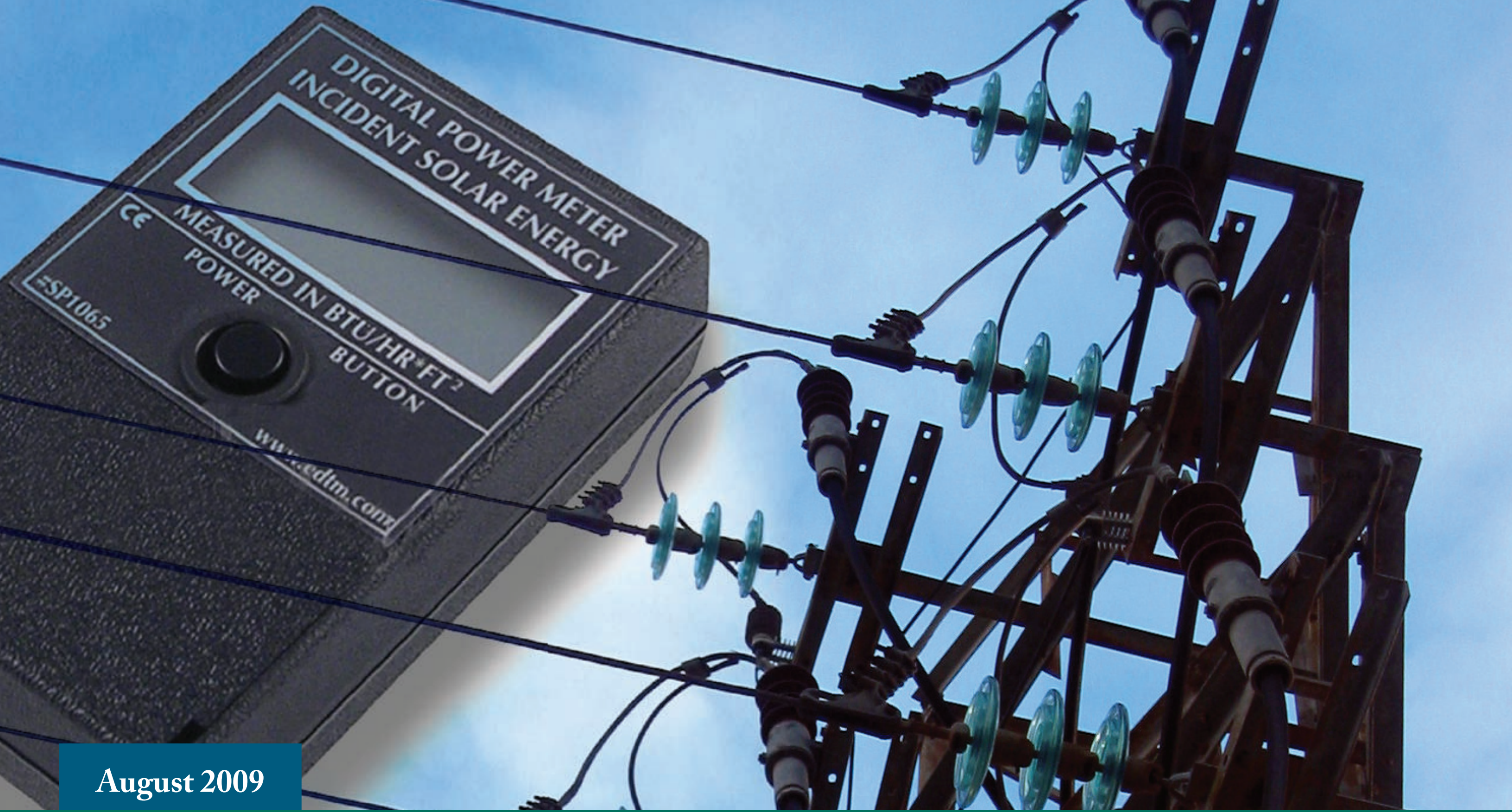

August 2009

Moving Forward on Smart Grid

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Lexington Institute

Moving Forward on Smart Grid

Executive Summary

New information technologies make it possible to put in place a "smart grid" capable of two-way communication and many more functions to control supply and demand.

A smart grid can help prevent black-outs, give consumers up-to-the-minute information on electricity usage and prepare the way for increased use of clean, renewable energy from sources such as wind and solar power. "Even as our economy has been transformed by new forms of technology, our electric grid looks largely the same as it did half a century ago," said President Barack Obama during a March 19, 2009 visit to an electric car factory in Orange County, California.

Today's power grid in America is a relic of the 20th Century. The idea behind smart grid is to inject a two-way information layer into the electricity distribution process. Smart grid components include advanced home meters, new grid management techniques and software. At the home or business, smart grid can aid conservation by showing customers their power usage and offering real-time choices about when they use electricity. Scaling up, smart grids allow utility managers to constrain peak load requirements through a combination of consumer incentives and accurate diagnosis of demand. Ultimately, smart grid technologies can open the door for more plug-in electric cars and vehicles. Added together, the impact of smart grid may help craft an environmentally-sustainable way of the life for the 21st Century.

Smart grid technology is proven, but the systems process of applying it is still maturing. Local smart grids implemented in cities and regions can create a wider, national grid responsive to renewable energy sources like solar and wind power. They can also maximize other sources of power from traditional fossil fuels and nuclear power. Experts call for the smart grid to take the best features of the Internet, such as open standards and easy upgrades. The smart grid will not just transmit power. It will distribute it from many sources and allow expanded supply and demand from the grid.

Smart electric grid experiments are under way in several states and cities. Local groups are employing a range of options from state-level legislation to public-private partnerships to test smart grid systems and expand their application.

The power of national policy and commercial ingenuity extended electricity to rural America. It can smooth the way for smart grid, too.

Details follow.

