State Climate and Energy Program

Smart Grid's Potential for Clean Energy
Background and Resources

U.S. Environmental Protection Agency
State Climate and Energy Program Technical Forum

Recent trends, including increased electricity needs and advancements in grid management technologies, are causing the electric industry and regulators to rethink how the grid is managed. The industry is starting to employ "smart" grids that use information and communication technologies to make electric power systems more reliable and efficient. These technologies may also help enable higher levels of renewable energy and additional energy efficiency.

Topics Covered in This Document

- What is a Smart Grid?
- Why Make a Grid "Smart"?
- Is a Smart Grid a Green Grid?
- Barriers to Smart Grid Implementation
- Federal Efforts to Implement a Smart Grid
- Current Examples of Smart Grid Deployment
- Additional Resources and Sources Cited

What is a Smart Grid?

A "smart" grid is an electric grid system where all participants in the grid system (from electricity generators, to transmission and distribution operators, to electricity consumers) communicate and work with each other to increase the efficiency and reliability of the grid.

A key feature of a smart grid system is the use of advanced technologies (such as smart meters) that provide participants with relevant, real-time information. These technologies allow generators, system managers, and customers to receive instantaneous information on electricity needs and prices, and to work together to meet electricity needs in the most efficient way possible. Complementary policies, which often must be established by utility regulators, are required to ensure that these technologies are effective. Such policies may include rate design and interconnection standards for clean distributed generation, funding for energy efficiency programs, and rate designs that encourage customers to save energy.

Smart grid systems can be part of a state's broader strategy to meet environmental and energy policy goals, such as renewable portfolio standards and energy efficiency programs. These implementation strategies are still under development and stakeholder engagement can be instrumental in designing and deploying the smart grid for clean energy benefits.[1]

[1] See *Smart Grid Stakeholder Roundtable: Perspectives for Utilities and Others Deploying Smart Grids* for more information. http://www.oe.energy.gov/DocumentsandMedia/stakeholder_roundtable_sept_09_final.2.00.pdf

Why Make a Grid "Smart"?

Demand for electricity continues to accelerate due to population growth and increased global reliance on electrical technologies.[2] Simultaneously, electric grid infrastructure in the U.S. is aging. As a result, improvements in the underlying electricity infrastructure are necessary.

Figure 1 illustrates the flow of electricity from centralized power plants to the end user in the current grid system. Smooth operation of the electrical system as a whole depends on reliable performance of each one of these components. As electricity needs increase, each component must be able to handle these new demands—or the entire system becomes unreliable.

Is Our Grid Smart Yet?

Many cities and states are starting to implement smart grid technology.

- Smart grid technologies and policies are still being developed and improved.
- Existing technologies have not yet been deployed on a large-scale.
- While California and Texas have emerged as the state leaders for smart grid implementation, they are followed closely by Florida, Illinois, Pennsylvania, West Virginia, Ohio and other states across the country.

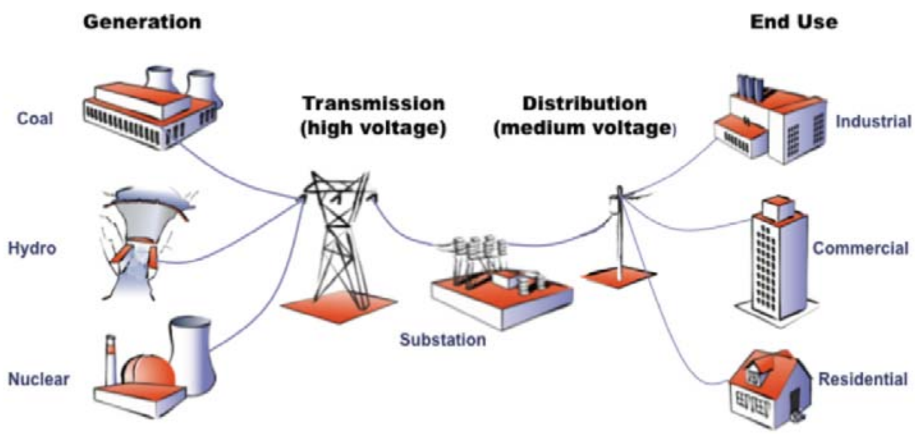

Figure 1: The current path of electricity generation and delivery to end users. At the left is large centralized generation, followed by high-voltage transmission, medium-voltage distribution, and end users.[3]

System Strain and Power Outages

Insufficient access to electricity can result in power outages, which cause negative economic and security effects. The U.S. Department of Energy estimates that power outages and power quality issues cost the national economy $25-$80 billion each year.

