SMART GRID Maryland

A Project of the Maryland Energy Administration

Maryland Energy Administration

Powering Maryland's Future

Smart Grid Maryland
Smart Grid Technologies and Programs

This report is the result of research conducted for the *Maryland Energy Administration (MEA)* under Implementation Grant Number 2009-01-B0577 from the U.S. Department of Energy (DOE) to recommend the elements of a Smart Grid system that would be most beneficial for Maryland consumers. MEA is partnering with *Energetics Incorporated*, *R. W. Beck*, and the *American Council for an Energy Efficient Economy (ACEEE)* on this grant. This publication represents the first of four reports to be conducted for this grant. Additional information on this project is available at www.smartgridmd.org.

ENERGETICS   ACEEE American Council for an Energy-Efficient Economy   R·W·BECK

May 2009

TASK 1. REVIEW OF SMART GRID TECHNOLOGIES & PROGRAMS

Maryland Energy Administration

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INTRODUCTION

The Maryland Energy Administration (MEA) was awarded a grant from the U.S. Department of Energy (DOE) to carry out a *Maryland Utility-Scale Clean Energy Capacity Project.* This grant provides funding to allow MEA to study the potential elements of a Smart Grid for Maryland and to analyze the costs and benefits of this type of system for Maryland consumers. MEA's grant partners include Energetics Incorporated, R. W. Beck Incorporated, and the American Council for an Energy-Efficient Economy (ACEEE).

The *Smart Grid Maryland* project[1] includes the following five activities:

- **Review of Smart Grid Technologies and Programs:** The project team has conducted an extensive literature review; research on Smart Grid activities at the state, regional, and national levels; a technology review; and a preliminary cost/benefit analysis of expected efficiency savings, reliability, and customer bill savings from Smart Grid programs.

- **Smart Grid Stakeholder Involvement:** MEA is sponsoring two Smart Grid Stakeholder Meetings at Chesapeake College and the University of Maryland to inform Maryland consumers and key stakeholders on the project. A Smart Grid Forum is planned for the fall of this year where the results of the project will be shared.

- **Analysis and Order of Implementation for Smart Grid Elements:** The project team will quantify the most effective mix of Smart Grid elements and Smart Grid alternatives for consumers and will rank them in terms of their cost-effectiveness and ease of implementation. Additionally, the project will also recommend an order of implementation for the recommended Smart Grid elements and alternatives.

- **Smart Grid System Design:** Depending on the results of the previous tasks, MEA and the project team will identify and recommend specific components of a Smart Grid program that might have the potential for success in achieving a 5 GW reduction in peak demand and 10.5 GWh of electricity savings in Maryland by 2015, directly contributing to the achievement of the *EmPOWER Maryland* goals.

- **Regulatory Report:** MEA and the project team will deliver a final summary report on the results of the previous four tasks, including the costs and benefits of Smart Grid deployment in Maryland. This report will be made available to the Governor, the Public Service Commission, and other key organizations and institutions in Maryland.

This report consists of the results of the first task of the project: Review of Smart Grid Technologies and Programs. The results are organized into four sections:

[1] For further information about the *Smart Grid Maryland* project, visit www.smartgridmd.org.

1.1 Smart Grid Literature Review

Over 30 reports on Smart Grid technologies, policies, regulatory issues, costs, and benefits have been examined. These publications reflect research and analysis conducted by government agencies, equipment vendors, technologists, research agencies, utilities, consultants, national laboratories, and non-government organizations. Technologies, policies, programs, implementation strategies, and resulting impacts on utility costs, consumer behavior, peak demand, and electric system efficiency have been identified. Each document has been analyzed to determine Smart Grid benefits, drawbacks and obstacles, costs, research methodologies, regulatory impacts and recommendations, uncertainty factors and assumptions, and data sources. A short summary of each report is included in the literature review.

1.2 Smart Grid Technology Review

Various types of smart metering and advanced metering infrastructure (AMI) system types have been reviewed. Communication protocols and standards, interoperability, and effects on utility operations, highlighting open and proprietary architecture options, have been examined. Alternative technologies and techniques that could contribute to achieving the capacity goals of *EmPOWER Maryland* have been examined, including energy efficiency programs, distributed generation and combined heat and power, transmission technologies, and renewable resources. A number of automation technologies have been reviewed, including electric supply automation, electric delivery automation, meter automation, customer automation, and the use of existing technologies and assets for use in a Smart Grid program for Maryland.

1.3 Smart Grid Costs and Benefits

The costs and benefits of Smart Grid deployment in Maryland are critical to this project. Preliminary analysis of the costs and benefits of Smart Grid deployment, as well as other alternatives that may include significant contributions from individual capacity-achieving technologies *without* a Smart Grid, has been conducted. This analysis includes effects on system efficiency and reliability, electricity bill impacts, and impacts on workforce creation. The costs and benefits of meter reading, resource planning, field service orders, outage restoration, energy theft and diversion, meter accuracy and registration, billing workload, bad debt write-off, improved cash flow, distribution transformers, sample testing, and load research have been presented in a preliminary fashion.

While AMI technology and other Smart Grid elements may create benefits to both utilities and end-users, utilities can seldom apply every functional benefit of them, due to differences in operations, reliability, back office processes, automation already deployed, and other circumstances. This preliminary analysis will allow MEA and the project team to further capture costs and benefits through research and analysis of Smart Grid proposals and pilot projects throughout the country, as well as data developed by national AMI and Smart Grid economic analyses that are currently underway.

1.4 Smart Grid Pilot Projects

Smart Grid (especially AMI) projects underway or completed in Maryland and other mid-Atlantic states have been reviewed. Other pilot projects that are underway, outside of this geographic area, have also been identified and reviewed. Each project summary includes geographic and technology scope, products deployed, costs and benefits (if available), and lessons learned.

1.1 SMART GRID LITERATURE REVIEW

For the Smart Grid literature review, more than 30 reports on Smart Grid technologies, policies, regulatory issues, costs, and benefits were examined and analyzed. Each document was analyzed to determine Smart Grid benefits, drawbacks and obstacles, costs, research methodologies, regulatory impacts and recommendations, uncertainty factors and assumptions, and data sources. In addition, technologies, policies, programs, implementation strategies, and resulting impacts on utility costs, consumer behavior, peak demand, and electric system efficiency were identified.

The publications selected reflect research and analysis conducted by government agencies, equipment vendors, technologists, research agencies, utilities, consultants, national laboratories, and non-government organizations.

The results are organized by the following focus areas:

- Utility Business Issues and Operations
- Grid Reliability
- Policy & Regulation
- Peak Load Shaving
- Metering Technologies and Other Technical Infrastructure Products and Services
- Data Acquisition Technologies and Products
- Economic Impacts from a Smart Grid
- Power Quality Technologies and Issues
- Energy Storage
- Consumer Attitudes and Preferences
- Energy Conservation and Efficiency

A short summary of each report is also provided.

Utility Business Issues and Operations

Title of Report:	San Diego Smart Grid Study: Final Report
Organization:	The Energy Policy Initiatives Center: University of San Diego School of Law
Date Published:	October 2006
Primary Focus Area:	Utility Business Issues and Operations

Document Summary	
Technologies Included	Distributed energy resources-based microgrids, distributed generation, advanced energy storage, advanced metering infrastructure, broadband over power line, advanced grid control devices, and supervisory control and data acquisition

Document Summary	
Benefits Identified	Benefits include reduced congestion costs, blackout possibilities, forced outages, restoration time, and peak demand; increased power quality, reliability, security, integration of distributed generation, and capital investment efficiency; job creation; tax savings for utility; and environmental benefits gained by increased asset utilization.
Drawbacks/Obstacles	Three of the study's six scenarios showing a "probable future state of the region" did not justify the need for a Smart Grid. These scenarios are titled "recession," "constrained environmental regulation," and "minimal technology development"; the environmentally friendly scenario makes no definitive case for a Smart Grid.
Costs	Total capital cost: $490 million; annual operation and maintenance cost: $24 million; total annual benefits: $141 million; system benefits over 20 years: $1,433 million; societal benefits: $1,396 million
Research Methodology	Identify technological, regulatory, and consumer system gaps between now and a future Smart Grid scenario; identify specific Smart Grid concept; prepare cost-benefit analysis; and develop implementation strategy for selected technologies
"Smart Grid" Definition(s)	The Smart Grid uses advanced sensing, communication, and control technologies to generate and distribute electricity more effectively, economically, and securely. It creates a digital energy system.
Regulatory Impacts/ Recommendations	Need for consistent, long-term policies (i.e., real-time pricing, incentives, interoperability, and a better understanding of the value San Diego consumers place on premium power quality and the creation of an appropriate rate structure to support investment in these technologies)
Uncertainty Factors/ Assumptions	Given external influences and trends, will San Diego's future more closely resemble a powerful economy or a recession? Will regulatory trends support environmental advances or will those be limited? Will the region's technological nature encourage breakthroughs in the grid or will that appetite retard innovation?
Primary/Secondary Data Sources	Report authors studied San Diego Gas & Electric infrastructure and the U.S. Department of Energy's Modern Grid Initiative and performed exhaustive primary research focusing specifically on San Diego's entire regional energy system.

After developing six model scenarios that map out the region's possible economic future, this study concludes that economic, technological, and regulatory trends in San Diego likely will create a desirable climate for the Smart Grid. The project team identified 26 specific technologies that can be deployed to advance the current electric grid toward a smarter, more modern system. San Diego Gas & Electric is planning to implement other advanced technologies, and still others are already part of the existing transmission and distribution grid.

"Results of a preliminary cost-benefit analysis suggest that implementing Smart Grid technologies and strategies could yield benefits that adequately exceed the initial installed costs and cover the ongoing operation and maintenance costs," states one of the first studies to apply U.S. Department of Energy Smart Grid concepts to a specific region. "This Smart Grid is a unique vision, very different from the local utility tradition. There will be unforeseen issues emerging, often requiring different thought, objectively applied with the overall vision clearly in mind."

Challenges inherent in such an undertaking include developing a Smart Grid vision that can be easily communicated internally and externally, smoothing out regulatory issues via open conversations, and retraining some of the utility workforce. Even though capital costs and operations and maintenance costs would be substantial, the study states that incorporating the 13 recommended improvement initiatives over a long, steady period of time represents the lowest risk to the region and the utility. These recommendations include implementing Ethernet over Fiber, 4G WiMAX Fixed—Private Wireless, Advanced Vizualization Methods, Zigbee / WiMedia / WiFi—Wireless, and concludes with Agent and Multi-Agent Systems. However, the report stated that programs lasting longer than three years tend to become sluggish and open to changes in scope, which reduces effectiveness.

The project team suggested that transition to a Smart Grid would be enhanced by conducting a pilot project to "debug" the process before tackling the entire region. This "test-bed" could demonstrate the integrated environment and results for each new improvement initiative. "While the overall concept of migrating San Diego to a Smart Grid is daunting, it is manageable," the report concludes. "With the proper leadership, skills and process, the results can be accomplished and the value realized."

Title of Report:	The U.S. Smart Grid Revolution KEMA's Perspectives for Job Creation
Organization:	KEMA
Date Published:	December 2008
Primary Focus Area:	Utility Business Issues and Opportunities

Document Summary	
Technologies Included	Advanced metering, T&D sensors, distribution protection adaptive for DG, building energy management systems integration, circuit and substation,; energy storage, high-temperature superconducting cable, integration of behind-the-meter systems, market integration of distributed renewable generation, PHEV/EV integration, six-sigma integrated, micro-grids, smart asset and management systems
Benefits Identified	This report explains that full Smart Grid deployment would generate 280,000 new jobs, many of which would be high-value jobs. In addition, it would support development in other industries, which could help in generating another 140,000 high-value jobs.
Drawbacks/Obstacles	Not addressed
Costs	KEMA's report anticipates a potential disbursement of $16 billion in Smart Grid incentives, which would act as a catalyst in driving associated Smart Grid projects that would be worth $64 billion.
Research Methodology	For direct utility employee job estimates, this report's methodology used the actual regulatory cost data from a utility that recently filed a Smart Grid deployment plan. Using this plan, KEMA projected a nationwide level of job creation, based on the premise that Smart Grid projects would be similar to the utilities used in the assumption. Methodologies for contract utility employee job estimate, supply chain job estimate, related industry job estimate, and broad industry job estimates varied from this assumption.
"Smart Grid" Definition(s)	A Smart Grid incorporates advanced applications and use of distributed energy resources, communications, information management, advanced metering infrastructure (AMI), and automated control technologies to modernize, optimize, and transform electric power and gas infrastructure.
Regulatory Impacts/ Recommendations	Not addressed
Uncertainty Factors/ Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report focuses on the labor impacts of Smart Grid implementation. The report finds that "implementing a Smart Grid represents an enterprise-wide initiative and impacts virtually the entire utility organization. Therefore, these projects will require a wide range of new skills, education, and talent." KEMA projects that 278,600 total jobs will be created between 2009 and 2012, in addition to 139,700 total jobs between 2013 and 2018.

This report also outlines the current status of Smart Grid programs in the United States. It finds that the current activity mostly focuses on AMI. "It is a generally accepted concept that AMI is often a precursor or foundational element to Smart Grid, or that the activity of Smart Grid efforts would incorporate levels of AMI. Presently, approximately 70 utilities have filed some form of AMI plan that also include pilots of this technology. Many have also filed business cases for implementation approval with their respective regulatory body." These AMI activities represent progress in nearly 30 states.

This report explains that the economic case for AMI and Smart Grid deployment can usually be made. It states that "typical AMI and Smart Grid regulatory filings present a business case with favorable benefit-to-cost ratios that may also include social benefits such as improved reliability and lower wholesale energy prices at peak. When these societal benefits are also factored in, the overall consumer benefit will further improve the financial attractiveness of AMI and Smart Grid as an investment."

Title of Report: The Smart Grid: Infrastructure Strategy for the Low Carbon Society
Organization: Horizon Energy Group
Primary Focus Area: Utility Business Issues and Opportunities

Document Summary	
Technologies Included	Clean coal technology, carbon management, plug-in hybrid electric vehicles, dispatchable distributed generation devices, distributed storage devices, renewables technology, and demand response
Benefits Identified	The paper cites information about how a reliable modern grid will lower our carbon footprint while giving us access to a vast wealth of renewable resources. Energy independence; increased reliance on systems and programs that reduce peak demand; and increased reliance on scalable, interoperable solutions leading to a plug 'n' play environment are other benefits to creating a modern grid.
Drawbacks/Obstacles	The cost of new generation and a delivery infrastructure has roughly doubled in the last five years. The financial investment proves to be the only drawback in implementing a Smart Grid with a carbon-efficient society in mind.
Costs	A Smart Grid study done by the University of San Diego showed that the total capital cost of implementing a San Diego regional Smart Grid would be $490 million.
Research Methodology	This document covers key elements of how the implementation of a Smart Grid will yield a more energy independent economy by lowering emissions and increasing access to renewable resources. The report brings forth the results of documented studies and efforts regarding the Smart Grid worldwide. It presents the benefits of a Smart Grid where carbon management is concerned, costs associated, and potential obstacles.
"Smart Grid" Definition(s)	A Smart Grid is a modern distributed infrastructure that will facilitate the ability to convert resources, such as coal, that have a clean alternative as a first step toward sustained energy independence. Smart Grid must be implemented in order to lower the carbon

	footprint and reduce emissions, increase access to renewable energy resources, and gain energy independence from foreign sources.
Regulatory Impacts/ Recommendations	This report documents that the vision of the Smart Grid must include three key areas to make the transition to the Smart Grid feasible on a wide basis: systems benefits, which affect the utility through system efficiency; consumer benefits, which affect the consumer through better quality power and reliability; and societal benefits, which affect society through environmental impact. It also recommends that the United States adopt a cellular structure approach when it comes to the grid, which has reaped a variety of benefits in Denmark's national infrastructure.
Uncertainty Factors/ Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report maintains that the United States has all the resources it needs to be energy independent and efficient. In addition, the electric industry is well equipped to accelerate demand response, to dispatch consumer-owned resources, and to convert resources that have a clean alternative, such as coal. The report answers the following questions: If the United States has all these resources and abilities, why is the nation not using them? Why does the United States continue to depend on foreign resources and conventional forms of energy?

According to this report, the absence of an intelligent infrastructure that is able to integrate existing technologies and foster the development of new technologies is responsible. Horizon Energy Group demonstrates how the implementation of a modern grid will foster energy independence by enabling the use of renewable resources. It will make a whole new set of solutions, including the use of advanced technologies, available for developing affordable and sustainable domestic resources.

Research shows that the Smart Grid will help the U.S. clean coal strategy by closing the gap between generation capacity and electricity supply, which increases the importance of coal as a base load resource. Closing this gap frees up capital investment needed to finance clean coal technology, emission projects including carbon management, and new base load coal generation plants.

The report cites Denmark's transition to a distributed, renewables-based, cell structure with a net export to other countries as a prime example for the United States to follow. A wind resource penetration greater than 30%, which is more than double anywhere else in the world, has been the result of Denmark's infrastructure transformation. The cellular structure of the grid has enabled their wind resources, aggregated with distributed combined heat and power (CHP) plants, to meet the economic and reliability goals of the country. The report recommends such a strategy for the United States, which would enable the industry to use its domestic coal resource in smaller, clean coal plants to act as the CHP units instead of natural gas, as in Denmark.

As for the costs, the results of a San Diego Smart Grid study show that if it is implemented for the primary purpose of improved reliability and quality, the cost will be about 6% more than the existing planned 10-year capital expense plan at the host utility. If the primary purpose is to gain a deeper penetration of renewable resources, then the cost will be about 20% less than the existing planned 10-year capital expense plan at the host utility.

Grid Reliability

Title of Report: "Grid 2030" A National Vision for Electricity's Second 100 Years
Organization: U.S. Department of Energy
Date Published: July 2003
Primary Focus Area: Grid Reliability

Document Summary	
Technologies Included	Advanced conductors made from new composite materials and high-temperature superconducting materials; advanced electric storage systems, such as flow batteries or flywheels; distributed intelligence and smart controls; power electronics devices for AC-DC conversion and other purposes; distributed energy resources, including on-site generation and demand management; and microprocessors
Benefits Identified	Increased efficiency, quality, reliability, and security of the electric grid; elimination of electric system constraints; encouraged market growth; emergence of new business models; reduction in greenhouse gases; greater use of renewable technologies; and more active involvement by consumers
Drawbacks/Obstacles	Obstacles include unprecedented levels of risk and uncertainty about the future, all-time low capital investment in new electric transmission and distribution systems, federal and state regulatory framework under stress, technological limitations and market barriers, and difficulty in siting new conventional overhead transmission lines.
Costs	Billions of dollars of investment will be required for electric power equipment replacement over the next several decades.
Research Methodology	This report describes the common vision agreed upon by 65 senior executives who met on April 2–3, 2003, to discuss the future of North America's electric system. Facilitated breakout sessions were used to gather ideas and priorities from the meeting participants.
"Smart Grid" Definition(s)	Grid 2030 is a fully automated power delivery network that monitors and controls every customer and node, ensuring a two-way flow of electricity and information between the power plant and the appliance, and all points in between.
Regulatory Impacts/ Recommendations	This report offers the following recommendations: clarify intergovernmental jurisdiction; establish a flourishing public-private RD&D partnership; establish workable competitive markets for all sectors and regions; ensure mechanisms for universal service and public purpose programs; support a stable business climate that encourages long-term investment; and resolve performance-based regulation, metering, and pricing issues.
Uncertainty Factors/ Assumptions	Not available
Primary/Secondary Data Sources	Sources include the electric utility industry, equipment manufacturers, information technology providers, federal and state government agencies, interest groups, universities, and national laboratories.

This document describes the common vision that emerged from a facilitated meeting of senior executives who discussed the future of North America's electric system. The meeting was held just two months after President George W. Bush addressed the need to modernize the electric system "for economic security…and for national security." The meeting participants identified the current status of America's electric system, discussed the positive and negative factors affecting future grid modernization and expansion, agreed on a vision for the future electric system, and recognized challenges to overcome and strategic goals to accomplish in order to achieve this vision. The report states that America needs electric power for economic prosperity, national security, and public health and safety. At the time this report was written, 40% of America's energy consumption was used to produce electricity.

Many factors will affect the future of America's electric system. Electricity restructuring, environmental regulations, and national security are all public policy drivers. The lack of cooperation between federal and state governments is a major challenge to restructuring the regulatory framework. Competition, an aging infrastructure, and consumer demands are examples of market drivers. As for technology drivers, advances in information technologies, materials science, high-temperature superconductors, electricity storage, advanced power electronics, and distributed energy technologies are all critical to the future of America's electric system.

The meeting participants agreed on the following national vision: "'Grid 2030' energizes a competitive North American marketplace for electricity. It connects everyone to abundant, affordable, clean, efficient, and reliable electric power anytime, anywhere. It provides the best and most secure electric services available in the world." Three major elements to this vision are a national electricity backbone; regional interconnections; and local, mini-, and micro-grids. The potential benefits of this vision include elimination of electric system constraints, support for economic growth, greater energy efficiency, less harmful environmental impacts, and improved grid security that is less vulnerable to terrorist attacks.

This document presents solutions to challenges that hinder this vision: overcome inertia, attract resources, develop better technologies, find profitable business models, address customer and public needs, and develop better public policies. A stronger private-public partnership is essential. The *National Electric Delivery Technologies Roadmap* will be used as a guide for achieving "Grid 2030."

Title of Report:	Prospects of Smart Grid Technologies for a Sustainable and Secure Power Supply
Organization:	Siemens
Date Published:	January 2004
Primary Focus Area:	Grid Reliability

Document Summary	
Technologies Included	High voltage direct current (HVDC), HVDC PLUS, voltage-sourced converters, modular multilevel converter, FACTS, SVC, and unified power flow converter
Benefits Identified	By enabling a modern grid, the United States' connections will reflect those of the systems development in Europe—where links will be strengthened between countries and where different but complementary renewable resources can be found. In addition, Smart Grid technologies will yield blackout prevention, due to fault-current-blocking characteristics. Also, transmission capacity and system stability will increase.
Drawbacks/Obstacles	The most urgent challenge is the deployment of Smart Grid technologies in the United States to boost system efficiency and stability and to reduce system losses and emissions.

Document Summary	
Costs	Estimated global investments required for the electricity delivery infrastructure until 2030 are $16 trillion, according to EIA statistics.
Research Methodology	This report utilized statistics and information from a variety of sources such as the International Energy Agency and the United Nations. Siemens also depicted information from the U.S. Department of Energy National Transmission Grid Study and a variety of other research studies and assessments.
"Smart Grid" Definition(s)	A Smart Grid will increase system enhancement and grid interconnection with the support of technologies that provide the necessary features to improve transmission capacity and system stability. It is a necessary response to environmental, social, and political demands made on energy supply.
Regulatory Impacts/ Recommendations	This report encourages the development and deployment of more transmission technologies in the United States and abroad to encourage better grid conditions.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report cites how smart technologies are being deployed throughout the world and the impact made to the electricity delivery systems of those countries. This vision comes from the European Union (EU) in acknowledgement of the fact that growing population and depleting resources are making the modern grid an important factor in the quality of life. The EU determined that there are four main features of the Smart Grid: flexibility, accessibility, reliability, and economic value.

The approach of EU's Smart Grid vision is an important step in the direction of environmental sustainability of power supply, and new transmission technologies can effectively help reduce losses and emissions. HVDC transmission technology has offered new dimensions for long-distance transmission. Its major benefit is a fault-current-blocking characteristic, which serves as an automatic firewall for blackout prevention. Flexible AC Transmission System technologies can also aid in transmission to control load flow and improve dynamic conditions.

The report maintains that these technologies provide the necessary features to avoid technical problems in the power systems because they increase transmission capacity and system reliability. They also assist in disturbance prevention, provide access to renewable energy resources, and reduce transmission losses by optimization of power flow.

Title of Report: Smart Grid Vision Meets Distribution Utility Reality
Organization: McDonnell Group
Date Published: March 2007
Primary Focus Area: Grid Reliability

Document Summary	
Technologies Included	Advanced metering infrastructure, distribution and outage management, distribution and substation automation, simulation and optimization, and enterprise business intelligence

Document Summary	
Benefits Identified	In a section of the report titled “Quantifying the Impact of the Smart Grid: Security, Quality, Reliability and Availability,” the authors list security and power quality reliability and availability as the primary benefits of a Smart Grid. A more in-depth example includes issues relating to the growth of electronics for utility load profiles. The report states that “it is estimated that 60% of an average utility’s load by the year 2015 will be required by sensitive electronics such as semiconductors and automated manufacturing. Furthermore, growth in the distribution system is leading to voltage stability problems due to the changing load composition.” The report then adds that “improved power quality is accomplished by considering the interaction between the transmission and the distribution systems. The Smart Grid will monitor this impact. Activities to ensure load compensation, voltage and system stability, load shedding and optimal use of distributed generation will all be controlled in real-time through smart Distribution Management Systems (DMS) to mitigate outages and maintain power quality.”
Drawbacks/Obstacles	The report explains that current Smart Grid technology deployment is somewhat minimal. The reports states that “by some estimates, distribution information and communications systems are installed at less than 75 percent of North American electricity substations and distribution automation penetration at the system feeder level is estimated at only 15–20 percent.
Costs	This report cites an October 2006 study by the Energy Policy Initiative Center in San Diego, which outlines a scenario of Smart Grid implementation on the San Diego electric grid. This study shows that an initial $490M investment would generate $1.4B in utility system benefits and nearly $1.4B in societal benefits over 20 years.
Research Methodology	Not addressed
“Smart Grid” Definition(s)	Not addressed
Regulatory Impacts/ Recommendations	Not addressed
Uncertainty Factors/ Assumptions	Not addressed
Primary/Secondary Data Sources	This report referenced the Electric Power Research Institute on numerous occasions. In addition, another source of interest was the NERC Security Guidelines for Critical Infrastructure Protection.

This report focuses on how Smart Grid technologies could impact distribution utilities. “Distribution utilities are under significant pressure to meet new electric energy needs. Despite this, investment in smart distribution systems has historically been low as companies struggle with tightened capital budgets and other critical priorities,” says the report.

The report argues that Smart Grid technologies that impact the distribution system are essential for improving the grid. “The focus of achieving cost savings and improved customer service lies in distribution management systems (DMS) that provide real-time response to adverse or unstable conditions. In a Smart Grid, software programs must provide self-healing functionality in order to instantly detect and react to power disturbances with minimal customer impact.”

