Smart Grid and Clean Energy for Local Governments
Background and Resources
U.S. Environmental Protection Agency
Local Climate and Energy Webcast Series

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, which may make electric power systems more reliable and efficient. These technologies also might help enable integration of higher levels of renewable energy and increased energy efficiency. Although smart grid technologies are evolving, the use of some is becoming widespread, and there are examples of deployments in communities across the country.

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
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What Is a Smart Grid?

Various definitions exist for a smart grid, and all involve using information and communications technologies on the electric grid system. The Energy Independence and Security Act of 2007 (EISA 2007) established federal policy support for a smart grid, characterizing it as the modernization of the nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth. A key element of a smart grid is the increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid, as well as integration of distributed generation, demand response, and energy efficiency.[1]

To date, the majority of investments in smart grid technologies have been in the deployment of advanced metering infrastructure or "smart meters." These technologies may be used to provide generators, system managers, and customers with instantaneous information on electricity needs and prices. Potential exists for these parties 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 use of these technologies results in the desired benefits.

[1] For more information on EISA 2007 and smart grid, see Title XII of EISA 2007, at http://www.oe.energy.gov/EISA_Title_XIII_Smart_Grid.pdf.

Such policies may include funding for energy efficiency programs, rate designs that encourage customers to save energy[2], and interconnection standards[3] for clean distributed generation.[4]

Smart grid systems can help local communities meet energy efficiency and energy conservation goals. They also can help communities achieve renewable energy and greenhouse gas emissions reduction goals by promoting integration of distributed renewable energy sources, such as small wind turbines and solar panels. For communities that are served by local, municipal utilities, a smart grid can help them upgrade aging infrastructure while maximizing the efficiency of the system and maintain reliability while integrating additional distributed generation, such as solar panels, combined heat and power, and waste-to-energy projects.

Similarly, 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.[5]

Why Make a Grid "Smart?"

Demand for electricity continues to accelerate due to population growth and increased global reliance on electrical technologies.[6] Simultaneously, electric grid infrastructure in the United States is aging. Improvements in the underlying infrastructure are therefore necessary.

Figure 1 illustrates the flow of electricity from centralized power plants to the end users in the current grid system. Smooth operation of the electric system as a whole depends on reliable performance of all components. As electricity needs increase, each component must be able to handle the 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 state leaders for smart grid implementation, they are followed closely by Florida, Illinois, Ohio, Pennsylvania, West Virginia, and others.

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 percent since 1990, but annual investment in new transmission facilities has declined over the past 25 years.[7] Transmission congestion reduces consumer access to power that may be cleaner or cheaper and results in less than optimal operation of the power system.[8]

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[2] For more information on how electricity rate design can provide incentives to customers to invest in energy efficiency, see the brief *Customer Incentives for Energy Efficiency through Electric and Natural Gas Rate Design* at http://www.epa.gov/cleanenergy/documents/rate_design.pdf.
[3] For more information on interconnection standards, see http://www.epa.gov/CHP/state-policy/interconnection.html.
[4] Regulatory Assistance Project (2009) and Kenkel (2009).
[5] For more information, see *Smart Grid Stakeholder Roundtable: Perspectives for Utilities and Others Deploying Smart Grids* at http://www.oe.energy.gov/DocumentsandMedia/stakeholder_roundtable_sept_09_final.2.00.pdf.
[6] Global Environment Fund (2008).
[7] DOE (2010b).
[8] Ibid.

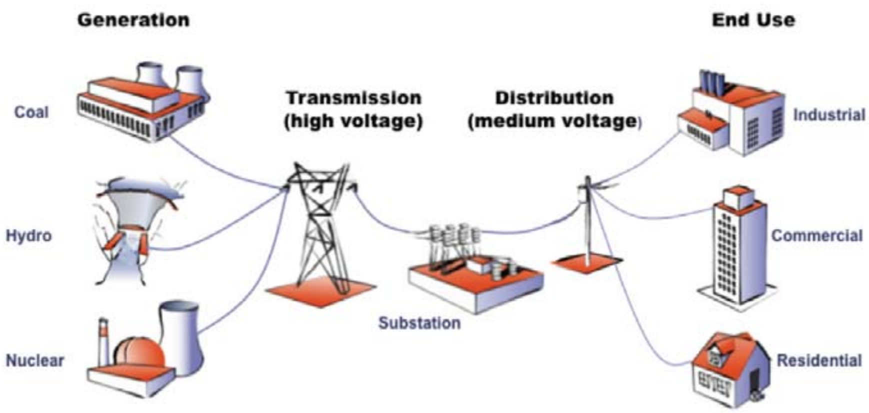

Figure 1: The current path of electricity generation and delivery to end users. At the left are large, centralized generation facilities connected to high-voltage transmission systems, followed by medium-voltage distribution substations and, ultimately, various end users.[9]

