Power Generation & Smart Grid

ALLIANCE TO SAVE ENERGY
Using less. Doing more.

Alliance Commission on National Energy Efficiency Policy

JANUARY 2013

PREAMBLE

The Alliance Commission on National Energy Efficiency Policy (the Commission) was organized to study energy-efficiency policies, programs, and opportunities to facilitate consensus recommendations on the next generation of domestic policies, programs, and practices on energy efficiency. The work of the Commission will include an assessment of the current state of energy efficiency in the U.S. economy and a review of the best local, state, and national practices. This work will culminate in a set of recommendations for the next administration and the 113th Congress to ensure that the U.S. can double its energy productivity (twice as much gross domestic product [GDP] from each unit of energy) from 2011 to 2030.

This report, Power Generation and Smart Grid, is one of seven research reports that analyzes the current state of energy efficiency within the economy and reviews the best local, state, and national practices. These assessments will serve to provide the technical basis for the Commission's efforts to develop a set of recommendations for doubling the nation's energy productivity. The other reports will address the following areas: history and the business case of energy efficiency; transportation, land use, and accessibility; residential and commercial buildings, American manufacturing, and system integration.

To provide a comprehensive assessment to the Commission, the last report identified as "system integration" will be a comprehensive analysis of the other research reports to identify common areas of consideration and areas of interdependency. It will also identify opportunities for the various sectors of the economy to work together.

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OVERVIEW

The U.S. electric system has become increasingly efficient in supplying delivered energy to meet customer requirements and has done so at costs that has declined relative to consumers' purchasing power.[1] In parallel, the nation's energy system has become more and more reliant on electricity, and the electric industry and its consumers face large investments and costs to keep pace with changing needs of a more modern, cleaner, and more reliable system.

The future of the U.S. power system—how it is generated and delivered—will depend on how the grid's design, assets, and operations change in coming years. A twenty-first-century electric grid that can facilitate the doubling of projected U.S. energy productivity by 2030 will require the implementation of a wide variety of technologies and techniques: renewable distributed generation and micro-grids; central station power generation; flexible generation systems; investment in and deployment of transformational grid equipment; power flow control systems and equipment; energy storage devices and integration mechanisms; real-time modeling to analyze and real-time systems to control and adjust complex systems; resources on the customer side of the meter as part of grid management; secure control systems and protections against cyber security intrusions; physical infrastructure protection; and many other systems and technologies.

This is the context in which enhanced energy productivity could—and should—take place. But just as was needed to build the twentieth-century electric grid, investing in a smarter, more efficient, more productive electric system will take leadership, vision, risk-taking innovation, will, and creativity. Great consideration will have to be given to existing rules, business models, paradigms of regulation and other human systems in tandem with replacing traditional technologies.

This transformation will involve reaching out to many more customers and engaging them in new ways, such as part of the system, rather than just customers. The greater deployment of measures to increase the efficiency of the system and customers' use of energy can help double the nation's total energy productivity by 2030. Without intervention or direct assistance by a government or third party, many customers already take myriad actions such as purchasing relatively efficient appliances, installing systems that tighten up their building's energy requirements, and adjusting heating and cooling systems to lower overall energy use on their own. Other consumers, however, do not, due to a number of market barriers that stand in the way of adopting energy-efficiency measures that would be economically beneficial to the consumers.

In recent decades, electric utilities have played an important role in delivering programs to overcome these market barriers. Utility programs, such as those that encourage consumers to take initiative in reducing their energy use, help the system meet its energy requirements, and they will continue to be important policy tools aimed at enhancing overall energy productivity. By focusing on the demand side or end-use customer engagement, utilities provide their overall services to the system at a lower cost, while enabling customers to better manage their electric consumption and ultimately their electricity bill.

Looking ahead, utility participation will be essential for the nation to achieve new energy productivity goals. To maximize utilities' contribution toward new goals, policy makers will need to address issues involving the recovery of fixed network costs and market rules for distributed energy markets.

INTRODUCTION

The electric power system (EPS) in the United States is composed of a vast physical and human network of centralized and distributed power generation that connects power between millions of customers and end-use applications. The electric power infrastructure is intricately connected by public and private enterprises and a large, complex operational and regulated system of federal, regional, state, municipal, and private entities.

The scope of this report encompasses power generation and the Smart Grid. Power generation is discussed in the context of electricity generation-central and distributed—and transmission and distribution. The Smart Grid is discussed in the context of serving as a means to improve electric power infrastructure through the integration of power, communications, and information technologies.

The purpose of this report is to focus on energy productivity, emphasizing power generation as it relates to Smart Grid and Smart Grid implementation as drivers for an improved energy economy that uses cleaner resources and to encourage continued investment in Smart Grid technologies with respect to reliability, security, efficiency and renewable integration, and affordability through this discussion.

1 *Measured as the ratio of customers' spending on electricity and gas as a percentage of disposable income.*

BACKGROUND DISCUSSION AND HISTORY

There is an increasing demand in the United States to upgrade the electric grid to integrate a two-way flow of information and power to and from the customers while still providing a service that is affordable, reliable, and based more on cleaner power sources. Modernizing the grid by integrating advanced communications and information technologies as well as central and distributed power supplies is often referred to as the "Smart Grid"—a broad term used to include the application of secure, two-way communication and information flow as well as two-way power flow.

Since 2007, both the electric power industry and the federal government have invested billions of dollars to begin the process of grid modernization in the United States. However, despite these investments, much more financial support is needed to realize the vision of a twenty-first century electrical grid.

THE ELECTRIC SYSTEM: A COMPLEX SYSTEM WITH UNIQUE CHARACTERISTICS

From the advent of the electric system, the U.S. electric power grid was developed gradually as a response to local and/or regional load expansion. This development pattern, plus the physical limitations of moving bulk power over very long distances, led to the establishment of state and regional planning and reliability organizations. Department of Energy's Office of Electricity Delivery and Energy Reliability reported that today, there are:

- 30,000 transmission paths,
- over 180,000 miles of transmission line, and
- 14,000 transmission substations, which are connected to over 100 million customer loads.[2]

Additionally, the office noted that there are:

- 3,170 traditional electric utilities,
- 239 investor-owned utilities (which serve the majority of customers),
- 2,009 publicly owned utilities,
- 912 consumer-owned rural cooperatives, and
- Ten federal electric utilities.[3]

Electricity in the U.S. flows at the speed of light within three major synchronous grids along paths of lowest impedance. Grid operation occurs in a decentralized manner, with over 140 control areas.[4] Electricity is unique in that demand and supply must be balanced at every moment. In addition, the U.S. power system has been focused on building supply to meet demand at any point in time. The availability of storage technologies, opportunities to manage demand, and the availability of decentralized sources of power will transform the power system. Just as the original grid fundamentally changed the twentieth century and unleashed economic activity, the smart grid will fundamentally change the twenty-first century.

THE SMART GRID: A COMPLEX SYSTEM OF SYSTEMS

The Smart Grid, as described by the Institute of Electrical and Electronics Engineers (IEEE), "encompasses the integration of power, communications, and information technologies for an improved electric power infrastructure that serves end-use applications and loads."[5] The Smart Grid can improve resilience to outages and security threats, lower operating costs, and allow the integration of cleaner energy sources. Smart Grid technologies offer the promise of increased responsiveness by grid operators, reduced blackouts and line losses, and greater insight for consumers about their own energy use and its costs. The Smart Grid can be viewed as the infrastructure component of smart energy, which includes two other components: smart power, the efficient and clean production of electricity using a variety of resources including renewables and energy efficiency; and smart choices, programs that help customers make use of current and emerging electro-technologies.[6]

2 *Parks, "Electricity Systems Activities."*

3 *Ibid.*

4 *Ibid.*

5 *Institute of Electrical and Electronics Engineers (IEEE), "Guide for Smart Grid," 6.*

6 *US DOE, "The Smart Grid."*

Traditionally, central power stations were relied upon to provide electricity to customers or consumers. As technology in the electric power infrastructure evolved so, too, did the management and control of equipment and loads. IEEE explains that these enabled improved monitoring and communication of parameter information by adjusting the schedules and settings of equipment and loads. Information about the consumption or delivery of electric power would then be better managed by controllers, which could be either equipment or people. As technology continued to evolve, interconnectivity in the power system grew to include distributed resources, both generators and electric storage systems. Today, a smarter, more integrated grid, facilitated by communications and information systems enable a modern, and enhances the reliability, asset use, and efficiency of U.S. electric power infrastructure.[7]

The "IEEE Guide for Smart Grid Interoperability" explains that the electric power infrastructure is composed of countless interrelated systems. A Smart Grid can be achieved through system flexibility, large-scale integration of communications and advanced controls, and interoperability of a greater diversity of technologies and end-use applications. The Smart Grid is moving towards improved interoperability by incorporating highly automated electric power systems. In addition to supporting infrastructure, these systems have the ability to monitor and manage power availability, power quality, and immediate and predicted load demands. Including myriad monitoring and control activities will enable a two-way flow of electricity and will communicate information about energy production, transportation, and consumption. This level of interoperability will improve communication throughout all areas of the Smart Grid operating with end-use applications and loads.[8] To be successful, a Smart Grid must be secure and operationally sound. A secure, flexible grid, such as a Smart Grid, is more resilient to physical and cyber-attacks and is able to minimize both significant service disruptions and time to restore service.[9]

Furthermore, a Smart Grid can assist in providing a cleaner environment by enhancing grid efficiency and enabling greater use of all energy resources including distributed and intermittent resources. Smart meters and other devices and software systems can provide energy price signals that reflect the true cost and value of energy to customers that influence demand and enable both energy efficiency and demand response.[10]

POWER GENERATION AND SMART GRID INTEROPERABILITY

Smart Grid interoperability represents a complex yet cost-effective system with the goal of delivering electric power to all customers with high reliability, availability, and quality. In order to achieve this, the power system operator must ensure that the amount of power produced equals the amount of power consumed for every fraction of a second. Should these amounts not balance each other, problems in the power system can occur nearly instantaneously. For example, the imbalance might result in damaged equipment or disruptions in electric power flow to customers. In addition to this, the amount of reactive power produced must be equivalent to reactive power consumed. Solutions for the best way to balance power consumed and produced can be achieved through existing EPS structures as well as through future developments for the EPS and the Smart Grid.[11]

Characteristics of individual electric energy sources can vary dramatically. They can range in size from less than a kilowatt to hundreds of megawatts. Some energy sources are easily managed by system operators, while others are harder to control. Energy sources, such as renewable solar and wind, can also vary extensively in their rate of output, sometimes going from full output to no output, or vice versa, in mere seconds.[12]

Since the consumer's electric load can also exhibit great levels of variation, the transmission system must be able to support large amounts of electrical energy. To minimize outages or system failures, the electrical transmission system has been designed to provide redundant capabilities that allow it to deliver large amounts of bulk power from bulk generation to load centers. This is further facilitated with bi-directional power flow in the transmission system.[13]

To provide customers with efficient and reliable electrical energy at low costs, the distribution system is being updated so that it can be reenergized manually or automatically in case of system failure. Traditional distribution systems only support unidirectional power flow that runs from the substation to the customer. As the system develops, many distribution systems now have or will allow for bidirectional power flow. This is possible because of topology of their design and because excess power from customer-owned generation is located on the distribution system.[14]

7 *IEEE, "Guide for Smart Grid," 6.*

8 *Ibid.*

9 *TThomas and Hamilton, "The Smart Grid," What is a smart grid?*

10 *Thomas and Hamilton, "The Smart Grid," A Smart Experiment.*

11 *IEEE, "Guide for Smart Grid," 28.*

12 *Ibid.*

13 *Ibid.*

14 *Ibid.*

By the nature of energy flow, the power system inherently allows for information flow about the condition of the power system at each location as it pertains to relevant pieces of equipment. If well-designed, simple control systems can operate with only minimal communication between devices. This means that with no external communication, a generator providing primary frequency regulation service can produce less power when frequency is high or produce more when frequency is low. To avoid unintended consequences from control interactions, more sophisticated control devices must take this communication of information in the electric power system into account.[15]

A POTENTIAL PATH FORWARD

A focused effort is required to establish a state-of-the-art grid that is secure, efficient, reliable, cost effective, and enables much greater penetration of cleaner energy resources. All generation options including nuclear, gas, coal, renewables, and efficiency will be necessary to meet the needs of the future. Potential near-term solutions can bridge the gap to long-term science and technology options with advanced technologies to improve reliability and increase transmission capacity using existing rights of way. Electricity storage and power flow control can revolutionize the operation of the electric grid. The future smart grid will integrate more intermittent distributed resources such as solar or wind, storage, demand response, and energy efficiency. The future grid will also fully value these resources, including locational values and avoided investments costs. Real-time controls, wide-area visualization, and systems modeling can improve the reliability and efficiency of the grid and increase the security of the power-delivery infrastructure.