The report also mentions how software platforms will allow distribution utilities to optimize and simulate different scenarios. These simulations could help a utility reap cost savings that could be passed onto the consumer. In addition, performance benefits could be expected for the distribution system. The report says that "the ability to analyze automation and budget scenarios will drive Smart Grid planning and performance even further."

Title of Report: [Metrics for Measuring Progress Toward Implementation of the Smart Grid]
Organization: U.S. U.S. Department of Energy
Date Published: July 31, 2008
Primary Focus Area: Grid Reliability

Document Summary	
Technologies Included	Meter devices, demand response, plug-in hybrid electric vehicles, distributed generation, storage, real-time operation, active voltage and VAR control, smart sensors and remote monitoring, and phasors.
Benefits Identified	Active participation by consumers; accommodation of all generation and storage options; new products, services, and markets; power quality for the range of needs in a digital economy; optimization of asset utilization and efficient operation; self-healing manner; and resiliency against physical and cyber attack and natural disasters
Drawbacks/Obstacles	Obstacles cited include unique baselines, targets, and measurements for each utility's transmission and distribution system; the need for further research and analysis to refine the metrics and develop methodologies and data; misunderstandings of what Smart Grid is and is not; the need for further education and training; and measurement issues.
Costs	Not available
Research Methodology	This report describes the major findings and path forward agreed upon by more than 140 experts who met on June 19–20, 2008, to identify metrics and discuss data sources and measurement methods for implementation of a Smart Grid. Facilitated breakout sessions were used to gather ideas and priorities from the meeting participants.
"Smart Grid" Definition(s)	A Smart Grid will enable active participation by consumers; accommodate all generation and storage options; enable new products, services, and markets; provide power quality for the range of needs in a digital economy; optimize asset utilization and operating efficiency; anticipate and respond to system disturbances in a self-healing manner; and operate resiliently against physical and cyber attacks and natural disasters.
Regulatory Impacts/ Recommendations	This report makes the following recommendations: set standards, fund the standard-setting process, and educate public utility commission regulators on Smart Grid basics.
Uncertainty Factors/Assumptions	Not available
Primary/Secondary Data Sources	Information was gathered from utilities, equipment manufacturers, state agencies, universities, and national laboratories.

This document presents the results of the breakout session discussions at the Smart Grid Implementation Workshop held by the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability in June 2008. Experts identified metrics for each of the seven major Smart Grid characteristics agreed upon by leading groups.

In reference to these seven major characteristics, a Smart Grid will 1) enable active participation by consumers; 2) accommodate all generation and storage options; 3) enable new products, services, and markets; 4) provide power quality for the range of needs in a digital economy; 5) optimize asset utilization and operating efficiency; 6) anticipate and respond to system disturbances in a self-healing manner; and 7) operate resiliently against physical and cyber attacks and natural disasters.

For each of the seven major Smart Grid characteristics, workshop participants determined key metrics for measuring progress toward implementation of Smart Grid technologies, practices, and services. Some of these metrics include the percentage of customers capable of receiving information from grid operators and the percentage of customers opting to make or delegate decisions about electricity consumption based on that information; the percentage of distributed generation and storage devices that can be controlled in coordination with the needs of the power system; the number of Smart Grid products for sale that have been certified for “end-to-end” interoperability; the number of measurement points per customer for collecting data on power quality, including events and disturbances; the amount of distributed generation capacity (MW) that are connected to the electric distribution system and are available to system operators as a dispatchable resource; the percentage of grid assets that are monitored, controlled, or automated; and the percentage of entities that exhibit progressively mature characteristics of resilient behavior.

Workshop participants also discussed measurement issues that complicate progress toward Smart Grid technologies, practices, and services. In addition, the report argued that to solve these issues, government and industry need to work together to refine the metrics discussed above, as well as develop methodologies for establishing baselines and collecting data that measure progress. This report emphasized that various baselines, targets, and measurement approaches will need to be tailored to each utility’s transmission and distribution system. The report also argued that education and training are essential in the development of these Smart Grid technologies, tools, and techniques to sustain the present and prepare for the future.

Title of Report: A Systems View of the Modern Grid: Resists Attack
Organization: National Energy Technology Laboratory
Date Published: January 2007
Primary Focus Area: Grid Reliability

Document Summary	
Technologies Included	Integrated communications for real-time information and control, sensing and measurement, advanced control methods, advanced components and distributed energy resources (DER), improved interfaces and decision support
Benefits Identified	This report discusses many benefits a Smart Grid would have at resisting attack. First, a Smart Grid would be able to prevent attacks from even occurring. Second, it could improve the operational readiness defenses by ensuring security-of-supply for electric power. In addition, the report says that a Smart Grid could reduce the geographic extent of any outages and improve the recovery time of outages.
Drawbacks/Obstacles	This report explains that there are many barriers for Smart Grid implementation in relation to resisting attack. Some of these include an incomplete understanding of threats and consequences, a perception that security improvements are prohibitively expensive, and an increasing use of open systems, an increasing number of grid participants, and a difficulty in recovering costs.
Costs	Not addressed

Document Summary	
Research Methodology	Not addressed
"Smart Grid" Definition(s)	Not addressed
Regulatory Impacts/ Recommendations	The report outlines many recommendations for policymakers and industry. It recommends creating a government-industry team, including state regulators, to address issues of acceptable risk to the public from disruptions and return on investment for industries' investments in security. The report also says that "government should also share their concerns about the cost and expected benefits of security and ensure that the developers of the modern grid integrate security as an inherent characteristic—not as an optional feature."
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Some of the sources include IEEE, and documents from the U.S. General Accounting Office and the U.S. Department of Homeland Security.

This report outlines key barriers, benefits, and recommendations for Smart Grid technologies in relation to national security. The report divides these national security threats into two categories, cyber attacks and physical attacks.

The paper explains that cyber attacks are increasing. "Computer security incidents are increasing at an alarming rate. According to the Government Accountability Office, in 2002, 70 percent of energy and power companies experienced some kind of severe cyber attack to their computing or energy management systems." The report explains that there needs to be a focus on physical attacks as well. "Physical attacks against key elements of the grid, or physical attacks combined with cyber attacks, cannot be discounted. From a terrorist viewpoint, damage from a physical attack may be more predictable than a cyber attack, and therefore promise more certainty in causing harm."

The report explains that the complexity of the electrical power system and its reliance on certain critical pieces of infrastructure create the potential for catastrophic failure. The report indicates that to resist an attack, a Smart Grid must consider these nodes and assist in protecting the integrity of the whole system.

Title of Report: A Systems View of the Modern Grid: Self-Heals
Organization: National Energy Technology Laboratory
Date Published: March 2007
Primary Focus Area: Grid Reliability

Document Summary	
Technologies Included	Advanced sensors; advanced switches; demand response; distributed energy resources; flexible alternating current transmission system devices; substation automation; distribution automation; high-speed switching, throttling, and modulating; advanced relaying; circuit-to-circuit ties; voltage and flow control; fault current limiters; and common information model

Document Summary	
Benefits Identified	Self-healing technology can be the Smart Grid's "immune system" at the transmission and distribution levels. This technology can reduce the number and duration of outages, minimize restoration times, reduce electrical losses and maintenance costs, and reconfigure the grid to produce optimum reliability and quality of service. It also can increase the grid's tolerance of a security attack. Environmental benefits include accommodating green technologies that produce zero emissions and reducing the impact of transformer fires.
Drawbacks/Obstacles	The investment is too expensive for utilities alone because they cannot justify the investment to attain the societal benefits. Investment to achieve societal benefits will require funding from the federal government and other stakeholders. Other barriers include the expense of "retiring" older equipment before it wears out, the speed of technology development such as integrated high-speed communications systems, and the reluctance of utility commissions to invest in new construction.
Costs	Labeled as "high" but not specifically defined
Research Methodology	This report is one of several separate papers supplementing "A Systems View of the Modern Grid," an overview by the Modern Grid Initiative team.
"Smart Grid" Definition(s)	In the context of the modern grid, "self-healing" refers to an engineering design that enables the problematic elements of a system to be isolated and, ideally, restored to normal operation with little or no human intervention.
Regulatory Impacts/ Recommendations	Utility commissions need to see a return on Smart Grid investments to merit funding new construction and technologies.
Uncertainty Factors/Assumptions	Will 30,000 diverse utilities cooperate to install technology and exchange the information needed to implement these concepts? Other concerns include development and deployment of intelligent electronic devices, demand response, distributed energy resources, and new control algorithms and control devices.
Primary/Secondary Data Sources	Information gathered from a bibliography of 16 sources, including the U.S. Department of Energy Office of Electric Transmission and Distribution, IEEE, and Carnegie Mellon Electricity Industry Center.

This report points out that the current transmission system incorporated the notion of a self-healing grid many years ago. The report concludes that significant advances in digital technologies, correctly applied, will dramatically improve this self-healing capability. While hardware, software, and individual components already exist for self-healing features to advance to reality, the report states that the key lies in integrating all of these elements to form a unified, single-purposed entity.

The ability to detect, analyze, and respond to undesirable grid conditions and events will lead to a self-healing grid that is reliable, secure, economical, safe, efficient, and environmentally friendly, according to this report. Of all the technologies that need to be advanced to make this a reality, the report concludes that integrated communications is the most vital because it provides the foundation for all self-healing features. "The self-healing grid will employ extensive voltage and flow control, along with fault current limiting capabilities," the report states. "Appropriate local and remote devices, running real-time analyses of electrical events, will issue control signals that address emerging problems. Frequently, the short time interval of such events will require all this to happen without human intervention."

To advance the self-healing aspects of the Smart Grid, the NETL researchers recommend that demonstration projects of untested and previously never-before integrated technologies are necessary to provide a platform for broader deployment. "Technologies that have never been integrated with other technologies in a system context need to be integrated and tested to provide the realistic, business-case quality data needed to cause broader deployment of the technologies," the report states.

The report maintains that society as a whole benefits from a modernized grid and they argue that legislators and regulators must collaborate to make these public goods known so that the utilities have the incentive to move forward. The researchers emphasize that the health of an electric system, like that of the human body, is determined in large part by the strength of its immune system and its ability to heal itself. Moreover, in that context, the report concludes, "the North American grid's immune system is not very strong."

Title of Report: A Systems View of the Modern Grid: Advanced Control Methods
Organization: National Energy Technology Laboratory
Date Published: March 2007
Primary Focus Area: Grid Reliability

Document Summary	
Technologies Included	Distribution automation, distributed energy resources, demand response, flexible alternating current transmission system, intelligent electronic devices, phasor measurement units, supervisory control and data acquisition, digital protective relay, intelligent tap changer, dynamic circuit rating tool, substation automation, outage management, and condition-based maintenance
Benefits Identified	Advanced control methods can increase grid reliability leading to decreased costs and increased revenues; prevent wide-area outages because of self-healing properties; prevent, detect, and mitigate security attack consequences; prompt consumers to participate in the electricity market; minimize transmission congestion; displace spinning reserve by using demand response; reduce out-of-service time and maintenance costs for assets; and improve efficiency in performing system and trouble work via integration with work and outage management systems.
Drawbacks/Obstacles	Obstacles cited include the lack of broad consensus and conflicting objectives for modern grid among stakeholders; the need for high-speed communications and more powerful computers; the lack of integrated, system-wide control perspective for automated control methods; the cost of intelligent electronic devices being too high; and no method yet existing to retrofit existing components to reduce their price.
Costs	Labeled as "high" but not specifically defined.
Research Methodology	The authors harvested information from various papers, reports, and presentations. This report is one of several separate papers supplementing "A Systems View of the Modern Grid," an overview by the Modern Grid Initiative team.
"Smart Grid" Definition(s)	The report implied that the authors followed the definition presented by the U.S. Department of Energy.
Regulatory Impacts/Recommendations	According to this report, new regulations need to motivate vision for a modern grid and regulated utilities need incentives for investing in advanced control methods. A new regulatory model was recommended to encourage use and dispatch of consumer distributed energy resources.
Uncertainty Factors/Assumptions	Will economies of scale and design innovation occur to drive sensor costs down? Placement of intelligent energy devices could take decades because components are not replaced until they fail.
Primary/Secondary Data	Information was gathered from a bibliography of 10 sources including the U.S.

Document Summary	
Sources	Department of Energy Office of Electric Transmission and Distribution, Electric Power Research Institute, and the Power System Engineering Research Center.

Advanced control methods are the devices and algorithms that can analyze, diagnose, and predict conditions in the modern grid and determine when and how to take appropriate actions to eliminate, mitigate, and prevent outages and power quality disturbances. Not only do these methods provide control at the transmission, distribution, and consumer levels, but they also manage both real and reactive power across state boundaries. The report states that these devices will incorporate predetermined expert logic and templates giving “permission” to the grid’s software to take corrective action autonomously when these actions fall within allowable permission sets.

The communication infrastructure supporting today’s control systems is made up of a wide spectrum of technologies patched together, the report notes. Information is transmitted from the sensor to the control systems, where it is processed, and then transmitted to the controlling devices. The reports’ authors contend that communication infrastructure is currently too limited to support the high-speed requirements and broad coverage needed by advanced control methods and does not provide the networked, open architecture format needed for the grid’s enhancement.

“Advanced control methods are technically achievable,” states the report. “The needed software and hardware systems can be developed relatively easily following the development of a comprehensive set of control-system specifications.” The report’s authors envision a future where advanced control methods will be distributed or centralized, depending on what is appropriate. They anticipate advanced control methods playing an integral role in collecting data, monitoring grid components, analyzing data, diagnosing and solving problems, taking autonomous action where appropriate, providing information and options for human operators, and integrating with other enterprise-wide processes and technologies.

In addition, the report cites numerous other ways where advanced control methods can enhance existing processes and technologies. These include load forecasting and system planning, maintenance, market operations with Regional Transmission Organizations, work management, outage management, simulation and training, geographic information systems for spatial analysis, and automatic meter reading.

Title of Report:	NETL Modern Grid Strategy Powering our 21st-Century Economy: Modern Grid Benefits
Organization:	National Energy Technology Laboratory
Date Published:	August 2007
Primary Focus Area:	Grid Reliability

Document Summary	
Technologies Included	Demand response, load management, real-time acquisition, smart sensors, distributed generation, storage, superconducting synchronous condensers, superconducting fault current limiters, synchronous switching, dynamic voltage restorers, demand energy

Document Summary	
	resources, micro grids, power stabilization software, flexible AC transmission systems, and advanced metering
Benefits Identified	Benefits include reliability, power quality, health and safety, national security, economic vitality, efficiency, environmental impact, and cost savings. This report explains that benefits to society could range from between $638 and $802 billion with savings of $40 billion each year.
Drawbacks/Obstacles	There are no drawbacks or obstacles associated with a new grid cited by this report.
Costs	$165 billion over the next 20 years for a modern grid in the U.S.
Research Methodology	The analysis included studies, reports, and white papers.
"Smart Grid" Definition(s)	A modern grid will self-heal, motivate and include the consumer, resist attack, provide power quality for 21st century needs, accommodate all generation and storage options, enable markets, and optimize assets and operate efficiently.
Regulatory Impacts/ Recommendations	Not included
Uncertainty Factors/Assumptions	The document assumes that the benefits outweigh the costs based on figures cited in EPRI study.
Primary/Secondary Data Sources	Information was gathered from the Electric Power Research Institute, the Pacific Northwest National Laboratory, the U.S. Department of Energy, etc.

This report describes all the benefits that a modern U.S. electric grid will offer once the current aging infrastructure is reformed with advanced technologies. According to this document, a modern grid needs to be self-healing, motivate and include the consumer, resist attack, provide power quality for 21st century needs, accommodate all generation and storage options, enable markets, and optimize assets and operate efficiently. Once this modern grid is developed, the areas of reliability, security and safety, economics, efficiency, and the environment will all reap the benefits.

With respect to reliability, a modern grid will greatly reduce the duration and frequency of outages, decrease the number of power-quality disturbances, and almost completely eliminate the chance of regional blackouts. As for security and safety, a modern grid will reduce vulnerability to terrorist attacks and natural disasters and improve conditions for grid workers. On the economics side, a modern grid will increase market efficiencies and reduce energy prices. In addition, a modern grid will provide new options regarding load management, distributed generation, energy storage, and demand response for participants in the electricity markets. Real-time data and advanced monitoring technologies will result in greater operational efficiency and improved asset management at lower costs. The environment will also benefit from a modern grid that deploys environmentally friendly resources and requires less generation, ultimately reducing harmful emissions.

The authors of this report gathered various statistics to help prove their case that a modern grid will "greatly improve the quality of life." Using EPRI as a source, the authors state that the cost of a modern grid over the next 20 years will be $165 billion, but the societal benefits will reach somewhere between $638 billion and $802 billion, a benefit ratio of 4 to 1. This report also documents that more than $40 billion could be saved each year with the modernization of the grid and a total cost of $46 billion to $117 billion for generation, transmission, and distribution could also be avoided.

Policy & Regulation

Title of Report:	Demand Response and Smart Metering Policy Actions Since the Energy Policy Act of 2005: A Summary of State Officials
Organization:	The National Council on Electricity Policy
Date Published:	Fall 2008
Primary Focus Area:	Policy and Regulatory

Document Summary	
Technologies Included	Smart metering, demand response, dynamic pricing, distributed resources, and demand-side management
Benefits Identified	Not addressed
Drawbacks/Obstacles	The report discusses Section 1305 of the Energy Independence and Security Act of 2007 relates to a Smart Grid interoperability framework. This Section discusses one of the most significant obstacles to overall Smart Grid implementation. This Section initiates a new effort by the federal government to ensure that protocols and standards necessary for “information management to achieve interoperability of Smart Grid devices and systems” are developed. The National Institute of Standards and Technology, an arm of the Commerce Department, is charged with coordinating the development of a “framework” that will accomplish this. This Section also states that the framework must be “flexible, uniform and technology neutral, including but not limited to technologies for managing Smart Grid information.” It must be flexible to incorporate “regional and organizational differences” and “technological innovations.”
Costs	Not addressed
Research Methodology	This report was prepared by the Demand Response Coordinating Committee (DRCC) for the National Council on Electricity Policy. The process of developing the report had three stages of research. The first stage consisted of reviewing the DRCC’s archive of demand response policy and legislative activity. The next step was to revisit the source and review the documentation of the known activity—mostly regulatory proceedings and legislation—to determine whether there had been any additional developments. The final stage was to investigate any leads, discovered through the earlier steps of research, to identify any policy or legislative activity previously unknown by the DRCC.
“Smart Grid” Definition(s)	This paper offers many different definitions of a Smart Grid. However, it states that “in almost all usage, demand response and smart meters and other smart technologies are considered to be one of the ways that the grid becomes ‘smart’ as connecting customers, their loads, and information about their usage to the grid is essential to the creation and operation of a Smart Grid.”
Regulatory Impacts/ Recommendations	This report discusses all of the regulatory and policy actions being taken by the federal government and the nation’s state governments relating to Smart Grid.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	This report is based on the best public information that was available as of August 2008 and not in-depth state-by-state research. Accordingly, and because of the rapid pace of policy developments in this area, this report may not contain all relevant policy developments.

This report represents a summary review of policy developments relating to Smart Grid technologies across the United States as of the date of publication. The report focuses on state and federal policy developments during the period from 2005 to mid-year 2008. It catalogues information on policy developments at both the federal and state level, both in the legislative and regulatory arenas.

At the state level, this report reflects the great diversity of approaches and techniques underway. According to the report, some of that activity has been undertaken pursuant to Congressional direction such as Section 1252 of the Energy Policy Act of 2005 but much has also been undertaken due to the state's own initiative. Additionally, this report finds that states are having significant roles in demand response programs because demand response involves modifying retail rates, which is under state jurisdiction.

Beginning on page 32, there is a significant summary of Maryland policy impacts from the past few years in relation to demand response and Smart Grid technologies.

This report also outlines policy and regulatory impacts from Energy Policy Act of 2005, a bill passed by the United States Congress on July 29, 2005, which impacts U.S. energy policy by providing tax incentives and loan guarantees for energy production of various types the Energy Independence and Security Act of 2007, the Emergency Economic Stabilization Act of 2008, and finally the U.S. Department of Energy and the Federal Energy Regulatory Commission compliance with federal legislation.

Title of Report:	Accelerating the Use of Demand Response and Smart Grid Technologies is an Essential Part of the Solution to America's Energy, Economic and Environmental Problems
Organization:	Demand Response and Smart Grid Coalition
Date Published:	November 2008
Primary Focus Area:	Policy and Regulatory

Document Summary	
Technologies Included	Demand response, smart meters, communication and control systems, and storage systems
Benefits Identified	Reduce or hold down overall electricity costs for consumers, both small and large; provide electricity customers with new information, technologies, and tools to control their electricity bills and increase their energy efficiency practices; improve the reliability and security of the nation's power grid and the ability to restore it after outages; and reduce CO_2 emissions and support climate change mitigation
Drawbacks/Obstacles	Not addressed
Costs	Not addressed
Research Methodology	This report outlines policy recommendations developed by the Demand Response and Smart Grid Coalition (DRSG). The DRSG is the trade association for companies that provide products and services in the areas of demand response, smart meters, and Smart Grid technologies.
"Smart Grid" Definition(s)	The Smart Grid is the concept of having all supply and demand resources dynamically managed via a combination of data, communications, and controls, whereby the operation of the grid for reasons of economics, security, reliability, emissions, etc., can be optimized in real time.
Regulatory Impacts/	Following are some of the policy recommendations found in this report: establish an

Document Summary	
	investment tax credit, establish accelerated depreciation, provide funding for implementation of the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007, create a Smart Grid infrastructure fund, include demand response in a renewable energy portfolio standard, decouple utility profits from sales volume, develop state demand response/Smart Grid "Action Plans," and use smart metering and Smart Grid technologies to verify CO_2 reductions.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report advocates for certain policy and regulatory actions to be taken by federal and state governments to promote Smart Grid technologies. For example, the paper states that "if a federal Renewable Energy Standard is enacted, it should allow the standard to be met in part through energy efficiency and demand response." While the report notes that federal and state policy actions are needed, it does acknowledge that they, alone, will not be sufficient to drive mass deployment. However, the report states that government support is still essential for Smart Grid technology market growth. This report also outlines many benefits of Smart Grid technology deployment. However, it does not speak to any drawbacks or costs associated with Smart Grid.

Title of Report: Challenges and Opportunity: Charting a New Energy Future
Organization: Energy Future Coalition
Date Published: November 2008
Primary Focus Area: Policy and Regulatory

Document Summary	
Technologies Included	This paper does not cite specific technologies, but instead states, "A Smart Grid is not defined by what technologies it incorporates, but rather by what it can do."
Benefits Identified	This paper addressed many benefits that could be realized with the adoption of Smart Grid technologies. For example, the report cites an Electric Power Research Institute estimate that power outages and power quality disturbances cost businesses in the United States more than $120 billion a year. The report states that some of the benefits of Smart Grid deployment include reducing customer exposure to costly outages and service disruptions, increasing security of the electricity infrastructure, supporting widespread use of distributed energy resources, enabling smart end-use energy management, and providing cost savings due to greater transmission grid throughput.
Drawbacks/Obstacles	Grid performance specifications are cited as one significant obstacle. This report proposes legislation that would encourage the North American Electric Reliability Corporation (NERC) to develop specifications for grid performance on a specified schedule with input from the National Association of Regulatory Utility Commissioners and its members.
Costs	Not addressed
Research Methodology	This report is the end product of the Energy Future Coalition's consultation with more than 150 individuals from business, labor, government, academia, and the non-government organization community. The Coalition's analysis of past efforts to affect U.S. energy policy found them to be too academic, too narrow, or too sectoral, and for the most part uninformed by practical political experience. To remedy these problems,

Document Summary	
	the Coalition decided to focus on practical political coalition building, aimed at breaking the gridlock that has prevented substantive advances in energy policy for the past three decades. The Coalition created six Working Groups that have shaped the recommendations found in this report.
"Smart Grid" Definition(s)	The term "Smart Grid" refers to an electricity transmission and distribution system that incorporates elements of traditional and cutting-edge power engineering, sophisticated sensing and monitoring technology, information technology, and communications to provide better grid performance and to support a wide array of additional services to consumers.
Regulatory Impacts/ Recommendations	Articulating a national vision of the 21st century grid is cited as a major recommendation. The report states that "the U.S. Department of Energy (DOE) should be charged with leading a multi-stakeholder process to expand and clarify the vision and goals statement for the future system, specifying in clear, customer-oriented perspectives the characteristics of the advanced electricity grid of the 21st century." Other recommendations include demonstration programs for advanced technologies, incentive rates at the Federal Energy Regulatory Commission for grid enhancement, and incentive rates at state commissions for transmission and distribution system enhancement.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report outlines the myriad of benefits that could be realized from Smart Grid technology implementation. For example, the report speaks at length about how a Smart Grid could support further distributed generation growth. The reports states that "a grid that supports widespread interconnection and use of distributed generation by both suppliers and consumers will lead to improved reliability and power quality, reduced electricity costs, and greater customer choice and control."

The report also discusses certain policy recommendations that federal and state governments should consider. For example, the report explains that "state regulators should adopt ratemaking standards for the transmission and distribution components of rates under their jurisdiction that provide sufficient incentives for system enhancements reflecting innovative technologies, using performance-based rates keyed to meeting specified performance criteria where possible."

The report does not address with any real depth the costs associated with Smart Grid deployment. In addition, it does not provide any uncertainty factors with the conclusions found.