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Introduction: The Smart Grid

- *Tomorrow is Saturday, and you, your wife and daughter are driving out to the lake for a picnic. It's been sunny all day and you want a full charge on your car's battery, so you make a mental note to plug in as soon as you get home.*

- *Back from lunch, and they were right about the heat wave. Temperatures downtown are crossing 98 degrees with no rain in the forecast yet. Time to dial down the load on the grid by briefly winking off and cycling power from refrigerators and other big energy appliances across the city. Later in the evening, when rates go down, will be a better time to mow the lawn.*

- *The solar panels installed on your new garage roof last year are working well. Tucked behind the dormer, your husband admits he hardly sees them anymore. Best of all, your website indicates that you'll be selling power back to the local grid again today, making it two weeks in a row, and summer not even officially started.*

The electricity grid that powers American homes and businesses has not changed much from the basic concept of connecting locally-run power grids that began in the early 20th Century. America's energy future includes a burgeoning demand for electricity at a time when environmental imperatives demand a switch to more power from clean, renewable resources like wind, solar and hydro-electric power. Smart grid technologies primed for adding renewable resources and improving conservation are an essential part of the nation's energy future.

"Today the energy grid is all about distribution; it's a one-way ride," noted one information technology expert. "A smart grid will act more like the Internet – exchanging information and energy among nodes for collaboration across the network resulting in a more efficient, sustainable grid."[1]

President Barack Obama called soon after his inauguration for action to "update the way we get our electricity by starting to build a new Smart Grid that will save us money, protect our power sources from blackout or attack, and deliver clean, alternative forms of energy to every corner of our nation." The Obama Administration and Congress backed it up with a potential $4.5 billion for smart grid projects in the 2009 stimulus package.

States and local communities are increasingly aware of the need to implement smart grid technologies to lower prices, conserve energy and permit inflow of electricity from advanced renewable sources. "Smart grid is the way of the future," said Massachusetts Lieutenant Governor Timothy Murray.[2]

What is a smart grid, and why is it at the center of so many proposals and debates on energy? 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."[3]

Scientist at the National Renewable Energy Laboratory measures the performance of solar cells using a continuous illumination concentrator at light levels from 1 "sun" to 100 "suns."
(Photo courtesy of NREL/Mike Linenberger)

An electric power blackout on August 14, 2003 affected some 50 million people in the states of Ohio, Michigan, Pennsylvania, New York, Vermont, Connecticut, New Jersey and the Canadian province of Ontario.

Expressed another way, a smart grid is, "a network for electricity transmission and distribution systems that uses two-way, state-of-the-art communications, advanced sensors, and specialized computers to improve the efficiency, reliability and safety of electricity delivery and use."[4] The improved communication between users and providers can do everything from reducing peak power demand to helping add power from solar homes and accommodate the variable distribution of wind power. "With two-way communication, the dishwasher may choose to run when electricity is less expensive or maybe the washing machine won't turn on until wind power is available," explained Alaska Senator Lisa Murkowski during a 2009 Senate committee hearing.

America's electrical grid stands in the way of faster progress toward renewable energy sources. "Our nation's electric grid generally depends on decades-old technology, and has not incorporated new digital technologies extensively," testified Suedeen G. Kelly, Commissioner of the Federal Energy Regulatory Commission.[5]

The grid of today is an aging construct built for one-way transmission. Multiple grids can be linked for back-up power and to market electricity across regions. But it's not designed to pick up power from solar homes or to plug in electric vehicle batteries on a large scale or even to be acutely aware of power outages. The grid's control suite also predates modern cyberspace technology.

"Digital technologies have transformed other industries such as telecommunications. A similar change has not yet happened for the electric grid," noted Kelly.[6]

A national "smart grid" would change the existing system into one better suited for the information flow required for conservation, higher reliability and the introduction of variable generation power from renewable sources.

The Grid Today

Today's grid provides over 955,000 megawatts of electricity, but few would argue that it is "smart" in the 21st Century sense of the word.

Take the case of blackouts. A blackout occurs when the grid's normal transmission and distribution is interrupted. In the blackout of August 14, 2003, it took just four hours for 256 plants to go off line affecting service across the northeastern United States and portions of Canada. The cause was later traced to a single failure in Ohio. Automated controls took some plants off line for safety reasons while others shut down due to the illusion of lower demand.

"It appears…the load shedding that perhaps they should have done was not done in a way that prevented the New York power grid from having to try to supply power," New York City Mayor Michael Bloomberg explained after it was over.[7] Since the load problems were actually far away from New York, a smarter grid could have sensed there were no local problems and might have prevented the New York City power from going off at all.

Not only are disruptions like these a sad sign of how America has neglected to infuse information technology into the grid, but power disruptions also cost money. Some estimates put the price-tag for grid failures at over $79 billion in lost productivity every year.

Modernizing the grid has become a necessary job, but not just to help level demand or prevent blackouts. A complete overhaul of the U.S. electrical grid is essential to open the door for a 21st Century energy strategy emphasizing conservation, renewable energy sources and diverse uses of the grid.