Transmission congestion is another challenge facing the industry. Investments in transmission facilities have not kept up with demand, resulting in congestion (i.e. electricity can be produced, but not moved to where it is needed). For example, electricity demand has increased roughly 25% since 1990, but annual investment in new transmission facilities has declined over the past 25 years.[4] Transmission congestion reduces consumer access to power that may be cleaner or cheaper and results in a less than optimal operation of the power system.[5] However, there

[2] Global Environment Fund (2008)
[3] Figure is from Global Environment Fund (2008)
[4] DOE (2010b)
[5] Ibid.

is often resistance to transmission construction projects, due to competing land uses, uncertainty about who should pay (particularly across states), high cost of project materials, and disagreements on project financing.[6]

The grid's problems extend beyond physical constraints. The demand and cost to produce electricity varies significantly throughout the year and within a single day. For example, in Massachusetts, 15% of peak demand occurs in just 88 hours per year.[7] Simply shifting some electricity demand from peak hours to non-peak hours can result in significant system-wide cost savings and reduce the need for new power plants or transmission lines. Energy efficiency, distributed generation and demand response programs can help reduce peak demand.

A smart grid offers solutions to these problems. For example, if at one moment electricity demand is very high, signals can be sent to customers to discourage unnecessary use of electricity. These signals can help balance out demand throughout the day, such as by switching use of appliances from peak demand times to low demand times. They can also encourage customers to simply use less electricity. Furthermore, system operators are able to "talk" to specific meters, and turn off electricity to certain appliances or customers during extremely high demand times. Doing so can prevent wide-spread power outages. This functionality may also be used to communicate the changing emissions profiles to customers, but most near-term activity is focused on communicating price signals.

Smart Grid: Technology and Policy Working Together

Smart grids, consisting of several technologies, such as Advanced Metering Infrastructure (AMI), can enable two-way communications between the local utility and the customer. AMI and in-home displays can provide customers with information on when electricity prices are high (and therefore when they may wish to limit energy use) and also provides system operators with the ability to turn off less important appliances and systems when demand is particularly high.

Because AMI requires coordination among many players, and because utilities tend to be heavily regulated, successful deployment of AMI requires that supporting policies be put in to place. For example, electric service providers may propose dynamic pricing mechanisms, such as peak hour pricing, in order to provide incentives to customers to decrease their electricity use.

Is a Smart Grid a Green Grid?

Smart grids can facilitate energy efficiency and renewable energy goals, resulting in reductions in greenhouse gas (GHG) emissions and other pollutants associated with fossil fuel power sources. A study from the Electric Power Research Institute in 2008 estimated annual reductions of 60-211 million metric tons of CO_2 due to smart grid implementation through:[8]

- **Greater integration of renewable generation**. Smart grid technologies help grid operators better predict daily wind and solar energy generation potential, and more easily adjust the system for the peaks and valleys of these intermittent resources.
- **Dynamic pricing and demand response**. Awareness of changing prices can help encourage consumers to reduce electricity demand during times of peak demand, thereby reducing strain on the system and overall energy consumption.
- **Enhanced measurement and verification capabilities**. Smart meters allow utilities and customers to track electricity use in real time, and to see how behaviors or energy-

[6] Ibid.
[7] Giudice (2009)
[8] EPRI (2009)

- **Improved equipment efficiency maintenance**. Commissioning equipment, or making sure that it is functioning efficiently in a particular setting, requires managers to manually monitor equipment. For example, major consumer equipment, such as refrigerators and air conditioning units, are often not properly commissioned when first installed. Smart grid technologies facilitate continuous commissioning, so equipment settings and performance of electrical equipment can be continuously monitored and optimized automatically.[9]

- **Reduced transmission and distribution line losses**. Over 5% of generated electricity is lost during its transmission and distribution. Smart grid allows utilities to reduce transmission and distribution losses without expensive updates to the structural infrastructure of the grid.