Title of Report:	Overview of the Smart Grid: Policies, Initiatives, and Needs
Organization:	ISO New England
Date Published:	February 2009
Primary Focus Area:	Policy and Regulation

Document Summary	
Technologies Included	Smart appliances, plug-in hybrid electric vehicles, Eastern Interconnect phasor

Document Summary	
	measurement equipment, demand response, alternative technology regulation, advanced grid simulator, distributed generation, demand response, peak shaving, advanced electricity storage, thermal-storage air conditioning, home area networks, wide area monitoring systems, micro grids, advanced metering infrastructure, and building automation and distribution control
Benefits Identified	The goal is to use advanced, information-based technologies to increase power grid efficiency, reliability, and flexibility and reduce the rate at which additional electric utility infrastructure needs to be built. A switch to digital equipment will improve cyber security, integrate distributed generation and demand response, contribute to energy efficiency, allow for use of advanced electricity storage and peak-shaving technologies, and provide customers with control options and the ability to employ smart appliances and devices.
Drawbacks/Obstacles	This report cites a variety of obstacles, such as the lack of interoperability standards, uncertainty over business practices such as cost allocation between transmission and distribution, a shift from a centrally controlled grid to a distributed system adds significant complexity, the need for new algorithms and control systems that co-optimize supply and demand technologies with variable output renewable resources and automated sense-and-respond devices, the need for sophisticated technology to handle exponential increases in data, and the need for advanced system and capacity planning processes.
Costs	Not addressed
Research Methodology	The authors collected information from various articles, reports, and studies with a special focus on on-the-ground New England Smart Grid projects.
"Smart Grid" Definition(s)	According to the Energy Independence and Security Act of 2007, "Smart Grid" refers to modernization of the nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth. This report compares numerous definitions.
Regulatory Impacts/ Recommendations	According to this report, there is a strong need for practical regulations that satisfy the needs of stakeholders across the entire electrical supply chain.
Uncertainty Factors/Assumptions	Success depends on collaboration and numerous characteristics, including an interoperability framework, long-term investments, timely deployment, methodical transition, and practical regulations.
Primary/Secondary Data Sources	This report's bibliography of more than 90 sources includes the U.S. Department of Energy, the Federal Energy Regulatory Commission, the Electric Power Research Institute, the National Electrical Manufacturers Association, Grid Wise Architecture Council, Xcel Energy, the National Science Foundation, and the Edison Electric Institute.

The report discusses the fact that for the last several years, the International Organization for Standardization points out the electric power industry has joined with state and federal regulators, government agencies, and academics to grapple with updating an aging infrastructure. This report notes that the idea of a Smart Grid is plausible but that cohesive movement toward a Smart Grid faces significant challenges. Chief among them are the inability of the Federal Energy Regulatory Commission and the states to agree on allocating costs for Smart Grid investments across federally regulated transmission and state-regulated distribution systems, limited technology interoperability due to a lack of consistent standards and protocols, and varying descriptions of the Smart Grid caused by a lack of coordination among forums.

The authors agree that an evolutionary process will be required to achieve real-time distributed control of the electricity grid and the Smart Grid vision defined by the Energy Independence and Security Act of 2007. The report argues that the most urgent needs now are for educational programs, knowledge sharing, and close coordination among the parties that are creating Smart Grid policies, regulations, standards, and project plans. Information about real market impacts of the Smart Grid is sparse. New paradigms are being explored for utility cost recovery, the way clean power is bought and sold, and the market potential for electricity storage.

From regulators to consumers, everyone will be affected by evolution to a Smart Grid. According to the authors of this report, all involved will have to navigate solutions during this time of increasing electricity demand, the diminishing availability of fossil fuels, climate change, air emission regulations, and the incorporation of renewable power sources. According to this report, New England is already taking significant steps toward the Smart Grid by replacing remote intelligent gateway communications with standards-based equipment, installing Eastern Interconnect phasor management equipment, building capacity with demand-response resources, and employing the advanced grid simulator.

Right now, the report states, the end-state Smart Grid is still largely an abstract concept of what could exist. The need to accomplish Smart Grid objectives and obtain financial incentives in the form of federal dollars has captured the attention of academia, equipment manufacturers, software vendors, venture capitalists, and energy companies. The authors praise the U.S. Department of Energy for its 2004 "technology roadmap" that they perceive as still relevant for developing and implementing the Smart Grid.

Title of Report:	NETL Modern Grid Strategy Powering our 21st-Century Economy: Barriers to Achieving the Modern Grid
Organization:	National Energy Technology Laboratory
Date Published:	July 2007
Primary Focus Area:	Policy and Regulatory

Document Summary	
Technologies Included	Not addressed
Benefits Identified	Not addressed
Drawbacks/Obstacles	This report offers significant information relating to regulatory and legislative barriers, cultural and communication barriers, industrial barriers, and technical barriers for Smart Grid technology deployment. These obstacles are discussed more in-depth in the narrative below.
Costs	Not addressed
Research Methodology	Not addressed
"Smart Grid" Definition(s)	Not addressed
Regulatory Impacts/ Recommendations	The report argues that regulators and legislators should change or eliminate statutes, policies, and regulations that inhibit progress and create those that encourage progress and create a "win-win" scenario for all stakeholders. The report says that increasing the understanding and awareness of stakeholders on the value of the modern grid is

Document Summary	
	essential. The report also states that there needs to be an increase in the speed of research, development, and deployment of Smart Grid technologies.
Uncertainty Factors/Assumptions	Not addressed

This report focuses on the obstacles for Smart Grid deployment. The first obstacles discussed are policy and regulatory. The report finds that legislators and regulators have not yet taken an adequate leadership role in supporting Smart Grid technologies. The second obstacle is discussed in rate design. The report explains that current rate designs limit progress in grid modernization. For example, the report states that "real time rates that reflect actual wholesale market conditions are not yet widely implemented, preventing the level of demand side involvement needed in the Modern Grid."

Another example of a regulatory hurdle discussed in this report includes policies that penalize utilities for supporting and investing in modern grid technologies. The report explains that "from a strictly financial perspective, utilities are motivated to address system peak issues by investing in new generating facilities—which increases their revenue requirement—rather than supporting consumer-side demand response (DR) opportunities—which reduces their revenues."

Communications is another barrier discussed in the report, including a discussion of the fact that stakeholders do not currently see a "burning platform" or a case for change. The report says that "societal consequences of inaction (i.e., not modernizing the grid) have not been clearly articulated to our diverse group of stakeholders. A lack of understanding of the fundamental value of a modern grid, and of the societal and economic costs associated with an antiquated one, has created the misperception that today's grid is good enough or at least not worth the sacrifices involved in improving it."

The report presents a number of industry obstacles to furthering Smart Grid deployment. For example, business cases for investing in modern grid processes and technologies are often incomplete and therefore not compelling. The report explains, "It is often easier to demonstrate the value of the end point than it is to make a sound business case for the intermediate steps to get there. Societal benefits, often necessary to make investments in modern grid principles compelling, are normally not included in utility business cases."

There are many technical barriers relating to Smart Grid discussed in the report. For example, the report argues that there needs to be common standards and codes. The report says that "universal communications standards and a common architecture that promote interoperability and enable the various communication technologies to work as an integrated suite are needed. Interoperability will enable data from virtually any source to be utilized by virtually any application."

Peak Load Shaving

Title of Report: Grid Friendly Appliance Project
Organization: Pacific Northwest National Laboratory
Date Published: October 2007
Primary Focus Area: Peak Load Shaving

Document Summary	
Technologies Included	Frequency protection, energy management systems, under frequency, cold load pickup, advanced metering infrastructure, application-specific integrated circuit, load control module, phase lock loop, response time, demand response, and real-time price
Benefits Identified	Technical feasibility is not standing in the way of applying distributed, frequency-responsive appliance load controllers. Owners of the tested appliances, which included clothes washers and water heaters, accepted and were not inconvenienced by such control being applied to their home appliances. The projects' electronic controllers reliably recognized and responded to under frequency events. Utilities can save money with grid-responsive devices by displacing their need for expensive spinning reserves.
Drawbacks/Obstacles	More work is needed to develop a viable business case that is acceptable for utilities, appliance manufacturers, and appliance owners.
Costs	Not addressed
Research Methodology	This report describes the field demonstration of the grid-friendly appliance controller, an under frequency load-shed controller. The appliance includes monitoring and questionnaires. The Grid Friendly Appliance Project was part of the Pacific Northwest Grid Wise Test Bed Demonstration project managed by the Pacific Northwest National Laboratory (PNNL) from 2005 to 2007.
"Smart Grid" Definition(s)	PNNL follows the U.S. Department of Energy's Smart Grid definition. Electronic controllers are seen as an integral role as part of the Smart Grid.
Regulatory Impacts/ Recommendations	The report states that it is not yet clear if deployment of these and other smart technologies should be left to the market or mandated by utility commissions or other regulators. Also, questions remain about scalability and public policy.
Uncertainty Factors/Assumptions	Simulation and larger field demonstrations are needed to prove or disprove the hypothesis that an army of electronic controllers attached to appliances can protect system frequency, prevent actuation of substation under frequency relays, and displace much of the need for spinning reserves. Utilities pointed out isolated cases, such as during export periods, where they do not want the controller devices to trigger during an under frequency event.
Primary/Secondary Data Sources	Information was gathered from monitoring specific devices for a year and via surveying three utilities, an appliance manufacturer, and 200 participating residents. A reference list of 12 sources includes the Virginia Tech Bradley Department of Electrical and Computer Engineering and the IEEE.

Pacific Northwest National Laboratory collaborated with utilities to install a small electronic controller on 150 new clothes dryers and 50 retrofitted water heaters in households in Oregon and Washington. The effort tested the hypothesis that the controller could directly contribute to frequency protection on the grid. It performed comparably to what now happens at some substations where under frequency relays automatically react to shed the load of entire feeders when low-frequency thresholds are crossed. This can leave entire neighborhoods in the dark just to prevent widespread outages.

Residents, the appliance manufacturer (Whirlpool), and the three utilities—Bonneville Power Administration (BPA), PacifiCorp, and Portland General Electric (PGE)—involved in the project generated positive feedback. "BPA expected the grid friendly controllers to work," a Bonneville spokesperson said. "This part of the study essentially validated what BPA thought would be the case. BPA sees value in showing skeptics that these automatic responding devices work as intended." According to a PacifiCorp spokesperson, "The fact that utilities participated at all is a testimony to the interest and potential benefits the autonomous grid friendly under frequency controller has to offer."

Typical under frequency events were short during the test. The majority of events were 16 seconds long and the longest event was 10 minutes. The project experienced about one event daily during the course of the experiment, amounting to 358 total events. A survey revealed that no households were inconvenienced or even aware that their appliances were being affected. Curtailment of the 50 water heaters resulted in 5 kW to 35 kW of load reduction, and the 150 dryers resulted in 3 kW to 30 kW of load reduction, depending on time of day.

This report concludes that commercialization of appliance controllers requires more work to tie the economic benefits to implementation costs. Is it fair, the authors inquire, to ask an appliance manufacturer and its customers to pay for a hardware controller that provides a universal benefit to the entire power grid? The report suggests that a solution might require imposing mandatory or voluntary appliance standards to downplay implementation costs. Finally, the authors proposed that in addition to frequency, the controller should monitor voltage. The report also concludes that if communications are included, controllers also might become responsive to price and conventional demand response inputs so that the device serves as many grid protection and control functions as possible.

Title of Report:	Rethinking Governance and Energy Efficiency Policies Friendly Appliance: Load Management and Smart Grid
Organization:	Northwest Energy Efficiency Taskforce (NEET)
Date Published:	December 2008
Primary Focus Area:	Peak Load Shaving

Document Summary	
Technologies Included	Load management, rate designs (time-of-day, real-time pricing, critical peak pricing, demand buy-back), automatic meter reading, net metering, advanced metering infrastructure, and distributed energy generation
Benefits Identified	To coordinate load management and Smart Grid technologies in the Pacific Northwest, NEET suggests that representatives from the region's utilities, government bodies, and nonprofit sectors gather regularly for an allotted timeframe to share information and experiences about emerging technology and practices pertaining to load management and the Smart Grid. This would allow for a holistic and coordinated approach to these new technologies.
Drawbacks/Obstacles	Without a forum to coordinate load management/Smart Grid efforts, the area is left with no clear voice to advance the region's understanding of benefits, risks (i.e., impact on low-income residents), and costs associated with these technological changes.
Costs	Funding is mentioned but not addressed.

Document Summary	
Research Methodology	NEET's 15 members met weekly (for an unreported time period) to discuss collected materials regarding the current state of load management and Smart Grid, figure out if these ideas could contribute to efficiency, identify policy barriers, and make recommendations for action to its executive committee..
"Smart Grid" Definition(s)	Smart Grid is the convergence of digital information technology and the electrical power grid to enhance communications and control capacities.
Regulatory Impacts/ Recommendations	Northwestern states have thus far taken a piecemeal approach to implementing and planning for Smart Grid adaptations. NEET recommends that a regional group of stakeholders closely monitor regulatory activity so each state is updated and can participate in coordinated lobbying activities. The NEET team also considered supporting the possibility of a sales and use tax exemption on the purchase of Smart Grid technologies.
Uncertainty Factors/Assumptions	Would utilities, legislators, policy makers, regulators, nonprofits, and other specialists be willing to work together in a united fashion to benefit the region, or would they be content with a piecemeal approach where each state or utility acts independently?
Primary/Secondary Data Sources	NEET's 15 members collected reports and policies and surveyed utilities, regulators, and specialists from the province of British Columbia and state offices in Washington, Oregon, Idaho, Montana, and California.

The report's authors note that load management is already important in parts of the country that have faced capacity constraints far earlier than the Pacific Northwest. As the Northwest adds more intermittent resources and the hydroelectric system reaches the limit of its ability to provide large amounts of on-demand and extended capacity, load management will become increasingly important. The task force's goal was to meet weekly to figure out how Washington, Oregon, Idaho, Montana, and California could form a united front in helping utilities, regulators, policymakers, and utility customers adapt most efficiently to the intertwined technologies of load management and the Smart Grid.

The report argued that coordination and cooperation could significantly speed the region's realization of benefits from load management, impacts on low-income customers, and adoption of Smart Grid components, as well as lessen the chance of costly mistakes. To foster regional cooperation and coordination on a load management/Smart Grid initiative, NEET recommended that a group with at least one representative from each sector be formed to share information and experiences about emerging technology and practices; lead regional efforts on analysis and research value of capacity, reliability, and energy efficiency; assess and monitor the state of applicable regulations and legislation; and assemble and share information about the impacts these technologies and applications will have on low-income households. It was recommended that group members consider such specifics as the idea of offering a sales and use tax exemption on the purchase of Smart Grid technologies and studying the long-term value of automated metering infrastructure.

The authors recommended that the Northwest Power and Conservation Council join with the Northwest Energy Efficiency Alliance and Bonneville Power Administration to take a leadership role in guiding the region toward a cohesive plan for integrating load management with the Smart Grid. Regional investor-owned utilities, publicly owned utilities, regional stakeholders (e.g., low-income representatives), national labs, universities, large businesses, and technology centers should be invited to join the group because they could provide diverse viewpoints and promote broader acceptance.

Further, the authors said the group could agree on simple cost sharing for work beyond the time or experience capabilities of the in-house resources, such as detailed cost-benefit studies. Governing bodies, such as the state public utility commissions, public utility boards, and member organizations, and other state government agencies should request that the group provide an annual report of its activities, findings, and plans for the following year. The authors also advised that this group have a defined life (e.g., three years) and an obligation to poll whether it should continue thereafter before going further.

Metering Technologies and Other Technical Infrastructure Products and Services

Title of Report:	Assessment of Demand Response and Advanced Metering
Organization:	Federal Energy Regulatory Commission
Date Published:	December 2008
Primary Focus Area:	Metering Technologies and other Technical Infrastructure Products and Services

Document Summary	
Technologies Included	Advanced metering infrastructure (AMI), home area networks (HAN) and HAN controllers, and smart thermostats
Benefits Identified	Benefits include real bill savings, grid reliability and efficiency, more accurate electricity readings (AMI), and aid to customers in reducing their electricity consumption (demand response).
Drawbacks/Obstacles	Obstacles that are limiting customer participation in demand response programs include the fact that there are a limited number of retail customers on time-based rates. Other obstacles include the restrictions on customer access to meter data, the scale of financial investment required to deploy enabling technologies during an economic downturn, and the availability of only a limited variety of demand response programs that accommodate the operating needs of potential demand response providers.
Costs	A large fraction of AMI costs (ranging from 50% to 90%) can be justified by a reduction in traditional utility costs of operations or improved services, such as avoided meter-reading costs, faster outage detection, improved customer service, and better management of customer connections and disconnections.
Research Methodology	In preparing this report, FERC staff prepared and released the Demand Response and Advanced Metering Survey (2008 Federal Energy Regulatory Commission [FERC] Survey), and conducted analysis of the survey responses. Staff also gathered additional information by participating in a technical conference held in support of the Commission's rulemaking on wholesale competition in organized markets. They also reviewed the literature; interviewed key experts; and analyzed recent developments on advanced metering, demand response programs, and time-based rates.
"Smart Grid" Definition(s)	A Smart Grid implements demand response and advanced metering to increase efficiency and reliability of power supply.
Regulatory Impacts/ Recommendations	This report encourages current coordination with National Association of Regulatory Commissioners (NARUC) on finding demand response solutions; exploring how to remove barriers to the comparable treatment of demand response resources in wholesale markets; coordinating the Commission's National Assessment of Demand Response and National Action Plan for Demand Response efforts; supporting the efforts of organizations such as NERC, North American Energy Standards Board, and

Document Summary	
	EIA to develop practical means to measure, verify, forecast, and track demand response; and exploring possible linkages among demand response, energy efficiency, and Smart Grid programs.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	The primary source of data for this report was the Demand Response and Advanced Metering Survey (2008 FERC Survey).

The 2008 FERC Survey, on whose results this report was largely based, presented customers with two sections, one on demand response and one on advanced metering. The questions were mostly related to electricity consumption, advanced meter usage, and existing demand response programs.

The results indicate that about 8% of customers in the United States are in some kind of demand response program. Demand response resources played a critical role in ensuring the reliability of the electricity grid during periods of severe strain in the past year.

Research shows that demand response resources helped meet peak load in California, the Mid-Atlantic, and New York; helped respond to other system emergencies, including addressing sudden changes in generation output in Texas; and participated in capacity markets in the PJM Interconnection and ISO-New England.

This report briefly introduces each type of demand response program, reviews demand response trends and developments, and summarizes and analyzes the barriers to demand response identified from various sources. It also presents the second section of the survey on advanced metering, the use of advanced metering, the developments in advanced metering, and the challenges and issues for advanced metering.

The report maintains that the Commission should continue current coordination with NARUC on finding demand response solutions and continue exploring how to remove barriers to the comparable treatment of demand response resources in wholesale markets.

Title of Report:	Powering our 21st Century Economy: Advanced Metering Infrastructure
Organization:	National Energy Technology Laboratory
Date Published:	February 2008
Primary Focus Area:	Metering Technologies and other Technical Infrastructure Products and Services

Document Summary	
Technologies Included	Advanced metering infrastructure, automated meter reading, broadband over power lines, distributed energy resources, demand response, home area network, meter data management systems, mobile workforce management, outage management system, and smart meters

Document Summary	
Benefits Identified	For consumers, modern meters provide less intrusion and more choices about price, service, and how to manage consumption. The benefits to utilities are measured in billing and operations, including avoiding estimated readings, providing accurate and timely bills, operating more efficiently and reliably, and offering better consumer services. For society, the benefits include improved efficiency in energy delivery and use, accelerated use of distributed generation, demand response, and innovative energy tariffs. Also, modern meters make inaccurate measurements, incorrect installations, and energy theft easier to identify.
Drawbacks/Obstacles	Obstacles include business case limitations, depreciation rules, standards, rate designs, consumer education, technical staffing resources, regulatory barriers, financial constraints, and technology hurdles.
Costs	$26 billion for full advanced metering infrastructure deployment
Research Methodology	The authors harvested information from various papers, reports, and presentations. This report is one of several separate papers supplementing “A Systems View of the Modern Grid,” an overview by the Modern Grid Initiative team.
“Smart Grid” Definition(s)	The Smart Grid motivates and includes the consumer, accommodates all generation and storage options, enables markets, provides power quality for 21st century needs, resists attack, self-heals, optimizes assets, and operates efficiently.
Regulatory Impacts/Recommendations	Overlapping federal, regional, state, and municipal agencies creates an impediment: industry neither fully regulated nor completely deregulated. State commissioners need to consider faster regulatory depreciation of existing meters and metering systems.
Uncertainty Factors/Assumptions	Will the utility industry and regulators be able to accurately communicate the full benefits of an advanced metering infrastructure to consumers and society at large?
Primary/Secondary Data Sources	Information gathered from a bibliography of 11 sources that include an IBM white paper, the Federal Energy Regulatory Commission, and the Edison Electric Institute.

“America’s grid, once the envy of the world, has lost that premier status,” the paper’s authors declare, adding that nationwide adoption of AMI is crucial to regaining that status. AMI is not a single technology, but rather an integration of smart metering, home area networks, integrated communications, data management applications, and standardized software interfaces that provides an intelligent connection between consumers and system operators.

To make the business case for AMI more compelling than the traditional option, the report’s authors suggest using a seven-part, more expansive framework proposed by Levy Associates that weighs financed or outsourced options; focuses on system-wide net benefits; folds metering into an integrated suite of utility applications; and also considers customer impacts, demand response, innovative pricing, and new customer service and revenue. The Brattle Group estimates nationwide deployment of AMI to cost about $26 billion, with utility operational savings covering between 50% and 80% of this cost. That 2007 presentation figures a long-run generation, transmission, and distribution system capital savings of $35 billion, along with an additional $5 billion to $10 billion annually in reduced electricity prices. Using an average of 65% for utility operational savings as an expected value (about $16.9 million), the remaining cost to be justified is $9.1 billion (0.35 x $26 billion). As the long-run savings in capital investment is $35 billion, the benefit-cost ratio is about 4:1. Reduced electricity costs make the case more compelling.

According to the report’s authors, AMI deployment approaches will depend upon the utility’s starting point, geography, regulatory situation, and long-term vision. Pilot programs that explore the performance of various solutions can be useful as the first deployment phase. AMI is the gateway to four major modern grid milestones. The other three are advanced distribution operations, advanced transmission operations, and advanced asset management.

When AMI serves as a modern grid platform, it can offer additional benefits, the authors indicate. For instance, a ubiquitous AMI communications network could be designed to accommodate transmission and distribution automation systems. That could create an opportunity to use excess bandwidth to provide broadband services such as Internet access and voice over Internet protocol to consumers. The Electric Power Research Institute estimates that a 4:1 total benefit-to-cost ratio is realized when enhanced functionality can be achieved by using AMI as a springboard to a fully enabled Smart Grid. Other benefits of AMI include an improved outage management system through links with GIS and real-time consumer status, improved equipment health assessment and condition-based maintenance, and improved mobile workforce management and operations

Data Acquisition Technologies and Products

Title of Report:	Smart Transmission Grid Applications and Their Supporting Infrastructure
Organization:	Washington State University
Primary Focus Area:	Data Acquisition Technologies and Products

Document Summary	
Technologies Included	Phasor data concentrator; SCADA; real-time, automatic generation control; synchrophasors; digital fault recorders (DFR); sequence of event (SOE) recorders; intelligent devices; voltage-VAR control; voltage stability control; small signal stability control; transient stability control; fast controllers, i.e., Flexible AC Transmission Systems (FACTS) devices; and wide-area controls
Benefits Identified	According to this report, implementing transmission applications will lead to the launch of a smarter, more secure, more reliable grid. The promise of new and improved applications to operate the power system more reliably and efficiently and the ability to handle real-time data are other benefits.
Drawbacks/Obstacles	A major obstacle is that actual applications have been slow to emerge. Another obstacle is that the financial support needed far exceeds the investment that stakeholders and industry have been historically willing to make.
Costs	Not addressed
Research Methodology	Not specified
"Smart Grid" Definition(s)	A Smart Grid is generally characterized by more sensors, more communication, more computation, and more control, but also needs a newly designed architecture.
Regulatory Impacts/Recommendations	This report recommends that any future design of the data architecture be highly distributed, thus also distributing the functionality of the new functions/applications. The report points out that in such a distributed architecture, the overview of the whole interconnection, which does not exist today, is only a natural extension.
Uncertainty Factors/Assumptions	This report assumes that the latest technologies of computers and communications will be ubiquitously available at all high-voltage substations at very high rates.

Document Summary	
Primary/Secondary Data Sources	Not addressed

This report discusses transmission applications for the success of the Smart Grid and their impacts on data management, real-time operation, as well as subsequent decision-making. It maintains that the emergence of new technologies will foster the use of these transmission applications.

For example, synchronized phasor measurements, which measure instantaneous values of voltages and currents with very accurate time stamping, have become economical for widespread installation. Although the potential for using this data appears to be large, actual applications have been slow to emerge due to the lack of an adequate infrastructure to collect, move, and analyze the data. Phasor measurements have also given rise to the possibility of two categories of new and improved applications. The first is wide-area control, which is in the same family as all existing automatic control and protection. Synchronized measurements and fast communication now make it possible for such control to be wide-area or regional. The other category affected by synchronized measurements is enhanced control center functions, with special attention to the state estimator. These are for the system operator to monitor the power system and make operational changes.

Most of the transmission applications presented in this report are dependent on transitioning to the architecture recommended for the Smart Grid. This architecture assumes a significant infusion of new measurement (synchrophasors) and communications and control devices (Flexible AC Transmission Systems). The report predicts that it will be a gradual process, implemented over many years because of the costs involved. Another factor affecting the amount of time it will take to implement the configuration is the fact that the system has to be fully operational during the transition.

This report concludes that a design with more sensors, more communication, and more computers is needed. After a general configuration is implemented, applications can be enhanced and new applications developed that will make the operation of the grid more secure and reliable. Finally, a systematic plan of transition from the present grid to the Smart Grid can be organized. The only significant obstacle, according to the report’s authors, is aggregating the component technologies into a coherent whole and transitioning from the present technologies to the new ones. Technically, the resources are available; however, financially, the value of a more secure Smart Grid must be realized before the appropriate investments can be made.

Title of Report:	2004 National Electric Delivery Technology Roadmap
Organization:	The U.S. Department of Energy
Date Published:	January 2004
Primary Focus Area:	Data Acquisition Technologies and Products

Document Summary	
Technologies Included	Advanced conductors; high-temperature superconducting materials and equipment; large- and small-scale electric storage devices, distributed sensors, intelligence, smart controls, and distributed energy resources; power electronics; and real-time monitoring
Benefits Identified	The benefits of the modern grid include increased efficiency and reliability, which will prevent power outages. It will provide economic and national security, as well as a clean, affordable, environmentally friendly source of power.
Drawbacks/Obstacles	The most urgent challenge is a lack of progress in critical technology and techniques. For example, advanced conductors, electricity storage, distributed intelligence, smart systems, controls, and distributed energy resources are critical technologies necessary to deploy the Smart Grid vision. Educating energy policy officials on the structural improvements to utility regulations is needed to uncover consumer benefits.
Costs	Not addressed
Research Methodology	The roadmap is based on the conclusions and suggestions of 250 electric industry professionals present at the National Electric System Vision Meeting on April 2 and 3, 2003, and the National Electric Delivery Technologies Roadmap Workshop on July 8 and 9, 2003.
"Smart Grid" Definition(s)	A Smart Grid is the combined effort of government, industry, and consumers to achieve the milestones that will lay the foundation for an enhanced electricity delivery infrastructure. It will be implemented when the grid architecture is designed, critical technologies are developed and accepted, electricity market operations are strengthened, and public-private partnerships are forged.
Regulatory Impacts/ Recommendations	This report recommends a variety of ways to foster the development of the five steps identified on the roadmap as crucial to the deployment of a modern grid. For each step, it presents the targets, challenges, and steps to deployment.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report provides an organizing framework to address the steps needed for implementing a modern grid. It outlines the key issues and challenges for modernizing the grid. Furthermore, it also serves as an action agenda for moving forward with Smart Grid development and implementation.