How the Grid Grew

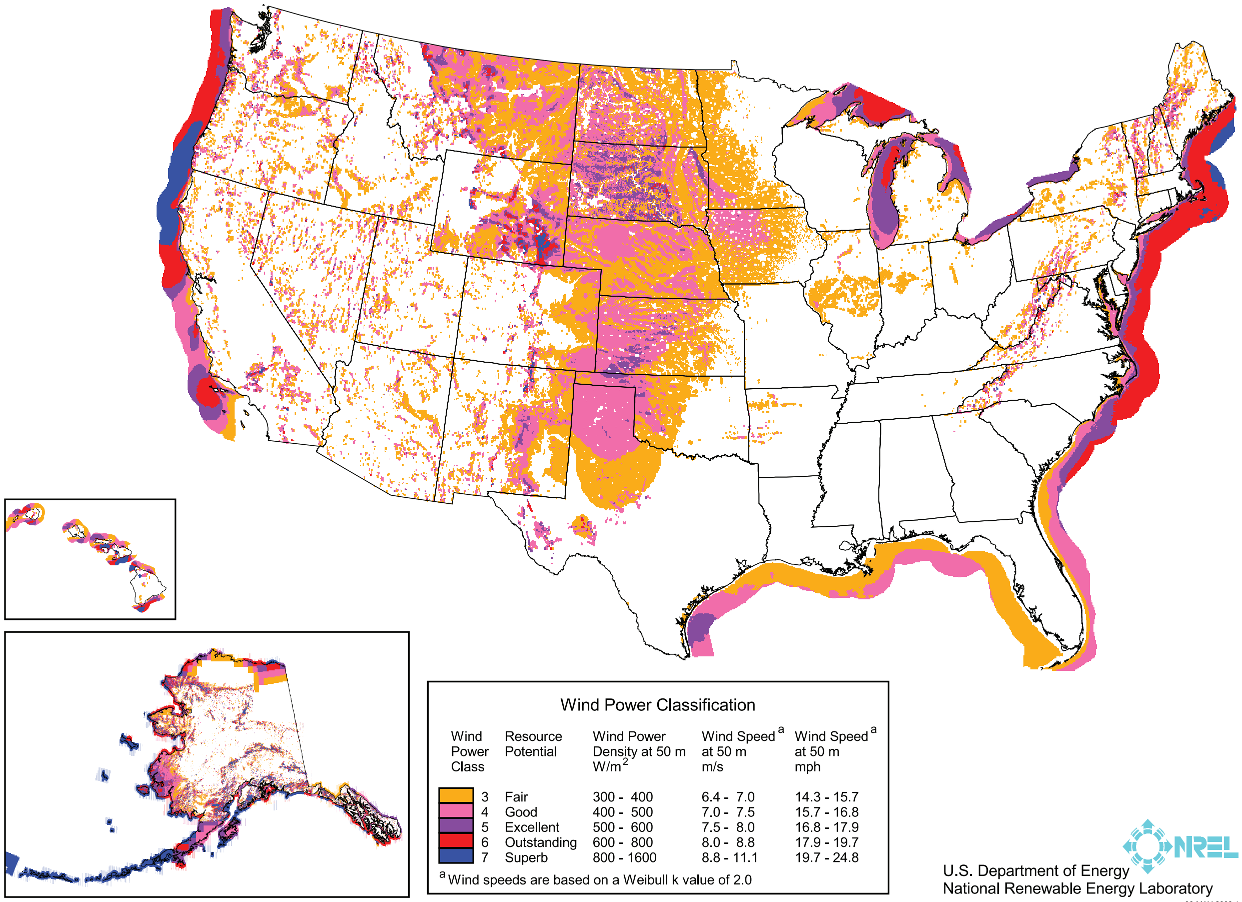
In 1886, Democrat Grover Cleveland was president, and the town of Great Barrington, Massachusetts, set up a small, direct current transmission line. Nikolai Tesla demonstrated alternating, polyphase current in 1888 – the same "AC" current still in use today. Converters and the use of step-up high voltage transmission soon allowed multiple power generating plants to be connected and reduced costs of production. Over 50 local grids were in operation in America by 1914.

The spread of electricity across America did not happen overnight. Reaching rural sectors required direct government intervention. As late as 1925, only 3.2 million of America's 6.3 million farms had electricity.[8] (Some Great Plains farmers erected wind-mill turbines to generate their own electricity.) In 1936, the Rural Electrification Administration (REA) was set up as part of President Franklin Delano Roosevelt's New Deal. Congress authorized the REA in 1936. By 1939, the number of farms with electricity had nearly doubled.

Today's power grid was designed in the 1950s and 1960s with the same basic goals. "The grid of the 1900s was designed for one purpose – to let electricity flow downstream from nearby generators to our homes, offices and factories," testified Evan Gaddis, President, National Electrical Manufacturers Association.[9] Grids today don't store power; they generate and send it out, modulating voltage, and bringing more coal, oil, hydro-electric, and nuclear plants on line as demand increases.

There are about 157,000 miles of high voltage (>230kV) electric transmission lines in operation in the United States.

Annual Average Wind Power Estimates at a Height of 50 Meters



Grids today don't store power; they generate and send it out.

Regulatory changes beginning in the 1970s opened markets but removed some economic incentives for changes to the grid. A 1978 federal law deregulated generation and opened production to entities other than utilities for the first time. New energy legislation in 1992 promoted competition in bulk power and in 1996, energy regulators seeking greater efficiency and lower prices opened up the wholesale trade by giving all electricity producers equal access to utility transmission lines. Customers got a choice of power providers, but the unintended consequence was to focus generators on price and competition rather than innovation and grid rebuilding.[10]

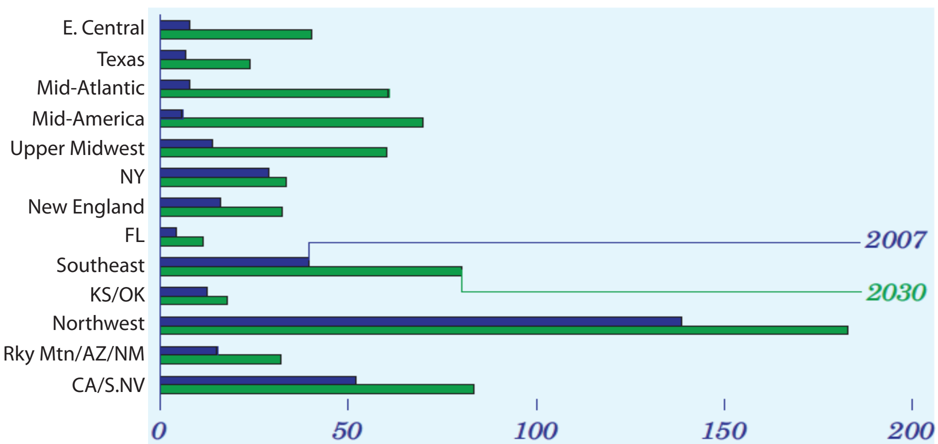
Deregulation touched off a wave of mergers among investor-owned power generators. It also changed the balance between utilities and investor-owned generators. For example, in New England, utilities provided 22,000 megawatts in 1988 but only about 8,000 megawatts in 1999. Non-utility generators took over and expanded their share from 5,000 megawatts to about 18,000 megawatts in the same period.

Changes in the business and regulatory context have not been matched by developments within the grid itself.

The national grid in America is composed of large regional grids and a number of grid operators. Grid operators may be electric utilities or independent system operators. One California-based operator, PG&E, is an investor-owned entity.