However, there 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.[10] There is also uncertainty about the extent to which distributed electric generation, clean demand response, and energy efficiency will affect where and how much transmission is needed. Future energy and environmental regulations also will affect the type of supply-side generation to be built and, in turn, their respective needs for new transmission.

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 percent of peak demand occurs in just 88 hours per year.[11] Simply shifting some electricity demand from peak hours to nonpeak 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. Demand-side programs also may evolve to help integrate higher levels of "variable" electricity generation, such as wind turbines, whose electricity generation is subject to weather, not just operator controls.

> System Strain and Power Outages
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> Insufficient access to electricity can result in power outages, which cause negative economic and security effects. The U.S. Department of Energy (DOE) estimates that power outages and power quality issues cost the national economy $25–$80 billion each year. State and local policies affect the distribution of these costs across communities and business types.
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> *Source: DOE (2010b)*

A smart grid can enable solutions to these problems if properly deployed. 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 may help balance demand throughout the day by encouraging customers to switch use of appliances from peak demand times to low demand times. They also could encourage customers to simply use less electricity.

[9] Figure is from Global Environment Fund (2008).
[10] Ibid.
[11] Giudice (2009).

Some utilities are exploring the ability for their systems to "talk" to specific customers' meters. This might allow them to turn off electricity to certain appliances or customers during periods of high electricity demand or high generation costs. Doing so can prevent widespread power outages, reduce costs to provide electricity, and permit greater use of variable generation. This functionality also might be used to communicate the changing emissions profiles to customers, but most near-term activity is focused on using smart grid technologies to improve the electricity system by communicating price signals.

> **Smart Grid: Technology and Policy Working Together**
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> 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 might 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.
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> 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 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 Pacific Northwest National Laboratory (released January 2010) estimated a 12 percent direct reduction in 2030 electricity sector carbon dioxide (CO_2) emissions, assuming a 100 percent penetration of smart grid technologies properly used to maximize energy savings.[12] Another study by the Electric Power Research Institute estimated a 2–7 percent CO_2 reduction in the electricity sector in 2030.[13] Both studies provide preliminary, first-order estimates. The actual uses of smart grid technologies to enable greater GHG emissions reductions vary by each of these studies as well as actual deployments. Applications of smart grid technologies may enable emissions reductions in the following ways:

- **Greater integration of renewable generation**. Smart grid technologies can 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 variable generation resources.
- **Dynamic pricing and demand response**. Awareness of changing prices may help encourage consumers to reduce electricity demand during times of peak demand, thereby reducing strain on the system and potentially reducing overall energy consumption. The effect of such reductions on emissions depends on how the local mix of electric generators is affected by the shift in electricity use to nonpeak hours. If electricity use is shifted to different times during the day where higher-polluting generators are used to meet demand, emissions may increase.
- **Enhanced measurement and verification capabilities**. Smart meters can provide more information to utilities and customers on their actual energy use. Such information may be used to better measure the effectiveness of energy efficiency programs, particularly programs intended to affect customer energy use behaviors. The utility, state, or local government also may want to use this information to better inform resource planning and efforts to maintain reliability.

[12] Pratt et al. (2010).
[13] EPRI (2009).

- **Improved maintenance of equipment efficiency**. Commissioning equipment, or making sure that it is functioning efficiently in a particular setting, requires energy managers, contractors, manufacturers, or homeowners to monitor equipment manually. Major consumer equipment, such as refrigerators and air conditioning units, often are not properly commissioned when first installed. Smart grid technologies may be used to facilitate continuous commissioning, so equipment settings and performance of electrical equipment can be monitored continuously and optimized automatically.[14]
- **Reduced transmission and distribution line losses**. More than 5 percent of generated electricity is lost during its transmission and distribution. A smart grid enables utilities to reduce transmission and distribution losses without expensive updates to the structural infrastructure of the grid.
- **Plug-in hybrid electric vehicles (PHEVs).** 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 into 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 energy back *into* the grid during peak demand hours. Smart grid technologies could assist with the complex coordination needed to implement this management strategy.