There are fundamental steps that need to be executed before our national electricity delivery system can transform into the modern grid vision. According to the roadmap, the first step is to design "Grid 2030" architecture to ensure grid flexibility, reliability, and cost effectiveness.

According to the report, R&D for critical technologies must accelerate, as well as the industry acceptance of those technologies. Also, there is a need for an assessment of market operations and an evaluation for how transactions can acquire lower financial risks. Lastly, building public-private relationships will allow the coordination of research and development efforts to make progress.

This report thoroughly outlines each of the five steps, presenting separate roadmaps outlining the targets, challenges, and strategies for research, development, and deployment. It recommends paths for the public and private sectors to work independently while also being able to coordinate their research efforts toward a common goal: the deployment of the modern grid.

Title of Report:	A Systems View of the Modern Grid: Integrated Communications
Organization:	National Energy Technology Laboratory
Date Published:	February 2007
Primary Focus Area:	Integrated Communications as a Foundation

Document Summary	
Technologies Included	Substation automation, advanced metering infrastructure, automatic meter reading, broadband over power line, distribution automation, distributed energy resources, demand response, and supervisory control and data acquisition
Benefits Identified	The grid can self-heal by detecting, analyzing, and responding autonomously to adverse trends and conditions; it enables more reliable dispatch of centralized generation, distributed energy resources, and demand response; the grid is protected from cyber and physical threats; and it will allow wider use of wind, solar, geothermal, and other cleaner power sources. Economic benefits include decreased costs and increased revenues, major long-term investments become more cost effective, and the need for costly hard assets will lessen.
Drawbacks/Obstacles	Two obstacles cited are the lack of industry vision and lack of understanding about the benefits. Other barriers include stakeholders not identifying clearly defined architecture; authorities not setting regulations or incentives; consumer education not yet being deployed; and vendors being reluctant to invest in technology until universal standards are adopted.
Costs	Not addressed specifically but labeled as expensive.
Research Methodology	Information was gathered from various reports, articles, and papers. This report supplements "A Systems View of the Modern Grid," an overview by NETL's Modern Grid Initiative team.
"Smart Grid" Definition(s)	The report implied that it followed the definition of Smart Grid presented by the U.S. Department of Energy.
Regulatory Impacts/ Recommendations	More regulations and legislation such as the Energy Policy Act of 2005 are needed as a catalyst for technology development; regulatory and policy-setting bodies have not yet provided regulations to ensure that investments in new technologies will not lead to losses.
Uncertainty Factors/Assumptions	Will energy consumers, companies, and vendors be willing to buy into technology that does not yet have a clear blueprint laid out?
Primary/Secondary Data Sources	Information was gathered from a bibliography of eight sources that includes the Electric Power Research Institute, the California Energy Commission, and Carnegie Mellon Electricity Industry Center.

The report's authors take the electric utility to task for lagging behind other industries that have already taken advantage of the recent and enormous strides in communication technology. Integrated communications is part of a foundation for a Smart Grid because it is an open architecture that supports plug-and-play interoperability. It is essential to modernizing the grid because it is the linchpin of the five key technologies cited as essential if the grid is to be modernized. An upgraded communications system links the other four key technologies:

advanced control methodologies; sensing, metering, and measurement; advanced grid components; and decision support and improved human interfaces.

"Due to its dependency on data acquisition, protection, and control, the modern grid cannot exist without an effective integrated communications infrastructure," the report states. "Establishing these communications must be of highest priority since it is the first step in building the modern grid." Integrated communications will create what the report's authors refer to as a dynamic and interactive mega-infrastructure for real-time information and power exchange. This allows users to interact with various intelligent devices in an integrated system.

The report emphasizes two important reasons for establishing technical requirements and standards for the system: 1) because various utility applications have different demands and 2) because widespread deployment of communications media technologies will be delayed unless the development of universal standards is accelerated. "Until these universal standards are set for the various functionalities required by the Smart Grid, investors will be reluctant to invest, and lack of funding will severely limit attainment."

The authors advise to hasten the widespread deployment of an integrated communications system center around energy consumers, energy companies, and vendors. Energy consumers who understand real-time pricing will be motivated to demand an integrated communications system that supports their ability to manage energy consumption. If energy companies see the benefits of improved reliability, reduced cost, and increased revenues, they will prod authorities for universal standards that allay the natural fear of stranding large investments because of changes in technology. Company executives need to see regional and national demonstrations of these technologies. Vendors will be motivated to invest in new products when they have demand from consumers and energy companies.

Title of Report:	A Systems View of the Modern Grid: Sensing and Measurement
Organization:	National Energy Technology Laboratory
Date Published:	March 2007
Primary Focus Area:	Data Acquisition Technologies and Products

Document Summary	
Technologies Included	Broadband over power line, demand response, supervisory control and data acquisition, wide area monitoring system, advanced meter reading, load control, local home network, dynamic line rating, conductor/compression connector sensor, insulation contamination leakage current sensor, backscatter radio technology, electronic instrument transformer, phasor measurement unit, and line sag monitors
Benefits Identified	Meter transformation will let consumers make informed usage decisions, have a real-time connection to the electricity market, participate in that market, and reduce energy costs. Utilities will gain greater load control, reduced operational costs, congestion relief, and reduced energy theft. Data collection and control instrumentation also will be enhanced by allowing for real-time contingency analyses; demand-response tools; and advanced monitoring, control, and protection systems.
Drawbacks/Obstacles	According to this report, private industry has been reluctant to invest in costly, long-term developments and federal and state funds needed to augment investment have been very limited. In addition, there is a lack of understanding of the value of a modern

Document Summary	
	grid and societal costs of an antiquated grid have created the impression that the current grid is “good enough.”
Costs	Labeled as “high” but not specifically defined
Research Methodology	The authors of this report harvested information from various papers, reports, and presentations. It is one of several separate papers supplementing “A Systems View of the Modern Grid,” an overview by the Modern Grid Initiative team.
“Smart Grid” Definition(s)	The authors implied that this report follows the definition presented by the U.S. Department of Energy.
Regulatory Impacts/ Recommendations	Customer metering and tariffs determining what customers pay for electric power fall under the purview of state regulatory bodies. Regulators need to support and encourage this metering transformation. Regulators need to be change agents that encourage, support, and increase research and development in the utility sector.
Uncertainty Factors/Assumptions	Will regulators, utilities, vendors, and policymakers have the foresight and ability to fund and coordinate Smart Grid technology that will benefit the economy? Will prices for sensing and measurement technologies become more competitive?
Primary/Secondary Data Sources	Information was gathered from a bibliography of 10 sources that includes the California Energy Commission, Schweitzer Engineering Lab, and IEEE *Power and Energy* Magazine.

This report emphasizes that an unintended consequence of restructuring in the electric power industry is a major reduction in research and development. Breakthrough technologies such as advanced monitoring systems have lost their appeal because they are frequently more costly. Early on, engineering-oriented power industry managers with long views created a world-class grid. Today’s business-oriented managers, however, have adopted a shorter-term perspective, according to the report. This deficit can be overcome, say the report’s authors, because economic projections are favorable and core measurement technologies (communications and information) are now within practical reach. In addition, the regulatory impetus provided by legislation such as the Energy Policy Act of 2005 could make extensive advanced sensing and measurement technologies commonplace a decade from now.

Successfully realizing sensing and measurement technologies requires the following: the broad development and deployment of supporting communication technologies such as broadband over power line and wireless, user-friendly customer interfaces and agents, tariffs effective from the utility and consumer perspective, low-cost sensing and measurement techniques and central information technology systems to process and analyze the large volume of collected data, and more proof-of-concept benefits to consumers and energy companies. Numerous advanced sensing and measurement technologies are available today that could have a major impact on modernizing the grid. However, the high cost to produce, install, and maintain these technologies have hindered their adoption. Included among these technologies are advanced communicating revenue meters, consumer portals and agents, major equipment health monitors, electronic instrument transformers, phasor measurement units, and line sag monitors. The report predicts that broader deployment will happen as technical performance is proven, costs drop, and societal value is recognized. The authors contend that government must ensure that the proper value is placed on these extended societal benefits.

Several other components that will have a major impact on upgrading sensing and measuring technologies are still in the research and development stage. These advances include wide-area monitoring systems, advanced low-cost communicating transmissions and distribution sensors, electromagnetic interference detectors, and sag monitors using a global positioning system.

"The full integration of multiple key technologies must occur before the complete modern grid vision can be realized, and this could take 10 to 15 years or more," the report states. "As these technologies are being incorporated into the power grid, many other synergies … will surface. For example, the implementation of integrated communications, advanced control methods, sensors and measurements, and advanced components will allow a new series of special protective systems that can be customized to a region's unique characteristics."

Title of Report:	[NETL Modern Grid Strategy Powering our 21st-Century Economy: A Compendium of Modern Grid Technologies]
Organization:	National Energy Technology Laboratory
Date Published:	June 2007
Primary Focus Area:	Data Acquisition Technologies and Products

Document Summary	
Technologies Included	This report is a 33-page "living compendium" covering the scope of Smart Grid technologies in the categories of integrated communications, advanced components, advanced control methods, sensing and measurement, and improved interfaces and decision support as of the date of publication. It includes notes about time-to-market use in years for each technology.
Benefits Identified	Technologies from five key technology areas—integrated communications, advanced components advanced control methods, sensing and measurement, improved interfaces, and decision support—can help the current grid evolve to a Smart Grid that is reliable, secure, cost effective, efficient, safe, and environmentally responsible.
Drawbacks/Obstacles	No specifics addressed.
Costs	Costs are addressed for some technologies but not for others.
Research Methodology	The authors harvested information from various papers, reports, and presentations. This report is based on website searches and interviews with industry, government, and academia experts. This compendium supplements "A Systems View of the Modern Grid," an overview by the Modern Grid Initiative team.
"Smart Grid" Definition(s)	The report implies that the authors followed the definition presented by the U.S. Department of Energy.
Regulatory Impacts/Recommendations	Not addressed
Uncertainty Factors/Assumptions	How long will it take for all of these technologies to be developed and deployed, and will they live up to their expectations?
Primary/Secondary Data Sources	Information was gathered from an extensive reference list that includes research from the U.S. Department of Energy, Tennessee Technology University, North Carolina State University Power Electronics Center, Vanderbilt University, dozens of websites, and interviews with field experts.

"Key technologies will fuel the development of the modern grid," this report notes. "Many of the required technologies are available today. Others are in various stages of development, and are expected to contribute to grid modernization by the end of this decade. Undoubtedly, still others residing in the minds of engineers and inventors will be revealed in the years ahead, particularly as the momentum for modernizing the nation's electric system grows."

The authors intended this report to provide interested parties with an inventory of technologies for each of the five key technology areas needed to support a vision for the modern grid. The 33-page "living compendium," with four columns labeled "title," "time to market use in years," "brief description from cited reference," and "references," will be updated periodically. As technologies will continue advancing, the listed references are referred to as starting points only.

Economic Impacts from a Smart Grid

Title of Report:	Wired for Progress: Building a National Clean-Energy Smart Grid
Organization:	Center for American Progress
Date Published:	February 2009
Primary Focus Area:	Economic Impacts from a Smart Grid

Document Summary	
Technologies Included	AMI, advanced home appliances, end-use technologies, real-time, smart meters, extra-high-voltage electricity transmission upgrades, energy storage, PHEV, large-scale renewable generation, demand response
Benefits Identified	Implementing a national electricity delivery infrastructure will reap a variety of benefits such as increased security, reliability, and efficiency, well paying jobs for our economy, positive effects on climate change and global warming, and increased use of renewable sources of energy.
Drawbacks/Obstacles	The greatest obstacle to Smart Grid implementation is the hindrance of Smart Grid technology deployment. This is caused by decisions being made by regulatory agencies that are not fully informed on the costs and benefits of Smart Grid investments, prohibitive up-front costs, and the fact that the benefits are not fully clear.
Costs	Smart meters, the most commonly discussed Smart Grid technology, cost about $250 per meter installed. Based on the fact that there are approximately 140 million residential and small-business electricity customers in the United States, the total cost for full deployment of digital smart meters would be approximately $35 billion. Another $7 billion would be needed for additional investments in distribution grid automation.
Research Methodology	This report utilizes research from papers, federal statutes, selected legislation, federal hearings, and a selection of reports from FERC, DOE, and various stakeholders.
"Smart Grid" Definition(s)	A Smart Grid must consist of two distinct components: 1) a "sustainable transmission grid" that will transport clean utility-scale renewable energy long distances to market and 2) a digital "smart distribution grid" to deliver this electricity efficiently to local consumers.
Regulatory Impacts/ Recommendations	This report recommends four steps for implementing a Smart Grid. These steps are to build a framework for collaborative multi-state planning, to create a stronger proposal for siting new transmission projects, to have the government implement a fair cost allocation to ensure that no single region bear the cost of a national undertaking, and to make Smart Grid investments and standards to deploy new information technology, controls, and AMI on the transmission and distribution grid.
Uncertainty Factors/Assumptions	Not Addressed

Document Summary	
Primary/Secondary Data Sources	Not addressed

This document states that a Smart Grid will help improve the fragile condition of the United States economy. Implementing a Smart Grid will bring about well paying jobs, prepare for the low-carbon energy, and present new opportunities for innovation and improved productivity.

"Today, we import nearly 70 percent of our oil—at a cost of $478 billion dollars in 2008 alone—representing a major contribution to our national trade imbalance," the report quotes as a way to emphasize how our nation depends on foreign oil. What is the answer? How can the United States get back on its feet as the number one sovereign superpower of the world? The report says that the answers to these questions lay in our energy system, specifically our electricity transmission and distribution grid. Largely unchanged in generations, the report states that the United States is using yesterday's technologies to power an increasingly global 21st-century economy.

The report claims that investments in our electric grid system can no longer keep up with our ever-changing economy. Our current electricity grid's inability to integrate new information technology has characterized it as inefficient, insecure, and unreliable. Therefore, the authors argue that the United States needs to reinvigorate its energy system by building a national clean-energy Smart Grid, which will create new markets, foster new businesses and business models, put people back to work in construction and manufacturing, and lay the foundation for long-term, sustainable economic growth.

This report utilizes research from a variety of sources to explain how a national clean energy grid will put our economy back where it needs to be. It demonstrates how the implementation and utilization of a Smart Grid will require a revolutionary action plan when it comes to transmission and distribution.

Lastly, this report recommends action items for the plan to implement a Smart Grid. These recommendations are made within the context of focusing on transmission and distribution. They include creating a stronger proposal for siting new transmission projects and making smart-grid investments and standards to deploy new information technology, such as AMI and demand response.

Title of Report: [Smart Grid: Enabler of the New Energy Economy]
Organization: Electricity Advisory Committee
Date Published: December 2008
Primary Focus Area: Economic Impacts from a Smart Grid

Document Summary	
Technologies Included	Some of the many technologies mentioned include smart meters, programmable thermostats, energy storage, real-time pricing, and fault location and analysis. For a total list, see page B-3.

Document Summary	
Benefits Identified	This report cites evidence from the Galvin Electricity Initiative by stating that "Smart Grid technologies would reduce power disturbance costs to the U.S. economy by $49 billion per year. Smart Grids would also reduce the need for massive infrastructure investments by between $46 billion and $117 billion over the next 20 years." In addition, it explains that "widespread deployment of technology that allows consumers to easily control their power consumption could add $5 billion to $7 billion per year back into the U.S. economy by 2015, and $15 billion to $20 billion per year by 2020."
Drawbacks/Obstacles	The report explains that financial, operational, and experiential rewards for first adopters are not generally recognized by many electric industry stakeholders. In addition, existing electric rate structures create further complications.
Costs	This report explains that a Smart Grid is "a significant undertaking that needs focused coordination both strategically and tactically. This undertaking also will require significant investment. Investors often face the challenges of access to capital to make these investments, as well as the lack of ability to bear the associated costs of the expenses. Utilities must grapple with making Smart Grid investments, knowing that significant utility and consumer benefits may not occur for several years."
Research Methodology	This report was developed through a process carried out in 2008 by the Electricity Advisory Committee. The members of the Electricity Advisory Committee represent a broad cross-section of experts in the electric power arena, including representatives from industry, academia, and state government.
"Smart Grid" Definition(s)	Smart Grid is defined as a broad range of solutions that optimize the energy value chain.
Regulatory Impacts/ Recommendations	This report has numerous policy recommendations: create a Smart Grid program office within DOE; develop a roadmap by December 2009 for the achievement of a coordinated nationwide cost-effective deployment of Smart Grid technologies; request that Congress appropriate the funds needed for the Smart Grid Regional Demonstration Initiative and the Smart Grid Investment Matching Grant Program authorized under Energy Independence and Security Act (EISA) of 2007; request that Congress provide the National Institute of Standards and Technology with the funds to coordinate the development of a framework as defined in Section 1305 of EISA 2007; develop, manage, conduct, and communicate appropriate R&D and deployment projects to identify and prove next steps, consistent with the roadmap, and direct the Smart Grid Regional Demonstration Initiative and Matching Grant Program as authorized in EISA 2007; conduct a focused U.S. Department of Energy education campaign that would focus on educating consumers on the cost of energy and how those costs can be better managed; and establish a Smart Grid engineer and technician development program that encourages students to pursue Smart Grid-related technical degrees.
Uncertainty Factors/Assumptions	This report states that Smart Grid interoperability will require interoperability among the many technology components involved. New solutions must also be configured to exchange information with legacy systems, including existing back office systems and other systems that need to be connected.
Primary/Secondary Data Sources	Many of the sources include the U.S. Department of Energy and numerous utilities such as Austin Energy and Southern California Edison.

This report discusses both the opportunities and challenges the United States faces in its journey to being a 21st century electrical system. The report provides numerous benefits of moving to a more "intelligent grid" for both utilities and consumers.

This report highlights reduced carbon emissions as a benefit of a Smart Grid. A Smart Grid will be able to leverage demand response and load management to minimize the use of costly peaking generation, which typically uses generation that is comparatively fuel inefficient.

In addition, the report discusses consumer attitude as an obstacle to deployment. The report explains that “intellectually, Americans can welcome a Smart Grid because it offers more efficient use of resources, while maximizing electricity services. However, in order for the typical consumer to accept and embrace the transformation to a Smart Grid, utilities and policymakers must communicate the benefits effectively to the public. Consumer benefits need to be defined and advocated by utilities and policymakers alike across all economic levels in order to overcome this hurdle.”

This in-depth report also outlines how interoperability standards must be created to allow different technologies to operate with each other. In addition, the report says that new solutions must be created so that new technologies can also communicate with legacy systems.

Title of Report:	The Emerging Smart Grid
Organization:	Global Environment Fund
Date Published:	October 2005
Primary Focus Area:	Economic Impacts from a Smart Grid

Document Summary	
Technologies Included	Some of the many technologies mentioned include advanced meters, advanced sensors and monitors, distribution automation, outage and workforce management, power systems monitoring and control, and electric storage.
Benefits Identified	This report states that “Smart Grid technologies would reduce power disturbance costs to the U.S. economy by $49 billion per year. Smart Grids would also reduce the need for massive infrastructure investments by between $46 billion and $117 billion over the next 20 years.” In addition, it explains that “Widespread deployment of technology that allows consumers to easily control their power consumption could add $5 billion to $7 billion per year back into the U.S. economy by 2015, and $15 billion to $20 billion per year by 2020.”
Drawbacks/Obstacles	This report describes interoperability as a major obstacle. “Today, the electric infrastructure is made up of islands of proprietary technology and (literally) hundreds of conflicting protocols.” As a result, utilities pay higher prices for equipment, for custom engineering, and for “translation” services. At the same time, they have fewer choices than they would in a standards-based world. Standards are not a panacea, but they do give customers a greater choice of vendors and migration paths. For representative standards initiatives, see page 13.
Costs	Not addressed
Research Methodology	This report leans heavily not only on the research, interviews, and surveys conducted by the Center for Smart Energy itself, but also on dozens of grid-related research reports and white papers produced over the past decade by national laboratories, industry research alliances, consumer and industry groups, economists, scientists, environmental groups, and many others.
“Smart Grid” Definition(s)	The Smart Grid is the application of digital technology to the delivery segment. More specifically, it is the use of computers, electronics, and advanced materials to modernize and optimize the electric power infrastructure.

Document Summary	
Regulatory Impacts/ Recommendations	This report claims that there are significant regulatory barriers. "The U.S. is a confusing patchwork of overlapping federal, regional, state and municipal agencies. Large projects may require approvals from dozens of different bodies, any one of which can stall the process. To make matters worse, the industry is neither fully regulated nor completely deregulated. Without clear rules, investors and entrepreneurs often hold back. In addition, current ratemaking structures make it difficult to roll out new technologies. Put in place in the middle of the last century (or even earlier), they reward investor- owned utilities for building new power plants but not for energy efficiency, demand response or grid automation. Utilities that install energy-saving systems can see their sales drop without any offsetting benefit to the utility and its shareholders."
Uncertainty Factors/ Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report outlines different phases of Smart Grid rollout from innovation to acceptance. For example, in phase 2, which it classifies as "Standards Development," the report notes that the key grid standards bodies include IEEE and ASME and notes that regulators should establish working groups to sort out the emerging standard. The report provides an overview of three leading vendors: Siemens, ABB, and GE.

This report states that there are technology hurdles to overcome for widespread Smart Grid deployment. "Some Smart Grid technologies have been tested in the labs but not proven in the field or in systems configurations, something that is essential to the ultra-cautious buyers described above. The electric power industry spends far less than other industries on research, development and deployment. This issue is made worse by a shortage of architectural standards, test beds, and modeling tools and by the fact many utilities have 'not investigated-here' syndrome, refusing to accept test results unless performed on their own systems."

The report also details how a Smart Grid rollout might impact different utilities. It examines investor-owned utilities, publicly owned utilities, rural cooperatives, transmission organizations, and public agencies. For example, the report finds that public agencies such as Bonneville Power Authority and the Tennessee Valley Authority have "large control centers and own significant transmission assets. In some cases, they are responsible for both transmission and distribution. They can be very influential—even dictatorial—about standards and technology choices."

Title of Report:	A Systems View of the Modern Grid: Optimizes Assets and Operates Efficiently
Organization:	National Energy Technology Laboratory
Date Published:	January 2007
Primary Focus Area:	Economic Impacts from a Smart Grid

Document Summary	
Technologies Included	Sensors, intelligent electronic devices, substation automation, real-time dynamic rating,

Document Summary	
	and advanced monitoring
Benefits Identified	This report outlines economic benefits of Smart Grid deployment. "Asset optimization has the opportunity for gaining economic benefits because greater power densities can be attained using the same existing assets. In an energy market, this increase in utilization increases revenue for the asset owner, and at the same time lowers energy costs for load-serving entities. This win-win scenario offers economic incentive to both asset owners and users of energy." Another benefit this report outlines relates to reliability. "The use of advanced monitoring technologies will provide the information for asset management programs to realize substantial cost savings through improvements in reliability. The detailed awareness of component and equipment condition reduces human errors in performing maintenance, and helps to avoid outages for unnecessary maintenance."
Drawbacks/Obstacles	According to this report, obstacles to Smart Grid deployment include a weak business case for the quantity of required sensors and their attendant communications infrastructure, as a result of the large financial investment needed. The report claims that the weak business case derives from the large financial investment necessary because of the quantity of sensors required for project deployment. In addition, it explains that there may be incompatible equipment for different Smart Grid infrastructure. "Some of the older equipment types do not have the embedded sensors to enable a predictive methodology, and in some cases, it may not be cost-effective to install it. With a mix of some automated maintenance equipment and some manual maintenance equipment, the benefits are diluted, further weakening any business case."
Costs	Not addressed
Research Methodology	Not addressed
"Smart Grid" Definition(s)	Not addressed
Regulatory Impacts/ Recommendations	This report outlines a number of recommendations. The first recommendation is to "develop investment criteria that acknowledge the systems view of the modern grid and its long-term benefits to the national economy." A second recommendation is to "provide incentives to replace older equipment with equipment designed to operate in a 21st century communication and information system infrastructure."
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report outlines the benefits and barriers of a Smart Grid and how they relate to asset operations and provides recommendations. The authors claim that using information from Smart Grid applications can reduce the cost of electricity transmission and distribution. The report finds that "whether optimizing assets or operating efficiently, information is the key. Gathering that information is one challenge for the modern grid, communicating it widely is a second, and processing it usefully is a third."

This report details how Smart Grid technology could become useful in optimizing the grid's infrastructure to make it more economical for utilities and consumers. It states that "unlike today's grid, the modern grid will apply the latest technologies to optimize the use of its assets. For example, optimized capacity can be attainable with dynamic ratings, which allow assets to be used at greater loads by continuously sensing and rating their capacities."

The report also claims that "as modern grid sensors provide more data, asset planning is also optimized. The optimization in planning occurs in the selection and timing of the installation of new assets. Using the data from all grid sensors, planners can decide more economically when, where, what, and how to invest in modern grid improvements."

Power Quality Technologies and Issues

Title of Report:	A Systems View of the Modern Grid: Provides Power Quality for 21st Century Needs
Organization:	National Energy Technology Laboratory
Date Published:	January 2007
Primary Focus Area:	Power Quality Technologies and Issues

Document Summary	
Technologies Included	Power quality (PQ) meters; system-wide PQ monitoring; grid-friendly appliances such as compressors and heating elements, storage devices, superconducting magnetic energy storage (SMES), and advanced batteries; power electronic devices; distributed generation devices; and sensing and measurement technologies
Benefits Identified	Avoiding the productivity losses of poor quality power to commercial and industrial customers can shed billions of dollars of waste from the economy. Improving PQ in the nation's power system will offer opportunities to broaden and enrich the commercial bases of struggling communities and regions.
Drawbacks/Obstacles	Challenges include the high costs of modern PQ-enhancing devices, the lack of policies and regulations to encourage investment in PQ programs, and the fact that codes and standards need to be updated.
Costs	Not addressed
Research Methodology	The research methodology for this report is unspecified; however, it is noted that although it can be read on its own, it supports and supplements "A Systems View of the Modern Grid," an overview prepared by the Modern Grid Initiative team.
"Smart Grid" Definition(s)	A Smart Grid will enhance power quality; deliver grades of power from standard to premium, and, with advanced sensing and measuring technologies, provide the ability to price the varying levels accordingly; and help to provide power quality for 21st century needs.
Regulatory Impacts/ Recommendations	The report recommends that PQ solutions be tailored to the differing requirements of customers, the presence of government leadership to hasten an answer to the question of who owns the PQ problem, and the implementation of programs to provide PQ education.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This paper provides a look at how the modern grid will help to provide power quality for 21st century needs. The paper asserts that a Smart Grid supplies varying grades of power and supports variable pricing accordingly. It supports the mitigation of PQ events that originate in the transmission and distribution elements of the electrical power system and buffers the electrical system from irregularities caused by consumer electronic loads.