Transmission lines are being operated at or near their capacity limits in some areas, and increasing loads and aging infrastructure place additional burdens on the grid. Policy, science, and technology solutions are needed to modernize some regions of the grid. Since it can take years to build transmission lines, even with federal backstop authority for siting, these solutions will take time. Alternatives to putting more steel in the ground will need to be addressed on a wider scale.

To establish a framework for commercial market innovation, government and utilities will need to show leadership to advance electricity research and development. Moreover, they will need to address issues related to the recovery of fixed network costs in retail rates and utility participation in evolving markets for distributed energy resources and services.

Technology can help relieve, but cannot totally resolve, fundamental grid inadequacies. New technologies must be complemented by policies that encourage more grid investment. According to a 2012 Edison Electric Institute report, utilities invested $77 billion in infrastructure improvements from 2001-2010 and anticipate additional investment of $64 billion from 2011 through 2022.[16] However, it has been estimated that investments of up to $2 trillion in the U.S. electricity infrastructure will be needed during the next two decades, much of it to replace or modernize assets that have reached the end of their useful lives.[17]

COMMON AND UNIFYING GOALS

Today's electric utilities are working with technology companies to modernize the grid. However, although federal regulators and policy makers play some role, the electric power sector is regulated largely at the state level. Hence, efforts to move forward to modernize the grid in a cost-effective and efficient manner must address state and regional differences and include the appropriate stakeholders—utilities, technology companies, state and federal regulators, state and federal policy makers, new market entrants, advocates, and customers.

At the state level, a key issue today is effective integration of distributed power supplies. Developing a forward-looking Smart Grid will require both a national vision for advancement and the cooperation of the electric power sector, technology companies and other new market entrants, regulators, policy makers, and other stakeholders.

15 *IEEE, "Guide for Smart Grid," 28-29.*

16 *Edison Electric Institute, "Transmission Projects."*

17 *Xu, "Listed Infrastructure," 3.*

The Smart Grid offers improved security and reliability in power service as well as cleaner, more affordable and more efficient energy. A more intelligent grid better integrates an end-to-end, advanced communications infrastructure into the electric power system, adjusts pricing based on supply and demand changes, and could offer more accurate energy use data to consumers . Customers could then lower their energy bills by using smart devices that track pricing changes. A more intelligent grid can also:

» reduce the duration and frequency of power outages,

» reduces generation requirements through greater efficiencies in energy delivery,

» provide for the efficient charging of electric vehicles, and

» increases the integration of wind, solar, and other distributed generation resources.[18]

A Smart Grid uses information and communication technology to provide energy that's more reliable, secure, efficient and clean, and affordable.

The grid offers reliable service and delivers a high level of power quality. A more intelligent system sends timely warning signals about potential disturbances, and should any problems occur the system would be able to make necessary adjustments to minimize the number of affected customers and to continue to provide dependable power to others. Additionally, a reliable grid would serve to facilitate-decision making in regards to service outages by communicating real-time information and providing helpful diagnostic tools.[19]

The grid must be secure and operationally stable such that it will be able to reduce the frequency of significant service disruptions and the time taken to restore service. This increased flexibility and security will also better protect it against physical and cyber-attacks. This improved information flow about infrastructural problems or malfunctions will also improve public and grid-employee safety. A safe grid will provide accurate and automatic data on the system's conditions so that operators can reconfigure the system as necessary.[20]

Initiatives to improve the efficiency of power generation, transmission, distribution, storage, and consumption will enable greater investments in efficiency resources and programs and distributed generation will result in a more environmentally responsible and cleaner grid. . Technological improvements will facilitate the economical delivery of renewable energy and will reduce energy losses. This system will also incorporate smart meters and other devices that provide price signals reflecting the true cost and value of energy to consumers, influencing consumer demand and enabling efficiency and demand response.[21]

Long term affordability will be achieved through Smart Grid by enabling greater interaction with the customer. Southern Company explains that "[a]s the grid becomes interactive through the use of smart meters and other advanced technologies, customers have access to detailed usage and pricing information that will help them make informed energy-usage decisions."[22]

Greater reductions in demand, which reduces the need for new generation, are expected due to customers modifying their energy use which saves them money and reduces their environmental impact."[23]

18 *National Institute of Standards and Technology. "What Is a Smart Grid."*

19 *Southern Company, "Smart Grid Overview."*

20 *Ibid.*

21 *Ibid.*

22 *Southern Company, "Smart Grid Overview."*

23 *Ibid.*

INVESTMENT

MARKET OVERVIEW

Increased energy productivity in the electric utility sector can be achieved through a combination of two strategies:

1. Greater efficiency in energy production and delivery, resulting in more energy delivered per unit of fuel or input energy
2. Greater end-use efficiency, realizing more useful work or value from energy used in homes, businesses, factories, and government

This report focuses on opportunities and barriers to investments in the utility sector, including Smart Grid technologies.

Growth in U.S. electricity demand has slowed significantly due to market- and policy-driven gains in efficiency, higher prices, and other structural changes in the economy. The average annual growth rate fell from 2.5% from 1979-1989 and 2.4% from 1989-1999 to only 0.7% from 1999-2009. Growth in U.S. electricity generation has followed a similar trajectory, growing an annual average of 2.4% from 1979-1989 and 2.2% from 1989-1999 and only 0.7% from 1999-2009. The Energy Information Administration (EIA) projects that electricity-demand growth will rebound somewhat over time but will largely remain slow "as the growing demand for electricity services is offset by efficiency gains from new appliance standards and investments in energy-efficient equipment."[24]

Due to low natural gas prices and economics, slower demand growth, and new regulations on plant emissions, utilities are expected to retire some older coal-fired electricity generating plants and switch fuels from coal to natural gas or biomass in others.[25] This provides additional opportunities for efficiency improvements.

This slowing pace of growth in U.S. electricity demand and rapid development of technologies for the Smart Grid offers favorable conditions for increasing U.S. energy productivity. However, sizeable investments in energy efficiency across all sectors will be required to reach the Commission's goal of doubling U.S. energy productivity by the year 2030.

INVESTMENTS IN THE SMART GRID

Investments in Smart Grid technologies can increase the efficiency of existing grid resources, allowing utilities to shift demand away from the peak, manage voltage, and detect problems remotely, reducing strain on the grid and lowering prices. Load-shifting technologies coupled with demand-side management programs can reduce peak electric demand, and consequently, utilities' need to build capacity in the future. McKinsey & Company estimated potential savings of more than $130 billion annually from the application of Smart Grid technologies and related programs: $59 billion in savings from shifted or saved energy consumption and avoided new capacity, $9 billion in saved labor costs and operational and billing benefits from advanced metering, and $63 billion in increased grid efficiency and reliability via more precise voltage control from conservation voltage reduction and better monitoring and detection of system outages and other problems.[26]

Significant Smart Grid investments are being made across the country. Recognizing that a Smart Grid entails not only advanced meters, but also requires advanced distribution infrastructure such as advanced sensors, advanced controls, intelligent transformers, and high speed communications. The Institute for Electric Efficiency estimates there is now 36 million smart meters in the United States and anticipates the installment of as many as 65 million smart meters by 2015.[27]

In states like California, legislation is driving Smart Grid investments to advance existing policies including a carbon cap, renewable portfolio standards, and efficiency targets.[28] The Public Utilities Commission (CPUC) established metrics to measure the performance of Smart Grid investments.[29] The CPUC has directed that workshops be held to develop consensus around environmental metrics that can ultimately be linked to utility performance.[30] Furthermore, the CPUC has opened a rulemaking to investigate a rate overhaul and rollout of time-variant and dynamic pricing.[31] In Maryland, which does not have legislation

24 U.S. EIA, "Annual Energy Outlook 2012," 86.
25 Ibid, 45-46.
26 McKinsey & Company, "McKinsey on Smart Grid."
27 Edison Foundation, Institute for Electric Efficiency, "Utility-Scale Smart Meter."
28 Latham & Watkins, "California's Cap and Trade," 1.
29 CPUC, "2011 Smart Grid Report," 8.
30 Ibid, 12-13.
31 CPUC, "Public Utilities Code," 25.

driving Smart Grid investments, the Public Service Commission (PSC) is requiring jurisdictional utilities to work through a public collaborative process to develop a set of consensus smart grid performance metrics; this as a condition of approval to proceed with smart grid deployment in Maryland, and an important factor in ultimate rate recovery for Smart Grid investments.[32]

Pennsylvania has achieved a high level of smart meter penetration, also driven by legislation. In other states, utilities are making Smart Grid investments as a matter of prudent business management, in some cases aided by the award of federal stimulus dollars in accordance with to the American Recovery and Reinvestment Act of 2009. Utilities such as the Arizona Public Service Company with distribution infrastructure upgrades, Austin Energy with high levels of smart-meter penetration, and Duke Energy with $1 billion in planned smart metering technology have been making or planning large investments in Smart Grid technology.[33] As a business decision, Southern Company has already deployed more than 4.2 million smart meters across the Southeast, resulting in over 32 million miles of avoided driving.[34] In addition, Southern Company has invested in numerous distribution-system enhancements, including power outage detection and verification, and electronic map boards, representing over $1 billion in investments.[35]

Independent transmission system operators technically called regional transmission organizations (RTOs) or independent system operators (ISOs) can also play a key role in promoting Smart Grid investments. Two transmission system operators—PJM and ISO New England (ISO NE)—have already incorporated both demand response and energy efficiency into their forward capacity markets; these resources can now be offered into the market.

INVESTMENTS IN CUSTOMER EFFICIENCY

United States customer-funded electric efficiency program budgets totaled $6.8 billion in 2011, 25% above the 2010 budget level, while actual expenditures were $4.8 billion in 2010, 28% above 2009 levels with not all budgeted money spent—a remarkable rate of increase.[36] Customer-funded electric efficiency and load management programs produced estimated savings of approximately 112 billion kWh of electricity in 2010, enough to power nearly 10 million homes[37] or nearly 3% of U.S. end-use electricity consumption in 2010.[38] In addition, U.S. customer-funded natural gas efficiency program budgets rose to nearly $1.2 billion for 2011, and those programs resulted in estimated savings to U.S. customers of nearly 81 trillion Btu in 2010,[39] 0.33% of U.S. natural gas consumption. [40]

These are programs to help residential, commercial, and industrial customers reduce energy use, through rebates on efficient appliances, energy audits, consumer education, professional training, improvements in building energy codes and appliance standards, and other approaches. The most common programs are incentives for efficient lighting, air conditioning, and drives and motors, but programs aimed at consumer behavior and energy management are increasing.[41] Most of the programs are run by utilities; often using contractors, but some states use state agencies.

Investment in efficiency programs is driven by the desire to provide customer value and reduce investment in new generation, transmission, and distribution facilities and by environmental concerns. Investment is spurred by a variety of legal and regulatory structures. Many states consider demand-side management, including energy efficiency, as a resource option when planning how to meet energy needs, such as in integrated resource planning. A number of states have dedicated funding from bill surcharges made of public benefit funds or system benefits charges. Roughly twenty states have adopted energy efficiency resource standards (EERS) as of 2011, which set long-term energy-savings targets and require utilities to save a percentage of sales through energy efficiency. Seven more states have established voluntary energy-efficiency resource goals, and others have a policy to use all cost-effective efficiency. An increasing number of states have modified the way they set utility rates in order to reward utilities for effective efficiency programs that save customers money rather than encouraging utilities to increase electricity sales.[42]

32 *Evans, "Benefits Realization."*

33 *Pollock, "Top Ten Utility."*

34 *Southern Company, "Taking Action," 14.*

35 *Ibid, 7.*

36 *Edison Foundation, Institute for Electric Efficiency, "Summary of Ratepayer-Funded," 2.*

37 *Ibid, 2.*

38 *This percentage was calculated by dividing electricity savings (112 billion kWh) by total electricity end use (3,884 billion kWh). Total electricity use was found in EIA's "Annual Energy Review 2010" on page 234.*

39 *American Gas Association, "Natural Gas Efficiency," 2.*

40 *This percentage was calculated by dividing 81 trillion Btu of energy by total natural gas consumption of 24.644 quadrillion Btus. Total natural gas consumption was found in EIA's "Annual Energy Review 2010" on page 9.*

41 *Consortium for Energy Efficiency, "State of the Efficiency Program Industry."*

42 *Federal Energy Regulatory Commission, "22 States Have."*

These policies suggest that increases in investment are likely for some years to come. But some of the states with the longest-standing, most aggressive programs have recently increased their investments. Massachusetts utilities, for example, recently adopted plans to achieve 2.5% incremental savings each year.[43] This suggests that potential for expanded investment remains untapped.

BARRIERS

The goal of increasing energy productivity through efficiency measures and Smart Grid improvements in the electric power sector is hindered by several primary barriers. Those barriers include high capital costs and potential rate effects and resulting costs to customers, market volatility as related to fuel, regulatory barriers and uncertainty, investment risks, and marketing challenges as a result of the aforementioned barriers.