Today's grid rolls up into a handful of major and minor connections spanning North America. The Eastern Interconnection handles 610 gigawatts of electricity, while the Western Interconnection reaching from northwest Mexico up into the Yukon territory of Canada runs 160 gigawatts.

Regional Growth in nonhydroelectric renewable electricity generation, including end-use generation, 2007-2030 (billion kilowatthours)



Source: Adapted from Report# DOE/EIA-0383 (2009). Available at: www.eia.doe.gov/oiaf/aeo/electricity.html

(Top) The National Renewable Energy Laboratory's Solar Energy Research Facility in Golden, Colorado combines innovative, whole-building design with highly-efficient heating, cooling and ventilation systems. *(Photo courtesy of NREL/Warren Gretz)*

(Bottom) The Golden Prairie Wind Farm near Lamar, Colorado utilizes 108 1.5MW wind turbines. *(Photo courtesy of NREL/David Jager)*

Quest for Renewables

Two types of photovoltaic cells, as well as dark blue solar water heating tubes, cover most of the roof of this home.
(Photo courtesy of NREL/Jim Tetro)

The grid remains dependent on a concept of local power plants providing steady baseload power in bulk by generating electricity mainly from fossil fuels and nuclear plants. Baseload power from these sources levels output around the clock and seeks to manage production prices. While advances in fossil fuel and nuclear technology may bring more sources into the picture, peak power adds on top of base power and is often generated at plants that are switched on and off as needed. Ancillary or reserve power juices into the system to meet sporadic critical demand. Different types of power plants supply the different market tranches. A big nuclear plant on a long-term contract may be most efficient for baseload power, while smaller generators – and one day, even electric cars plugged into the grid – can serve as back-up power.

The grid itself handles bulk power production. (Distribution is the job of transmission lines, from the large power lines silhouetted against the sky to the line that comes off from the pole or underground conduit and into a building.)

The grid of today stores very little power. Its job is to put bulk power in motion for local distribution. When demand increases, power to the grid increases, too. According to the National Electric Resources Council (NERC), "the bulk power system is designed to meet customer demand in real time – meaning that supply and demand must be constantly and precisely balanced."[11]

Renewable energy calls for a shift in thinking so that the future grid includes better distribution and storage options.

The whole concept of renewable energy calls for a shift in thinking about the grid so that a future grid can include better distribution and storage options. Renewable energy from solar power, wind and similar sources is what engineers call a variable power source. A power plant built to run on coal, oil or nuclear fuel can churn steadily as long as fuel is available. Solar and wind power vary in intensity. With solar, the reason is easy to understand. The intensity of the sun's rays are greatest on a cloudless summer day, and basically absent on a frigid December night.

Wind, too, is more abundant in some places than in others. America's best sources of steady wind power are the high plains, the Appalachian mountains, the Great Lakes, the tip of Maine and the Sierra Nevadas. Only a few cities like Chicago and Denver are in close proximity to wind source. For the most part, the map of power demand centers around major cities is different from the prime locations for wind farms. NERC estimates that "only seven percent of the U.S. population inhabits the top ten states for wind potential." Beyond this, the peak times for available wind power frequently occur during low customer demand. Yet wind is, as of today, the best renewable resource when measured in megawatt availability.

Net electric generation capacity in the U.S. for summer 2007 showed the dilemma. Total electric generating capacity stood at 998,837 megawatts – meaning the various grids could muster about that amount of power, which was slightly more than demand. Of that, electricity from renewable sources accounted for 106,554 megawatts or about 10 percent of capacity. The lion's share came from conventional hydro-electric power which provided over 77,000 megawatts of capacity. According to these statistics, wind accounted for 15,616 megawatts while solar and photovoltaic contributed just 498 megawatts of capacity.[12]

Most prime locations for wind farms in the United States are far from cities and major power demand centers. Offshore turbine blades, like those pictured here, can measure over 100 meters in length.

Can wind power from prime locations make its way to Houston and New York City? As solar power matures, how will it be integrated into the mix? How can homeowners and businesses return power they generate to the larger grid? The challenges are clear, but one where technology is close in hand is the smart grid.

The localized, utility-dominated electric grid served 20th Century America very well. But recent experience has already shown the grid to be inadequate for the 21st Century.

Four factors are contributing to the urgency behind smart grid:

- **Increased demand.** First is the need to increase the supply of reliable power. Demand for electricity will increase up to 40 percent by 2030, according to one estimate. Meeting this demand will require an additional 214 gigawatts of generating capacity.

- **Diversification.** "The need for overhaul is driven by the fact that the grid will be used in different ways in the future," commented Carey Cook, Senior Strategic Marketing Manager for S&C Electric in Chicago.[13] The grid needs to provide customer feedback and go beyond the old model of just supplying power. Applications may include creating home charging stations for plug-in vehicles.

- **Conservation.** Rolling back demand through better choices about power use is a key element of a future national energy strategy. Consumer visibility will be enhanced by smart grid.

- **Cleaner electricity.** Smart grid technology is essential for adding power from wind, solar and other variable sources and decreasing reliance on fossil fuels. It would take 357 typical coal-fired plants to meet projected demand for a 40 percent increase with the current system.[14] Simply put, there is no way to add conventional power plants and meet climate and other economic security goals at the same time. Emission reduction standards now set in U.S. law demand progress on a smart grid that can boost conservation and add energy from renewables.