> Smart Grid and Clean Energy:
> Key Points to Consider
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> - Smart grids can help system managers integrate wind and solar energy sources into the grid
> - Smart grid technology can provide immediate price signals to consumers that may encourage them to make energy-efficient choices
> - However, these benefits are not guaranteed
>   - Renewable energy faces other barriers, and appropriate policies can help promote more renewable energy generation
>   - Appropriate pricing systems must be put into place to ensure that customers do respond to price signals
> - It is important that the energy needs of smart grid technologies do not negate the energy benefits of the system

- **Plug-in hybrid electric vehicles (PHEV).** A challenge to widespread adoption of PHEVs (which would reduce GHG emissions) is how electricity demand would be affected by a large number of PHEVs plugging in to the grid. One way to manage a large PHEV fleet is to have the PHEVs charge at night (when electricity demand is low), and then plug them in to feed back *into* the grid during peak demand hours. Smart grid technologies could assist with the complex coordination needed to implement this management strategy.

However, there is no guarantee that the benefits of smart grid will actually be realized (see next section). In addition, the act of collecting and conveying the large amounts of data needed in a smart grid system may result in increased energy use itself (although this increase is difficult to quantify).[10] Therefore, expected energy savings must be weighed against the energy demands of the equipment.

Barriers to Smart Grid Implementation

In order to realize the potential benefits of a smart grid, a number of barriers must first be overcome. Important issues in particular are: uncertainty in costs, difficulty in measuring benefits, cybersecurity and privacy concerns.

Uncertainty in Costs

While smart grid can save costs through efficiency improvements, the significant cost of implementing the system can erase some of those savings. Because smart grids rely on sophisticated technology for communication and control activities, large investments in

[9] Electricity Advisory Committee (2008)
[10] Kenkel (2009)

infrastructure are needed. Decision makers must therefore weigh the expected benefits against the expected costs. However, there is a large degree of uncertainty regarding costs, making it difficult for decision makers to assess how much it will cost to implement a smart grid system. Smart grid technologies may need to be upgraded within a few years, unlike traditional utility infrastructure, such as power plants, which can operate with minor or no modifications for decades. The industry is working to establish interoperability standards that would reduce the long-term costs of deploying smart grid technologies.

For example, the cost of installing smart grid technology in Boulder, CO was nearly triple the expected cost, mainly due to uncertainties in creating the fiber optics infrastructure. Dominion Power in Virginia is currently revisiting both the expected costs and benefits of their smart grid program before proceeding with implementation.

Difficulty in Measuring Benefits

Many of the benefits of a smart grid come from expected changes in consumer behavior. However, it is difficult to accurately predict how customers will react to price signals. It is possible that customers may not change their electricity demands much, even when faced with different prices at different times of the day. For example, in Connecticut, customers were given a globe that glowed different colors based on the price of electricity. Even with this visual signal, however, customers did not change their electricity usage behavior to the extent predicted. If customer demand is not notably affected, then the costs of smart grid implementation may outweigh the benefits. Putting into place proper, complementary policies (such as funding broader programmatic efforts to educate and encourage customers to save energy, and adopting fair rates and interconnection standards for distributed generation) are therefore critical for successful implementation of smart grid.

Cybersecurity and Privacy Concerns

Installation of "smart" devices gives potential hackers new targets for exploitation. Because these devices monitor and collect large amounts of information, there is concern that customer privacy could be at risk. Since advanced metering infrastructure often relies on wireless technologies, hackers could infiltrate the computer systems to extract recorded information, insert malicious software, identify network authentication keys, and then access other parts of the system using the grid's communication systems.[11]

Federal Efforts to Implement Smart Grid

Smart grid requires large-scale coordination among the various players of the electricity system, including the federal government, which regulates transmission. Thus, over the past few years, the federal government has focused increasingly on smart grid implementation. The most significant piece of federal smart grid legislation is the Energy Independence and Security Act, passed in 2007 (EISA 2007), which authorizes funding for smart grid development.

Coordinating Federal and State Authorities

One of the major challenges in implementing smart grid is the coordination required between FERC and each of the states involved. While FERC has authority over interstate issues, the responsibility for the construction and maintenance of power generating plants and transmission lines primarily resides with the state Public Utility Commissions (PUC), which also have authority over electricity distribution systems and the rates paid by retail customers.

[11] DOE (2009c)

EISA 2007 made the National Institute of Standards and Technology (NIST), a non-regulatory federal agency within the Department of Commerce, responsible for developing interoperability standards for smart grid equipment.[12] According to NIST, hundreds of consistent standards will eventually be necessary to help regulate the smart grid.[13]

EISA 2007 also directs the Federal Energy Regulatory Commission (FERC) to consider adopting standards and protocols related to smart grid interoperability. FERC has responsibility for approving and enforcing mandatory reliability standards for the bulk power system and adopting smart grid interoperability standards for the interstate transmission of electric power.[14] In 2009, FERC adopted a Smart Grid Policy that provides guidance to achieving interoperability.

