200 billion, or as much as \$2 trillion, depending on various estimates.

Progress to date has been slow. Only 3,000 miles of transmission lines of 230 kv have been put into service since 2001. Just 682 miles of transmission line above 345 kv entered service in that period.

Integrated resource planning is, basically, requiring utilities to look at long-term load forecasts and the requirements of their load and ultimately determine how they’re going to meet that load in the most reliable least-cost way for their customers.

Jon Wellinghoff, Chairman,
Federal Energy Regulatory
Commission

The challenges in building new transmission lines have pointed out that by default, no one is really sure who should take the lead in the improvement of infrastructure for Smart Grid. This implementation challenge is somewhat different in that it requires action by regulators and providers. All this makes development of regional master plans for placement and construction of new lines a real requirement for implementing the Smart Grid.

Planning is complicated by the fact that there is no single owner of transmission lines. In fact, there are as many as 300 individual owners. Most new power lines erected in the 2000 to 2009 decade were built within a single state. In contrast, interstate connections for natural gas have proven much easier to build, with over 13,000 miles of new pipelines running across state lines put in service since 2001.³⁵

“There’s no question that if we had a single owner of the entire grid in the United States, publicly-owned, for example, managed like the federal highway system, it would be a lot easier,” said Charles Gray, Executive Director, National Association of Regulatory Utility Commissioners. He pointed out that the current grid has at least four different categories of ownership, including municipalities, co-operatives, investor-owned utilities and even the federal government.³⁶

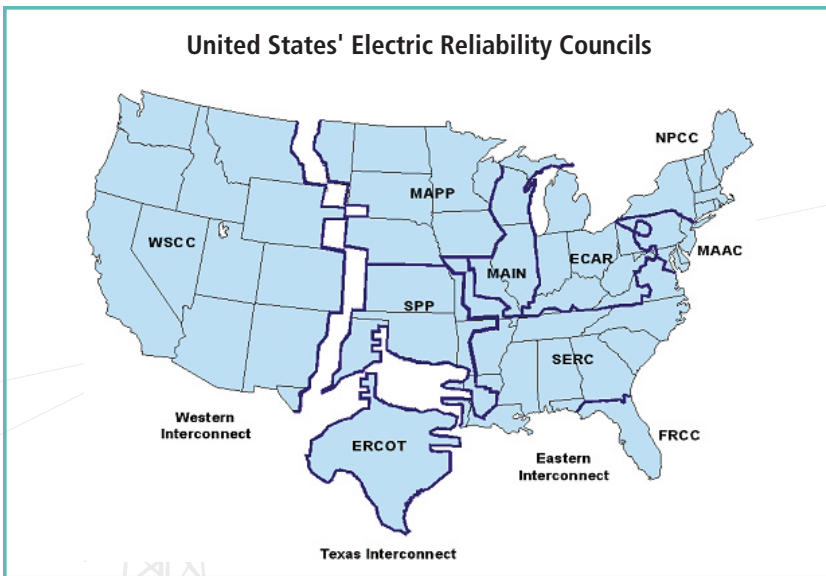
One happy exception is federally-owned land. The Interior Department is processing more than 30 applications for major transmission corridor rights-of-way on lands it manages and seven of these applications – in Idaho, California and Nevada – are being “fast tracked” and could clear the permitting process during 2010. Together, these seven projects would add more than 1,000 miles of new transmission lines, wrote Andy Maslowski in a survey of how Texas-based Centerpoint Energy is using its Smart Grid funds.³⁷

The current grid has at least four different categories of ownership, including municipalities, co-operatives, investor-owned utilities and even the federal government.

No federal takeover is in sight – nor does it need to be. Expert consensus suggests that regional initiatives and federal encouragement are the most effective formulae for working through transmission development issues. New lines are sited under state authority. FERC can step in if an area is particularly congested; or to site a line coming from a hydroelectric dam. Beyond that, “it’s entirely up to the states,” said Wellinghoff.³⁸

Many stakeholders agree that selecting sites for new transmission lines should be first and foremost a state responsibility. “We think that state and local governments should be given the first opportunity to do siting of lines, including large interstate lines,” said Bill Gaines, CEO of Tacoma Power. He also favored federal backstop authority “to the extent that states can’t ultimately agree.”³⁹

A good example of the regional focus comes from efforts to identify renewable energy sources and map transmission lines through the Western interconnection. One of the most powerful bodies addressing the problem is the Western Governors’ Association (WGA). (Eleven states fall within the Western interconnection, compared with 36 in the Eastern Interconnection.) This group has made electricity transmission and Smart Grid a priority. The WGA was awarded \$12 million from the federal Department of Energy’s stimulus funding to move forward with proposals. “Western governors recognize that we do not have time to waste, and we are prepared to move ahead with needed transmission development,” said Montana Governor Brian Schweitzer, head of the WGA. “We look forward to partnering with the federal government in making it happen.”⁴⁰



Source: U.S. Energy Information Administration.

The Eastern Interconnection Planning Collaborative also got a stimulus grant of \$16 million from the Department of Energy for transmission planning.⁴¹ The Eastern interconnect spans territory from the Rockies to the Atlantic seaboard.

Congressional opinion is also leaning toward strengthening federal jurisdiction. This is important because some states and regions will have a harder time than others identifying corridors for installing the new transmission equipment. In

population-dense New York and New England regions, current plans to site the new transmission equipment within existing right-of-ways seem well nigh insurmountable in certain locations. Federal authorities may more regularly exercise their limited power of eminent domain with regard to siting in cases where it is essential for Smart Grid implementation.

Of course, transmission lines are not the only solution. Keeping distribution local wherever possible pays off with greater efficiency. However, to bring renewables into the bulk power market, long transmission lines optimized by a Smart Grid are essential.