> Potential Impacts of Smart Grid Technologies on CO_2 Emissions
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> *Potential CO_2 Increases from More Electricity Use*
> - Smart grid technologies (networking equipment, meters, computing, etc.)
> - Data center load
> - Electric vehicles, plug-in hybrid electric vehicles
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> *Potential CO_2 Reductions from Electric Grid Changes*
> - Reduction in informational barriers to energy efficiency in buildings
> - Electric vehicle charging from low/no GHG generation
> - Reduced transmission and distribution line losses
> - Greater use of renewable energy, combined heat and power, and clean demand response
> - Grid support without fossil fuel combustion

However, there is no guarantee that the benefits of a 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).[15] Therefore, expected energy savings must be weighed against the energy demands of the equipment and data storage.

To address these emissions increases, state and local governments can support data center and electronics efficiency efforts. Federal programs, such as ENERGY STAR, provide support to various stakeholders to encourage greater efficiency of electronics and data centers. In addition, the Federal Communications Commission plans to determine how information and communications technologies can improve its energy efficiency and environmental impact as part of the recent National Broadband Plan.[16]

[14] Electricity Advisory Committee (2008).
[15] Kenkel (2009).
[16] For more information, see a description of the National Broadband Plan and links to each chapter at: http://www.broadband.gov/issues/energy-and-the-environment.html.

Barriers to Smart Grid Implementation

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

> **Smart Grid and Clean Energy: Key Points to Consider**
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> - Focus on developing and ensuring benefits
>   - Gather environmental and consumer input
>   - Adopt complementary clean energy policies
> - Measure and verify energy savings
>   - Learn from successes and failures
>   - Incorporate electricity savings into energy planning
> - Learn from existing clean energy activities to achieve benefits
>   - Incorporate best practices from customer programs
>   - Recognize that utility and market barriers to energy efficiency and distributed generation will persist
> - Ensure that smart grid technologies and data centers do not waste energy

Uncertainty in Costs

While smart grid may reduce total electric grid costs through labor savings and potential 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 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. Unlike traditional utility infrastructure such as power plants and their pollution control technologies, which can operate with minor or no modifications for decades, smart grid technologies may need to be upgraded every few years. The industry is working to establish interoperability standards to reduce the long-term costs of deploying smart grid technologies.

For example, the cost of installing smart grid technologies in Boulder, Colorado, was nearly triple the expected cost, mainly due to uncertainties in creating the fiber-optic infrastructure. Dominion Power in Virginia is currently revisiting both the expected costs and benefits of its 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.

> **Coordinating Federal and State Authorities**
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> One of the major challenges in implementing a smart grid is the coordination required between the Federal Energy Regulatory Commission (FERC) and each of the states involved. Although 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 (PUCs), which also have authority over electricity distribution systems and the rates paid by retail customers.

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 a 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.[17] Additional consumer privacy concerns surround the role energy usage information may play in crime enforcement and the potential for energy information to be sold to outside vendors without consumer consent.

Federal Efforts to Implement Smart Grid

Smart grid requires large-scale coordination among the various players in 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 EISA 2007, which authorizes funding for smart grid development.

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.[18] According to NIST, hundreds of consistent standards will eventually be necessary to help regulate the smart grid.[19]

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.[20] In 2009, FERC adopted a smart grid policy that provides guidance to achieving interoperability.

> **Interoperability**
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> Interoperability is the ability of different systems to exchange information. A smart grid requires 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 technologies varies significantly across states and communities, but certain smart grid technologies are becoming widespread. In 2009, an estimated 7.95 million advanced meters already had been installed and an estimated 80–141 million are expected to be installed by 2019.[21] California is currently considered the state leader in smart grid implementation, and the state has installed advanced meters and phasor measurement units, which provide real-time grid monitoring. California also has begun automating substations, circuits, and switches. Both California and Texas have passed legislation requiring Public Utilities Commissions to create and implement a smart grid plan.