HIGH CAPITAL COSTS

A 2011 report by the American Society of Civil Engineers estimated that in order to keep up with electricity demand, increases in generation, transmission, and distribution capacity would require annual investments of $107 billion by 2020 and nearly $732 billion by 2040.[44] From 2001 to 2010, annual capital investment in these three areas averaged a total of $62.9 billion (of which $35.4 billion went towards generation, $7.7 billion to transmission, and $19.8 billion to local distribution), with significant variation on a year-to-year basis.[45]

Looking ahead, investor-owned utilities' ability to raise the large sums needed for infrastructure upgrades and expansion could depend on their ability to recover fixed network costs. From this point of view, it is significant that rates in place today could lead to under-recovery of fixed costs.

Additionally, power plants have high capital costs, especially for some types of generation capacity. Nuclear power plants are one example. They have low fuel costs and provide reliable base load generation with zero carbon emissions but they have higher capital costs, and can face significant citing and permitting opposition. Onshore wind capacity has similar capital costs to that of nuclear and no fuel costs. However, the best sites for power generation may not be located near demand centers and can require additional investment for transmission and distribution. Other renewable energy sources like solar photovoltaic, and solar thermal still have a capital cost significantly higher than that of fossil fuels, wind, or nuclear but offer opportunities for efficiency gains through distributed generation in reduced transmission and distribution losses.[46] The cost implications for customers of various generation options must be considered in making decisions about future energy supply. Regulatory issues also affect cost considerations. Some investments require rate increases in excess of limits imposed by legislation or regulators such as public utilities commissions.

FUEL PRICE VOLATILITY

Adding further uncertainty to the investment process and future generation mix is fuel price volatility. Utilities must consider fuel prices over decades. But the EIA predicts in the 2012 Annual Energy Outlook that U.S. natural gas production will grow by nearly three times, increasing to 13.6 trillion cubic feet (cf) in 2035 from 5.0 trillion cf in 2010, due to improvements in shale gas production.[47]

UNCERTAIN ENVIRONMENTAL REGULATIONS

In addition to the larger forces slowing electricity demand, current uncertainty regarding policies related to greenhouse gas emissions, air quality, and other environmental issues have contributed to some companies slowing investment in certain types of new capacity, especially new coal-fired power plants lacking carbon capture and sequestration. Implementation of increasingly stringent EPA rules for power plants could shift investors' choices towards lower-emission fuels or lead them to invest more heavily in energy-efficiency programs and technologies. However, court challenges and delays in the rulemaking make any such shift a slow one.[48]

43 *American Coalition for an Energy-Efficient Economy, "Energy Efficient Resource."*

44 *American Society of Civil Engineers, "Failure to Act," 5*

45 *Ibid.*

46 *EIA, "Levelized Cost.".*

47 *U.S. EIA, "Annual Energy Outlook 2012," 3.*

48 *Weiss and Weidman, "They Fought the Law".*

END-USE EFFICIENCY INVESTMENTS

A number of regulatory barriers dissuade utilities from investing in energy-efficiency and demand-response programs. Some utilities face difficulties in treating demand-side resources in the same manner as new generation resources, since most utilities rates are set by the state public utility commission for a period of years based on estimates of future revenue needs to cover costs and future sales.

In order to meet EERS savings requirements, and sometimes to receive incentive payments, energy-efficiency programs require evaluation, measurement, and verification (EM&V) of energy savings, with differing methods for each aspect in each state. In California, where the Public Utilities Commission also hired its own evaluators, the discussion of the savings estimates became contentious. There are a number of efforts to harmonize EM&V in different states, including a Department of Energy (DOE) project to bring stakeholders together to agree on uniform methods for a number of common program types, a DOE and EPA State and Local Energy Efficiency Action (SEE Action) Network committee working on a best-practices document, and a Northeast Energy Efficiency Partnerships regional forum.

There also are cultural barriers to investing in energy efficiency as an alternative to energy supply. Utilities often view their business as providing electricity to meet customer needs and see themselves as having expertise in building and running supply facilities. Both utilities and their regulators may be skeptical that efficiency programs will really reduce demand, given the difficulty of EM&V, and are reluctant to rely on the programs to reduce demand below available supply.

MARKETING CHALLENGES

Implementing improved Smart Grid infrastructure presents a significant marketing challenge for the utility industry which traditionally has not “marketed” to its customers due, in part, to the regulatory environment. Utilities are now starting to communicate the operational benefits of smart meters to their customers– improved reliability, automated outage detection and faster outage restoration, and remote connect/disconnects. However, consumer misconceptions and misinformation about Smart Grid infrastructure remain and consumer concerns can create delays in the rollout of Smart Grid infrastructure and undermine willingness to integrate smart meter information into their consumption decision making process. Increased customer engagement by utilities, including behavior-based energy efficiency programs also offer opportunities to augment Smart Grid deployments. Advanced meters and other Smart Grid technologies have dramatically increased the resolution of data available about customer energy usage. Information- and behavior-based products and programs, such as web portals, home energy reports, in-home displays, and information access protocols enable utilities to offer their customers more insight into how to save energy.

OPPORTUNITIES

While a variety of barriers stand in the way of wider investment that could drive increased energy productivity, market conditions, innovative financing, and regulatory tools may help provide the means to overcome those barriers. The table found in Appendix D illustrates some of those opportunities and actions that could increase energy efficiency.

TECHNOLOGY

TECHNOLOGIES TO IMPROVE STEAM PLANT HEAT RATES

Improving energy conversion efficiency, also known as thermal efficiency or heat rate, is a proven method for lowering the operating costs of coal- and gas-fired generating plants. When a plant's heat rate, the amount of fuel consumed per kilowatt-hour (kWh) of electricity produced, is reduced and less fuel is used, it also results in decreased in emissions of nitrogen oxides (NOx), sulfur dioxide (SO2), particulates, and mercury on a per kWh basis.[49] Some heat rate improvements are commercially proven and immediately available, while other heat rate improvements will require development of improved technologies.

Basic thermodynamics dictate that engines and power plants can achieve higher thermal efficiencies by operating at higher pressures and temperatures. The very first steam turbine-generator, built in 1884, had a thermal efficiency of just 1.6%. Early turbines were improved, and in the early 1900s, steam turbine-based power plants reached a thermal efficiency of about 15%, and operated at about 400 pounds per square inch (psi).[50] By the 1960s, supercritical plants were developed, reaching thermal efficiencies of 38%, and operating at temperatures up to 1,050°F and pressures of about 3,600 psi.[51] Today, goals have been set to further increase thermal efficiency and reach steam turbine conditions of up to 1,400°F and 5,000 psi.[52]

There is a similar story for natural gas-fired power cycles. The first gas turbines in the 1940s had turbine inlet temperatures of about 1,000°F and converted less than 20% of the fuel's energy to electric power. Today's modern gas turbines have turbine inlet temperatures exceeding 2,600°F.[53] In combined cycles, which include both a gas turbine and steam turbine, up to 60% of the fuel is converted to electric power.[54]

More improvements in thermal efficiency can be gained in the future through the use of advanced materials that can withstand even higher temperatures and pressures. The U.S. Department of Energy is working on developing nickel alloys that will allow steam turbines to operate at 1,400°F.[55] This would increase the thermal efficiency of a coal unit to 48%, which would reduce coal consumption by 20% on a per kWh basis.[56] Meanwhile, the Japanese government is sponsoring a project that will create a gas turbine capable of operating at turbine inlet temperatures of 3,100°F, which could open the way to combined cycles exceeding 60% thermal efficiencies[57]

In addition to heat rate improvement in new plants, there are a number of options for improving the heat rate of existing power plants. Typically, they do not provide an improvement as large as those mentioned for new plants, but they are readily available today and some can provide very quick payback.

An Electric Power Research Institute (EPRI) fleet study showed that approximately sixty projects across the fleet could be implemented at an avoided CO2 cost of $0/ton or less. The "free" CO2 reductions occur because the fuel savings is greater than the cost to implement the project. In addition, another thirty projects could be implemented at an avoided CO2 cost of less than $26/ton. The cumulative impact of implementing all of these projects would reduce the fleet's CO2 emissions and fuel use by approximately 3%.

TECHNOLOGIES TO IMPROVE THE EFFICIENCIES OF AUXILIARY SYSTEMS

A typical fossil fuel plant's auxiliary systems consume 7-15% of the power generated within the plant's boundaries.[58] Fans, pumps, conveyer belts, and lighting are among the typical consumers of in-house electric power. Projects that improve the efficiency of these so-called auxiliary power loads could yield meaningful contributions to the overall fuel-to-end-use efficiency of electricity.

While many potentially cost-effective techniques for reducing auxiliary loads exist (e.g., using more efficient electric motors), the industry lacks a well-established framework to measure and verify energy savings from generation loss reduction activities and to account for their associated costs and benefits.

49 *Pew Center on Global Climate Change, "Natural Gas."*
50 *Termuehlen and Emsperger, "Evolutionary Development."*
51 *Viswanathan, Shingledecker, and Purgert, "Evaluating Materials Technology."*
52 *EPRI, "CoalFleet for Tomorrow."*
53 *Temperatures were converted from Celsius to Fahrenheit.*
54 *Cogeneration & On-Site Power Production, "Gas Turbines."*
55 *Ohio State University, "$300K Grant to Develop."*
56 *Poddar and Yadav, "System Design," 5.*
57 *Mitsubishi Heavy Industries, Ltd. Global, "New Trends."*
58 *ABBT Ltd, "Making Power Plants," 2.*

SMART GRID

Electric power transmission and distribution systems typically have aggregate annual energy losses ranging from 7-10%.[59] Based on the 2010 U.S. annual electric power generation of 4,126 million megawatt hours (MWh), these energy losses amount to approximately 290 MWh,[60] which equates to about the energy needed to power approximately 25 million homes.[61]

Approximately two-thirds of these losses are incurred at the distribution voltage levels. From a historical perspective, power-delivery loss reduction, especially distribution system losses, has often been a secondary priority because of uncertainties in quantifying loss improvements and the difficulty in obtaining sufficient return on investment for projects undertaken. Recently, however, an increased focus on climate change and energy efficiency from an industry and regulatory perspective and energy efficiency has resulted in an interest in reevaluating the efficiency of U.S. power distribution.[62]

Reducing transmission losses must be balanced with increased use of the overall grid. Engineering options for power delivery include adopting highly efficient equipment, designing lines to reduce magnetic and electric effects, and operating lines at higher voltages. Operational options include managing the voltage profile on distribution circuits and the transmission grid and reducing auxiliary loads in substations. Other transmission options include adjusting dispatch and actively controlling the power flow using power-electronics-based controllers. Having a clear framework to compare these efficiency options, along with the analytical capability to assess them, is necessary to achieve a balance between increased use and efficiency.

Smart Grid technologies face a variety of hurdles on the way to widespread adoption. Among these, cost is of note. Estimates differ, however, as to how much investment will be required by 2030 to fully implement a U.S. Smart Grid. An Electric Power Research Institute (EPRI) study claims it will cost $338-$476 billion,[63] while the Brattle Group predicts a cost closer to $880 billion.[64]

Industry-wide standards for communications protocols do not yet exist, encouraging developers to innovate and bring a variety of products to market, but also creating a fragmented marketplace in the process. In some regions, smart meter deployment has faced hurdles created by public backlash over privacy and public health concerns like those associated with radiation emitted by the meters. This has prompted some homeowners to refuse the installation of the new meters and prevent utility personnel access to their meter.

TRANSMISSION EFFICIENCY OPTIONS

Transmission losses are estimated to be 3% of total energy generated in the electricity sector.[65] While this percentage may appear relatively low, the total amount of energy involved is considerable. The percentages equate to about 124 million MWh lost each year based on a total U.S. annual generation of 4,126 billion kilowatt hours in 2010.[66] Transmission losses are anticipated to grow in proportion to total energy generated, or about 1% per year.

EXTRA HIGH VOLTAGE (EHV)/VOLTAGE UPGRADE (12.4% REDUCTION IN TRANSMISSION LOSSES):

Increasing the voltage of the transmission system is the best way to reduce transmission losses. Doubling a line's voltage cuts the required current to deliver a unit of power in half. As few as 23% of today's transmission system operates at 345 kilovolts (kV) and above.[67] In order to reduce transmission losses by 2030, the industry will need to operate at higher voltages. According to an EPRI analysis on opportunities to enhance energy efficiency in the electric sector, these savings can be achieved assuming 75% of new lines by 2030 are installed at voltages of 345 kV or higher.[68] This report also assumes that by 2030, 15% of existing low voltage lines can either be upgraded to higher voltage or decommissioned altogether. Reductions in standard voltage variation, or voltage rationalization, can also cut back on transformation losses by reducing the need for additional transformation at interconnections.[69] This analysis should also incorporate system planning needs, growth rates, and overall project economics.