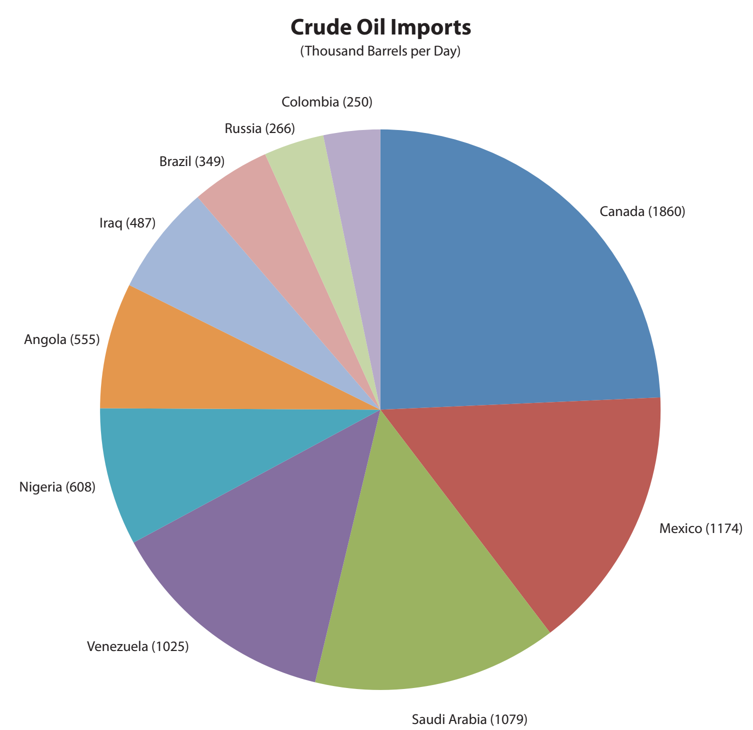
Smart Grid's Role in Energy Independence

Another possible benefit of smart grid is to reduce dependence on imported sources of oil. Top oil suppliers to the U.S. in April 2009 included Canada, Mexico, Saudi Arabia, Venezuela, and Nigeria. These top five suppliers accounted for 59 percent of U.S. oil imports. The next five nations added another 21 percent. They were Iraq, Angola, Algeria, Russia, and Colombia. Fast friends and allies are on these lists but so are many of the world's more troubled nations.[15]

Total oil consumption in the U.S. has tripled since 1949. While oil is used to produce electricity, the quantity is tiny. Most oil goes for transportation and in a distant second, for industrial uses. Home heating accounts for another small share.

The benefit of a smart grid to energy independence rests primarily with electric vehicles. To cut oil imports Americans must use less gasoline. One way to do that is to mix electric drive with gasoline or diesel-powered drive. Hold constant the number of miles driven and oil imports could still drop. The value of smart grid comes from facilitating the transition to more electric drive vehicles and adding renewable energy sources for electricity generation.

As with other measures, development of the smart grid is an important potential contributor to greater energy efficiency and independence.



Source: EIA Crude Oil and Total Petroleum Imports Top 15 Countries, accessed August 4, 2009.

Small scale demonstrations are preparing the way for developing a set of guidelines for implementing smart grid on a national scale. While experiments to date have been limited in scope, they have yielded considerable data on technology prospects, consumer reaction and business case challenges to implementing a smart grid. The next section examines three very different approaches.

Smart Grid in Action

Massachusetts, Colorado and Texas are among those leading efforts in developing smart grids as part of their future energy strategies. Combinations of private ventures and comprehensive state regulatory changes show the potential for policy and business-case stimulus in these areas – and varying roles for government and private industry.

Massachusetts: Legislative Leader

Massachusetts' General Assembly broke new ground on Beacon Hill when it passed a suite of energy policy measures in 2008. The state's initiatives blended public mandates with financial incentives to achieve progress on energy efficiency. Massachusetts now has the toughest greenhouse gas cap in the U.S. with a goal of dropping state emissions below 1990 levels by 2020, and reaching an 80 percent emissions cut by 2050.

The Green Communities Act of 2008 set a goal for providing 25 percent of the 2020 electricity load through efficiency measures and ruled out building new plants before efficiency measures were taken. Massachusetts set targets for renewable growth at 1 percent per year with the goal of providing 15 percent of state power from renewables by 2020. The act also empowered utilities to sign long-term contracts for renewable energy, thereby providing a revenue stream for forward planning.

Strong state-based legislative action quickly sweetened the climate for private initiatives. In Worcester, Massachusetts, more than 15,000 customers will embark on a two-year pilot smart grid program beginning in 2009.[16] Pilot programs like these can be replicated in most any city or town.

"This proposal is one of the smart-grid pilot projects required under the Green Communities Act, and I look forward to seeing whether it can deliver the strong benefits we believe are possible," said Massachusetts Energy and Environmental Affairs Secretary Ian Bowles. "Today, we can all manage our cell phone plans, but not our electricity use. Smart grid technology is a tool that can help consumers and reduce environmental impacts, and the sooner we learn how to use it, the better."

Texas: Pecan Street Project and Beyond

In Texas, over 85 percent of the electricity demand is filled by a state-run provider known as ERCOT, the Electric Reliability Council of Texas. Texas and Florida are unique in having most of the electric power in their state borders supplied from a single reliability council. Texas has also been the leading generator of wind power among the 50 states, followed closely by California.[17]

For Austin, Texas, the city council also serves as the utility regulator, making it easier for a group of corporations to partner with the city in the Pecan Street Project. The project aims to devise and test not only the technologies but the business model for smart grid on a city-wide scale. Assistance from the Environmental Defense Fund helped bring together the project.

An overriding lesson from all cases is the benefit of tailoring solutions to local structures.

The Pecan Street Project is a different type of smart grid venture in that its goals began with mapping out a comprehensive city and business plan for changing the way Austin uses energy. Where the Boulder, Colorado, project launched an experiment with commercial investment, Pecan Street's plans were to gain consensus among the city, taxpayers and industry partners before moving ahead. The Pecan Street Project has ambitious goals to craft a detailed new energy strategy. As one key civic leader in Austin described it, the goal is to: "Design a system that can cost-effectively generate a power plant's worth of clean energy within the city limits and do it in a way that preserves Austin Energy's financial stability and strengthens Austin's economic future."[18]

Civic leaders in Austin see the smart grid as not just a project but a new industry and a source of skilled, green jobs. "Austin has the opportunity to play the same role in the evolution of America's energy economy that it did with the semiconductor boom in the '80s," said Austin city councilman Brewster McCracken.[19]

Colorado: Smart Grid in Boulder

The city of Boulder, Colorado, is the site for an experimental application of smart grid technology. A dense cluster of homes, commercial businesses and even facilities at the University of Colorado at Boulder are receiving new two-way meters and connecting to a smart grid already in operation. Proponents bill it as the first city-sized smart grid in the nation.