[17] DOE (2009c).
[18] NIST (2008).
[19] NIST (2008).
[20] FERC (2009a).
[21] FERC (2009b).

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.[22] 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.[23]

- *Illinois Statewide Smart Grid Collaborative*: Founded in 2008, this initiative has worked to engage all stakeholders in examining the potential benefits and costs of a smart grid for Illinois. The collaborative is focusing especially on consumer protection issues, such as data privacy.[24]

- *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 partners to identify existing use of smart grid technologies and encourage further smart grid deployment.[25]

- *Advanced Metering Systems*: In 2008, Arkansas, Idaho, North Dakota, Pennsylvania, 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 percent in 2006 to 24 percent in 2008.[26]

> **Smart Grid: The Role of Local Governments**
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> Local governments can be key players in implementing a smart grid. They can promote smart grid growth in the following ways:
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> - Encouraging the local utility to offer dynamic pricing.
> - Encouraging distributed renewable generation to be installed in the region.
> - Developing community outreach programs to educate consumers on how to achieve the potential benefits of a smart grid.
> - Offering incentives to utilities to improve their system reliability using smart grid technologies (e.g., smart feeders, outage management systems).

Smart grid is also receiving a boost from the American Recovery and Reinvestment Act (ARRA) of 2009. ARRA provided approximately $4.5 billion to smart grid investment and demonstration projects. DOE is responsible for awarding these funds and is distributing 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 technologies. 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 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

[22] FERC (2008).
[23] Walsh (2009).
[24] EnerNex (2010).
[25] Manchin (2009).
[26] FERC (2008).

switches, line monitors, and substations beginning in late 2010, and to complete the majority of the Intelligent Grid program by the end of 2012.[27]

Demonstration projects account for about $620 million of smart grid ARRA funds.[28] 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.[29]

In addition, EPA launched the Climate Showcase Communities grant program in 2009 to assist local and tribal governments in implementing climate initiatives, and two of the first 20 grantees are implementing smart grid technologies as part of broader efforts to achieve GHG emissions reductions. The West Chester Area School District in West Chester, Pennsylvania, received funding to develop a Student Conservation Corps that will promote energy efficiency within the school district and the local business community. As a part of this project, the three middle schools and three high schools that are responsible for 75 percent of total district energy use will receive a "Building Dashboard" that illustrates real-time resource and energy use in the school. The dashboard will enable students to further their understanding of how their behaviors affect energy and resource use.

> **Smart Grid Cities**
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> Some cities have served as pilots for testing new smart grid technologies and strategies.
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> **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 also will 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.
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> **Tallahassee, FL**: Tallahassee has been developing a smart grid strategy since 2005. In fall 2010, the city will launch the nation's first smart grid that integrates electric, natural gas, and water services into one smart grid. Tallahassee anticipates that smart grid will save the city $1.5 million over 15 years. Recently, the local utility received $8.9 million in ARRA funding to expand on existing efforts.
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> **San Diego, CA**: In 2006, San Diego completed one of the first cost-benefit studies of investing in smart grid. The study estimated the net present value of the smart grid investment in San Diego to be between $403 and $508 million. Last year, San Diego Gas and Electric Company received $28 million in ARRA funds to implement an advanced wireless communications system that will connect 1.5 million smart meters and enable dynamic pricing.
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> *Source: Nichols (2010), SAIC (2006), Soto (2009).*

The Department of Community Services (DCS) in Honolulu, Hawaii, received funding to promote mass individual behavior changes and efficiency retrofits that result in long-term GHG emissions reductions. The project is focusing specifically on marginalized communities throughout the state that have been slow to implement efficiency and conservation measures. Included in DCS's approach is the installation of real-time energy monitors, as well as intensive community outreach, development of a Hawaii-specific energy audit, training and deployment of household energy auditors, installation of weatherization kits, promotion of renewable energy sources, and ongoing engagement of individuals in a social network that fosters continued GHG reductions.

EPA will be sharing lessons learned and results from all Climate Showcase Communities awardees. For more information about this grant program and current grantees, please visit http://www.epa.gov/statelocalclimate/local/showcase/index.html.

[27] CenterPoint Energy (2009).
[28] DOE (2010a).
[29] SmartGridNews.com (2009).

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