59 *Fuel Cell and Hydrogen Association, "Stationary."*

60 *The 290 million MWh was found by calculating 7% of US annual electricity generation. Annual electricity generation was found in EIA's "Annual Energy Outlook 2012" on page 204.*

61 *This was approximated by dividing energy lost from transmission and distribution by the average annual electric consumption for a US household. Average consumption in 2010 was 11,496 kWh according to the EIA's answer to the Frequently Asked Question, "How much electricity does an American home use?"*

62 *Electric Power Research Institute, "Estimating the Costs," 1-4*

63 *Electric Power Research Institute, "Estimating the Costs," 1-4.*

64 *Chupka et al., "Transforming America's Power Industry," xi.*

65 *EPRI, "Program on Technology Innovation," 1-2.*

66 *124 million MWh was calculated by rounding 3% of total US annual generation of electricity. Total generation was found in EIA's "Annual Energy Review 2010" on page 204.*

67 *Power delivered can be calculated by multiplying the current and the voltage. Losses are cut by three quarters, because they are a function of the square of the current, and because they are inversely proportional to the resistance.*

68 *EPRI, "Program on Technology Innovation," 3-11.*

69 *Ibid.*

SUBSTATION / TRANSFORMER EFFICIENCY (1.4% REDUCTION IN TRANSMISSION LOSSES):

Incorporating optimal HVAC units, higher efficiency fans and pumps, and automated control of components in the substation yard are some of the many options available to substantively reduce energy consumption in substation control rooms. Significant savings can be achieved by standardizing best practices and promoting industry collaboration. Appropriate efficiency measures to reduce auxiliary losses can yield potential savings of about 30%. By 2030, it will be possible to reach 50% implementation of existing substations and 80% of new substations through aggressive industry application.[70]

In terms of transformer efficiency, many electricity providers have gradually shifted to a lowest initial cost approach. Efficient transformers can reduce both the load and no-load losses by about 20%.[71] Though more efficient transformers in the core and the windings can have a high initial cost, they can improve transmission system efficiency and can deliver lower lifecycle costs. Replacing healthy in-service transformers with more efficient ones would not be cost effective, but electricity providers should consider replacements for failed units. Currently, about 1% to 2% of transformers are replaced annually, but aggressive industry application approximately 20% of the existing transformer fleet can be replaced with more efficient units, making 80% of new transformers efficient by 2030.[72]

TRANSMISSION LINE EFFICIENCY (4.2% REDUCTION IN TRANSMISSION LOSSES):

Further improvements in transmission line efficiency can be gained by replacing traditional aluminum conductor steel reinforced (ACSR) conductors with trapezoidal stranded conductors (TW). This switch can be made at a low cost and without significant changes to the structure design. Trapezoidal wires exhibit 25% lower resistance because of a greater aluminum cross section and have approximately the same diameter as the standard conductor and provide additional transmission capacity. Assuming 10% rate for replacing existing lines to TW, about 80% of new lines can be installed as TW by 2030.[73]

Furthermore, transposition or segmentation can reduce shield wire losses by approximately 50%. To achieve this by 2030, 20% of existing lines must be updated annually, with 80% of all new lines employing transposition or segmentation.[74]

SYSTEM LOSS REDUCTION

Smart Grid employment and associated new technologies such as voltage control optimization, smart transmission control of power flow controllers, and economic dispatch with loss optimization can serve to reduce system losses and reduce transmission losses by 2.1%.[75] As much as 95% of the transmission system can be adapted with various smart controls by 2030.[76]

DISTRIBUTION EFFICIENCY OPTIONS

Electrical distribution system losses make up about 3.7% of the power needed for producing and delivering electricity.[77] Efficiency standards and carbon-emission-reduction requirements should lead utilities to consider their options for addressing distribution losses. Recent technology developments help in achieving this. Among these are:

» advances in modeling capabilities that enable better loss estimation, identification of loss-mitigating technologies, and verification of improvements;

» time-stamped metering data that enable improved quantification of distribution losses by providing information on end-use patterns and diversity factors;

» communications and control capabilities that create opportunities to implement precise voltage and volt-ampares (VAR) control algorithms to reduce line losses, transformer losses, and lower end-use consumption; and

» communication and control capabilities that make automatic reconfiguration or looped operation feasible.[78]

70 *Ibid, 3-12.*
71 *Ibid.*
72 *Ibid.*
73 *Ibid.*
74 *Ibid.*
75 *EPRI, "Program on Technology Innovation," 3-12 – 3-13.*
76 *Ibid, 3-13.*
77 *Ibid, 1-2.*
78 *Ibid, 3-3.*

Voltage optimization is becoming integral to distribution-control strategies in the Smart Grid. Initial indications reveal a number of benefits from optimizing the distribution voltage profile. For many years, voltage reduction has been used as a demand management function in times of heavy demand. Recent research has shown that it can be part of the daily operation of the distribution system, both for demand management and energy reduction.

In 2008, EPRI initiated Green Circuits, a distribution efficiency program to assess the viability of various efficiency measures to be applied to distribution circuits. Green Circuits was created with the objective of identifying costs and benefits of these efficiency practices and determining obstacles and technical feasibility. This program's initial assessments revealed that upgrading the distribution system with highly efficient components when performing system upgrades can reduce losses by 5-10% in about 10-15 years.[79] By changing the operating standards and controlling the voltages within a more optimum band for lowering overall losses and end-use of energy, overall efficiency also can be improved. Reconductoring and phase balancing or capacitor placement are other options.[80]

The Green Circuits distribution project identified two major areas of focus for potential improvements including more efficient transformers and voltage optimization:

EFFICIENT DISTRIBUTION TRANSFORMERS

Various studies have shown that one of the significant contributors of distribution losses are the no-load transformer core losses. DOE issued a ruling on minimum efficiency for distribution transformers. Before setting the rule, the DOE did an extensive analysis of tradeoffs between energy savings and transformer costs with all available, practical material options, including amorphous metal prior to setting the rule in January 2010.

Amorphous metal transformers (AMT) are an example of efficient distribution technology that reduces loss in the energy grid. In early 1990, once energy prices stabilized after the 1973 oil embargo, AMTs were developed in the U.S. largely under a program at the Electric Power Research Institute with General Electric. Unlike the crystalline structure of most metal alloys, amorphous metal have an random atomic structure. Higher energy efficient units are the result of utilizing transformers built with these materials which have about a third of the energy core losses as compared to regular silicone-iron based core transformers. Amorphous metal transformers are slightly more expensive but have significantly lower operating costs than conventional units, resulting in lower lifecycle or total ownership costs.[81]

DOE estimates suggest that these standards will save approximately 2.74 Q Btu of energy from 2010 to 2038. These 29-year savings are equivalent to the amount of energy consumed by 27 million American households in a single year, based on 2007 data. By 2038, the DOE expects the energy savings from the standards to eliminate six 400-megawatt (MW) power plants (2400 MW) and 238 million tons of CO2.[82] Using a 3% discount rate, the cost of the standards is $460 million per year in increased equipment and installation costs, while annualized benefits are $904 million per year in reduced operating costs.[83]

VOLTAGE OPTIMIZATION

Voltage optimization, or conservation voltage regulation (CVR) is practiced when the voltage along the feeder is managed to be within the lower end of the standard supply service voltage band and distribution losses and end-use consumption are reduced. Utilities have used voltage regulation to reduce demand during periods of peak consumption for many years. To address both peak reduction and energy savings during nonpeak periods the practice of voltage regulation is now seeing renewed interest from utilities.

Reductions of 1-3% in energy reduction, a 2-3% in demand reduction, and a 5-10% in VAR have been validated by EPRI's Green Circuits Program as achievable. Annual savings of approximately 4-28 million MWh by 2030[84] through voltage optimization could be achieved, assuming an adoption rate of 25-30 percent of residential and distributional substations. Further fine tuned optimization can be achieved with the deployment of Smart Grid systems using the data from advanced metering information (AMI) systems to measure and determine the minimum service voltages, eliminating assumptions and potentially producing an additional 1-2% energy savings.

79 *Roger, Short, and Forsten, "Modeling Energy Efficiency Alternatives."*

80 *Forsten et al., "Green Circuits."*

81 *Forsten, "The Most Economical."*

82 *US DOE, "Energy Conservation Program," 58192.*

83 *National Research Council, "American's Energy Future," 628.*

84 *Forsten et. al., "Green Circuits."*

POWER GENERATION

Power plants convert fuel, such as coal, natural gas, water, wind, solar, and uranium, into electricity. The conversion can be direct, such as through wind rotating generators on towers, or it can use several stages, like heating water with coal to create steam that spins turbines to produce electricity.

During 2010, the U.S. electricity sector produced 4,126 million MWh of electricity.[85] About 70% of this output came from steam-cycle coal, natural gas, and nuclear power plants. Sixty to 65% of the energy stored in the fuels was lost in the fuel to electricity conversion process. Reducing these losses, even by small percentages, would have substantial impact U.S. energy productivity.

Advances in technology categories can substantially improve the efficiency of fossil-fuelled power plants. These technologies would improve the thermodynamic efficiency of converting fossil fuels (whether coal or gas) into electricity, mechanical efficiencies of carbon capture and storage systems, and efficiencies of auxiliary power loads at plants, such as fans, motors, and pumps.

While there are many ways that the efficiency of a power generation can be improved, from asset optimization to new compressor blades and turbines, there are associated costs and legal and regulatory barriers. In any effort to improve plant heat rates, additional factors that are inherent in the basic plant operation and the fact that plant design affects efficiency, as do operational practices, should be considered.

DISTRIBUTED GENERATION - MICROGRIDS

DOE describes a microgrid as “a group of interconnected loads (applications) and distributed energy resources (generation and storage) within clearly defined electrical boundaries that acts as a single controllable entity.”[86] A microgrid is very versatile in that it can connect to larger grids, or they can disconnect to operate separate from major grid systems.[87] Much like the centralized grid system, microgrids are much like a small-scale, local version of the centralized electric systems that achieve specific local goals on reliability and diversification of energy sources. Like their larger counterpart, microgrids have the ability to generate, distribute, and manage electric power flow to customers locally. Micogrids allow for renewable resources at the community level to be integrated while also allowing customers to participate in the electricity enterprise.

85 U.S. EIA, “Annual Energy Outlook 2012,” 204.

86 Electricity Advisory Committee, “OE Microgrid.”

87 Ibid.

CUSTOMER ENGAGEMENT AND BEHAVIORAL EFFICIENCY

Utility-delivered efficiency measures that help consumers reduce their energy usage have been and will continue to be important components of resource planning. Behavioral programs, which have received little attention in the past, present an emerging and significant opportunity to explore new methods for reaching our energy productivity goals. Behavior-based efficiency programs can improve efficiency gains above normal productivity improvements in the economy. The estimated extent of these gains range dramatically from 2-3% savings realized through actual results of behavior- based programs occurring in the US today (based on efficiency program results) to an American Council for an Energy-Efficient Economy(ACEEE) estimate of a 25% efficiency gain that could occur above normal productivity improvements in the economy.[88]

OVERVIEW: ENERGY IMPROVEMENT OPPORTUNITIES

For many utilities, utility resource planning has traditionally focused on creating supply-side assets to meet energy demand. Some utilities consistently continued integrated resource planning, including demand side management planning, while others did not. In recent years, changing regulatory frameworks and evolving utility business strategies have increasingly put demand-side resources on the same footing as those on the supply side. The advent of regulatory compensation mechanisms like revenue decoupling and offering performance incentives for utilities that meet or surpass energy-efficiency targets have leveled the playing field for many demand-side resources, while dedicated funding mechanisms and savings requirements have spurred rapid growth.[89] More recently, behavior-based energy efficiency programs that achieve verified savings by altering the energy usage patterns of consumers have become reliable, scalable, and affordable methods of providing demand-side resources. In addition, with the deployment of smart meters (expected to be in over half of all US households by 2015), many other options have become available to help consumers manage their energy use such as smart rates, energy use goals, and bill alerts, among other options. By focusing on demand side or end-use customer engagement, utilities have an opportunity to become more energy efficient while enabling customers to better manage their electric consumption and ultimately their bill.[90]

BARRIERS TO DEPLOYMENT OF BEHAVIORAL ENERGY EFFICIENCY PROGRAMS

A number of regulatory, economic and information roadblocks currently restrict the role that energy-efficiency programs can play in improving our energy productivity. Addressing these barriers will be critical to unlocking the potential efficiency savings and customer-engagement benefits that can be delivered by behavioral programs.

THE CHALLENGE OF IMPLEMENTING A NEW CATEGORY OF EFFICIENCY PROGRAM

Traditional energy-efficiency programs have focused on improving buildings and the end-uses inside them. That is, they have sought to achieve efficiency by aggregating savings from installed measures like compact fluorescent lamps (CFLs) or building upgrades. Measurement of the efficiency savings from appliances, lighting, or building stock improvements is conceptually simpler. Typically there are detailed protocols for measuring savings, with "deemed or calculated savings" values determined for the most common interventions—it is a projection of how much each intervention is likely to save over its useful life.[91] These improvements go through extensive measurement and verification to quantify the deemed savings. Over time, these verifications lead to more accurate predictions of the savings, helping to ensure that utility energy-efficiency programs achieve savings targets within program budgets. Behavioral programs, on the other hand, represent a less tangible form of efficiency. Measuring the changes in the usage pattern across millions of consumers as a result of the provision of energy data requires complex evaluation, verification, and measure (EM&V) methods. Lack of familiarity and proven history with the EM&V methods that are used to ensure the reliability, sustainability, and accuracy of behavioral savings present a hindrance to expedient regulatory approval of these programs in many states.