A consortium of private companies led by Xcel Energy selected Boulder for the site. Boulder is also home to a branch of the National Institute of Standards and Technology (NIST), the federal agency empowered in 2007 to set standards for future smart grids. By early 2009, over 15,000 smart meters had been installed as part of the consortium's $100 million investment. About 100 miles of new fiber optic lines for grid monitoring have also been installed. The Boulder grid employs a technology called broadband over power lines. With BPL, existing electrical wires are used to provide digital communication capabilities and create a multi-directional, high-speed communication network.

Smart grid upgrades enable Boulder customers to monitor and manage power use – including controlling the thermostat – via secure website.

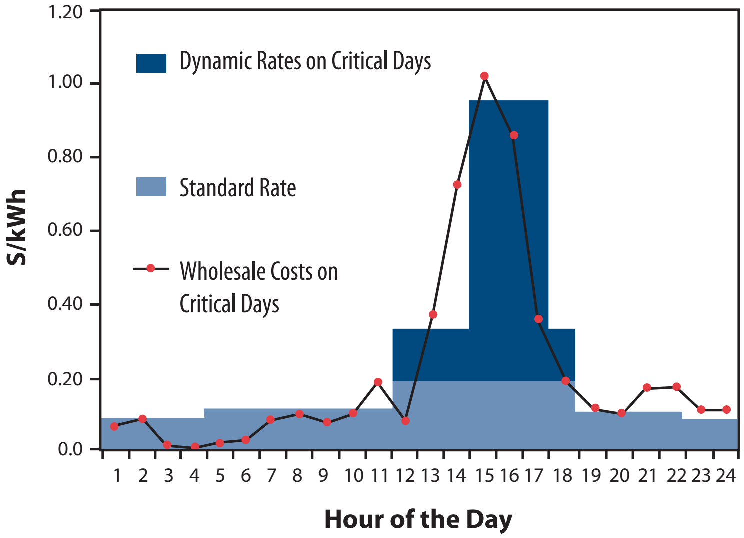
For Boulder, the immediate goals of smart grid are:

- Add more clean and green power sources in the fuel mix – greatly improving power delivery and reliability while optimizing environmental benefits.
- Give customers more choice about when, how much and what kind of energy they use and ways to conserve and manage their energy dollars.
- Provide a digitally enhanced, more resilient and stable energy grid that is less prone to outages and improves power reliability.[20]
- The SmartGridCity project managers estimate their grid could draw about 30 percent of its power from renewables, a much higher percentage than in conventional grids. Over time, the Boulder grid should be able to accommodate vehicle plug-in and storage, too.[21]

The city of Boulder has augmented the energy program with a model for climate-smart loans borrowed from Berkeley, California. Homeowners can borrow against home equity for improvements such as insulation or installation of solar panels. As implementation of Boulder's grid fills out in 2009, the city and the consortium plan to assess the results and use them in discussions "with state, federal and regulatory officials about a larger deployment throughout the company's eight-state service territory," according to Xcel Energy.

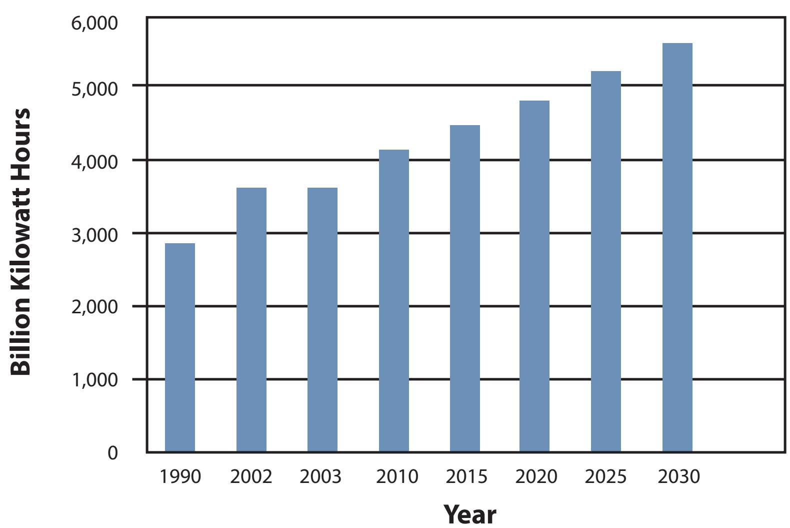
The different approaches capture the full breadth of changes needed and the range of stakeholders who will take smart grid forward. An overriding lesson from all cases is the benefit of tailoring solutions to local structures. The legislative-driven agenda in Massachusetts contrasts sharply with the corporate-led investment in Boulder. All the municipalities expect strong lessons learned as they look for ways to scale up approaches to implementing smart grid technology. What all have in common is a passion for a better energy future.

Hourly Price of Electricity on Critical Summer Weekdays



Source: California Energy Commission, Energy Systems Integration - Demand Response. Accessed July 2009 at: www.energy.ca.gov/research/esi/pricing/index.html

United States Net Electricity Consumption, 1990-2030



Average Annual Percent Change, 2003-2030 = 1.6

Source: Energy Information Administration/ International Energy Outlook 2006. Accessed July 2009 at http://www.eia.doe.gov/oiaf/ieo/pdf/ieoreftab_9.pdf

Conservation and the Grid for Tomorrow

Getting to energy efficiency is not possible without smart grid. The benefits include conservation, facilitating wide use of electric vehicles and, of course, transitioning to clean renewable power sources.

Motivating consumers to conserve electricity can be an immediate benefit of smart grid technology. In Boulder, Colorado, a husband and wife who signed up for the smart grid quickly found they did not know much about each other's energy habits and preferences. The Boulder couple sparred over an extra deep freezer, the clothes dryer and where to set the thermostat when they had guests over the holidays. Although they resolved their differences, "it took about four months," the husband said. [22]

Analysis suggests that evaluating personal energy choices is well worth the effort. Consumers stand to benefit from lowering consumption and strategizing about when and when not to use particular appliances.

The larger point is that part of the smart grid revolution will be infusing more awareness into individual consumer choices. Few Americans alive today recall life without cheap, plentiful electricity. Hefty summer air conditioning or winter electric heating bills have been virtually the only source of feedback on household energy consumption.