> **Interoperability**
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> Interoperability refers to the ability of different systems to exchange information. The smart grid will require interoperability on a number of levels. For example, smart grid technologies installed by one utility must be able to communicate with those installed by another and with control centers.

Current Examples of Smart Grid Deployment

Existing and planned deployment of smart grid varies significantly across states, but certain smart grid technologies are becoming widespread. In 2009, an estimated 7.95 million advanced meters had already been installed and an estimated 80-141 million are expected to be installed by 2019.[15] California is currently considered the state leader in smart grid and the state has installed advanced meters and Phasor Measurement Units, which provide real-time grid monitoring. California has also begun automating substations, circuits and switches. Both Texas and California have passed legislation requiring Public Utilities Commissions to create and implement a smart grid plan.

However, California and Texas are not the only ones pursuing a smart grid strategy. For example, in the past three years, Colorado, Maryland and Ohio have instituted new legislation and utility regulations to promote demand response. Alabama (and California) approved time-based rates for customers.[16] Other smart grid activities include:

- *Energy Smart Miami*: Florida Power & Light has begun a $200 million project to connect all residents of Miami-Dade County to the smart grid by 2011. The pilot project will install smart control panels and thermostats in approximately 1,000 homes to help consumers reduce energy demand during peak hours.[17]

- *Illinois Statewide Smart Grid Collaborative*: Founded in 2008, this initiative has worked to engage all stakeholders in examining the potential benefits and costs of smart grid for Illinois. The collaborative is focusing especially on consumer protection issues, such as data privacy.[18]

- *Smart Grid Implementation Plan in West Virginia*: West Virginia developed the first state-wide smart grid plan in the country. The state is now working with utilities and other

[12] NIST (2008)
[13] NIST (2008)
[14] FERC (2009a)
[15] FERC (2009b)
[16] FERC (2008)
[17] Walsh (2009)
[18] EnerNex (2010)

partners to identify existing use of smart grid technologies and encourage further smart grid deployment.[19]

- *Advanced Metering Systems*: In 2008, Pennsylvania, Idaho, Arkansas, North Dakota, and South Dakota were the five states with the highest penetration of advanced metering systems. For example, smart meter penetration in Pennsylvania increased from less than 1% in 2006 to 24% in 2008.[20]

Smart grid is also receiving a boost from the American Recovery and Reinvestment Act (ARRA) of 2009. ARRA provided approximately $4.5B to smart grid investment projects and regional demonstration projects. DOE is responsible for awarding these funds and reporting on the results. DOE has distributed funds in two categories: Smart Grid Investment Grant Projects and Demonstration Projects.

Smart Grid Investment Grants comprise the bulk of the funding and are designed to quickly implement smart grid solutions. Most projects are Advanced Metering Infrastructure programs. For example, Houston Electric, a subsidiary of CenterPoint Energy, received $200 million to accelerate deployment of 2 million smart meters in Texas. The grant will help Houston Electric begin the first phase of its Intelligent Grid program. CenterPoint Energy began its smart grid work by piloting an advanced metering project in Houston, TX in 2005. By 2009, the company had installed 100,000 meters and a communications infrastructure that delivers 15-minute usage data and provides a web portal for retail electric providers. CenterPoint Energy plans to automate switches, line monitors and substations beginning in late 2010, and to complete the majority of the Intelligent Grid program by the end of 2012.[21]

Demonstration projects account for about $620 million of smart grid ARRA funds.[22] For example, Massachusetts-based NSTAR Electric received funding for two projects. The first project enables customers to use existing automated meters to receive information on electricity prices using Broadband internet service. The second project will explore connection of distributed generation into an urban electric grid.[23]

SmartGridCity™: Boulder, CO

Xcel Energy began building the nation's first smart grid city in Boulder, CO in March 2008. The project plans to deliver power to 100,000 customers and reduce carbon emissions by 24%. Phase I includes full system automation and provides smart meters for an initial group of customers. This phase will also provide customers with a web portal to help track home energy use and information. Phase II is the completion of the distribution and communication network as well as the integration of renewable energy into the grid.

[19] Manchin (2009)
[20] FERC (2008)
[21] CenterPoint Energy (2009)
[22] DOE (2010a)
[23] SmartGridNews.com (2009)

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