88 *Ehrhard-Martinez and Laitnet, "People-Centered Initiatives," iii.*

89 *Edison Foundation, "State Electric Efficiency."*

90 *A 2010 Accenture report titled "Understanding Consumer Preferences in Energy Efficiency: Accenture End-customer Observatory on Electricity Management 2010" found that 77% of U.S. respondents believe that they understood their actions well enough to manage their electricity use more effectively, yet only 34% knew of programs that would allow them to consume less energy. In addition, the report found that the largest deterrent to participation in energy-management programs was an increase in the amount of an electric bill but the largest motivator was a decrease in the amount of an electric bill. This suggests that customers believe they are more informed about energy efficiency and energy management than they really are, but that they would be willing to participate in energy-management programs if it could help them save money.*

91 As noted in the 2012 American Council for an Energy-Efficient Economy report titled "A Defining Framework for intelligent Efficiency," there is a ceiling on energy efficiency at the device level. While appliances and electric devices have become more energy efficient, those gains have diminishing returns; there is only so much that can be done physically and economically to make devices more efficient. Yet, there is substantial untapped potential for energy efficiency through system and customer behavior modification.

LOW INTEREST AMONG CONSUMERS TO SPEND SIGNIFICANT TIME OR MONEY ON ENERGY INFORMATION

Energy efficiency may be accepted by consumers generally as a good thing, but understanding how to reduce energy usage may not be readily available information to all customer segments. Acquiring this actionable information may not be a high priority, and reducing home energy usage can require considerable upfront investment. Households with little discretionary income, seniors, and low-income households in particular are often unable to participate in traditional energy efficiency programs. Others may not be interested in investing a lot of time into a behavior-focused initiative.

EXPLAINING AND JUSTIFYING SMART GRID INFRASTRUCTURE

Rolling out Smart Grid infrastructure may present a marketing challenge for some utilities. Utilities are now starting to communicate the operational benefits of smart meters to their customers: improved reliability, automated outage detection, and faster outage restoration, and remote connect/disconnects. However, consumer misconceptions and misinformation about Smart Grid infrastructure remain. Critics also express concerns over radio frequency and electromagnetic field exposure from smart meters, although there is no scientific evidence to back up these claims. In the past customers expressed concerns over the billing accuracy of the new meters, but two major studies in California and Texas have addressed that issue. Nonetheless, consumer concerns can create delays in the rollout of Smart Grid infrastructure and undermine consumer willingness to integrate smart meter information into their consumption decision making.

Increased customer engagement by utilities, including behavior-based energy efficiency programs, also offers opportunities to augment Smart Grid deployments. Advanced meters and other Smart Grid technologies have dramatically increased the resolution of data available about customer energy usage. Information- and behavior-based products and programs, such as web portals, home energy reports, in-home displays, and information access protocols, enable utilities to offer their customers more insight into how to save energy. Thus, providing behavior-based energy efficiency services in conjunction with robust customer outreach may spur greater customer engagement in Smart Grid programs.

Investments have been and can continue to be made in Smart Grid infrastructure to improve customer satisfaction. The Institute for Electric Efficiency (IEE), an Institute of the Edison Foundation, found that about 30% of US households now have a smart meter as of May 2012, an increase from September 2011, in which about one in four households had a smart meter. IEE projects that over half of American households will have a smart meter within the next few years.[92] For example, Southern Company has invested more than $6 billion on Smart Grid implementation in transmission and distribution since 2000. Reliability has improved by 34% in outage frequency and 40% in outage duration since 2001. Its customer satisfaction ranking is among the highest in the industry.[93]

LACK OF INFORMATION ON HOW CUSTOMERS ARE CURRENTLY USING ENERGY

The vast majority of consumers and utilities do not have access to granular electricity usage data. This lack of detailed usage data prohibits a comprehensive understanding of electricity consumption patterns and limits the opportunity to adjust those patterns to optimize consumption. The energy industry has lagged behind other consumer-facing industries like banking and telecommunications, which allow users access to extensive, up-to-the-minute information on their usage. Availability of this level of detailed information, which has largely become the norm in these industries, permits consumers to both understand and control their usage.

92 IEE, "Utility-Scale Smart Meter," 1.

93 Southern Company, "Smart Energy."

OPPORTUNITIES

OUTREACH AND EDUCATION

Smart Grid deployments offer an opportunity for utilities to enhance their role of trusted energy advisor for their customers. Presently most customers interact with their utility company only when they have a problem or a need for assistance with issues such as high bill complaints, reporting outages, requests for service. And generally customers are passive buyers of electricity in that people consume electricity without much thought as to the amount used or the time when it is used and then pay the bill a month or so later.[94] Utilities will have to continue to engage customers and focus on programs with the end user in mind, since behavioral based energy efficiency programs, time of use rates, or other measures require the customer to change their behavior. Some early adopters of smart meters and of advanced metering infrastructure (AMI) met strong opposition from customers. Negative customer responses were in large part due to customers' lack of understanding as to how a smart grid would benefit them and what changes they could make to receive those benefits.[95] This highlights the importance of comprehensive customer outreach and education when implementing Smart Grid and Smart Grid-enabled behavioral energy efficiency.

ENERGY EFFICIENCY PROGRAMS ARE PROVEN AND HAVE LARGE-SCALE SAVINGS POTENTIAL

Measure-based and behavioral programs have proven track records of providing cost-effective energy savings at scale. Decades of measure-based installations and studies offer energy efficiency gains at all levels of energy savings and costs per kWh saved. A Massachusetts Institute of Technology study concluded that efficiency gains from behavioral programs of between 1.4-3.3% can be achieved with an average cost of 3.31 cents per kWh saved.[96] Furthermore, vast energy-efficiency potential from behavioral measures has yet to be tapped on a large scale. A 2011 study by the Environmental Defense Fund estimated that behavioral programs, if applied nationwide in the United States, could save 26 terawatt hours (TWh) of electricity per year in the residential market alone. Such savings would reduce greenhouse gas emissions by around 8.9 million metric tons of CO2 per year, and would save American households over $3 billion annually.[97] Savings opportunities continue for measure-based programs and customer awareness and education initiatives. Behavioral efficiency programs often have an added effect of improving savings from installed measures, whether by augmenting savings achieved through other utility-led programs or by spurring consumers to pursue more efficient installed measures themselves. Indeed, provision of energy usage data not only motivates consumers to change behavioral patterns, it also motivates them to improve their efficiency via traditional methods

NEW EFFICIENCY PROGRAM OPTIONS

Utilities are likely to face some challenges in coming years in achieving efficiency targets as gains from low-cost, scalable CFL lighting programs become more difficult to achieve. CFL programs have composed 25-50% of the total portfolio savings of many utilities.[98] This will become more difficult as deemed savings from CFLs are reduced due to increased federal lighting standards and as the market approaches saturation. However, light-emitting diode (LED) programs, codes and standards programs, consumer electronics programs, and Behavioral programs all present opportunities to help utilities meet more stringent targets with cost-effective savings that can be scaled across a large service territory.

MANAGING ENERGY

As digital smart meters are deployed to residences around the United States, opportunities to manage energy use increases through the use of both technology and information. For example, home energy reports that build on data from smart meters and give consumers an understanding of how they are using electricity, along with specific measures they can take to reduce their consumption can help residential consumers realize savings. Information coupled with technologies that automate energy savings behavior can provide even greater benefits.

94 *White and Warren, "Lessons Learned on the Road to Smart Grid."*

95 *White and Warren, "Lessons Learned on the Road to Smart Grid."*

96 *Allcott, "Social Norms and Energy," 2,7.*

97 *Davis, "Behavior and Energy Savings,"* 2.

98 *Bickel, Swope, and Lauf, "CFL Market Profile," 1.*

GOVERNMENT

While states have primary authority over electric utilities, Smart Grid, and energy efficiency, the federal government plays a role in the nation's power generation systems, with several agencies contributing to the federal effort. As noted in the White House's National Science and Technology Council's report entitled A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future, "a twenty-first-century electric system is essential to America's ability to lead the world and create jobs in the clean-energy economy of the future."[99]

RESEARCH AND DEVELOPMENT

The DOE conducts research in several areas to address the needs of modernizing the electric grid. As part of the American Recovery and Reinvestment Act of 2009 (ARRA), $4.5 billion was invested in the modernization of the system.[100] The DOE's Office of Electrical Delivery and Energy Reliability provides national leadership by working with industry to modernize the power system, facilitate improvements in security and dependability in grid infrastructure, and ensure rapid recovery in case of complications in the energy supply flow.[101]

The DOE operates four power marketing administrations (PMA), which operate in thirty-four states serving approximately 60 million people, as well as the Tennessee Valley Authority, which operates in seven states and serves 9 million people.[102]

According to the DOE, the PMAs maintain over 33,000 miles of transmission lines in twenty states.[103] In a March 16, 2012, letter to the administrators of the PMAs, Energy Secretary Chu stated that the U.S. power grid must become more flexible and resilient in order to take greater advantage of energy efficiency and demand resources.[104] In this memorandum, he noted that how vital the electric grid is to the nation's prosperity, and he emphasized the important leadership role that PMAs play by operating this infrastructure.[105]

The National Institute of Standards and Technology (NIST) play a key role in the growth and development of the Smart Grid. It brings together energy providers, regulators, consumers, and manufacturers to develop interoperable standards to ensure that the many pieces of the Smart Grid system are able to work together. That authority was granted to NIST by the Energy Independence and Security Act (EISA) of 2007.[106]

As stipulated by EISA, the Federal Smart Grid Task Force has been meeting monthly since March 2008 "to ensure awareness, coordination, and integration of the federal activities related to Smart Grid technologies, practices, and services" among eleven agencies, including Federal Energy Regulatory Commission (FERC), the Department of Commerce (both NIST and the National Oceanic and Atmospheric Administration [NOAA]), the EPA, the Department of Homeland Security (DHS), the Department of Agriculture (USDA), and the Department of Defense (DOD).[107, 108]

The USDA provides support and funding for rural electric cooperatives. These cooperatives distribute electricity to consumers that covers more than 75% of the nation's land mass, generate about 5% of the electricity generated in the US, and deliver about 10% of the electricity sold in the nation.[109]

The DOD is the nation's largest user of energy and is responsible for more than 1% of the nation's total energy consumption.[110] The DOD has a long history of support for research and development (R&D) of power-generation sources, investing in improving energy efficiency and in power generation from hydropower, biomass, wind, solar, and geothermal to meet the agency's needs across its facilities and operations.[111] Based upon funding from the American recovery and Reinvestment Act and per the DOD's Near Term Energy-Efficient Technologies Program Plan of May 2009, the DOD conducts research on domestic energy supply/distribution.

99 White House, "A Policy Framework."

100 Intel, "Building a Smarter," 2.

101 DOE, "National SCADA Test Bed Program," 1.

102 Testimony of the Honorable Glenn English, CEO, National Rural Electric Cooperative Association to the United States House of Representatives Committee on Natural Resources hearing on Increased Electricity Costs for American Families and Small Businesses: The Potential Impacts of the Chu Memorandum on April 26, 2012.

103 Chu, "America's Competitiveness."

104 Chu, "Memorandum for the Power Marketing Administrators," 1.

105 Ibid.

106 US Department of Commerce, "NIST Smart Grid Advisory Committee".

107 U.S. Senate, "Smart Grid Initatives."

108 U.S. DOE, "Federal Smart Grid Task Force."

109 National Rural Electric Cooperative Association, "Facts and Figures."

110 Andrews, "Department of Defense Facilities," 1.

111 Ibid, 2.

Included in the 2009 plan were waste-to-energy and waste-to-fuel technology research and development, landfill gas use, biomass and algae fuel oil production, multifunction solar photovoltaic for cells and sensors, wave and thermal energy from oceans, and wind power and analyzing radar cross sections and noise control on wind turbines.[112] The Navy, as part of its Science and Technology program, is conducting research on distribution and control systems to support the next generation of naval combatants. This program seeks to develop more efficient electrical distribution architectures, switching devices, control strategies, and thermal management techniques. The Navy's approach is to provide multidisciplinary modeling and simulation tools allowing for better, more efficient system architectures.[113]

REGULATORY

The Federal Energy Regulatory Commission (FERC) regulates the interstate commerce of the transmission and wholesale sale of electricity, the transmission of natural gas for resale, and the transportation of oil by pipeline. Additionally, FERC reviews certain mergers and acquisitions of electric companies, approves siting of gas pipelines and facilities, ensures safe operations and reliability of liquefied natural gas (LNG) terminals, and licenses and inspects hydroelectric projects. It should be noted that FERC does not regulate retail electricity and natural gas to consumers, nor does it approve the physical construction of electric generating facilities.