Part of the smart grid revolution will be infusing more awareness into individual consumer choices.

Still in the realm of the unknown is the extent to which consumers will conserve. "Just because you plug in a smart meter," noted Southern Company chief executive David Ratcliffe, "doesn't mean a customer will immediately take smart actions."[23] Others are more sanguine. "Studies show that when consumers can see in real time how much energy they are using, they save 5 to 15 percent on their electricity use with simple behavioral changes, and even more with investments in energy efficiency," testified Edward Lu, a Google smart grid projects manager, at a Senate hearing in March 2009.

An experiment in Washington state suggested that the potential may be quite deep, but smart grid proponents and utilities managers will have to work to get it. Customer choices in the Olympic Peninsula experiment initially led to a 15 percent decrease in overall demand. After a storm, customers were informed that cutting back could ensure everyone had at least some electricity, and demand dropped 50 percent. Ongoing efforts are likely to land somewhere in the middle, but the point is that smart grid technology is necessary to tap the full potential of consumer conservation.

Currently, price is an obstacle. "Most consumers will not change behavior without price signals, education and technological assistance," testified Katharine Hamilton, President, GridWise Alliance, in March 2009. "With increased information, and technological innovation, consumers could see in real time the impact of their electricity use and take action to reduce their bills."[24] Price and other incentives will have to be part of the deal as smart grid technology expands.

The ultimate appeal of a smart grid system may rest in its ability to gather and store power, not just distribute it. The Boulder, Colorado, experiment included special modifications to the official residence of the Chancellor of the University of Colorado. A battery pack was installed to store 40 hours' worth of solar power for household systems. With a smart grid, the utility could also tap the power reserves and redistribute them back to the grid. One house might not make much difference. But hundreds or thousands of homes capable of sending power drawn from solar or wind back to the grid could have an impact on local usage.[25] The result might be less need to build new power plants to meet electricity demand.

Smart grid technology is necessary to tap the full potential of consumer conservation.

While standard hybrid electric vehicles contain both a battery pack and electric motor, PHEVs can recharge their batteries with electricity from a standard outlet. *(Diagram courtesy of NREL/Jim Snyder)*

Electric Vehicles and the Smart Grid

Another source of urgency for the smart grid is meeting goals for getting more "clean" cars and vehicles on the road. Electric vehicles largely eliminate greenhouse gas emissions from vehicle tail pipes.

As part of the stimulus package, President Obama set a goal of putting one million or more plug-in electric hybrid vehicles on the roads of America by the year 2015. Several manufacturers have electric vehicle programs in the works. Congress included a taxpayer credit of up to $7,500 for purchase of plug-in electric vehicles.

Passenger cars aren't the only hybrid vehicles. Most cities operate hybrid buses that combine electric battery operation with back-up power from diesel, gasoline or another source.

Smart grid technologies are an essential step toward a large-scale conversion to electric-powered hybrid vehicles. Pure electric vehicles rose from 11,380 in use in 2000 to over 55,730 in use in 2007.[26]

Sales of non-gasoline vehicles are expected to increase from 11 percent in 2007 to 41 percent of all vehicle sales by 2022, according to the Energy Information Administration's Annual Energy Outlook 2008.[27]

California Cars Initiative (CalCars.org) founder Felix Kramer converted this Toyota Prius to a plug-in hybrid in 2006, and has taken it around the country to promote the potential of PHEVs. *(Photo courtesy of CalCars.org)*

A major challenge to large-scale usage of electric vehicles will be matching the ease of distribution of today's street corner and freeway off-ramp gas stations. Electric cars will require a reliable, ubiquitous recharging network allowing consumers to recharge conveniently including at their work place.

With a smart grid, part of the recharging demand can be met at home, in the garage. But a recharging system for cars on a larger scale is necessary for a significant replacement of petroleum-powered vehicles. Smart grid technology can provide the basis for more consumers to adopt plug-in hybrids or pure electric vehicles.

It's not all about what the smart grid can do for the electric car. Pooled together, electric cars can do a lot for power management, too. The concept of vehicle-to-grid, or V2G, envisions electric cars with batteries can also act as storage. They may take power from the grid when wind power surges, for example, then store it to feed back. An energy executive involved with the Boulder, Colorado, grid projected that one day a network of electric vehicles, "can be a small power plant for us."[28]

A smart grid could also enable electric vehicles to serve as a source of ancillary power for the grid. For example, smart grid technology enables household solar collection to be stored in batteries and used to recharge a plug-in hybrid electric vehicle. Once these vehicles reach the market, gasoline price spikes and eco-friendly marketing will fuel their popularity – made much easier by an integrated, at-home charging method flowing from smart grid.

The original battery pack in the CalCars Prius used short-life but resilient lead-acid to develop design criteria for higher-performance batteries. *(Photo courtesy of CalCars.org)*

Two scientists who evaluated vehicle-to-grid capacity and revenue posited that V2G could evolve into an effective supplier of quick-response, high-value electric services to balance load fluctuations. "The societal advantages of developing V2G include an additional revenue stream for cleaner vehicles, increased stability and reliability of the electric grid, lower electric system costs and eventually, inexpensive storage and back-up for renewable electricity," they concluded.[29]

V2G could evolve into an effective supplier of quick-response, high-value electric services to balance load fluctuations.

The grid may one day help power the increasing numbers of hybrid-electric buses, shuttles and trucks, too. Several manufacturers have offered hybrid buses for over a decade and New York City already operates over 300 hybrid buses.

Policy and Prospects

Just as the grid of today required presidential initiative, the smart grid will take a high-level policy push, too.

The actual process of distributing meters and integrating smart grid technology rests primarily with the utilities and to a lesser extent, with business initiatives. All the grassroots clamor for smart grid will come to naught if it meets opposition or indifference from utilities or crashes on impact with the costs of moving to smart grid.

So far, utilities are deciding on their own when and whether to explore and implement smart grid integration.

Major steps forward may depend on national-level policy initiatives coming from Congress and the White House. Two major pieces of legislation have moved smart grid forward. In 2007, Congress passed the Energy Independence and Security Act. It contained several provisions for exploring and extending smart grid standards.