Policy Recommendations: What Can Washington Do?

For all the enthusiasm surrounding the concept, none doubt that it will take concerted action and long-term commitment to reap all the benefits of Smart Grid. Cutting across this report is the tension between federal leadership on Smart Grid and the fact that much of the concrete action must come from states, utilities and businesses. Because the grid was a local matter for so long, there is no straight path for the federal government to mandate the full implementation of Smart Grid. However, many critical pieces such as setting interoperability standards are in federal hands. This brief section highlights some recommendations for what Washington can do to assist those on the front lines of Smart Grid implementation.

- Congress should provide additional funding where necessary to accelerate NIST work in setting interoperability standards, to include physical security measures.
- Congress must also ensure adequate communication between federal and state authorities.
- The White House should prioritize cybersecurity standards in accordance with national infrastructure protection plans. Mandate compliance with federal standards.
- The White House should expand federal leadership for mapping placement of new high voltage transmission lines, but let states and regional groupings continue to take the lead in siting decisions. Under this concept, FERC could be granted powers to mandate that a siting plan is put in place, but states could be given responsibility for the draft plan and details.
- The White House, as part of its national Smart Grid strategy, should set a timeline for developing regional master plans for new transmission lines suitable for greater efficiency and the ability to carry energy from renewable sources.
- The Department of Energy should assist utilities and their state regulators in providing ample public information on their Smart Grid implementation programs.
- While ultimate success in Smart Grid will depend on a viable business market, federal tax credits can continue to assist companies willing to make the investments in Smart Grid transition.

Action in Washington is by no means a panacea for the implementation hurdles. However, Smart Grid needs to be implemented quickly enough to improve delivery, reliability and contribute to America's energy security by tapping more renewables. The national importance of Smart Grid calls for strong federal action where it can do the most good.

Conclusion: Moving Toward a Sustainable Market

Another “macro” issue is whether Smart Grid and associated technologies can carve out a viable market space that attracts capital beyond government stimulus.

“Smart Grid may be the most hyped words of 2009 in the green tech space, but that doesn’t mean there isn’t a lot of hard, cold cash behind the hype,” noted two commentators writing on the future of energy.⁴² Morgan Stanley estimates that the Smart Grid market could grow to \$100 billion in 2030.⁴³

We can bundle home energy management technology with home entertainment management technology all into one portal and give consumers a bundled product or service that they hadn't even imagined before was possible.

Lynne Kielsing,
Senior Lecturer
Department of Economics at
Northwestern University

And cash will be needed. The stimulus funds so far are seed money only. “We need \$100 billion to \$200 billion worth of investment, and I believe we’ll see that money coming from the private sector,” Wellinghoff commented.⁴⁴ A market governed by interoperability standards and cybersecurity best practices must eventually form to sustain Smart Grid. Enlightened state and federal planning and regulation will be its backbone. The ideal end-state for Smart Grid implementation is a national market for power, loaded with renewables to reduce carbon emissions.

None dispute that the entering costs are high. The Electric Power Research Institute pegged the costs at \$165 billion, or about \$8 billion a year for two decades.⁴⁵ A different report by The Brattle Group found that approximately \$1.5 trillion will be required between 2010 and 2030 to pay for this infrastructure.⁴⁶

However, investment can also return benefits. A 2010 Sandia National Laboratories/Lockheed Martin report by Jim Eyer and Garth Corey identified \$220 billion total in potential benefits to the United States economy of 19 different electric energy storage technologies between 2010 and 2020. Electric storage can best be utilized with a Smart Grid in place and is also essential to implementing strategies to ease strains on supply during peak use hours. More than a third of these potential benefits, \$79 billion over ten years, might come from time-of-use energy cost management – a major payback related to implementing Smart Grid.⁴⁷

The end state vision of a revamped electricity market is compelling. Consumers and suppliers alike may transform the ways they manage power. A key incentive for implementing Smart Grid will be the vision of the future benefits it can bring.

The U.S. has plenty of incentive to move forward on Smart Grid. But should any more be needed, it’s important to note that international competition is moving fast, too.

China and South Korea have pursued some of the most aggressive national policies to promote growth of their clean energy manufacturing sectors. One benefit of this has been a fast-growing market for manufacturing and exporting clean-energy components. China recently embarked upon a



Advanced metering systems offer the consumer a gateway for tracking real-time power use and cost. Consumers can feed the information directly to home computers, if they prefer.

\$400 billion, 10-year investment program, along with regulatory incentives to promote innovation and lower prices. A February 2010 report by the Pew Center on Global Climate Change noted that with over 1.2 million workers employed in renewable energy industries and 100,000 new jobs added every year, China exports more solar panels and wind turbines than any other country, while restricting imports of these two technologies. Meanwhile, South Korea's annual investment of \$17 billion in clean energy industries, 2% of its gross domestic product, is in the process of creating 1.5 million jobs.⁴⁸

A 2010 Sandia National Laboratories/Lockheed Martin report identified \$220 billion total in potential benefits to the United States economy of 19 different electric energy storage technologies between 2010 and 2020.

Google Chairman and CEO Eric Schmidt compared U.S. investment to activity on Smart Grid technologies in other countries: "China, who is the competitor here, has decided to become the world's leader in all the piece parts and all of the necessary hardware and supplies to do this globally. To that end, they are spending more than \$100 billion on the same thing that today, the largest awards we have done in America, the private sector plus the government, will invest \$8 billion. You can see the gap," Schmidt noted.⁴⁹

It's time to take advantage of the political conditions and technology edge to make Smart Grid in the U.S. a reality.

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The Lexington Institute is grateful to the
Severns Family Foundation for their
support for this project.



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