During the past two years, the FERC has issued several orders that could enhance the opportunities for unconventional suppliers of energy services to participate at the wholesale and transmission level. The FERC's Order No. 1000 requires that public transmission utilities participate in regional planning processes. It also requires that bordering regions work jointly to determine which interregional transmission facilities meet needs more efficiently or cost-effectively than regional facilities, in each case considering non-transmission alternatives such as energy efficiency and demand response.[114] The order also requires the consideration of public policy-driven transmission needs, where stakeholders bring such needs to the providers' attention. Such public policy requirements are likely to include, for example, new environmental regulations or renewable portfolio standards.[115]

Demand response in wholesale markets has been growing as a resource in some wholesale markets over the past few years; for example, demand response has grown significantly in both PJM and ISO New England over the past few years. However, there is significant support for demand response, and the issue of appropriate pricing of demand response resources remains controversial.

FERC Order No. 745 requires that demand response resources that clear as supply in wholesale energy markets be paid the same locational marginal price (LMP) as generation resources that clear, provided that a net benefits test is satisfied.[116] FERC has explained that this approach is designed to address demand response barriers, including "the lack of a direct connection between wholesale and retail prices, lack of dynamic retail prices (retail prices that vary with changes in marginal wholesale costs), the lack of real-time information sharing, and the lack of market incentives to invest in enabling technologies".[117] However, others have argued that paying demand response the LMP is an economic subsidy and that the appropriate payment is LMP minus the retail rate.[118] The wholesale demand response pricing debate is still unfolding.

Additionally, FERC Order No. 755, by improving the relative compensation of fast-ramping providers of frequency regulation, gives small but accurate frequency regulation providers credit for their accuracy, recognizing a competitive advantage of such providers in the provision of an ancillary service where speed matters.[119]

The Environmental Protection Agency (EPA) in conjunction with state, tribal, and local air quality regulators are responsible for implementing the Clean Air Act, including requirements pertinent to utility power plants and other electric generating units. In recent years the EPA has increasingly recognized energy efficiency as an approach for mitigating emissions and reducing compliance costs. In the mid-2000s, the EPA issued guidance to states for including energy efficiency as well as renewable energy in state implementation plans (SIPs), including by allocating nitrogen oxide (NOx) allowance "set-asides" for qualifying projects.[120] For various reasons that has been little used, but the EPA has just issued a roadmap that describes several more usable pathways for states to incorporate efficiency policies and programs into their air quality planning. Also, a number of recent regulations affecting utilities incorporate provisions that could encourage energy efficiency. These include, for example, the use of output-based emissions limits, which calculates base allowable pollution per unit of output rather than per unit of fuel burnt, and crediting of useful thermal energy captured by combined heat and power (CHP) systems.

112 US DOD, "American Recovery and Reinvestment Act," 3.

113 US Department of the Navy, "Distribution and Control."

114 FERC, "Transmission Planning," 2- 5.

115 Ibid., 23.

116 FERC, "Demand Response Compensation," 1.

117 Ibid, 45-46.

118 Ibid, 26.

119 FERC, "Order on Compliance Filings," 1,10.

120 US EPA, "Evaluation, Measurement, and Verification."

STATE REGULATIONS

State public utility commissions regulate services within the states. They are responsible for ensuring reliable utility services at fair, just, and reasonable rates. They typically have far-reaching powers to meet their responsibilities. Commissions have the authority to regulate various aspects of power generation, transmission, and distribution of electricity.

In a recent report, the Institute for Electric Efficiency stated "that supportive regulatory frameworks are the key to expanding to the electric's power industry already large commitment to energy efficiency even further."[121] The report highlights three main mechanisms that are necessary for utilities to hold efficiency programs and supply-side investments as financially equal: direct cost recovery, fixed cost recovery, and performance incentives. The status of those regulatory frameworks is:

- thirty-five states have or are in the process of implementing fixed cost recovery by aligning utility fixed costs with efficiency program investments;
- fixed cost recovery mechanisms have been approved by twenty-seven states, fourteen of which have approved revenue decoupling, and the other thirteen have approved lost revenue adjustment; and
- twenty-three states have implemented performance incentives, while regulators are still deciding in six other states.[122]

GOVERNMENT FINANCE

The federal government has made significant investments in the deployment of new technologies as a means of promoting the Smart Grid. ARRA appropriations call for funds to go towards the DOE's Smart Grid Investment Grant (SGIG) program. Congress has approved federal reimbursements of up to 50% for qualified Smart Grid investments. Such investments might include the purchase and installation of smart meters and other devices. A significant portion of meter installation can be attributed to the SGIG program: FERC noted that since 2011, around 7.2 million smart meters were in part funded by SGIG.[123] FERC estimates that by the end of the program, SGIG will have contributed at least a portion of the costs for 15.5 million meters. IEE estimates that at least 65 million smart meters will be in use in the U.S. by 2015.[124]

BARRIERS

ECONOMICS

Falling energy prices have an impact on the implementation of energy efficiency measures and make it more difficult for efficiency efforts to meet targeted payback periods. According to the Bureau of Labor Statistics, the leading cause of low inflation in June of 2012 was the decline in energy costs. In June, the cost of gasoline fell by about 2%, and overall energy prices decreased by 1.4%.[125] Furthermore, according to Alliance to Save Energy estimates, national average residential energy expenditures have remained steady since 2009. However, it should be noted that low energy prices are helping provide a positive offset to a weak U.S. economy.

CYBER SECURITY

After cyber security emerged as a critical issue in the utility-led development of the Smart Grid, federal efforts to improve the cyber security of the electrical grid were focused upon.[126] Smart devices and communications potentially increase the risk of cyber-attacks to the grid. Risk analysis and mitigation strategies for communication systems, smart devices, and smart applications will require additional investment to better secure legacy technologies and to design new, more inherently secure technologies.

The Energy Policy Act of 2005 established FERC as the primary organization in charge of reliability in the bulk power system. In turn, the North American Electric Reliability Corporation (NERC) the Electric Reliability Organization (ERO) was tasked with establishing and enforcing reliability standards, meaning compliance shifted from being traditionally peer-driven and voluntary to being mandatory. Later requirements added to the Energy Independence and Security Act of 2007 placed an emphasis on developing Smart Grid infrastructure in a reliable and secure manner. With this, NERC was also given the responsibility of protecting critical grid infrastructure through planning and maintaining the grid's physical security.[127]

121 Edison Foundation, "State Electric Efficiency Frameworks," 1.

122 Ibid, 2.

123 Murrill, Liu, and Thompson, "Smart Meter Data," 2.

124 Ibid.

125 Crawford, Church, and Rippy, "CPI Detailed Report," 2.

126 Campbell, "The Smart Grid and Cyber-Security," Summary.

127 Ibid.

INTEROPERABILITY

The National Institute of Standards and Technology (NIST) has "primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems," as established by the Energy Independence and Security Act (EISA) of 2007.[128]

To encourage long-term sustainable and affordable smart grid deployment, a consensus among utilities, vendors, and regulators must be obtained on sound interoperability standards for smart grid technologies. The development of these standards creates a number of challenges:

- The scope of the required standards will address the grid from the generation source all the way into retail customers' homes, in addition to the overarching communication standards that will be required.
- This extensive scope creates a massive volume of standards to be considered for development.
- Given the complexity and technical nature of Smart Grid standards, considerable attention and time is required to ensure quality results.
- The industry has a limited number of subject matter experts who can address this complexity creating significant competition for access to this expertise.

Additionally, utilities and regulators are tasked with addressing questions and concerns associated with continued investment in retrofitting what is already a high functioning grid. Smart Grid standards are being developed in parallel with the construction of the grid, leaving utilities with the risk that equipment installed today may not be in compliance with standards developed further down the road.

OPPORTUNITIES

There are opportunities to develop new champions for energy efficiency within the government. Outreach can play a significant role in getting policy makers and key staff fully aware of the changes taking place in the power generation and Smart Grid area and how these changes can have a positive effect on consumers.

Aside from the federal government being the largest consumer of energy in the country, its procurement practices also offer enormous possibility to influence the electricity marketplace.

The full deployment of advanced meters is a key to realizing the energy efficiency potential of the Smart Grid. Government's continual support for the standards development is one strategically important element in this process. Compatibility of systems will enable interaction with smart appliances and home energy management systems, providing greater benefits to and fostering acceptance of the technology by consumers. As we have learned in the past, consumers are the key to full deployment.

Some members of Congress are currently considering legislation in their respective states to use utility energy efficiency programs as a means of generating additional efficiency gains for utilities. Efficiency targets as high as 17% by 2025 are under consideration.[129]

The DOE and the EPA are working with state and local officials through the State and Local Energy Efficiency Action Network (SEE Action Network) to develop protocols to improve energy efficiency management by increasing the accuracy, credibility, and timeliness of EM&V results. If successful, these will help in the scaling and cost effectiveness of these types of efficiency projects.

128 US DOE, "Title XIII," Sec. 1305.

129 Molina, "Missouri's Energy Efficiency Potential," vi.

CONCLUSIONS

The future of electric power generation in the United States and how we deliver energy in a safe, reliable, efficient, and affordable way will depend on how the grid's design and operations evolve in response to advances in electricity generation efficiency and the Smart Grid. A Smart Grid enables more reliable, secure, efficient, clean and affordable energy while allowing the integration of demand side resources such as demand response and distributed generation. The efforts and resources applied to future energy efficiencies and clean energy sources must be integrated into an electricity-delivery system that is modern, digital, and smart. Interoperability and interconnection technology must be supported and partnerships must be formed to allow efforts to take place successfully. Like the building of the twentieth-century electric grid, it will take leadership, vision, risk-taking innovation, and the will to succeed if the U.S. is to stay in the forefront of modernization. There is no easy solution, but the tools are available to get the job done. Changes will be evolutionary, with acceleration based on consumer demand and the value of electricity.

A twenty-first-century electric grid that can enable doubling of projected U.S. energy productivity by 2030 will require implementation of a wide variety of technologies and techniques: renewable distributed generation and microgrids and penetration of stationary and mobile distributed generation by providing a diverse energy mix at or near load centers; transformational grid equipment; power flow control, that is, advanced switching and conditioning hardware; energy storage; advanced components of superconductivity, advanced conductors, fault current limiters; advanced grid management in visualization and controls; situational awareness; real-time modeling and analyzing of complex systems; real-time grid control and response; demand incorporated as part of optimal grid management; nontraditional generation integration; national security entities; secure control systems; and physical infrastructure protection. Furthermore, twenty-first century electricity infrastructure is a critical foundation for US economic competitiveness and technology leadership. Continuing research and development is vital to achieve this transformation.

To meet the goals of the Commission, the future grid must meet the electric system's challenges of demand transformation, an expanding digital economy, power quality needs, and cyber security needs.

INVESTMENT

Marketing new integrated or interoperable products by the utility industry to the customer base at no cost or for purchase will spur on an evolutionary change to the electricity markets and will establish the value proposition needed for success. Not only will financial investment be a catalyst, but investment in human capital is required in education and training of all participants.

TECHNOLOGY

More efficient use of today's transmission and distribution assets, including distributed generation, need to be modernized with digital controls, sensors, and communications that will allow optimization of grid operations. Interoperability, the core principle of Smart Grid, of the electric power grid is the future and evolutionary approach to operating and maintaining a complex and multifunction grid.

CUSTOMER ENGAGEMENT AND BEHAVIORAL EFFICIENCY

Educational and simplified approaches that provide all customers with information about their energy usage, as well as an understanding of dynamic pricing need to be addressed and implemented.

POLICY INSTRUMENTS AND CONCLUSIONS

Energy efficiency is one part of a comprehensive national energy policy that includes all energy resources. A balanced portfolio of options including education, programs, products, and services should be available to help consumers use energy as wisely and efficiently as possible while taking into account price, reliability, and customer service. A number of policy mechanisms can be rolled out more broadly to help shape the regulatory landscape in a manner conducive to scaling up efficiency programs: utility incentives to undertake efficiency programs, focused research and development and on developing new and more efficient technologies, and specific policies that can help finance efficiency investments.

GOVERNMENT

Adoption of a clear and understandable national energy policy that is accepted on a bi-partisan basis is vitally important to a globally competitive U.S. energy sector and economic growth. Government leadership through investments in R&D and technology and to remove regulatory barriers through national and state policies which are conducive to a twenty-first-century grid and the associated new technologies can lead the way.