This report describes how this technology can be applied to the problem of power quality in the near future. The authors contend that in order to apply this technology, government, utilities, regulators, and standards bodies such as IEEE must coordinate their efforts and conduct widespread education to all the modern grid's stakeholders.

This document also delves into the fundamental issues of power quality such as the disturbances that can disrupt the flow of power. Power quality in its current state encounters a variety of problems such as power outages, disruptions in power, and inaccurate meter readings. The implementation of the modern grid will eliminate these problems and enhance the quality of the power coming from the grid, according to the paper. For example, advanced technologies deployed by the modern grid will both mitigate power quality events in the power delivery system and protect end users' sensitive electronic equipment.

In essence, research documented in this report shows that the benefits to productivity in the economy could mean many billions of dollars in costs avoided. Harder to measure, but just as important, are the new opportunities for economic growth that emerge when new 21st century industries answer the call from regions that offer clean, reliable power.

Energy Storage

Title of Report:	A Systems View of the Modern Grid: Advanced Components
Organization:	National Energy Technology Laboratory
Date Published:	March 2007
Primary Focus Area:	Energy Storage

Document Summary	
Technologies Included	Flexible alternating current transmission system devices, high-voltage direct current, superconducting magnetic energy storage, superconducting synchronous condensers, fault current limiters (FCLs), high-efficiency motors and generators, distributed energy resources (DER), distributed storage devices, distributed generation devices, and advanced power quality devices
Benefits Identified	According to this report, a Smart Grid with advanced components will reduce problems at the transmission level to produce better quality power. Various technologies such as FACTS will provide voltage support and load isolation to minimize power-quality events at the distribution level. Various advanced components will add reliability, security, and efficiency to the grid by increasing its self-healing characteristics. Advanced components will yield a more environmentally friendly and more interoperable grid.
Drawbacks/Obstacles	A major obstacle is the fact that, while industry managers are still seeking incremental improvements, they have lost interest in costly breakthrough technologies that are needed for the modern grid. The industry lacks understanding of the resultant benefits of integrated technologies; therefore, industry leaders do not see the importance of a modern grid and managers are reluctant to invest in these long-term technologies.
Costs	Not addressed
Research Methodology	This report covers key elements of one of the seven principal characteristics of the modern grid—advanced components. It supports and supplements "A Systems View of the Modern Grid," an overview prepared by the Modern Grid Initiative team.
"Smart Grid" Definition(s)	A Smart Grid employs advanced components to foster the implementation of the modern grid and requires an industry understanding of the current grid's limitations.

Document Summary	
Regulatory Impacts/ Recommendations	This report recommends an industry prioritization of R&D for advanced component technology, an understanding of the benefits of advanced components, and a stakeholder consensus on the value of these technologies.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report demonstrates the importance of implementing advanced components to foster the success of the modern grid. Advanced components can be applied in stand-alone applications or be connected together to create complex systems such as micro grids. The execution of these advanced components, which will greatly affect the grid's reliability, security, and efficiency, is based on the development of breakthrough technologies.

The report emphasizes that, unless the industry becomes more educated on the significance and need for advanced components, technology R&D will continue to decline. For example, it cites the significance of economical FACTS devices to employ low-cost power semiconductors that far outweigh today's semiconductors in terms of energy-handling. Also, superconductivity should be economically applied to fault current limiters, storage, low-loss rotating machines, and lossless cables. In addition, new storage technologies must be deployed for both DER and large central plants.

The report also maintains that advanced components will aid in making the grid more environmentally friendly. Environmental emissions will reduce when DER technologies, such as wind, fuel cells, and solar, are incorporated. When all of the advanced components work together in a coordinated manner, only then can the grid work efficiently and reliably to support the energy needs of our modern society.

Research shows that technologies such as FACTS are making their mark on the industry through transmission and distribution applications through voltage control and various load conditions, affected stability with energy transfer over long distances, and enhanced the quality of power. Additionally, the U.S. Department of Energy has taken a lead in superconductivity R&D. These efforts have yielded short lengths of second-generation wire, which have raised electric system reliability and improved power delivery systems in urban areas without new rights-of-way.

The report encourages industry education as a way to foster advanced components for the modern grid, which will also stimulate investment and government support. Understanding the benefits of advanced components' implementation is another important step. Unless these goals are achieved in some capacity, the execution of a much-needed modern grid could be severely delayed, the report states.

Consumer Attitudes and Preferences

Title of Report: A Systems View of the Modern Grid: Motivates and Includes the Consumer
Organization: National Energy Technology Laboratory
Date Published: January 2007
Primary Focus Area: Consumer Attitudes and References

Document Summary	
Technologies Included	Advanced metering, smart thermostats and appliances, distributed generation, energy storage, demand response (DR), communications networks, smart meters, end-use devices, distributed energy resources (DER) broadband over power lines, and real-time pricing
Benefits Identified	According to this report, demand response has progressed considerably. For example, a program in Illinois implementing DR saw a 20% decrease in overall demand. Active participants in the vision of the modern grid all believe that DR will be its driving force and will increase efficiency. The deployment of DER will accelerate consumer usage of small generation and storage devices and pave the way for larger ones.
Drawbacks/Obstacles	A major obstacle is the constant evolution of required technologies such as metering, communications, and information technologies. Non-technological work in the way of consumer education and stakeholder agreement also stand in the way of effective enabling of DR and DER.
Costs	Not addressed
Research Methodology	This report covers key elements of one of the seven principal characteristics of the modern grid—how to motivate and include the consumer. It supports and supplements "A Systems View of the Modern Grid," an overview prepared by the Modern Grid Initiative team.
"Smart Grid" Definition(s)	A Smart Grid requires informed consumer knowledge about electricity choices, employs mechanisms to manage customer consumption of electricity (DR), and uses emerging storage technologies (DER).
Regulatory Impacts/Recommendations	This report recommends clear directives on state and federal levels that encourage DR/DER, broader education on DR/DER deployment and its benefits, and improved cost and performance of required technologies.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report demonstrates the concept of motivating and including the consumer as a key element in the functionality and efficiency of a modern grid. With the deployment of new technologies and increased consumer education, consumers will have choices that will ultimately affect the way they purchase and use electricity.

Researchers note that a connection between consumers and grid operators must be forged, which will allow consumers to make informed consumption choices. Research has shown that consumers with choices are better equipped to utilize DR/DER and employ end-use devices, which aid in wise power consumption and are integral to the efficiency of the modern grid.

The modern grid must address consumer needs, from the cost of electricity to its reliability and quality. In order to address these needs, the modern grid must involve consumers by providing easy-to-understand resources. The report predicts that, as technologies make more consumer choices available, the amount of actively involved customers will increase, cost will drop, and DR/DER will become more attractive.

The report cites already successful DR programs such as the program in Illinois, which has reduced demand by 20% and has brought consumer savings to 15% for the first two years of the program. Prominent agencies such as the Environmental Protection Agency, the Federal Energy Regulatory Commission, and the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability identify demand response as a crucial element for the modern grid.

The Modern Grid Initiative makes it clear that motivating and including the consumer through a variety of different avenues is the best path towards the implementation of a modern, cohesive, efficient grid. The report maintains that federal and state officials should promote DR and DER as the best solutions to the required balancing of generation and load. Additionally, consumer education on the benefits of DR and DER and continued technology deployment will invite participation, which will benefit both the consumer and the utility.

Energy Conservation and Efficiency

Title of Report: The Green Effect
Organization: Public Utilities Fortnightly
Date Published: March 2007
Primary Focus Area: Energy Conservation and Efficiency

Document Summary	
Technologies Included	Demand response (DR), such as lighting and emergency management systems; real-time monitoring
Benefits Identified	Increased overall energy efficiency, reduction of electricity consumption, decrease in CO_2 and other pollutants, improved air quality, and increased use of renewable energy
Drawbacks/Obstacles	According to this report, DR can increase electricity usage in some circumstances (shifting the timing of thermally related equipment); some backup generators used for DR are fossil-based; and there is an increased use of coal when shifting from peak to off-peak.
Costs	Not available
Research Methodology	Demand response pilot programs, such as day-ahead hourly pricing
"Smart Grid" Definition(s)	Not available
Regulatory Impacts/ Recommendations	Following are the recommendations found in this report: conduct system and time-specific analyses; update building codes; ensure that air-quality rules and programs, such as state implementation plans are enforced; recognize DR and energy efficiency's contribution to reducing emissions; and fully recognize the contribution to electric reliability made by energy efficiency and DR.
Uncertainty Factors/Assumptions	Not available
Primary/Secondary Data Sources	Sources cited include Energy-Smart Pricing Program and Automated Demand Response System pilots and the Electric Power Research Institute.

This report defines the relationship between demand response and both energy efficiency and the environment. To illustrate that DR can increase overall energy efficiency; this report describes the results of a "day-ahead hourly pricing pilot" in Chicago. The pilot participants are using 3% to 4% less electricity than they would have used without receiving the hourly electricity prices. The participants' income levels were not a factor. Energy efficiency is increased through many DR technologies and practices. Lights and emergency management systems (EMS) are "a platform…serving both business areas and…providing maximum benefits to the customer." The authors mention that DR is currently underfunded and needs to be considered a utility resource instead of just a program.

Electricity consumption is reduced through many DR technologies and practices, such as the dimming of lights, switching off of certain fixtures, or reducing air conditioning late in the workday. The authors note that it is important to know that these DR technologies and practices eliminate the load with no rebound. The authors believe both economics and psychology play a role in the conservation of energy through DR. They say, "Consumers who are made better aware of energy use, its price tag, and environmental costs tend to use it more carefully and frugally."

Regarding the environment, the report states that DR decreases CO_2 and other pollutants as a direct result of less electricity consumption. Some of the backup generators used for DR, however, are fossil-based. The authors state that this is not reason enough to reject DR. State environmental regulators are aware of this issue. As DR programs become more prevalent, "the efficiency and cleanliness of the DG units…will improve." DR can increase and decrease environmental impacts. For instance, a shift from peak to off-peak is likely to increase coal use because many systems use coal for base load. DR, however, can also improve air quality by shifting the precursors of ground-level ozone and smog from afternoon to evening, decreasing the likelihood of these pollutants forming.

A significant aspect of DR is its association with renewable energy. DR can be used for load balancing, a critical need for intermittent power generation, such as wind. The authors recommend five actions for utilities and government to consider in order to reduce energy consumption, peak demand, and environmental degradation. The authors ask them to "appreciate that customers…are interested in…bottom-line results—lower power bills, rebates on new equipment, lessened risk, and better environmental performance."

Title of Report:	Powering Up the Smart Grid
Organization:	Climate Solutions
Date Published:	July 2005
Primary Focus Area:	Energy Conservation and Efficiency

Document Summary	
Technologies Included	Distributed generation interconnection, energy storage integration, real-time monitoring, transmission/distribution automation, demand response, communications networks, smart meters, smart building equipment, smart appliances, and voltage regulation
Benefits Identified	This report cites information stating that with widespread application of Smart Grid

Document Summary	
	technologies there could be a net present value of $57 billion in generation-transmission-distribution savings over 20 years.
Drawbacks/Obstacles	One major obstacle is that new devices must prove that they operate reliably and offer superior services and/or economics as compared to more conventional electrical system components.
Costs	Not addressed
Research Methodology	This report is the end result of a yearlong effort that began in the summer of 2004, which engaged regional and national energy entities and experts.
"Smart Grid" Definition(s)	A Smart Grid integrates a multitude of distributed energy resources, uses solid state electronics to manage and deliver power, and employs automated control systems.
Regulatory Impacts/ Recommendations	Following are some of the policy recommendations found in this report: provide financial incentives for implementing smart energy technologies, break the link between energy throughput and profits, employ performance-based ratemaking to provide positive incentives, and improve grid efficiency with incentives to reduce line losses.
Uncertainty Factors/Assumptions	Not addressed
Primary/Secondary Data Sources	Not addressed

This report recommends that the Pacific Northwest undertake Smart Grid acceleration efforts for both reliability and economic reasons. The report explains that as of the date of publication, a number of organizations, including the Bonneville Power Administration, Pacific Northwest National Laboratory, and the Northwest Energy Efficiency Alliance, has already begun implementing Smart Grid initiatives.

The researchers maintain that a Smart Grid will lead to a "cleaner grid" and a more efficient one. With the implementation of Smart Grid technologies, the grid could enhance digital control systems. These systems could assist in increasing efficiency, which would lead to reduced power needs. For example, the paper cites a RAND Corporation projection that explains that in 20 years, Smart Grid deployments could reduce annual power demand by 52–106 billion kilowatt hours annually. Additionally, a Smart Grid could reduce the need for a certain amount of spinning reserves required to meet load requirements. This could lead to smoother load curves, which could significantly enhance the efficiency of generating plants.

The authors identify how a Smart Grid could reduce line losses experienced by utilities. "By making local generation more financially rewarding, smart energy technology offers significant gains in overall efficiency of the power system," reads a section of the report. With an increase in distributed generation, line losses could conceivably decrease from 9% to 2%, thereby greatly increasing overall efficiency. In addition, certain Smart Grid technologies, such as voltage control, could also lead to a reduction in line loss.

The authors contend that a Smart Grid could also lead to "smarter buildings" and "smarter appliances." With the use of smart meters, which enable variable electricity pricing, professionals can control and monitor HVAC systems in buildings and different appliances in order to adjust them for optimal operating efficiency and energy conservation. In addition, demand response programs and policies could be initiated that would allow utilities to cycle appliances and building systems down during times of high load, resulting in increased efficiency and reduced electricity demand.

Title of Report: [Enabling Tomorrow's Electricity System: Report of the Ontario Smart Grid Forum]
Organization: Independent Electric System Operator
Primary Focus Area: Energy Conservation and Efficiency

Document Summary	
Technologies Included	Home energy management systems, smart metering, communications spectrum, transformer monitors, automated distribution, advanced sensing, generation, storage, demand response, micro-grids, and plug-in electric vehicles
Benefits Identified	Increased consumer participation, increased system economics, potential reductions in congestion, greater ability to integrate generation and load, improved analytics, automatic grid restoration, lower environmental impacts, incorporation of distributed energy resources, enhanced operational performance, increased productivity, and improved public and worker safety
Drawbacks/Obstacles	Obstacles include the uncertainty regarding how smart devices will be provided to utility consumers and under what conditions, greater promotion of smart meters, safe connections to distribution lines, economic and regulatory issues, no single Smart Grid communications solution, cyber security risks, and plug-in electric vehicle charging impacts.
Costs	Preliminary cost projections for incremental annual capital spending on a Smart Grid in Ontario would average about $320 million over the initial five years. Additional spending for smart meters, grid expansion, and grid refurbishment are not included in this estimate.
Research Methodology	This report documents the work of the Ontario Smart Grid Forum, who convened over a seven-month period to learn more about the Smart Grid, discuss its benefits for consumers, and develop recommendations for advancing it in Ontario.
"Smart Grid" Definition(s)	A Smart Grid is a modern electric system. It uses communications, sensors, automation, and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system.
Regulatory Impacts/ Recommendations	This report makes the following recommendations: clarify authorities, establish requirements, create incentives, propose contractual and pricing arrangements, create a task force to develop a comprehensive plan for enabling plug-in electric vehicles in Ontario, and create a task force to produce a framework for Smart Grid research in Ontario.
Uncertainty Factors/Assumptions	Not discussed
Primary/Secondary Data Sources	Information was gathered from a group of industry leaders who participated in the Ontario Smart Grid Forum.

This report documents the work of industry leaders who participated in the Ontario Smart Grid Forum. These discussed the Smart Grid vision; current activities in Ontario, the United States, and the European Union; benefits to consumers; various technologies related to generation, distribution, and transmission; distributed energy resources; security; and opportunities and challenges to achieving a Smart Grid. The Forum presented key recommendations for the Province of Ontario to "develop a Smart Grid to improve the prosperity of its citizens, the performance of its electricity system, and the environment."

This report states that the role of the current grid is to move electricity from generators to consumers. The grid of tomorrow, however, will be a new electricity system that "enable(s) two-way flows of electricity and information as new technologies make possible new forms of electricity production, delivery, and use." Ontario has already begun to move toward a Smart Grid, such as leading efforts for smart meters. The Ontario Centers of Excellence has contributed half of a $12 million investment in 14 projects related to Smart Grid.

The report states that many challenges will be met to achieve the vision of a Smart Grid. Maintaining reliability and quality of service will be very difficult while trying to implement new grid infrastructure. Smart Grid technologies also come with their fair share of risks. Ontario must determine "the roles and opportunities for all the potential market players" and "continue to educate and train employees" if it wishes to transform its electricity infrastructure.

The conclusion of this report emphasizes the need for coordination among all divisions of the electricity system. The electric industry will also have to communicate with other industries. Technological devices from various suppliers will need to interact with each other and exchange information regarding operation and price. The forum recognizes the opportunity that Ontario has to create a Smart Grid and believes in further promoting this innovative development.

INTRODUCTION TO SMART GRID TECHNOLOGY REVIEW AND COSTS AND BENEFITS

The State of Maryland can apply a number of electric grid tools and technologies that can contribute to achievement of one GW of utility scale capacity, and those outlined in *EmPOWER Maryland*[2], which required a 5 GW peak demand reduction and a 15% reduction in per capita consumption by 2015. Technology based solutions—coupled with policy, pricing, and regulatory mechanisms—create the potential for Maryland to reach its goals, align with Federal goals and create a better environment. This report outlines, at a high level, those areas which may have the potential to meet these requirements, recognizing that there will have to be significant investments; changes in policy; and cooperation across government and regulatory communities, as well as in the public power, investor owned utility organizations and other agencies and institutions. At the same time, it will be critical to link end use customers into the process.

The opportunity—and challenge—is in building a practical path to the smart grid that may include grid efficiency, Advanced Metering Infrastructure (AMI) and customer technologies, energy efficiency and broad sustainability goals with technology that is readily available. While much discussion of future potential technology developments is already occurring, the time constraint outlined in *EmPOWER Maryland* requires a focus on those opportunities that can happen within a practical period of time. This concept also dramatically reduces risk, providing the State takes a "no regrets" strategy to build a technology roadmap that is flexible enough to take advantage of current technologies and open enough to allow improved technologies and programs in the future.

Intelligent infrastructure[3] is not the only way for the State to meet its goals, but can provide the synapses to link smart grid technologies. Certain stand alone actions such as deploying more energy efficient transformers can occur outside the broader rubric of smart grid—but are more powerful when coupled with advanced sensors in an overarching system. Similarly, Conservation Voltage Regulation (CVR)[4] can be accomplished by using specialty stand alone meters in order to ensure proper end of line voltage, but is more logically and economically applied when AMI is deployed and every meter becomes a source of voltage data.

The "greening" of the transmission and distribution system includes a number of critical components to work in concert. This includes:

- Grid efficiency programs
- Loss reduction plans
- Distributed generation integration

[2] Empower Maryland Energy Efficiency Act of 2008
[3] Intelligent infrastructure broadly incorporates the smart grid with other technology options.
[4] CVR is achieved by operating the distribution feeder voltage in the lower half of the ANSI standard to cost effectively save energy and reduce kW and kVAR demand, without negatively affecting service to customers.

- CVR implementation
- Rates and pricing
- Operating policies and standards

AMI is clearly at the "heart" of the smart grid in that it provides the granularity necessary to truly understand system operations down to the customer level and to influence energy consumption via direct load control, passive load management and develop price responsiveness. By providing customer engagement, many of Maryland's goals can be achieved, assuming there is policy, financial and other support.

Of course, all of the opportunities provided by intelligent infrastructure come at a cost—and that cost needs to be measured in terms of today's business drivers. There is a significant dependency on pending carbon and related legislation[5] as the dollar amount creates a more receptive atmosphere and strengthens business cases.

It is also important to recognize that there are a number of AMI and demand response efforts and activities within the State that are currently being pursued by utilities serving Maryland customers. Baltimore Gas & Electric (BGE), for example has one of the nation's largest direct load control programs involving nearly 25% of its customer base.

The critical question is how the State—supported by recent Federal legislation and regulation—can incentivize and support utilities to purchase and use the next generation of equipment in a coordinated fashion to economically maximize capacity reductions and reduce peak. The choices present the strategic challenge of relying on the experience and methods of the past while choosing to invest in the future. The investment will reach toward new goals and must rely on new technologies. The elements of this balance are illustrated in Figure 1.

[5] Much current thinking places the price of carbon in the $50 per ton range. This could translate into increases of nearly 3 cents per kWh.

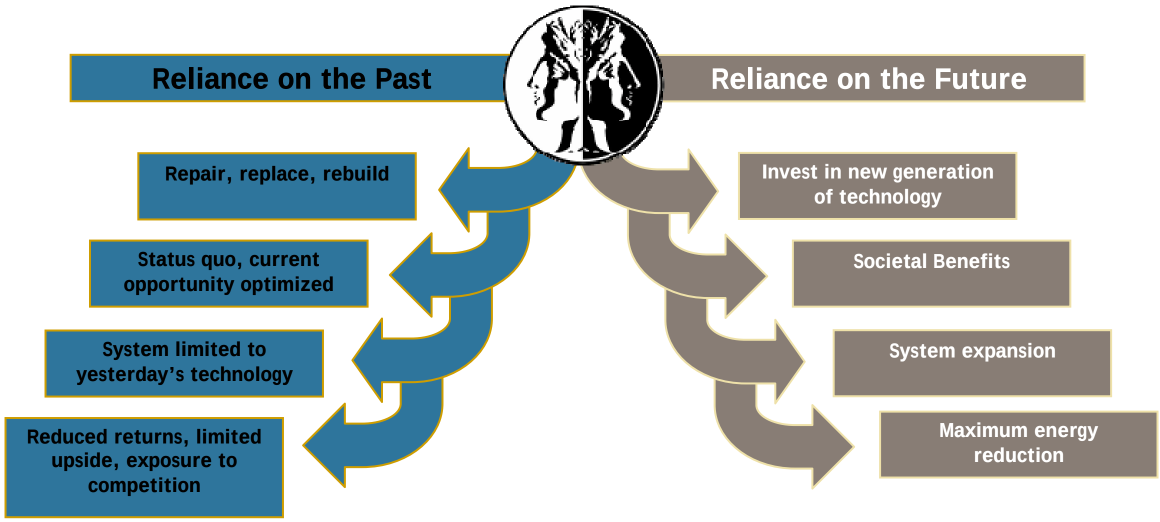

Figure 1. Drivers in Capital Investment Choices[6]

Traditional ratemaking has often driven utilities to make technology decisions based on "tried and true" equipment that offers surety in the rate recovery mechanisms. To maximize the potential from the system, it may be necessary to develop a different paradigm: one that encourages deployment of the most functionally advanced equipment, even if it is not the lowest cost.

Individual technologies can and should be deployed in order to move the process of reducing peak demand and capacity ahead. But it is most likely in the interplay between technologies where the maximum benefit can be found. This potential also illustrates the need for interoperability[7] between systems. Often the Master Stations[8] of systems do not speak to each other so that, for example, the Outage Management System and Automated Voice Recognition system cannot link without costly customized software overlays.

Smart grid/intelligent infrastructure involves strategies and technologies that provide information, communications, control and automation to the energy enterprise from customer devices through the power source either centralized or distributed. This includes taking advantage of energy efficiency options in a proactive (versus passive) way. The technology options can be classified into three basic types:

- Stand alone (SA)

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[6] Adapted from graphic in "Visions for a Sustainable Energy Future," by Mark Gabriel, published by The Fairmont Press, p. 238.
[7] Interoperability has not historically been considered in utility system planning and is just now moving to the forefront. NIST, in a project led by R. W. Beck, is establishing these standards.
[8] The Master Station is the computing platform, provided as part of the system, that resides at the utility, connects to the utility's enterprise network, and controls the system.

- Passive (P)
- Active (A)

Table 1 outlines some of the basic functions and concepts of these three types.

Table 1. Energy Efficiency (EE) and Demand Response (DR) Technology Options

Measure	Description	SG Benefit	Technology Options
Energy Efficiency	Traditional Utility efficiency programs	Limited	SA
Demand Response-Residential	Signaling customers at times of peak demand and requesting reductions	Moderate	P
Demand Response-Commercial	Signaling customers at times of peak demand and requesting or controlling reductions. Powerful tool if demand charges apply.	Moderate	P
Auto Demand Response-Residential	Automating the signaling and action process to reduce demand (system creates action)	High	A
Auto Demand Response-Commercial	Automating the signaling and action process to reduce demand (system creates action)	High	A
Advanced transformers with Sensors	Transformer efficiency is "purchased" based on line loss acceptance. SG is not required for transformers to be replaced but can benefit if advanced units are placed in the field.	High	A
System Visualization and Control	System operations are gated by reserves necessary due to the lack of visibility across multiple control centers requiring additional reserve margins. SG improves visibility across operating areas.	High	A
Advanced Metering Infrastructure	Bring intelligence to the end use devices. SG not required but will be empowered by AMI.	High	A/S
Conservation Voltage Regulation	Utilities maintain system voltage on the higher end to assure reliability. CVR[9] coupled with SG allows fine tuning of voltages.	High	A/S
Phase Shifting	Phases are generally selected randomly as the system is installed. Visibility into the system can allow for optimization of phases resulting in better performance and lower costs.	High	A
Grid Energy storage	Through the use of approaches such as FACTS[10], the grid can provide short term storage for power.	High	A/S
Renewable Energy Integration	A variety of energy sources can be better integrated with the development of the SG.	High	A/P
Distributed Energy Integration	A variety of energy sources can be better integrated with the development of the SG.	High	A/P

SA = Stand Alone; P = Passive; A = Active
SG = Smart Grid; CVR = Conservation Voltage Regulation; FACTS = Flexible AC Transmission System

[9] CVR can be done without Smart Grid and/or AMI; but it would then require special monitoring to enable system performance.
[10] FACTS devices do not require Smart Grid, but they support it.