Then in 2009, Congress passed the American Recovery and Reinvestment Act, popularly known as the stimulus package. NIST has already been authorized to coordinate development of protocols and information standards for smart grid devices and systems.

Many are recommending high-level national attention. Ernest J. Moniz, Director of the MIT Energy Initiative, called for a White House commitment to implement a smart grid within ten years to "enable development of large-scale resources for renewable electricity." Measures may include energy efficiency standards for new construction and financial incentives for retrofits. The power of national policy extended electricity to rural America. It can smooth the way for smart grid, too.

Investment

Of course, a smart grid will not come cheap. The grid of today is the result of uncalculated billions in cumulative investment reaching back more than a century.

Hard numbers for implementing smart grid and bringing renewables online await a more formal treatment of the policy. Some estimates are available. Costs for implementing a U.S. smart grid range from $100 billion to $400 billion.

Sustained growth in the renewable-energy sector is reliant on federal and state policies that promote stable investment and long-term revenue certainty.

The United Nations (UN) estimates that global investment in sustainable energy could meet the goal of halting the rise in carbon dioxide peak levels by 2020. "Annual investments in renewable energy, energy efficiency and carbon capture and storage need to reach $500 billion by 2020, rising to $590 billion by 2030, representing an average investment of 0.44% of GDP *[gross domestic product]* between 2006 and 2030," found a recent UN report. "These levels of investment are not impossible to achieve, especially in view of the recent four year growth from $35 billion to $155 billion," the UN concluded, while recognizing that "reaching them will require a further scale-up of societal commitments to a more sustainable, low-carbon energy paradigm."[30]

Hydro-electric power remains the nation's most prevalent renewable source of energy, providing about 10 percent of current capacity.

Despite recession and a global credit shortage, investment in renewable energy has continued, although levels are lower. Wind remains the largest global investments sector with $51.8 billion in new investment in 2008. Solar again came in second among renewables at $33 billion. However, 2008 saw a key milestone. For the first time, total investment in renewables surpassed that in fossil fuels. Given the willingness of the market to commit, smart grid technologies make sense and entail even lower levels of risk.

Incentives

Smart grid will most likely require federal, state and local government incentives. The federal government has been down this road before with rural electrification. In the 1930s, the REA did not work with consumers directly. Instead, backed by national policy, REA provided long-term loans to state and local governments, farmers' cooperatives and non-profit groups to set up the power transmission infrastructure.

More recently, government incentives have been effective in stimulating the photovoltaic (PV) solar cell market, for example.

PV cells are the central component of solar power systems and have supplied remote regions for years. Grid-connected PV solar can channel excess energy from a sunny day back into the grid – but taking full advantage of more distribution requires a smart grid. Costs are still a factor which has led to effective use of federal tax credits in the U.S. and abroad.

Investment tax credits initiated by Congress in the Energy Policy Act of 2005 led to 50 percent yearly increases in shipment of PV cells. With that stimulus, peak kilowatt hours for grid-interactive solar cell electric generation jumped from 129,265 in 2004 to 274,197 in 2007. The stimulus pushed forward a market already on the upswing; 21,713 peak kilowatt hours were generated in 2000. Up to 94 percent of these cells have been used for grid-interactive power generation (as opposed to remote-site uses not connected to the grid).[31] While PV cells are a small part of the market, their example shows that the response of private industry to federal energy incentives can be powerful.

Conclusions

Smart grid technologies won't solve America's energy dilemma overnight. However, moving forward with smart grid can begin to tackle the problem from many angles. In the near term, the smart grid technologies will give consumers greater visibility into ways to conserve power. In the medium term, smart grid technologies can enable green communities (as in the Boulder, Colorado, experiment) to dramatically reduce energy consumption and boost the share of electric power from renewables.

Policy action is worthwhile to move promising technologies closer to full adoption. The smart grid is essential to meeting goals for the transition to more rechargeable hybrid vehicles. In the longer term, full grids may provide a back-up ancillary power source.

America's energy transition depends on major breakthroughs in efficiency for solar power, batteries and more. Many of these improvements are still at the stages of basic science. In contrast, smart grid technologies are on hand because of mature growth in information technologies. America knows how to put together the smart grid. Policy and regulatory challenges remain, but the technology is here today. Making progress on the smart grid is one sure step America can take now to ensure its energy future.

Glossary

Alternating Polyphase Current – in alternating current (AC) the movement of electric charge periodically reverses direction. Polyphase systems have three or more energized electrical conductors carrying alternating currents with a definite time offset between the voltage waves in each conductor.

Baseload Power – the minimum amount of power that a utility or distribution company must make available to its customers, or the amount of power required to meet minimum demands based on reasonable expectations of customer requirements. Baseload values typically vary from hour to hour in most commercial and industrial areas.

Gigawatt – one billion watts – one gigawatt can power as many as 750,000 homes.

Kilowatt – one thousand watts – the average annual power consumption of a household in the United States is about 8,900 kilowatt-hours.

Megawatt – one million watts – U.S. nuclear power plants have net summer capacities between about 500 and 1300 megawatts.

Photovoltaic Solar Cell – a device that converts light directly into electricity. This is an example of solar energy.

Plug-in Hybrid Electric Vehicle (PHEV) – is a hybrid vehicle with batteries that can be recharged by connecting a plug to an electric power source. It can also power a home during an outage.

Renewable Energy – energy that is generated from natural resources – such as wind, sunlight, rain, tides – which are renewable. Also includes hydro-electric power generated by dams.

Smart Grid – a network for electricity transmission and distribution systems that uses two-way, state-of-the-art communications, advanced sensors, and specialized computers to improve the efficiency, reliability and safety of electricity delivery and use.

Utility Transmission Lines – the material medium or structure that forms a path from one place to another for directing the transmission of energy. Types of transmission lines include wires, coaxial cables, dielectric slabs, striplines, optical fibers, electric power lines, and waveguides.

Vehicle-to-Grid (V2G) – technology allowing an electric drive vehicle to generate or store electricity when parked, and feed power to the grid.

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