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APPENDIX A – LIST OF ACRONYMS AND ABBREVIATIONS

ACEEE – American Council for an Energy-Efficient Economy

ACSR – Aluminum Conductor Steel Reinforced

AMI – Advanced Metering Information

AMT – Amorphous Metal Transformers

ARRA – American Recovery and Reinvestment Act

Btu – British thermal units

Cf – Cubic Feet

CHP – Combined Heat and Power

CFL – Compact Fluorescent Lamp

CO2 – Carbon Dioxide

CPUC – California Public Utilities Commission

CSAPR – Cross-State Air Pollutant Rule

CVR – Conservation Voltage Regulation

DRA – Division of Ratepayer Advocates

DPS – Distributed Power System

DHS – Department of Homeland Security

DOE – U.S. Department of Energy

DOD – U.S. Department of Defense

EERS – Energy Efficiency Resource Standards

EIA – Energy Information Administration

EISA – Energy Independence and Security Act of 2007

EM&V – Evaluation, Measurement, and Verification

EPA – Environmental Protection Agency

EPRI – Electric Power Research Institute

EPS – Electric Power System

ERO – Electric Reliability Organization

FERC – Federal Energy Regulatory Commission

GPD – Gross Domestic Product

IEE – Institute for Electric Efficiency

IEEE - Institute of Electrical and Electronics Engineers

ISO – Independent System Operators

ISO NE – ISO New England

kWh – Kilowatt-Hour

LED – Light Emitting Diode

LMP – Locational Marginal Price

LNG – Liquefied Natural Gas

MW - Megawatt

MWh – Megawatt Hour

NERC – North American Electric Reliability Corporation

NIST – National Institute of Standards and Technology

NOAA – National Oceanic and Atmospheric Administration

NOx – Nitrogen Oxides

NRECA – National Rural Electric Cooperatives Association

NREL – National Renewable Energy Laboratory

PMA – Power Marketing Administration

PSC – Public Service Commission

Psi – Pounds per Square Inch

R&D – Research and Development

RTO – Regional Transmission Organization

SEE Action – State and Local Energy Efficiency Action

SGIG – Smart Grid Investment Grant

SIP – State Implementation Plan

SO2 – Sulfur Dioxide

TOU – Time of Use

TW – Trapezoidal Stranded Conductor

TWh – Terrawatt Hours

USDA – U.S. Department of Agriculture

VAR – Volt-Ampares

WVPA – Wabash Valley Power Association

APPENDIX B - DEFINITIONS

Distributed energy resource (DER): Source of electric power that is not directly connected to a bulk power transmission system. Distributed energy resources include both generators and energy storage technologies.

Electric power system (EPS): Facilities that deliver electric power to a load.

End-use application: A process that monitors, administers, and/or controls the consumption or production of electricity for equipment, systems, or facilities.

Energy management system (EMS): A system of tools used to monitor, control, and optimize the generation, delivery, and/or consumption of energy.

Interface: A connection from one entity to another that supports one or more data flows implemented with one or more data links.

Interoperability: The capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively.

Load: The true or apparent power consumed by power utilization equipment.

Reliability: The ability of a component or system to perform required functions under stated conditions for a stated period of time.

Smart Grid: The integration of power, communications, and information technologies for an improved electric power infrastructure serving loads while providing for an ongoing evolution of end-use applications.

APPENDIX C- TABLE 1

	DESCRIPTION	OPPORTUNITIES
Market conditions	» Continued low interest rates may continue to facilitate power generation and energy efficiency project development and deployment » Sustained low natural gas prices may undercut financial feasibility of other generation technologies (expensive renewables, nuclear, coal w/carbon, capture and storage) » Ratepayer-funded energy efficiency programs are highly cost competitive even with natural gas, with an average cost estimated by utilities of 3.5 cents per kWh saved for electric efficiency programs and 37 cents per therm saved for natural gas efficiency programs[111]	» Implement all cost-effective energy-efficiency programs
Transmission and distribution	» Investment in transmission and distribution has increased significantly since 2006, with future investment (2011-2015) projected at close to 18,000 circuit-miles, nearly triple the amount over previous 5-year periods.[112] » Many transmission lines are running near or at capacity	» Investment in higher voltage lines on existing corridors could reduce line losses and increase the efficiency of electricity delivery » Targeted energy efficiency and other DSM programs can reduce load in areas affected by high transmission congestion. » In order to incorporate increasing amounts of distributed generation and intermittent renewable resources, invest in Smart Grid technologies to manage and deliver generated energy from those resources effectively
Utility investment in energy efficiency & load management	» Investment in ratepayer-funded efficiency programs has increased by 150% in just 4 years after declining by about 50% some years earlier, but just 4 states (CA, NY, MA, and FL) account for half the spending[113] » 5 states have binding near-term targets for close to 2% additional savings each year, and another 10 have targets of at least 1% each year, e.g., NY is seeking to achieve 15% savings by 2015.[114]	» There appears to be a very large opportunity for further growth. The states with the longest history of efficiency programs are increasing their targets and spending. Massachusetts electric utilities recently adopted plans for 2.5% incremental savings for each of the next three years
Carbon market funding	» Regional market-based initiatives to reduce GHG like the Regional Greenhouse Gas Initiative (RGGI) have been driving investments in energy efficiency and renewable energy » The Analysis Group's report on RGGI showed the majority of the $912 million in purchased allowances was spent on energy efficiency programs, renewable energy installations, and related training and labor, producing $1.6 billion in net present value (NPV) economic value to the 10-state region between 2009 and 2011 » Over time, those investments in energy efficiency resulted in electric bill savings of nearly $1.1 billion and natural gas and heating oil savings of $174 million[115]	» While the Midwest has stepped back from plans for regional climate action, California continues to work on its program. Similar regional markets with proceeds from carbon allowances devoted to efficiency programs would cost-effectively reduce energy waste and carbon emissions

130 Friedrich et al., "Saving Energy Cost-Effectively," page

131 American Society of Civil Engineers, "Failure to Act," 32-37.

132 Consortium for Energy Efficiency, op. cit.

133 Sciortino et al., "2011 State Energy Efficiency Scorecard," page.

134 Analysis Group, "Economic Impacts," page.

	DESCRIPTION	OPPORTUNITIES
Distributed generation (DG) / combined heat & power (CHP)	» Certain DPS/CHP technologies, integrated cycle engines and gas turbines with CHP, medium- and community-scale wind, could be considered cost-competitive on a per-MWh basis with central-station generation under higher cost fuel price scenarios; other technologies considered near cost-competitive include medium-sized solar PV (2-5 MW), microturbine CHP, and fuel cells[116] » An Oak Ridge National Laboratory study found that CHP accounted for 9% of generating capacity in 2008[117]	» DG/CHP projects could provide 20% of U.S. electric capacity by 2030, saving an estimated 5.3 Q Btu of energy annually;[118] additional investment and/or incentives could spur project development
Decoupling, lost revenue recovery, or other mechanism to promote utility investments in EE.	» Decoupling allows small, regular rate adjustments to prevent over- or underrecovery of authorized revenue to cover fixed costs. As of 2011, electric decoupling was approved in 12 states and pending in 7 others[119] » Most common form is based on a revenue-per-customer basis; CA uses a fixed-rate case and adjusts revenues up or down based on consumption[120] » Additional states have a lost revenue recovery mechanism specifically to compensate for revenue lost due to efficiency program savings	» Treat energy efficiency as a resource for meeting energy needs; align utility incentives with benefits of energy efficiency to customers
Utility performance incentives	» 23 states currently offer performance incentives, like performance target and shared savings incentives, to utilities to make cost-effective investments in energy efficiency[121] » Estimation of savings for incentives can be contentious	» Incentivize utility programs that benefit customers and the public » Refine EM&V efforts.
Access to new pools of long-term capital	» Projects may be enabled by tapping into new avenues of funding or adapting existing ones like energy service agreements (ESA), project bonds, or loans from pension funds or insurance companies, for use on energy-efficiency or demand-response projects	» Standardization of EM&V protocols would enable market valuation of energy efficiency projects » Identify and publish best practices around new financing mechanisms for energy efficiency

135 Brookings Institution and Hoover Institution, "Assessing the Role."

136 Shipley et al., "Combined Heat and Power," page.

137 Ibid.

138 Institute for Energy Efficiency,

139 Regulatory Assistance Project, "Revenue Regulation and Decoupling."

140 ACEEE, "Performance Incentives."

APPENDIX D - CASE STUDIES

INVESTMENTS CASE STUDIES

Below are a few examples of actual investments made by utilities and the return on investment (ROI) realized. It is important to note that many other investments by utilities are underway around the nation are not summarized here.

» VIRGINIA DOMINION POWER

This utility intends to install $600 million worth of equipment to create a Smart Grid. First Dominion installed 30,000 smart meters, and then invested $1.5 million in synchrophasors, devices installed at substations that monitor grid conditions. These real-time data help utilities transmit more electricity across a high-voltage grid.

The operational efficiencies derived from a smarter power distribution and transmission system, coupled with Dominion's EDGE conservation voltage reduction program, are yielding real savings. This Smart Grid implementation is expected to save more than $1 billion over the project's life of 15-20 years, against Dominion's $600 million investment. Plus this program will yield environmental and societal benefits, such as avoiding the construction of two power plants, and delaying the construction of two more.[141]

» WABASH VALLEY POWER ASSOCIATION

Wabash Valley Power Association (WVPA) is a rural electric cooperative which distributes electricity to over 200,000 residential, commercial, and industrial consumers throughout Indiana, southern Michigan, and northwestern Ohio. WVPA works to mitigate wholesale price volatility, especially in the summer season, through two load management programs: the Customer Payback Plan, a commercial-industrial voluntary interruption program, and "It Pays to be COOL", a residential air conditioner and electric water heater control program. In order to participate in the Customer Payback Plan, consumers must participants must generate over 50 kW but hourly interval meters are not required. Customers interested in participating work with representatives to conduct a facility review and to determine in advance strategies to curtail specific load requirements during afternoon peak periods on summer days.

Serving over 31,000 MW of load, especially in the Midwest, member-owned utilities and co-ops play a unique role in rural electric generation and transmission. Cooperation and trust emerge as key factors that influence demand management program design and implementation which also allow the co-ops to form close relationships with their customers. Wabash Valley Power exemplifies this system of trust by emphasizing simplicity in program design and providing a good multichannel communications program.[142]

» SEATTLE CITY LIGHT

Seattle City Light (SCL) has the oldest energy conservation program in the country, started in 1977. It is a municipal utility, part of the city government, which serves nearly 1 million customers in Seattle and seven suburbs. It has invested more than $500 million in energy efficiency and saved over 1.5 billion kWh. And it has doubled investment and savings since 2007; in 2011 it invested 5% of retail revenue in conservation programs. Seattle City Light uses energy efficiency to reduce customer utility bills, reduce risk, and reduce environmental impact. Because 95% of SCL's electricity is hydropower, as well as due to its energy efficiency efforts, SCL has been greenhouse gas neutral since 2005.[143,144]

Seattle City Light provides a wide range of rebates for efficient equipment, efficient new construction, building commissioning, and energy audits for residential, commercial, and industrial customers, as well as installing efficient LED street lights. It uses door-to-door outreach to serve hard to reach populations. Program plans are based on a study of potential savings and subsequent savings targets, and are incorporated into a broader integrated resource plan.

141 Dominion Energy, "EDGE Energy Efficiency Program."
142 Heffner and Goldman, "Demand Responsive Programs."
143 Kate Rowland, "Seattle City Light."
144 Seattle City Light, "2011 Annual Report."

» SOUTHERN COMPANY

Southern Company is making significant investment in what it calls Smart Energy. In the Smart Power component, Southern Company is investing in new nuclear, twenty-first-century coal, natural gas, and renewables including solar, wind, biomass, and landfill gas.

For Smart Grid, Southern Company has spent over $6 billion in transmission capital improvements and will spend an additional $3.6 billion through 2015. The company has invested over $1 billion in distribution Smart Grid equipment over the last 20 years and is developing one of the largest self-healing networks in the U.S., a Distribution Management System by Automated Fault Location and Service Restoration. Southern is expanding its Conservation Voltage Reduction program with the addition of capacitors and automated voltage regulators to achieve 400 MW of demand reduction, delaying the need for traditional generation resources.

In Smart Choices, Southern Company has achieved over 3,600 MW in peak load reduction with another 1 million MW reduction planned, and saved 1.5 billion kWh through its Energy Efficiency and Demand Side Management Programs since 2000 (compared to 43,000 MW in generation capacity and 160 billion kWh in retail sales in 2011). In 2012, over 120,000 energy audits were completed for homes and businesses either on line or in person. Southern Company offers a wide range of programs and services for customers from flexible rate options, consumer information, and new home and home energy improvement programs to refrigerator recycling and innovate energy education programs delivered to school systems. Southern Company will invest another $600 million over the next 10 years on energy efficiency programs.[145]

» SALT RIVER PROJECT

Phoenix's Salt River Project focused on improving efficiency and reducing costs. The SRP, the largest provider of electricity to the greater Phoenix metropolitan area and third-largest public power utility in the nation, needed to eliminate costly truck rolls, improve employee safety, and increase operating efficiency. Truck rolls related to meter readings, meter connects/disconnects, and general services represent significant operational costs to the SRP. The utility hoped to automate these processes and offer expanded customer services such as time-of-use (TOU) pricing by deploying one of the nation's first advanced metering infrastructure (AMI) Smart Grid projects. By remotely monitoring and controlling energy consumption at the meter, the SRP has avoided more than 1.7 million driving miles and conserved 169,000 gallons of fuel. The reduction in onsite field visits has saved the SRP more than 249,000 labor hours. The SRP has redeployed some of these labor hours toward the installation of the network and smart meters.[146]

» TECHNOLOGY CASE STUDIES

Below are a few examples of projects involving the use of Smart Grid technologies; it is important to note that many other efforts are underway around the nation but are not summarized here.