Beyond the promises of a smart grid in the future, the reality exists with today's equipment to link a number of coincident technologies to form the basis for intelligent infrastructure that can provide a robust backbone for additional development and expansion

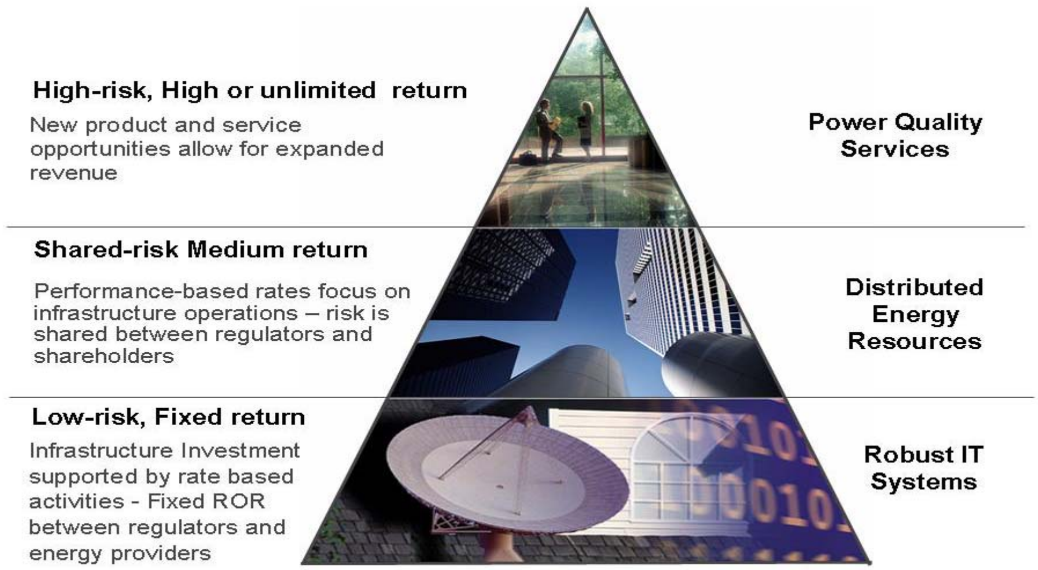

Figure 2. Risk/Return Alternatives[11]

Rates and regulation play a critical role by allowing intelligent infrastructure technology to fill the gap in avoiding new capacity additions and reducing peak demand. It is crucial to build a financial model that allows investments in new technology that are costlier than the least cost option and where the payoff may be years in the future—a payoff that may not be quantifiable in a business case today. It is in the definition of that financial model that will allow or prevent smart grid technologies from succeeding—as opposed to the technical challenges.

[11] Graphic from "Visions for a Sustainable Energy Future," by Mark Gabriel, published by The Fairmont Press, pg 106.

1.2 Smart Grid Technology Review

Smart Grid Technology Domains

The name "Smart Grid" means different things to different people, and our industry has not yet settled on a focused consensus of what it includes. The Energy Information & Security Act of 2007 (EISA 2007) defines a Smart Grid as one that encompasses:

> … ''smart'' technologies … that optimize the physical operation of appliances and consumer devices … for metering, communications concerning grid operations and status, and distribution automation.

For purposes of this report, we will formalize this definition by saying that a Smart Grid comprises automation in four domains, as illustrated in Figure 3 below.

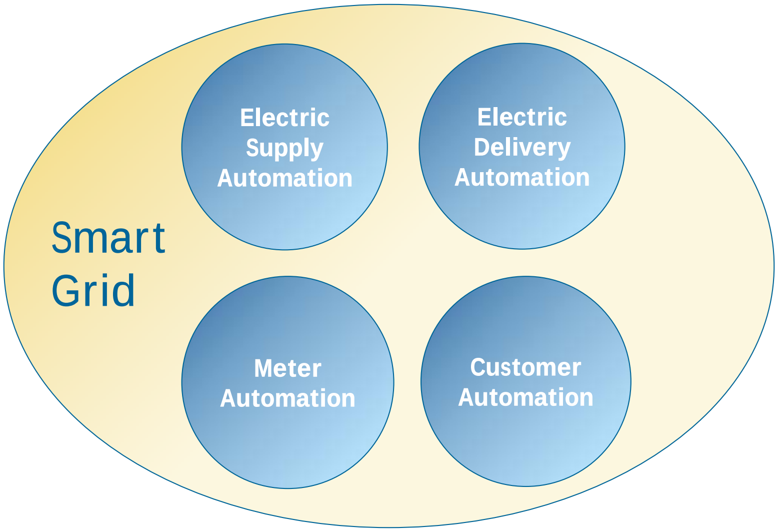

Figure 3. Smart Grid Domains

These four domains encompass the entire electric system from generation through energy consumption by customer-site appliances and other end uses.

More could be added to this picture. For example, we could say that another bubble belongs in the figure for Security, and perhaps another for Operating & Control Logic. And there may be further enhancements. For our purposes here, we will reason that both of those functions are essential within all four of the domains shown, and we will discuss the four domains below.

Electric Supply Automation

Large, central station generation currently provides almost all our electric energy. Newer technologies for distributed supply are available and work well, but have not been cost-competitive with existing central station sources, except in niche applications.

This is changing as the economics of wind, solar and other renewable sources improve. Wind and solar power are now economically competitive in many situations and locations due in part to Federal subsidies, but their regional scale is limited by technical issues of source and grid stability.

The prominent advantages of small, distributed, renewable sources—lower environmental impact, reduced dependence on foreign fossil fuels, and avoided transmission and distribution losses—are complemented by complex technical problems of availability, capacity, system control, and grid protection.

In the supply domain, a principal role of smart grid is to solve these problems with control and communication technologies that will enable distributed, renewable sources to contribute when they can, while maintaining service and protecting the other elements in the supply/delivery system.

Innovative work is being done in these areas. None is in commercial service on a large scale at this time, with the exception that wind generation is now emerging into medium scale operation. In addition, Combined Heat & Power (CHP) systems are in commercial operation all over the country, including Maryland.

Electric Delivery Automation

The U.S. electric transmission and distribution (T&D) infrastructure has evolved slowly over the last few decades from being entirely electric to including some electronic equipment. Most of the electronics in electric delivery serves to monitor it, and to enable remote control. Some automated control is common for local management of voltage and power factor, but control that is both automated and remote is rare.

The Smart Grid concept envisions extensive intelligence and automation in T&D that serves to monitor, control, and even reconfigure the delivery infrastructure automatically, consistent with rules defined by the system operators. While electronics is available to do a wide range of monitoring and control functions, those rules have not been defined, or even identified, in detail sufficient to support implementation.

Numerous organizations, including the Electric Power Research Institute (EPRI) and utilities large and small, are doing development work in distribution automation. It is widely expected that commercially and operationally practical results will emerge over the next few years.

Meter Automation

Introduction

Meter automation is now available and in service on a commercial scale. Depending on how it is defined, between 10% and 35% of the electric revenue meters in the U.S. have some degree of automation and communication.

The first widespread form of meter automation is now called “drive-by” or automated meter reading (AMR). AMR meters are equipped with radios that communicate one-way to a mobile radio in a utility-owned vehicle. The meters radiate their register value (and a few other parameters) every few seconds. When the utility vehicle with the receiving radio is within a few hundred feet, it receives and stores the register readings. Meter data are transferred to the utility’s internal data systems when the vehicle is back at the utility offices.

About 40% of electric revenue meters in the U.S. are equipped with AMR. The substantial book value of these meters—for most utilities with AMR, less than half the original book value of the meters has been claimed in depreciation—is a significant obstacle to replacing them with more capable advanced metering infrastructure (AMI) meters. One (now unmet) challenge of smart grid is to find an economic and practical way to leverage this existing one-way investment to accomplish the most valuable functions now offered by the newer AMI.

After AMR and before the current generation of AMI, the first generation of AMI supported one-way or two-way communication to meters and daily recovery of consumption data. AMI replaced the roving vehicle with a fixed communication network that allows the utility to communicate with the meters at will. Most[12] of these installations served principally to provide meter readings. They support functions far beyond billing, but do little more than read the meters. Some of these AMI systems were unable to gather data more frequently than daily. Adding a service switch incurred a cost of $200 per meter. Between 15 million and 20 million[13] meters are currently equipped with this kind of AMI.

[12] Some also support other functions, such as direct load control.

[13] Alert readers may notice that the numbers of meters in various generations of automation do not seem to add up correctly. This is because the functions of the automation generations overlap, and some meters count in more than one generation.

Features of the newest generation of AMI include those shown in Table 2 below.

Table 2. Advanced Metering Infrastructure Features

Typical	Available in Some or All Systems
Fixed communication infrastructure supports full two-way data communication between each meter & the utility	Two-way data communication with customer-owned devices, i.e., a display or thermostat
Standardized data interfaces to other utility IT systems	Hourly (or more frequent) reporting of consumption data
Daily reporting of hourly consumption data	Remotely operable service switch
Meter tamper detection and reporting	Direct load control capability
Service outage and restoration detection and reporting	Distribution monitoring & control
	Standardized data interfaces among AMI system elements

AMI Technologies and Architectures

AMI systems with the features shown above are available right now from more than a half dozen suppliers, all with active utility customers, emerging new products, and substantial development resources. Selected examples are shown in Table 3.

Table 3. Major AMI Developers in the U.S. Market

Company Name[1]	AMI Network Name[2]	Meter Communication Technology[3]
Aclara	TWACS, Star Network	Power line, cellular[5] licensed radio
Cooper Power Systems	Cannon PLC	Power line
Eka Systems	EkaNet	Unlicensed radio mesh
Elster Integrated Solutions[4]	EnergyAxis	Unlicensed radio mesh
Itron[4]	OpenWay	Unlicensed radio mesh
Landis+Gyr[4]	GridStream, TS2	Unlicensed radio mesh, power line
Sensus Metering[4]	FlexNet	Cellular[5] licensed radio
Silver Spring Networks[6]	—	Unlicensed radio mesh
SmartSynch[6]	—	Public digital wireless phone network
Tantalus Systems	TUNet	Unlicensed radio mesh
Trilliant Inc.	SecureMesh Network	Unlicensed radio mesh

Notes:

1 Others compete in the North American market. This list includes only the most prominent names.

2 All network names are trademarked or service marked by the developers.

3 Unless otherwise stated, the meter communication network is private, owned by the utility.

4 These firms also develop, sell, and support revenue meters.

5 The term "cellular" refers to the radio network architecture, not the public cellular network.

6 These networks are standards-based and do not have proprietary names.

Although there are many differences among them, the AMI system feature that most distinguishes one system from another is the communication method used to and from the meter. Other communication back to the utility is by any of several means and generally is not a distinguishing feature. This is discussed in "Communication & Interoperability" later in this document.

AMI Radio Communication

Terrestrial radio[14] is the dominant communication method in the United States for electric revenue meters, with power line a close second. Alternative radio methods use different frequencies and different architectures.

Radio Frequencies

The frequencies used for AMI in the United States are in the 400 MHz[15], 900 MHz, and 2.5 GHz[16] bands. The Federal Communications Commission (FCC) defines and regulates licensed and unlicensed frequencies in all of those bands. Available AMI devices use licensed bands in the 400 MHz range, and both licensed and unlicensed frequencies in the 900 MHz band.

The significance of the frequency is that a lower frequency signal propagates better than higher frequency one. All other things being equal, a lower frequency AMI signal will more readily reach a distant meter, or one that is below grade or in an alcove of a house with aluminum siding.

But all things are not equal. The AMI developers adjust other parameters of their systems—power, bandwidth, modulation and coding methods, etc.—to get best performance for the price. At comparable prices, the available systems are comparable in performance, with each having "sweet spots" where it is the best choice.

Licensed frequencies allow higher power, which usually allows a longer distance between the meter and the next higher node in the communication chain back to the utility. This longer distance means that fewer such nodes are needed, which mitigates both the initial cost and the operating and maintenance cost of the infrastructure that supports meter communication. But it creates a higher network vulnerability to a single point of failure or sabotage.

Radio Architectures

A single basic architecture model can be used to describe all the AMI communication systems. We will use slightly altered versions of Figure 4 to show different architectures. The model includes the following devices.

- Meters – The principal end points of the AMI network. It may have other end points, too, such as distribution monitoring and control devices, and devices in the customer premises, such as load switches and thermostats.

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[14] Satellite radio is available and is used for high-value sites, such as remote substations and intertie equipment. Its relatively high cost makes it uncompetitive for large-scale use at customer meters.
[15] MHz = millions of cycles per second.
[16] GHz = billions of cycles per second.

- Concentrators – Devices that talk to hundreds or thousands of meters to funnel data and commands to and from the utility.
- Regional nodes – A high-level data traffic handler that connects concentrators to the utility.
- Utility master station – The computing resources at the utility that control the entire AMI network and system.

These devices are interconnected with the following communication elements.

- Meter network – The data network that connects the meters to the concentrator and, in some AMI systems, connects the meters to each other.
- Intermediate backhaul – The communication path that connects the concentrators to the regional nodes and back to the utility.
- Backhaul – The communication path that connects the regional nodes to the utility. This usually is some part of the utility's corporate data network.

These elements are illustrated in Figure 4.

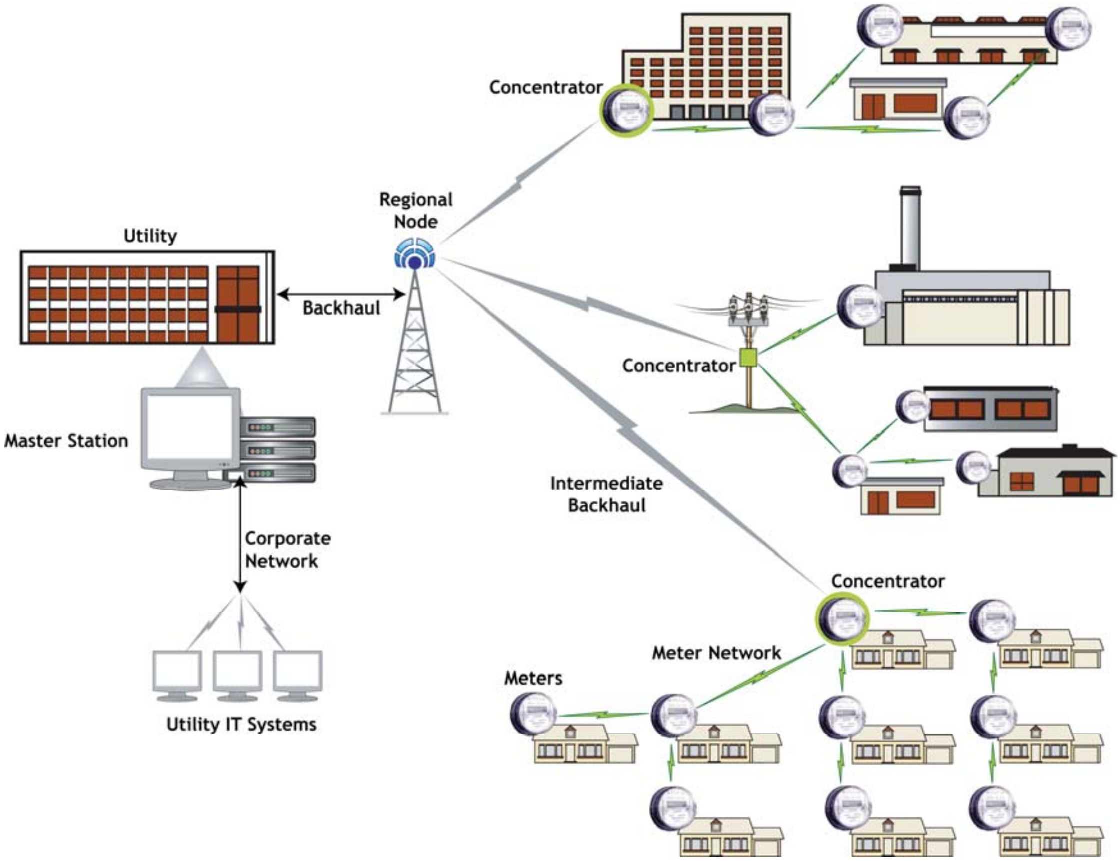

Figure 4. AMI Communication Architecture

The figure illustrates a radio mesh network. The green communication bolts shown between individual meters are the "mesh" network. Individual meters communicate with each other and pass data and commands from one meter to another until a concentrator is reached. The concentrator may be another meter, as shown at the bottom of the figure, or it may be a radio box mounted on a pole or other location, as shown in the middle of the figure. Mesh networks can reconfigure themselves to optimize the speed and reliability of the mesh communication. The optimization algorithms are a major part of the art of mesh networking, and the detailed characteristics of the mesh networks differ substantially.

In AMI networks that are not mesh networks, the meters do not communicate with each other. Instead, they all communicate directly to the concentrator. This forms a cellular architecture similar to the public cellular phone networks, except that these meter networks are entirely private to the utility. As shown in Figure 5, all the small green bolts go to the concentrator instead of to the other meters. Doing this with the low power allowed by FCC rules for unlicensed frequencies requires that the concentrators be closer together than needed to support a mesh network, which would add infrastructure cost. Therefore, all the AMI systems that are not mesh networks use licensed frequencies that allow higher power and correspondingly longer distances from each meter to a concentrator.

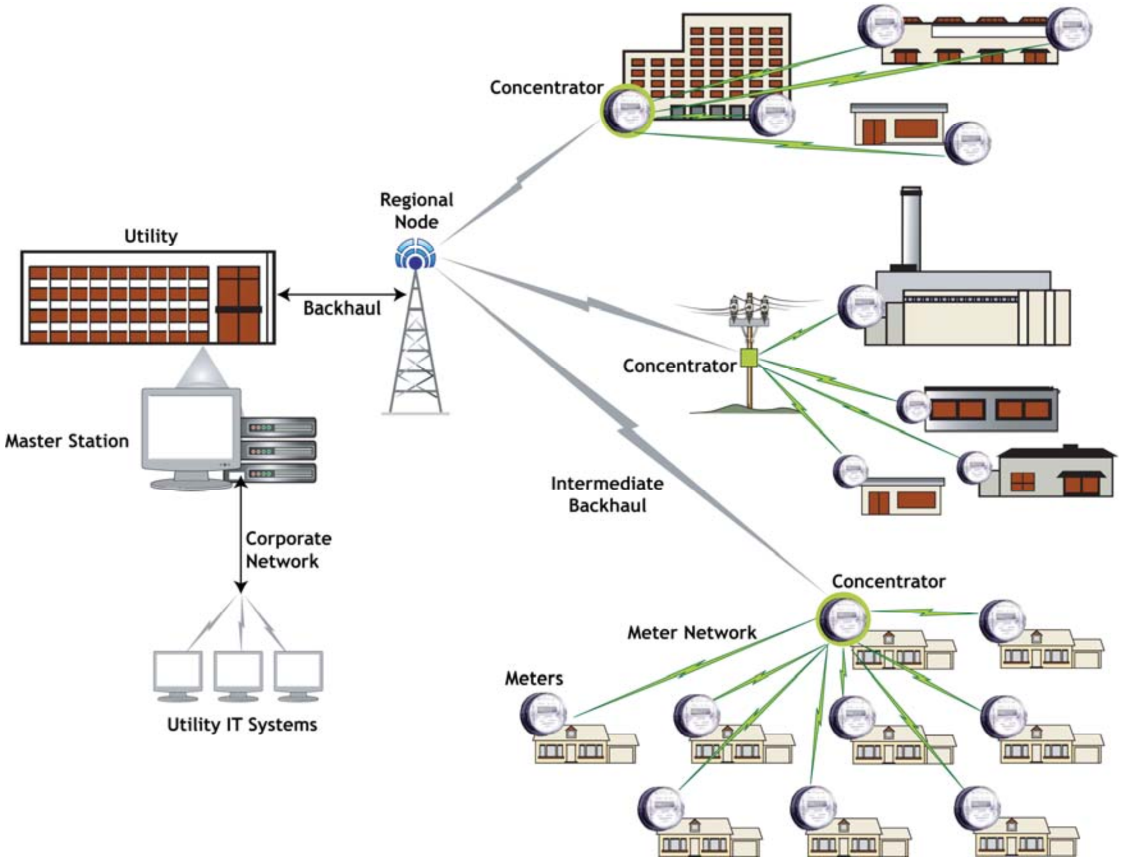

Figure 5. AMI Communication Architecture – Cellular Radio

licensed networks may have many fewer concentrators than a mesh network serving the same locations. In such a case, the network looks like Figure 5, but with all the meters communicating to the regional node. These networks are referred to as "tower based" AMI systems.

Power Line Communication

Power line communication is presently used by utilities to communicate with between 5 million and 10 million revenue meters in the United States. Nearly half of these use one-way communication, and the others are fully two-way.

In most power line AMI systems, the concentrators shown in Figure 4 are in the substations, and the communication path shown by the radio zigzags between the concentrators and the meters is the power line itself, not radio. The intermediate backhaul may be any utility communication method—a common example is MAS[17] radio—that carries data from substations to a corporate office, where it is backhauled on the corporate network. Or the

[17] MAS = multiple address system, a point-to-multipoint radio network defined and licensed by the FCC and widely used by utilities.

substation may be connected directly to the corporate network, for example, by a fiber network.

The power line is designed to carry 60 Hz[18]—that is, the power itself—very efficiently. But it carries other frequencies relatively poorly. This is notable because higher frequencies carry more data, so when we want to pass data down the wire, we want the highest frequency we can get. High frequencies like the radio ones mentioned above decay very quickly on a power line. That is, they become too weak to detect. After traveling just a thousand feet or so along the wire, they require a signal booster to restore the signal and send it the next thousand feet. Signal boosters add cost, making the high frequency power line approach more expensive than just using radios.

Available AMI systems that communicate long distances on power lines use much lower frequencies—that is, much closer to the 60 Hz—that the electric network is designed to carry. Because the signal frequencies are lower than radio, the data transport capacity is lower. Therefore, a notable characteristic of the most widely used power line AMI systems is that their raw data transfer rate is slower than that of radio systems.

A modest data rate is not necessarily a limitation for power line AMI communication. Because the power lines reach all meters, the power line AMI signal can reach all meters, which is not always true of radio systems. In addition, some power line AMI systems can communicate with more meters simultaneously than radio AMI systems, which further mitigates the lower data transfer rate. Further, the power line systems communicate reliably with all meters even where the geographic density of meters is very low, as it is in rural areas and on country roads where the roads define long lines of meters that do not readily support "mesh" communication by radio. Making radio meter communication reliable in low density areas can require a relatively high number of concentrators, which may make it more costly than power line communication.

Power line communication has other advantages. Using the power line as a data path provides information about that path. Some power line AMI systems provide detailed data on the locations and kinds of problems developing on distribution lines, such as poor connections. In addition, they also provide topographical information, identifying which meters are supplied by which feeders and phases. This information can be extremely useful during storm recovery and also during routine operations.

Internet for AMI

The Internet is so ubiquitous that it may seem like an obvious "good thing" for meter communication. The technology is amply capable and available, and many—maybe most—energy consumers have Internet access. Why is this not the preferred AMI communication path?

The answer is simple economics: Right now, connecting a meter to the Internet costs more than connecting it to a more conventional AMI network. This may change in the future but, even in locations where the Internet is available at every home, it is less expensive for the

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[18] Hz = cycles per second.

utility to install an AMI meter network and use the Internet for the backhaul. This is shown in Figure 6

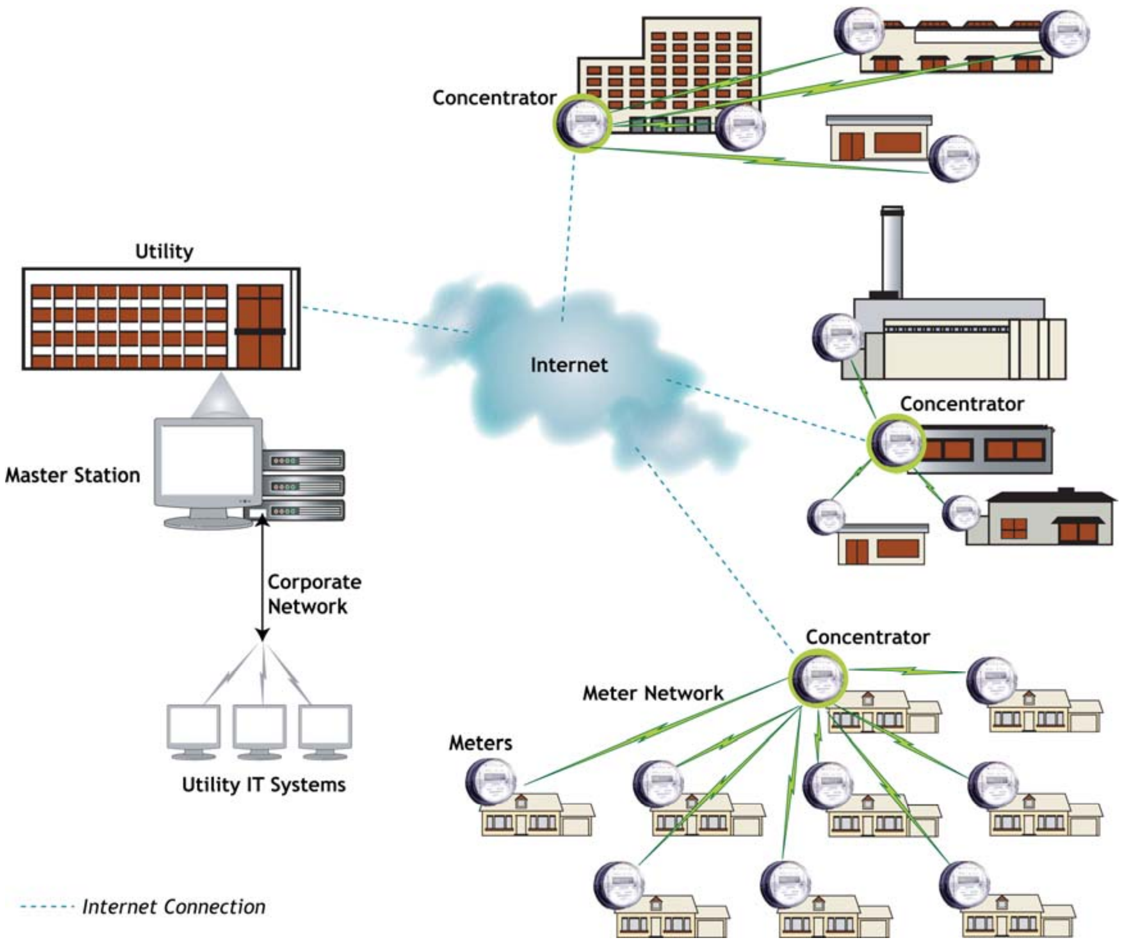

Figure 6. AMI Communication Architecture – Internet

In the case illustrated in Figure 6, cellular radio AMI meters communicate to a concentrator meter on a house in the neighborhood, and that concentrator meter connects to the Internet at that house. It does not matter whether the Internet path is DSL, fiber, or coaxial cable. Presently known uses of meter data do not require the high data speed and capacity of Internet connections, and any of these will serve well without interfering with the customer's use of the communication path.