» ALCOA ALUMINUM PLANT

Through experimentation at its Warrick, Indiana, plant, which was slated for closure and underpriced by global competitors, engineers at Alcoa Aluminum discovered that their long-held commitment to consistently drawing precisely the same amount of electricity was wrong. In fact, they could make small, fast adjustments in demand without compromising smelter function. Those adjustments, used to stabilize voltage and frequency, are exceptionally valuable to grid operators, who must otherwise pay power plants premium prices to ramp up and down to supply these ancillary services, with the collateral effect of compromising those plants' efficiency. Alcoa is contributing to productivity beyond its factory; it is helping to supply quality, reliable power to all customers, including other manufacturers, at lower cost, and enabling more efficient operation of power plants.

Alcoa earns enough from selling regulation services into the Midwest ISO to keep its Indiana plant open and preserve 2,100 jobs. If market rules were replicated into the other federally regulated RTOs, Alcoa could provide 3,000 MW of capacity from ten smelters. The opportunity across the industrial sector is orders of magnitude greater, creating an opportunity to eliminate the massive surpluses that must now be kept operating, while opening new revenue streams for those manufacturers.

145 Southern Company, "Smart Energy."
146 Elster, "Smart Grid Done Right."

» SNOHOMISH COUNTY SMART GRID MODERNIZATION PROJECT

The Snohomish County, Washington, project involves several types of Smart Grid systems to enhance distribution system performance and reliability. The project includes a digital communication network covering Snohomish Public Utility District entire distribution system to better respond to changes in electricity demand and grid conditions. The project upgrades forty-two of eighty-five substations with automated control capabilities to prepare the substations for full-scale deployment of distribution automation and integration of distributed energy resources. The project is deploying advanced automation equipment to ten circuits to reduce line losses and to improve service reliability.

The Public Utility District sees an attempt to change a customer's energy consumption behavior through smart meters as more challenging than the projects it can complete to optimize its transmission system. It is planned that the back-end automation will provide better information and benefits to the customer in the long run, and will allow for an easier transition away from traditional meters.[147]

» ALABAMA POWER AMI EFFECTIVENESS DURING HISTORIC STORM

On April 27, 2011, Alabama Power's service territory experienced more than thirty tornados covering more than 690 miles, the most devastating and notable of which was the tornado that ripped through the Tuscaloosa and Birmingham areas. At the peak of the storms around 412,000 customers were without power. The storm damaged or destroyed over 5,200 poles and more than 400 transmission system structures. More than 300 substations lost power and six substations were suffered significant damage or were destroyed, resulting in t least 10,000 customers that could not receive power. While this storm was far from the norm, storm events are common for any utility, and Alabama Power's recovery response protocol proved highly effective.[148]

The tower-based communication network remained largely intact during and after the storm and provided valuable information that helped those responsible for the utility's restoration efforts. With the outage management system and AMI combination, the utility could ensure power was on without having to dispatch personnel. This allowed restoration work to be prioritized for the most affected areas and to slowly bring daily life back to normal. When feeders were rebuilt and placed back in service, AMI feedback from individual accounts could relay the status of individual premises on the feeder to the outage management system. Meter data could also be graphically displayed to understand the level of damage and help prioritize recovery operations. Additionally, the data helped personnel estimate with some degree of accuracy the number of premises that were no longer received service because of storm damage.

Most service was restored two days faster than what had been experienced in the region's worst storms up to that point, including Hurricane Katrina in 2005. While it would be difficult to quantify how much the AMI system contributed to the speed of restoration, there is no question that it was a contributing factor to effective response management by continually presenting an up-to-the-minute illustration of the effects of what was likely Alabama's storm of the century.[149]

» PECAN STREET DEMONSTRATION

The Pecan Street Demonstration is an integrated clean energy Smart Grid demonstration project in Austin, Texas, that is run by Pecan Street, Inc. in partnership with Austin Energy. Pecan Street is a nonprofit research and development organization whose founding members include the City of Austin, Austin Energy, the University of Texas, the Austin Technology Incubator, the Greater Austin Chamber of Commerce, and the Environmental Defense Fund.

The Pecan Street Demonstration tests systems in up to 1,000 residences and 75 businesses in and around the Mueller community in Austin, Texas. The systems include distributed clean energy, energy storage, Smart Grid water and irrigation systems, electric vehicles, advanced meters, home energy-management systems, and appliances. Benefits include fuel savings, decreased line losses, and lessened need for transmission and distribution lines.

This project also lays the groundwork for the changing relationship between the consumer and the utility. In the future, the consumer will be a fully integrated partner with renewable generation devices on site and a participant in demand response programs.[150]

147 U.S. Energy Information Administration and SAIC, "U.S. Smart Grid Case Studies."

148 FlextNet and Sensus, "Case Study," 2.

149 Derl Rhodes, Alabama Power Company, "AMI Extends Alabama."

150 Rowan, "Pecan Street."

» COMMONWEALTH EDISON'S SMART METER PROGRAM

Commonwealth Edison's (ComEd) Smart Meter Program, also called the Advanced Metering Infrastructure program, comprises of advanced metering technology designed to provide customers with key energy usage data and billing information to help them make more informed decisions about energy use and lower energy costs and carbon emissions. Smart Meters provide consumers with reliability and unprecedented control over their electricity.

The smart meters gave consumers energy usage data so that they could know what they were spending before the bill arrived in the mail. Most of customers used this information to take smart steps to reduce energy consumption, thus saving money. One of the primary goals of the smart meter pilot program was to test both operational and customer benefits. The pilot allowed ComEd to assess the potential operational, environmental, and other benefits of installing smart meters for all ComEd customers. It also tested operational efficiencies of remote disconnection and reconnections, which can allow it to quickly suspend and restore service when customers move.

Although the smart meters provide customers with energy usage information and the power to manage it, they still do not provide the full potential benefits of a full Smart Grid system. For example, they do not automatically notify ComEd if there is an outage. Even though the smart meters can interact with some in-home energy-management devices currently on the market, they will not work with home appliances such as dishwashers or air conditioners.

» BPA PACIFIC NORTHWEST GRIDWISE DEMONSTRATION PROJECT – OLYMPIA PENINSULA PROJECT

The purpose of the Olympic Peninsula project was to create and observe a futuristic energy-pricing experiment that illustrates several values of grid transformation related to the GridWise concept. The central principle of the GridWise concept is that inserting intelligence into electric grid components at the end use, distribution, transmission, and generation levels will significantly improve both the electrical and economic efficiencies within the EPS. Specifically, this project tested whether automated two-way communication between the grid and distributed resources allows resources to be dispatched based on the energy and demand prices signals that they receive.[151]

» XCEL ENERGY – SMART GRID CITY

Throughout Boulder, Colorado, Smart Grid City from Xcel Energy linked more than 20,000 smart meters to high-speed broadband data networks. The Smart Grid's interconnected inputs, real-time monitoring, and enhanced substations and transformers work to reduce the city's power outages. New pilot programs included special pricing structures based on renewable energy availability, plug-in hybrid electric vehicles, and wireless smart air conditioning thermostats. The Smart Grid City program was cancelled due a lack of funding and cost issues. Xcel Energy underestimated construction costs, as well as costs associated with software and permitting.[152]

CUSTOMER ENGAGEMENT AND BEHAVIORAL EFFICIENCY CASE STUDIES

» NATIONAL GRID'S WORCESTER SMART GRID PILOT
DEMONSTRATING CUSTOMER OUTREACH AND EDUCATION

Recognizing the need for a strong foundation with customers upon which to build its smart grid offerings, National Grid set out to approach its smart grid pilot in a customer-centric way. While preparing its filing for the Massachusetts Department of Public Utilities (DPU), National Grid sought out stakeholder and customer input to better shape its outreach and education plan and some of its technology offerings. The culmination of National Grid's efforts to co-create Smart Grid-enabled solutions for its customers was a two-day Appreciative Inquiry Summit called Green Today, Growth Tomorrow, which took place September 2011 in Worcester, Massachusetts.[153] The summit was not as much about Smart Grid as it was about sustainability of which Smart Grid was seen as a key enabler.[154]

151 *Pacific Northwest National Laboratory, Pacific Northwest.*

152 *Xcel Energy & MetaVu, SmartGridCity™ Demonstration Project, Evaluation Summary.*

153 *"An Appreciative Inquiry Summit is a large group planning, designing, or implementation meeting that brings a whole system of internal and external strengths together in a concentrated way to work on a task of strategic importance." Massachusetts Electric Company and Nantucket Electric, "Outreach and Education Plan."*

154 *White and Warren, "Lessons Learned on the Road to Smart Grid."*

From the summit the Company has adopted a "listen, test and learn" approach for its Smart Grid Pilot. The Company listened to the needs of its customers and chose to invest in customer-driven initiatives, then test those co-created solutions and learn from each iteration to improve customer offerings and services.[155] This type of two-way communication help bring the utility and customer closer together, thereby bridging the trust gap and helping to enforce the utility's role as trusted energy advisor.

In order to continue the momentum built locally by the Green Today, Growth Tomorrow Summit, National Grid has partnered with the City of Worcester to create the Green2Growth Council, an organization of community groups, stakeholders, customers, the city and National Grid to advance all the opportunity areas identified at the summit. While this is an unconventional approach for a utility, National Grid recognizes that for Smart Grid to be successful, it must have actively engaged customers long before introducing new rates, new information, or Smart Grid-enabled behavioral energy efficiency programs.

SOCIAL NORMS AND ENERGY CONSERVATION CASE STUDY OF OPOWER PROGRAMS

Behavioral efficiency programs have been the subject of a number of independent studies and evaluations. A case study conducted by Dr. Hunt Allcott of the Center for Energy and Environment Policy Research at the Massachusetts Institute for Technology reviewed seventeen behavioral energy efficiency programs run by Opower in partnership with seventeen utilities across a number of states. The study comprehensively analyzed the effectiveness and cost competitiveness of programs in which consumers are provided home energy reports that compare a household's energy use to similar homes in their neighborhood and provided tips and suggestions for reducing usage. Published in the *Journal of Public Economics* in 2011, it analyzed 22 million utility bills across nearly 600,000 participating households. The study conducted randomized trials that compared electricity usage in treatment households that received reports with electricity usage in control groups that did not receive reports. Statistical methods were used to evaluate the treatment effect of providing usage information and tips to consumers on their actual electricity consumption.[156]

The study concluded that efficiency gains between 1.37-3.32% were achieved from the behavioral programs, with a mean savings rate of 2.03%. Furthermore, it concluded that the treatment effect of home energy reports not only persisted but increased over time as additional reports were sent. The programs provided savings at an average cost of 3.31 cents per kWh, with cost effectiveness increasing in populations with higher numbers of heavy consumers. This compares favorably to other efficiency programs, which range in cost effectiveness from 1.6 to about 6.0 cents per kWh. To benchmark these findings against the supply side, this finding places behavioral efficiency programs at around one-third the cost of producing energy through generation.[157]

Furthermore, the study noted that, because the savings from these programs are estimated using randomized control trials, the actual savings achieved are much more certain than for traditional energy efficiency programs that apply deemed savings values to interventions into the market based on their expected savings and measure life.[158]

GOVERNMENT CASE STUDIES

» ON-BILL FINANCING

In 2011, South Carolina's Central Electric Power Cooperative received a loan of $740,000 from the U.S. Department of Agriculture (USDA) for a pilot program testing the effectiveness of on-bill financing of residential energy efficiency upgrades. The cooperative offered loans averaging more than $7,200 to a total of 125 households, which the homeowners used for upgrades such as new insulation, air sealing, and replacement of outdated HVAC equipment. Monthly payments on the loans, on average $80 per home, are included as part of the residents' utility bills. Two-thirds of the estimated electricity cost savings are applied toward replaying the loan, while the remaining one-third of savings serves to reduce the homeowner's utility bill.

While full results will not be available until 2013, an economic analysis of the project by Coastal Carolina University researchers estimated that homes in the program would save an average of more than 11,000 kWh per year, over 35% of the homes' annual electricity consumption. The same study estimated that when fully implemented, the cooperative's program could save its customer base as much as $270 million per year in electricity costs and create up to 1,500 jobs in the first year.[159]

U.S. Department of Agriculture Secretary Tom Vilsack announced on July 18, 2012, that the USDA would be allocating $250 million for a national implementation of the South Carolina on-bill financing pilot. Additional funding has been proposed in several bills, most recently in the 2012 Senate farm bill.

155 Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid, "Outreach and Education Plan."

156 Allcott, "Social Norms and Energy Conservation," 4, 2.

157 Ibid, 6, 7, 8

158 Ibid, 2.

159 "Rural Energy Efficiency Effort," 2012.

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