There may be a significant exception to the viewpoint expressed above, which applies to meter locations that currently have non-communicating meters. Between 20 million and 30 million meters in the U.S. have one-way drive-by radios in them (described earlier in this section). It is technically possible, and has been demonstrated several times, to place a device—say, a display—in the customer's home or business that receives the signals from such a meter. If we connect that device to the customer's Internet access path, then the utility can receive up-to-date meter readings every few seconds, and can send messages to that device to give the customer information and/or messages. Although the technology is available, several important dimensions of this approach remain undefined. How much will such a device cost in volume? How many customers have a suitable Internet connection? Will those customers be willing to let the utility use their Internet communications? How costly might it be for the utility to replace these devices as customers change from cable or DSL to fiber? And what happens to the utility's data access if the customer changes Internet service providers?

It is possible that all these questions can be resolved favorably, and that the productive capabilities of the current large population of drive-by meters will thus be significantly expanded. But this hypothesis is untested at this time.

Customer Device Communication

Several options exist for communicating with customer devices. There is little precedent for this communication, as this idea is quite new and is not yet in large scale practice. Technology is not a major limitation, as any of numerous available technologies can do the job. The ubiquitous Wi-Fi comes to mind as one example. The industry is waiting and working to see what approaches will be most cost-effective and most acceptable to consumers.

The option that is now most commercially prominent is to put a ZigBee[19] radio in each meter, and communicate to ZigBee devices in the customer site. ZigBee is a simple, low power, radio communication standard for transferring relatively low-rate data over distances of up to a few hundred feet (but typically much less). It has many applications in many industries. Presently it is being deployed in utility meters throughout Texas and California. In large volume, the incremental cost of adding this to residential meters is between $5 and $25 per meter.

As ZigBee becomes more widespread, it is widely expected that ZigBee prices will decline and ZigBee devices for consumers will become available. Examples include thermostats, in-home energy usage displays, and devices to let a home computer read the utility meter for energy management purposes. Although none of these devices is common at this writing, companies developing them number between 10 and 100 and are easy to find on the Internet as this emerging market heats up.

Other standardized protocols could be used in the meter, but ZigBee is the one that has emerged as the hands-down leader from the last two years of consideration by AMI companies and leading utilities.

Communication with customer devices does not have to be through the meter. Another option is to put the same AMI radio that is in the meter in the customer device (display, thermostat, etc.), and let it communicate with the other meters or the concentrator, just as the meters do. This approach allows the customer's device or computer to receive meter readings and utility information without requiring the meter itself to communicate into the home. It avoids the cost of putting communication (say, ZigBee) inside every meter, which might be relatively costly if only, say, 20% of customers participate in programs that require that communication.

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[19] See http://www.zigbee.org/.

Depending on the expected customer participation, this may be an attractive approach to communicating with customer devices.

Communication & Interoperability

Introduction

Even a superficial review of the interoperability of data systems will show that interoperability requires shared protocols[20], and that more shared protocols result in higher capability systems at lower prices. We will not review the reasons or the arguments for that here.

Shared protocols may be proprietary or they may be "open". An open protocol is one for which the developer pays no (or no significant) royalty, and for which the specifications are readily available. In contrast, many proprietary protocols are widely shared. A highly visible example is the CDMA[21] protocol widely used in cellular telephones. The dominant implementation of CDMA was developed by Qualcomm Inc. of San Diego, California, which now holds over 7,000 patents on the devices it sells. Many cell phone makers buy Qualcomm circuits and incorporate them into phones that compete with each other, *and interoperate with each other*, in the market place. In electric distribution and metering, Sensus Metering makes a meter automation system that uses the proprietary FlexNet radio. Any maker of distribution monitoring and/or control equipment can negotiate an agreement with Sensus to include the FlexNet radio in that distribution equipment, making the equipment interoperable with the utility's FlexNet AMI system. This kind of protocol sharing creates limited but very productive interoperability in many applications.

As in many industries, communication protocols in distribution and meter automation and the other domains of smart grid were almost entirely proprietary until TCP/IP emerged in the 1970s. Protocol standardization has expanded slowly since then.

Shared Protocols

Presently standard protocols are pervasive at the backhaul and Master Station interfaces shown in Figure 4. The ubiquity of Ethernet at the lowest protocol layers, and of TCP/IP at the transport and internetwork layers of the protocol, have made these protocols mandatory for all providers to be compatible with utility enterprise networks. Beyond that, a variety of widely used—though not necessarily open— protocols are available to provide interoperability. These include Oracle and IBM database query languages, http and https, ftp, SSL ODBC, SQL, XML, and Active Directory. In some cases, interoperability is achieved by using the same proprietary tools and products. As just one example, the Tivoli storage management framework (by Tivoli, now owned by IBM) defines and implements a comprehensive set of storage management and business continuity functions, and is widely used in industry, including by utilities. Providers of utility IT systems therefore often choose to make their IT

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[20] Here we will use the definition of a communication protocol used by the ISO in creating its well-known 7-layer reference model. A communication protocol specification defines everything from the physical medium and signal characteristics to the language, vocabulary and syntax of the message, with the networking, transport, security, and session, etc. all defined by the different "layers" of the protocol.

[21] CDMA = code division multiple access.

systems compatible with this (and other similar and competitive) product suite so that their products will be compatible with existing utility operations.

Proprietary Protocols

Communication among meters and between meters and meter concentrators has been—and, as of this writing, remains—proprietary. No AMI system widely deployed in North America offers fully standardized meter communication. However, two providers have made significant movement toward "open" standards. One developer of a mesh radio AMI system has defined a meter communication protocol it says is consistent with TCP/IP, and is participating in standards work to make that protocol a publicly available standard. The other offers a power line AMI system employing a standardized protocol for communication to the meters.

If either of these succeeds in significant commercial volume, it may become possible for any technology supplier to make devices that communicate with those meters. Recent history suggests that the business opportunity this creates may precipitate emergence of a wide array of energy measuring and management products for residential and business energy users. Events in Texas and California—where thousands of meters are now being deployed every day with ZigBee radios in them—will reveal over the next two years the degree to which this potential will be realized.

Coordination Activities

The National Institute of Standards and Technology (NIST) was tasked by the Energy Information and Security Act of 2007 (EISA 2007) to coordinate the collaborative development and implementation of a framework for interoperability among the devices, systems, and people composing the smart grid. NIST's assigned role is delineated in EISA under Title XIII, Section 1305, which says, briefly, that the framework shall:

- Be flexible, uniform, and technology-neutral.
- Include standards, protocols, and models for information exchange and management.
- Foster alignment among policies, business processes, and applied technologies in a manner that enables all electric resources, including demand-side resources, to contribute to a safe, efficient, and reliable electricity network.

As the framework forms and matures, NIST and the framework collaborators will develop consensus opinions on the standards, protocols, and models most suitable for supporting grid intelligence and interoperability.

One way these standards will be widely influential is that they may be embodied in Federal Energy Regulatory Commission (FERC) rules. EISA 2007 directs NIST to present these general agreements as recommendations to FERC when they affect interstate transmission of electric power and/or regional and wholesale electricity markets. When FERC judges that such rulemaking is warranted, and when sufficient accord supporting the recommendations has been reached, FERC will initiate rulemaking proceedings to adopt these recommendations.

Customer Automation

Technologies for residential and business customer automation are widely available, though not widely implemented. Particularly in the residential sector, building automation has not succeeded as its proponents have predicted in the last three decades. However, major changes are in motion.

Consumer Home Automation

As mentioned earlier, utilities in Texas and California are now deploying ZigBee-equipped meters on a large scale. This has prompted a substantial commercial movement to produce and promote energy management products and services for the residential sector. Although home automation systems and devices have constituted a boutique industry, that industry offers a wide array of device types, functions, and prices that may quickly adapt to and integrate with the emerging energy management opportunity. The stage is set for the long-predicted expansion of home automation to occur.

Whether consumers will respond to all this business activity remains to be seen, and it is likely to become clear within a year or two. The continuing increase in energy prices—widely predicted to continue—may be a significant economic motivator that will help residential automation achieve a higher market penetration and effectiveness.

Utility Connectivity

Most existing home and business automation products and systems operate without connection to the utility, of course, because utility interactions have generally not been standardized. Exceptions to this situation exist in the demand response programs implemented by utilities for large customers. Systems provided, for example, by Retx and Comverge establish communication between energy suppliers and energy users. Except for this type of demand response equipment—all of which has been introduced in response to the activity of the energy industry in last decade—widely available residential and commercial building automation equipment operates to optimize the building or home on an isolated basis, unresponsive to outside influences.

Development work to establish and standardize customer-utility interactions is intense. As discussed earlier, ZigBee has been chosen as the standard protocol for meter-to customer device communication, and the markets are responding crisply. The NIST project described in Communication & Interoperability, above, encompasses emerging standards and development for utility interaction with several business sectors.

Leveraging Existing Technology & Assets in a Smart Grid

Smart Grid Resources Are in Place

Traditional T&D designs include protection schemes using (usually electromechanical) protective relays, station breakers, line reclosers, voltage regulators, transformers with load tap changing controls, and capacitors with controls. Many utilities have moved to designs that now include digital relays, and manage all these assets using supervisory control and data acquisition (SCADA). Some utilities have even begun the migration to applying distribution automation (DA) on discrete sections of their distribution networks.

All of these existing resources are starting points for smart grid. Applying sensing, control, and communication to each of these devices, and establishing operating algorithms will turn these existing, isolated devices into eyes and ears, hands and feet connected to the smart grid brain. The devices are out there now, both in the electric system and on equipment suppliers' shelves. What is needed to create a smart grid is the automation, including the sensing, control and communication, and the algorithms that will govern them.

Distribution Automation (DA)

While utilities have many types of automated technologies and distribution devices in service today, they tend to be "islands of automation," each operating individually to manage a small segment of the distribution system. Moving to an environment where outages are "self healing" will require significantly more investment to coordinate many automated devices. DA is currently implemented, for example, with devices that automatically (or prompted by an operator) reconfigure circuits by isolating a piece of a circuit (that is, sectionalizing it) when a fault is detected. This is accomplished by leveraging devices that can communicate to a central processing location where prescripted logic is defined to respond to anticipated conditions on the circuit.

A principal challenge associated with expanding DA beyond a discrete portion of the network—as the smart grid concept requires—is performing the analytics required for large networks. The logic must reflect all the dynamics of system load flow. As the network becomes larger, the complexity of this analysis increases dramatically. This is further complicated in practice because it is required to be executed all within a few seconds of a system event. Processing the huge amounts of data from widely dispersed distribution sensors, including advanced meters, needed to produce useful information is a substantial technical challenge.

Risks include the loss of control by system operators. A central area of concern is correctly signaling protective relay devices. Automated circuit reconfiguration requires dynamically calculating feeder ratings, and updating the protection coordination schemes as the network is switched.

Conservation Voltage Regulation (CVR)

Early work with CVR has demonstrated that it has substantial potential to reduce demand, energy consumption, and electric system losses. The work described here employed dedicated voltage sensors at key distribution points. Implementing CVR using voltage measurements taken by AMI meters will achieve even better results due to the more widely distributed voltage data.

The Northwest Energy Efficiency Alliance (NEEA), R. W. Beck Inc. (R. W. Beck), RLW Analytics, Auriga Inc., and Hunt Power, together with 13 utilities, completed the Distribution Efficiency Initiative (DEI) study in the Pacific Northwest. The DEI study quantified the effects of power consumption in relation to the applied voltage. Design and operational techniques were used to optimize the performance of a distribution system to achieve energy and demand reductions.

The results of the study conclusively show that operating a utility distribution system in the lower half of the acceptable voltage range (120-114 volts) saves energy, reduces demand, and reduces reactive power requirements without negatively affecting customers. Energy savings results are within expected values of 1 to 3 percent total energy reduction, 2 to 4 percent reduction in kW demand, and 4 to 10 percent reduction in kVAr demand. Computer model simulations showed that by performing selected system improvements, between 10 and 40 percent of the total energy savings occurs on the utility side of the meter. Table 4 shows the potential energy savings that can be achieved by implementing different ways of controlling the voltage and various system improvements at the substation and feeder level, as well as the expected cost per kWh over a 15-year period.

Table 4. Potential Savings and Investment

Type of Improvement[1] (Cost per Substation)	Energy Savings	kW Demand Reduction	kVAr Demand Reduction	Cost in Mills ($0.001/kWh)
Voltage Regulation LDC[2] ($15k to $25k)	0.5% to 1%	1% to 2%	3% to 5%	0.1 to 2
Voltage Regulation LDC[2] w/ Minor System Improvements ($40k to $60k)	1% to 2%	2% to 2.5%	3% to 7 %	2 to 8
Voltage Regulation LDC[2] w/ Major System Improvements ($80k to $100k)	1.5% to 2.5%	2.5% to 3%	5% to 10%	10 to 15
Voltage Regulation EOL[2] w/ Major System Improvements ($100k to $350k[3])	2% to 3%	3% to 3.5%	10% to 20%	20 to 50

Notes:
1 The costs and benefits are for performing system improvements at the substation and feeder level, which are representative of the Pilot Demonstration projects.
2 LDC is Line Drop Compensation and EOL is End of Line voltage control methods.
3 Globally applies to Northwest region. By matching specific substations and voltage regulating methods, the cost could be reduced to 5 to 30 Mills but the total energy saving would also be reduced.

One of the main objectives of the DEI study was to look at different techniques for lowering the voltage to the customer without falling below the minimum acceptable level (114 volts as defined by ANSI C84.1) and measuring the impact on demand (kW and kVAr) and energy. The Load Research and Pilot Demonstration projects controlled the voltage for 24 hours (On days) and then the normal utility voltage (uncontrolled) was applied for the next 24 hours (Off days), alternating back and forth for the duration of the project. The actual energy savings for the project was 8,563 MWh, or 1.88 average megawatts (aMW) (8,563 MWh/No. of Hours ON). If the DEI projects were in operation full time (instead of every other day) for an entire year, the annualized savings would have been 16,490 MWh.

The industry-accepted metric for energy response to delivered voltage is the Conservation Voltage Regulation factor (CVR factor or CVRf). CVR factor is defined as the percentage change in load resulting from a 1 percent reduction in voltage. A positive CVR factor value means that the reduction in voltage has resulted in energy savings. Table 5 shows the average voltage reduction, the amount of energy saved in the DEI study, and the corresponding CVR factor for both the Load Research project with 395 homes and the Pilot Demonstration projects that included 31 feeders at 10 substations.

Table 5. Summary of CVR Voltage and Energy Results

Project	Voltage Reduction (ΔV)	CVRf (%ΔE/%ΔV)	Project Energy Savings (MWh)1	Percent Energy Savings
Load Research	5.2 V (4.3%)	0.5692	87	2.15%
Pilot Demonstration	3.03 V (2.5%)	0.69	8,476	2.07%

Notes:

[1] Actual savings for DEI project (not annualized).

[2] Based on random selection of residential sites, weighted to represent expected results for the Pacific Northwest Region.

[3] Values are shown for the purpose of calculating the savings for project and do not represent expected values for the Pacific Northwest Region.

1.3 Smart Grid Costs and Benefits

Anticipated AMI Benefits

AMI technology enables a variety of functional benefits to both utilities and end-use customers. A given utility can seldom apply every functional benefit of AMI due to differences in operations, reliability, back office processes, automation already deployed and other circumstances. Twelve common benefits are presented here for analysis. These twelve benefits are depicted for three utilities for which R. W. Beck provided AMI business case support, and are referred to as Utility A, B, and C in Table 6.

All the benefit estimates were vetted by R. W. Beck staff to guard against unusually high or low benefit estimates inconsistent with their experience in other utility AMI projects. This is done in an effort to ensure that the benefit estimates are reasonable, achievable, and supported by utility staff. Converting these benefit estimates into tangible savings will require attention and focus by both utility management and the AMI project teams. R. W. Beck staff has observed that many utilities that have deployed an AMI system later discovered their original benefit estimates were conservative or later identified additional benefits.

Functional Benefits

Meter Reading

An AMI system will eliminate almost all meter reading labor (utility staff and contractors) and vehicle costs. Other costs eliminated include the cost to annually maintain and periodically replace hand-held meter reading data collectors, insurance liabilities and claims, cell phones, 2-way radios, training costs, etc.

Resource Planning

AMI is often viewed as an enabling technology for a variety of time-of-use, demand response, and direct load control programs intended to shift or reduce peak load demand and improve utilization of generation resources.

Field Service Orders

Utility office staff can use an AMI system with service switches to remotely connect/disconnect most electric services and remotely obtain a meter read needed for a final bill in lieu of scheduling field personnel to visit the premises. In addition, meters that were previously flagged by a traditional billing QA/QC process and checked on-site by field personnel can now be remotely read by utility office staff.

Outage Restoration

Low voltage "alarms" from AMI meters can be exported to an outage management system (OMS) or related application to improve outage prediction. Improving outage prediction helps utility staff prioritize resources to restore service to the greatest number of customers in the least amount of time. In addition, a two-way AMI system with sufficient bandwidth and latency can be used to "ping" or verify that communications and service voltage exists at the meter, i.e. service is "on."

Energy Theft and Diversion

AMI meters are capable of reporting suspected tampering in near real-time or as part of the standard meter reading data packet. In addition to tamper alarms, read data from AMI meters can be used to verify that usage is occurring at accounts where the occupants have recently moved out and the premises is supposed to be vacant.

Meter Accuracy and Registration

Solid-state meters deployed with an AMI system are more accurate than electromechanical meters. Use of solid-state meters will result in accurately registering energy used by customers and reduce the cost to investigate suspected incidents of reduced phase registration due to under-voltages.

Billing Workload

An AMI system can provide utility office staff frequent and accurate information on customer's energy usage profile to help address phone calls related to bill complaints and questions. Also, an AMI system substantially lowers the cost of group billing options and reduces billing error complaints by customers that are based on incorrect or estimated reads submitted by meter readers.

Bad Debt Write-off

An AMI system with remotely controlled service switches can be used to promptly disconnect delinquent accounts, which prevents unpaid balances from growing and eventually contributing to the annual uncollectible account balance that is ultimately expensed by the utility as a bad debt.

Improved Cash Flow

AMI systems are capable of accurately reporting all meter reads on a daily, hourly, or 15-minute interval. This frequency of accurate meter reads will allow utility staff to reduce costs associated with quality assurance / quality control (QA/QC) processes and reduce the time lag from meter read to sending out bills.

Distribution Transformers

The overall number of transformers purchased for inventory during the year can be reduced if utility staff uses AMI data to detect overloaded transformers and schedule an upgrade replacement in lieu of replacing the unit to restore service after it fails.

In addition, the annual decrease or increase in the number of distribution transformers purchased assumes that utility staff will use AMI data to monitor transformer loads and refine transformer sizing practices for all new customers.

Sample Testing and Load Research

Sample meter test costs are reduced after AMI is deployed because all new solid-state meters planned can be placed in fewer sample groups. In addition, AMI will reduce the utility's cost of performing load research by eliminating field data collection and the use of interval demand recorder meters.

Other

Miscellaneous category of AMI related benefits reported in the sample group of utilities that are not included in any of the above benefit categories.

Utility Benefit Estimates

Annual savings are depicted in Table 6 are for three sample utilities, in various functional areas described above.

Table 6. Estimated Annual AMI Benefits ($/meter)

Benefits	Utility A [1]	Utility B [2]	Utility C [3]
Meter Reading	$6.26	$8.15	$6.94
Resource Planning	$12.49	$7.96	$3.09
Field Service Orders	$1.59	$2.97	$0.54
Outage Restoration	$0.46	$2.64	$0.12
Energy Theft & Diversion	$1.32	$1.47	$1.30
Meter Accuracy & Registration	$2.45	$1.04	$2.46
Billing Workload	$0.00	$1.08	$2.57
Bad Debt Write-off	$4.88	$0.96	$5.10
Improved Cash Flow	$0.47	$0.47	$0.18
Distribution Transformers	$0.51	$0.31	$0.00
Sample Testing & Load Research	$0.14	$0.16	$0.34
Other	$0.16	$0.07	$0.10
Total Annual Benefits	$30.72	$27.29	$22.73

Notes:
1 Utility A's anticipated resource planning benefit includes a voluntary TOU demand response program, where 15% of the meter base is expected to participate.
2 Utility B's anticipated resource planning benefit includes voluntary direct load control and TOU programs, where 20% of the meter base is expected to participate in each program. Customers may opt for one or both programs.
3 Utility C's anticipated resource planning benefit includes conservation voltage regulation (CVR) program on 20 distribution substations, using AMI as the voltage feedback loop. CVR was achieved via upgrading transformers with tap changing controls and installing capacitor controls.

Intangible Benefits

In addition to functional benefits, AMI enables utilities and customers to realize a variety of intangible benefits. These intangible benefits are also considered by utility staff, but they are difficult to quantify and are not typically included in AMI business cases. Examples of intangible benefits include, but are not necessarily limited to the following:

Selectable Bill Dates: AMI meters will be read at least once daily. The time of billing is now constrained by the customer's position in the billing cycle. With AMI, utilities can offer customers greater choice on their preferred billing dates. This will improve the payment performance of many customers who have trouble managing cash flow, reducing the utility's receivables.

Customer Usage Profile Information: Utility staff can assist customers in managing their energy use by offering customers usage profile information via an online web portal. Accurate usage profile information will reduce the frequency and cost of meter testing associated with high bill complaints.

Effective Rate Design: Utility staff can evaluate (data mine) customers' consumption profiles to develop more effective time-of-use and related rate designs, encouraged by the Energy Policy Act (EPAct); the profiles are beneficial to both the utility and to customers. Avoided peak generation can be significant.

Power Quality Monitoring: Related to Outage Restoration described above, the outage detection capability of AMI enables utility staff to use momentary outage (aka "blink") and voltage variance reports to help identify and prioritize power quality, right-of-way, reduced phase registration on polyphase metering due to under-voltages, and other operations and maintenance issues.

Distribution Planning: The "system load snapshot" capabilities of many AMI systems can be utilized to import demand reads for a given date and time into engineering software models. This gives utility staff greater flexibility to investigate distribution voltage levels, phase balance, line and equipment loading, and contingency planning to improve reliability and capital budgeting.

Automation Costs

Customer Automation Costs

As described earlier in "Consumer Home Automation," the home automation business currently serves a relatively small fraction of the potential market, and is poised to expand substantially as (*and if*) consumers respond to the emerging opportunity to manage their energy in response to utility signals. This is significant for the energy industry because studies[22] have shown that homes with automation respond substantially more—up to double the response—to demand response signals than homes without automation.

Currently, an energy consumption display with a sensor that attaches to the electric revenue meter is available at retail price for about $100[23]. Some utilities offer them in promotional and pilot programs for as little as $30. A utility with an AMI system can buy displays that are compatible with the AMI to give or sell to consumers for under $50.

However, the earlier-described rush to sell displays to consumers in Texas and California is widely expected to result in a sharp drop in prices. And the impact may go far beyond the cost of the devices. Presently, a utility conducting a customer display program must educate the customers in what the display can tell them and how to respond to that information. Overall, customers are not aware of what a kilowatt hour is, or of how many kWh their actions incur. But the emergence of a single meter communication standard—ZigBee—may take this responsibility away from the utility.

As commercial firms compete to sell displays, they will educate customers as a way to show the high value of their products. Not only will the price of the product will come down, but also the price of making the product effective may come down, and its effectiveness may increase as popular awareness of how to use it increases. The second order effects of this expanding consumer market are impossible to foresee. But we can say that if utilities continue on the present path to time-varying rates, demand response programs, and communicating meters, it is entirely possible—it even looks likely—that residential (and consequently business) automation equipment will decline appreciably in price and increase in effectiveness.

Representative AMI Costs

R. W. Beck staff has developed representative capital costs to deploy each of the candidate AMI solutions based on three recent AMI evaluation projects for utility clients with similar AMI requirements. A rollup summary of these representative capital costs to deploy AMI over a 5-year period is illustrated in Table 7 by infrastructure category.

Table 7. Infrastructure Capital Costs ($/meter)

Capital Costs	Utility A	Utility B	Utility C
Distribution Infrastructure	$184.95	$142.99	$161.33
Communications Infrastructure	$5.71	$18.08	$26.41
IT Infrastructure	$1.30	$1.22	$1.69
MDM[4] Infrastructure	$49.21	$17.50	$4.16
Total Infrastructure	$241.17	$179.79	$193.58

[22] "Impact Evaluation of the California Statewide Pricing Pilot; Final Report," Charles River Associates, March 16, 2005, page 9.

[23] For example, see http://www.bluelineinnovations.com/default.asp?f=shop&action=ViewCart&mn=1.274.285.388.394, where the Blue Line Innovations Power Cost Monitor is offered for $119.

Notes:
1 Utility A plans to implement a voluntary TOU demand response program, where 15% of the meter base is expected to participate.
2 Utility B anticipated costs includes voluntary DLC and TOU programs, where 20% of the meter base is expected to participate in each program. Customers may opt for one or both programs.
3 Utility C anticipated costs includes CVR program on 20 distribution substations, using AMI as the feedback loop. CVR was achieved via upgrading transformers with tap changing controls and through installation of capacitor controls.
4 Meter Data Management (MDM) solutions are database applications that store metering data from multiple metering and/or AMI systems, which is then used as needed by multiple utility applications such as billing.

AMI solutions are available to deliver AMI data to the utility via several backhaul communications technologies, including telephone, digital cellular telephone, general packet radio service (GPRS), MAS radio, or fiber. For a given utility, several factors will affect capital costs for AMI communications infrastructure such as the utility's service area, existing communication resources, customer density, and geographic location of distribution substations

Effects of System Efficiency Savings

Using sources cited, annual energy efficiency savings and energy loss reductions are prorated for Maryland households in Table 8 below.

Table 8. Maryland Annual Smart Grid Voltage Optimization Energy Savings

Annual U.S. energy reduction est:[1] 3,500,000,000 kWh

Description	Total U.S. kWh[2]	Total MD kWh[2]	MD kWh Savings[1]	MD Revenue/kWh[2]	MD Savings
Residential Class	1,379,307,315,000	27,250,418,000	25,628,071	$0.1381	$3,539,237
Commercial Class	1,352,453,305,000	29,532,916,000	27,774,681	$0.1282	$3,560,714
Industrial Class	982,149,952,000	6,099,065,000	5,735,859	$0.1040	$596,540
Transportation	7,651,689,000	528,583,000	497,114	$0.1255	$62,388
Total	3,721,562,261,000	63,410,982,000	59,635,825		$7,758,878

Notes:
1 EPRI low-end estimate of energy savings achievable by 2030 using Smart Grid voltage optimization to reduce voltage levels 1%. Energy savings may be as high as 28 billion kWh by 2030 using Smart Grid voltage optimization to reduce voltage levels 4%. Both figures assumes Smart Grid voltage optimization will penetrate 25-50% of all residential distribution substations by 2030 net 7.5% of all distribution circuits estimated to already have voltage optimization capabilities. Also, the above calculations assume all anticipated voltage optimization savings are allocated as a proportion of Maryland energy sales by sector to total U.S. energy sales by sector. This allocation of anticipated voltage optimization benefits to Maryland do not take into account customers' mix of resistive and reactive loads.
2 2008 EIA Form 826. See "Current & Historical Monthly Retail Sales, Revenues & Avg Revenue per kWh by State & by Sector".

Voltage optimization is achievable through various approaches including conservation voltage regulation, dynamic control of reactive support, and more efficient system modeling of the transmission & distribution network. The use of advanced sensors, including AMI, provides utilities the data needed to optimize voltage while maintaining a reliable voltage source, conducting phase balancing, and minimizing losses.

Demand Response Savings

Demand response program savings, from the sources cited and prorated for Maryland, are shown in Table 9 below:

Table 9. Estimated Maryland Demand Response Savings

Annual U.S. demand response savings:[1] $3,000,000,000

Description	Total U.S. kWh[2]	Total MD kWh[2]	MD Savings[1]
Residential Class	1,379,307,315,000	27,250,418,000	$59,269,789
Commercial Class	1,352,453,305,000	29,532,916,000	$65,509,654
Industrial Class	982,149,952,000	6,099,065,000	$18,629,737
Transportation	7,651,689,000	528,583,000	$0
Total	3,721,562,261,000	63,410,982,000	$143,409,180

Notes:

1 Brattle Group estimates demand response based on advanced metering and dynamic pricing can reduce U.S. peak load by 5-percent or $3 billion over the next 5 years. Also, the above calculations assume all anticipated demand response savings are allocated as a proportion of Maryland energy sales by sector to total U.S. energy sales by sector. This allocation of anticipated demand response benefits to Maryland does not take into account any characteristics of customers' loads.

2 2008 EIA Form 826. See "Current & Historical Monthly Retail Sales, Revenues & Avg Revenue per kWh by State & by Sector".

Demand response savings are a result of customers (residential & commercial) reducing their use of electric equipment and appliances, either through direct load control, passive notification, and/or through price signals. Demand response is typically requested during brief periods of peak demand.

Impacts on Workforce Creation

Using sources cited, impacts on workforce creation are prorated for Maryland in the following table:

Table 10. Maryland Smart Grid Investment & Jobs Creation Estimate

Total est. U.S. smart grid investment: [1]	$64,000,000,000
Total U.S. electric customers: [2]	142,121,652
Total MD electric customers: [2]	2,411,240
Total MD smart grid investment: [1]	$1,085,825,825

Total est. U.S. smart grid related jobs: [1]	280,000
Total est. MD smart grid related jobs: [1]	4,750

Note:

[1] GridWise Alliance jobs report, January 2009. The figure on estimated Smart Grid investment is over the next four years. The allocation of anticipated Smart Grid related investment and jobs are allocated as a proportion of total Maryland electric customers to total U.S. electric customers.

[2] 2007 EIA Form 861. See "Number of Retail Customers by State by Sector".

Impact on Carbon Footprint Reductions

Using sources cited, impacts on carbon footprint reductions are prorated for Maryland in Table 11 below:

Table 11. Maryland Carbon Footprint Reductions

MD CO2 emissions: [1]	31,165,417 Metric Tons
Est. MD CO2 emission reduction: [1]	201,062 Metric Tons

Note:

[1] 2007 Forms EIA 767 and EIA 906. See "U.S. Electric Power Industry Emissions by State". Reduced CO2 emissions are assumed to be proportional anticipated Maryland kWh savings and total Maryland kWh consumption.

1.4 REVIEW OF SMART GRID/AMI PROJECTS

Smart Grid (particularly AMI) projects underway or completed in Maryland and several other PJM states were reviewed. A select number of other pilot projects underway outside of this geographic area were also identified and reviewed.

Each project summary includes the following information: geographic and technology scope, products deployed, costs and benefits (if available), and lessons learned.

Smart Grid/AMI Deployment in Maryland

BG&E --- Maryland	
Description	On January 23, 2007, BGE first filed a proposal for AMI programs with the Maryland Public Service Commission. On April 13, 2007, the Commission conditionally accepted BGE's proposed AMI pilot. The Commission's approval was contingent upon "BGE developing and proposing a comprehensive pilot, inclusive of a viable critical peak pricing pilot component to gather statistically significant, measurable and meaningful information as to the potential positive effect of AMI on reducing peak system demand." BGE then proposed a two-phase pilot for AMI deployment, which started in late 2007 and is projected to end in 2011. **Phase I**: Approved in January–March 2007 and started in late 2007, it deployed about 9,000 meters to 5,000 customers, the purpose being to field-test technology and limited system integration, assess deployment processes, evaluate vendor performance, confirm resource requirements, and validate the business case. **Phase II**: In mid-2008, BGE filed with the PSC for approval to implement Phase II with cost recovery via a tracker mechanism. With a three-year timeframe, it would encompass the full deployment of 2 million gas and electric meters, both residential and I&C. Simultaneously, IT integration activities will occur to smoothly transition the infrastructure to reap the benefits of AMI deployment. The two-phase pilot could cost up to $460 million, $10 million for Phase I and $350–$450 million for Phase II. According to BGE, AMI deployment will result in operational savings in terms of meter reading, meter maintenance, service orders and collections, T&D planning, outage response, and other structural elements (reduction in UFE, load research, IT support, etc.). Most importantly, AMI will revolutionize the outlet of communication between BGE and its customers, such that it will allow for detailed and timely information on energy use, which will yield better informed consumer decisions. Moreover, AMI is the foundation for demand response programs and other technologies that will enhance consumer-controlled energy consumption.
Start / End Dates	On March 31, 2008, BGE filed its Smart Energy Pricing pilot proposal pursuant to the April 13, 2007, order. The Commission approved the Smart Energy Pricing pilot on April 23, 2008.

BG&E --- Maryland	
AMI Solution / Product Used	BGE initiated a competitive bid process and contracted with the following vendors to execute the AMI pilot project: - AMI Technology – Sensus, Aclara - Meter Data Management (MDM) System – Oracle (Lodestar) - Field Installation – VSI - Program Support Services – Accenture - Systems Integration – Accenture
Number of Meters	The AMI team designed the pilot to test the most varied and extreme conditions. The company deployed roughly 5,300 electric meters and gas modules in two different zip codes in the greater Baltimore region.
Evaluation Process and Responsible Parties/Experts	According to BGE, the utility has achieved the following: - Verification that AMI reads match meter register values - Verification that AMI bills match CIS production bills - Evaluation of network capability and reliability - Evaluation of vendors - Business case development - Final report to the PSC
Driver	Increased regulatory and industry activity
Next Steps	The company cited numerous next steps in their pilot program. For example, BGE will continue monitoring new AMI/Smart Grid technology and other installations. In addition, the company will update their AMI RFP and select a primary vendor. Finally, BGE will present an AMI business case to the PSC for approval.

Pepco --- Maryland	
Description	The Smart Community Plan will demonstrate a number of technologies including power line sensors and smart meters. The plan will demonstrate different Smart Grid technology capabilities, provide an opportunity for customers to experience technology benefits, and provide a platform for customer program offerings. The plan will also help Pepco fine-tune various aspects of these technologies and, thereby, improve efficiencies of energy delivery. Additionally, it will combine many Smart Grid components in one complete package, enabling the company and the commission to better understand how customers adopt and benefit from the technology. There is no timeline set for the approval of the plan; the commission has not even discussed it as of yet; however, if approved, the pilot program would affect 10,000 homes in Prince Georges and Montgomery counties. The plan includes installing sensors in power lines, allowing Pepco to pinpoint outages and have them repaired quicker. Smart meters would be installed so homeowners can see how much energy they are using each month.
Start / End Dates	Pepco has requested authority from the Maryland PSC to move forward with the Smart Community Plan.
Number of Meters	Between 2,500 and 3,500 selected customers will participate in the demonstration project and receive AMI meters.
Evaluation Process and Responsible Parties/Experts	Overall customer satisfaction with program offering, changes in behavior to reduce critical peak demand, and system reliability measures will be evaluated to make business process and design improvements for rolling out the Smart Grid. After the first year of operation, Pepco will evaluate the success of the distribution system operational aspects of the Smart Community Plan and provide a report to the Commission.
Costs/Benefits	The estimated cost of the program is approximately $1.7 million.

Pepco --- Maryland	
Driver	Governor's directive and federal funding under the American Recovery and Reinvestment Act of 2009
Next Steps	The company filed on March 26, 2009, a Request for Expedited Approval to establish a regulatory asset for the deployment of AMI to the Maryland Public Service Commission. In its expedited request, Pepco states that by establishing a regulatory asset, cost recovery would be assured, and Pepco would strengthen its ability to receive funding under the American Recovery and Reinvestment Act of 2009 (ARRA). Pepco is proposing to begin as soon as regulatory approval is obtained. With expeditious approval, system implementation for AMI would begin soon after approval, so customers could begin enrolling in related programs within a year after approval. Distributed automation improvements, including installation and verification of substation and feeder equipment, have already begun, with completion on the select feeders in line with the AMI deployment. With regards to financing, Pepco has revised financial projections for the business case for AMI to reflect the potential impact of stimulus funding. The 50% cost share, contingent on receipt of a federal grant, reduces the total cost of full AMI deployment of approximately $26 million in Maryland.

Smart Grid/AMI Deployment in Other PJM States

Pepco --- Washington, DC	
Description	Pepco serves as the sponsoring utility for PowerCentsDC™, which is a residential program that incorporates smart meters, smart thermostats and dynamic pricing. The dynamic pricing program includes three different pricing options: hourly pricing, critical peak pricing, and critical peak rebate. The program is voluntary by invitation with an opt out provision. There is a $100 incentive to participate ($50 initially, $50 at conclusion), and a smart meter is installed in the home. The program was conceived in 2007 and launched in 2008.
Start/End Dates	July 2008 – March 2010
AMI Solution/Product Used	eMeter, and its subcontracting partners: UtiliPoint International Inc., Mincom, Sensus Metering Systems, Comverge Thermostats, and Honeywell installation services
Number of Meters	Approximately 1400
Evaluation Process and Responsible Parties/Experts	eMeter consulting personnel, business processes, and technical capabilities monitor the program to ensure successful implementation of the program. The Smart Meter Project Program, Inc. board oversees the project. It is compromised of representatives from the DC Office of the People's Counsel, the DC Public Service Commission, the DC Consumer Utility Board, the International Brotherhood of Electrical Workers Local 1900, and Pepco.
Results and/or Lessons Learned	Still in deployment phase.
Costs/Benefits	NA
Driver	Pepco's Blueprint Plan for pilot project
Next Steps	On April 4, 2007, Pepco submitted an Application to the Public Service Commission of the District of Columbia for a comprehensive demand response, AMI, and energy efficiency plan for all of Pepco's DC customers. On April 2, 2009, Pepco filed a motion to expedite consideration of the implementation of the AMI, which also included a cost recovery mechanism, and the creation of regulatory asset for the deployment of the AMI. On April

Pepco --- Washington, DC	
	29, 2009, the motion to expedite was approved. A hearing will be held June 30–July 1, 2009.
Other Notes	Pepco presented the Company's plans to obtain American Recovery and Reinvestment Act of 2009 (ARRA) funds for its proposed AMI project at a March 27, 2009 DC Public Service Commission hearing. The hearing was held to explore available options for obtaining ARRA funds for DC. After the hearing, Pepco submitted additional information to supplement the record in supports of its proposed AMI deployment.

Delmarva --- Delaware	
Description	Delmarva is set to deploy 10,000 meters for both electricity and gas customers on April 1, 2009. The advance metering infrastructure (AMI) deployment is part of Delmarva's Blue Print for the Future Plan for Demand Side Management, Advances Metering and Energy program. There are a number of targets that Delmarva would like to accomplish, including eliminating meter readers and having the ability to remotely access the meters. However, they are initially manually reading the meters and accurately measuring the usage of the customers.
Start/End Dates	The start date will be April 1, 2009, with a project duration of about two years.
AMI Solution/Product Used	GE Energy Smart meters are being used for the deployment, with flexibility to expand usage of the smart meters in other areas of the service territory.
Number of Meters	10,000
Evaluation Process and Responsible Parties/Experts	Delmarva will evaluate the meters by reading them manually at first.
Results and/or Lessons Learned	It is still in the deployment phase.
Costs/Benefits	The estimated cost will be $250–$300 for each meter.
Driver	Control energy costs
Next Steps	Deployment
Other Notes	Delmarva is the only Delaware utility company deploying AMI, according to the PSC of Delaware. On May 9, 2006, the Commission signed PSC Order No. 6912 to evaluate the desirability, the feasibility, and the cost effectiveness of requiring smart metering technology, including time-of-use metering, to be utilized throughout, or selectively within, the service territories of Delmarva Power.

Commonwealth Energy (ComEd) --- Illinois	
Description	The Illinois Commerce Commission (ICC) recently approved ComEd's approach to developing and implementing an AMI program. The first part involves a workshop process that is underway to develop project goals, timelines, and evaluation criteria for an AMI pilot for approximately 200,000 meters. The second part of the AMI program is expected to be a five-month deployment starting in the fourth quarter of 2009. The 200,000 meters being deployed in this AMI pilot would reach approximately 5% of ComEd customers.
Start/End Dates	Five-month deployment starting in the fourth quarter of 2009
AMI Solution/Product Used	Still developing the AMI deployment; currently conducting workshops.
Number of Meters	200,000 meters
Evaluation Process and Responsible Parties/Experts	R. W. Beck was retained to facilitate stakeholder meetings to build consensus among diverse constituencies. ComEd is working with the ICC on an evaluation process.
Costs/Benefits	At the end of 2010, a detailed assessment of the pilot will quantify the costs and benefits for a full-scale AMI deployment of roughly 4 million advanced meters in ComEd's service territory. It is currently estimated that total AMI vendor implementation costs for ComEd's entire service territory range from $600 million to over $1 billion.

Commonwealth Energy (ComEd) --- Illinois	
Driver	Increased regulatory and industry activity
Other Notes	The ICC is aware of a pilot project being conducted by ComEd to deploy 100,000–200,000 meters, and the pilot project should be starting soon; however, it is still under review and no set plan has been approved by the ICC. ComEd is also working with other utilities and other interveners to work on a Smart Grid deployment that will focus on "other pieces to the puzzle" as well as the cost of the program.

Community Energy (with ComEd) --- Illinois	
Description	ComEd began a voluntary program with 1,500 households in 2003, using Interval Recording Meters. The program used hourly energy pricing information provided through ComEd to develop hourly prices for participants and interval meters funded through the Illinois Department of Commerce and Economic Opportunity to record hourly energy usage.
Start/End Dates	2003–2006
AMI Solution/Product Used	Used ABB Interval Recording Meters that ComEd already had deployed; read once per month manually
Evaluation Process and Responsible Parties/Experts	Summit Blue Consulting did a third-party evaluation to determine whether energy use changed due to peak pricing. Summit Blue found that, overall, participants showed significant responses to hourly prices that were over and above the "high price" notifications.
Results and/or Lessons Learned	Over the life of the program, the average savings in decreased electricity consumption were 10%, with peak reductions of 15%–20% and a small conservation effect. Additionally, in 2003 and 2004, there was a recorded 12% cost savings for the participants. The Illinois Legislature passed a law in 2006 requiring that the state's two large utilities offer a residential real-time pricing program and subsidize the cost of advanced meters, as well as make a Program Manager available to interface with customers.
Driver	First large-scale real-time pricing program to test customer response and magnitude of effects on energy consumption
Next Steps	"Power Smart Pricing" and "WattSpot" are two programs that have begun due to the success of the pilot. Power Smart Pricing is a voluntary hourly pricing program for residential customers served by Ameren Illinois Utilities; the program gives residential customers access to hourly prices based on market prices. The program launched in 2007. WattSpot is a voluntary real-time pricing program monitored by ComEd. The program allows ComEd customers to choose lock-in savings real-time pricing, allowing the customer to choose the level of pricing online. An electric meter that has the capability of measuring and recording electric use is installed in the home, and the HVAC system is linked to the meter so that when the hourly electric price hits a level determined by the customer—either 10 or 14 cents—the central air conditioner in the home switches to a conservation mode for a two-hour time period. The program launched in 2007.

Ameren --- Illinois	
Description	Ameren is deploying the Cellnet metering reading system on the electric and gas meters to approximately half of their customer base. They are hoping to fully deploy the meters by the end of 2009. In 2006, Ameren began deploying AMR equipment for their 1.1 million

Ameren --- Illinois	
	residents in Illinois; however, the program has recently been transitioned to full AMI deployment, with AMI technology rather than solely AMR meter reading.
Contact Information	Carl Zetterberg, AMI Deployment Superintendent, 217-778-0731
Start/End Dates	April 2006–2009
AMI Solution/Product Used	Ameren is using Landis&Gyr for its AMI metering and network system.
Number of Meters	About 1.1 million meters will be converted to AMI at the end of this year, consisting of 635,000 electric meters and 465,000 gas meters.
Evaluation Process and Responsible Parties/Experts	Ameren is monitoring the program as they go forward, but thus far, they are very happy with the technology. Ameren is coordinating the AMI project with Landis&Gyr, which has coordinated with Terasen, who will perform the installation work. Terasen representatives will install the AMI meters for Ameren's residential customers and will install some commercial electric and natural gas meters as well.
Results and/or Lessons Learned	As a utility, Ameren has come to realize that they need to be heavily involved in the deployment and integration of processes. AmerenUE managers discovered they had to implement quality checks on gas meter retrofits because such procedures included ad hoc record keeping. Mid-way through AmerenUE's first deployment, the utility's managers had to implement audits and quality checks to ensure that what the people in the field were doing was accurate. For the electric metering, there have not been as many issues.
Driver	Directed to participate in statewide collaborative on smart grid technologies
Next Steps	Complete deployment

PECO --- Pennsylvania	
Description	PECO has deployed 2.2 million automated meters for both electricity and gas customers in both residential and large commercial/industrial customer classes.
Start/End Dates	Installation project lasted from 1999 to 2003
AMI Solution/Product Used	Cellnet Fixed Network solution was used for 2.2 million meters. 3,000 large C&I customers are on MV-90 and Metretek.
Evaluation Process and Responsible Parties/Experts	Cellnet manages the network, performs meter maintenance, and provides data to PECO. All meters are read daily. Additional features include on-demand reads and event processing.
Driver	Pilot to improve the operation of the electric distribution system
Results and/or Lessons Learned	AMR has been shown to reduce the number of estimated bills, improve the meter to cash cycle, increase revenue, reduce the customer average interruption duration index (CAIDI) and customer call volumes, and increase asset utilization, among others.

PPL Electric Utilities --- Pennsylvania	
Description	PPL implemented a meter data management system composed of a data repository and various applications to leverage the data. These applications include complex billing, revenue protection, distribution planning and operations, and ISO settlement. PPL Electric Utilities is the first major electric utility to provide hourly usage data in a full system deployment via the web.
Start/End Dates	Rollout began in spring 2002 and installation was completed in September 2004. The program is ongoing, and the company would like to provide customers access to their information via the internet by 2010.

PPL Electric Utilities --- Pennsylvania	
AMI Solution/Product Used	Aclara's two-way automation communication system (TWACS), advanced metering infrastructure (AMI) technology, and Aclara's meter data management system (MDMS) perform back-office data processing including advanced validation. Dashboard on PPL's website is hosted by Aclara.
Number of Meters	1.37 million electric meters
Costs/Benefits	Total capital costs of $160 million, and meters were $123 each. Costs were offset by operating savings. The O&M savings came from remote meter reading, fewer customer calls resulting from estimated meters reads, shorter phone calls as a result of having better data and daily data, remote collection of move-in/move-out meter reads, and lower cost to handle high-bill investigations. The present value utility benefits were estimated to be $205 million vs. costs of $198 million, with a present value analysis over 15-year life.[24] These figures came from the original plan that was implemented in 2004.
Driver	Changes in the regulatory, customer and operational environments
Next Steps	PPL Electric Utilities is using the hourly data to develop time-of-use rate options, which the utility plans to offer to all its customers starting in 2010. These plans provide different rates based on the cost of power throughout the day, allowing individuals to make more informed decisions about when they use electricity and how much they pay for it.

Indiana & Michigan Power (I&M – Subsidiary of AEP) --- Indiana	
Description	Indiana & Michigan Power (I&M) began installing nearly 10,000 General Electric Smart Meters in selected homes and businesses in the City of South Bend, Indiana during the fall of 2008, with intended full deployment by January 1, 2009. The purpose of the pilot is to test the technology and to see how customers respond to the benefits of Smart Meter technology. The program will also include two programs that have rate options: SMART Shift and SMART Cooling. SMART Shift is a time-of-day rate plan, and SMART Cooling is a program that includes a smart thermostat that can adjust air conditioners to conserve electricity. I&M and AEP will also be testing the grid technology by partnering with General Electric to install digital controls on the distribution system. The project will be the first deployment of Smart Grid technologies that AEP could implement in model cities across the company's 11-state service territory. The pilot is also part of an AEP initiative with General Electric announced last October. AEP and GE Energy, a business unit of General Electric, will pursue the development, integration, and deployment of advanced energy delivery infrastructure and metering technologies. The Indiana Office of Utility Consumer Counselor is also conducting a part in the pilot project.
Start/End Dates	January 1, 2009 (tariffs approved in January) to January 2010 (tentative)
AMI Solution/Product Used	GE Energy kV2c Meter Equipped (first deployment of this type of meter) with the Silver Spring Networks PowerPoint Network Interface Module
Number of Meters	10,000 (8,000 have been installed as of March 2009)
Evaluation Process and Responsible Parties/Experts	I&M plans to do evaluation with internal resources.
Results and/or Lessons Learned	No customer lessons learned as of yet. There have been some barriers faced due to the new technology, but I&M believes that this is because of the novelty of the system. They have continued to work with their vendors to overcome technical issues with the meters and the systems. Things in large part have gone pretty well and they are staying on a timetable that is acceptable to everyone.
Costs/Benefits	The pilot program resulted from a settlement agreement reached with the Indiana Office of Utility Consumer Counselor in 2007, under which the agreement stipulated that I&M would

[24] www.pplweb.com/rateinfo/pdf/testimony/Krall/Statement_4.pdf

Indiana & Michigan Power (I&M – Subsidiary of AEP) --- Indiana	
	invest up to $7,000,000 to install up to 10,000 meters.
Driver	To test technology and gauge consumer benefits associated with smart grid technologies
Next Steps	As of March 2009, 8,000 of the 10,000 meters had been deployed. I&M intends to go live on the distribution model piece of the pilot. The price tariffs are already available to consumers and have been approved by the Indiana Utilities Commission. The next step will be a direct load control program. The Indiana Commission has approved the load tariff. They are in the direct load control phase of the deployment with programmable thermostats installed in interested customer's homes. These thermostats will be able to communicate with appliances in the customers' homes and cycle-up and cycle-down according to the directions given by the programmable thermostats.

DTE Energy --- Michigan	
Description	DTE Energy, in partnership with Itron, has announced the launch of an AMI program that involves the installation of metering technology for all of their residential and commercial electric and gas customers. It will take approximately five years to replace or modify all 3 million DTE Energy customer meters. Itron will provide the equipment and help implement the program in Southeastern Michigan. A vendor has not yet been selected for AMI implementation in other areas of Michigan. DTE Energy awarded a contract for 2.6 million advanced meters at its Detroit Edison subsidiary with full deployment to begin in 2009.
Start/End Dates	2009–2015
AMI Solution/Product Used	R. W. Beck provided consulting services to expand AMI business case, and carry the project forward through AMI procurement and deployment. Additionally, R. W. Beck supported its MDMS solicitation. Itron, OpenWay CENTRON® electric meters, gas modules and related system software and implementation services. A vendor has not yet been selected for AMI installation in the service territory served by MichCon. DTE Energy has a project under development to install and integrate an MDM system using EnergyICT's product. DTE will be using ZigBee Smart Energy.[25]
Number of Meters	3 million; planning to automate 2.6 million electric and 700,000 gas meters starting in 2009
Costs/Benefits	$350 million program over six years
Driver	Technology to serve as a major driver for service quality and to provide more options for customers to manage energy bills

Consumers Energy --- Michigan	
Description	Consumers Energy is investing $500 million in advanced metering infrastructure. The system will integrate smart appliances so that customers have complete control over their energy consumption. Customers will have the option to manage their own energy consumption or can allow Consumers Energy to do it for them. Participating customers can expect to save up to 10% off their energy bill. Beginning in February 2009, Consumers Energy began to install around 6,000 smart meters in Jackson County, Michigan, in an installation project scheduled to last until June. Customers who have been selected to receive the devices will be notified of the scheduled installation by mail.
Start/End Dates	February 2009–June 2009
AMI Solution/Product Used	SAP® AMI Integration for Utilities software
Number of Meters	6,000 smart meters for the pilot

[25] www.zigbee.org/imwp/download.asp?ContentID=14741

Consumers Energy --- Michigan	
Evaluation Process and Responsible Parties/Experts	IBM (plan, deploy, and test an AMI and Smart Grid field pilot network)
Results and/or Lessons Learned	Project is still in deployment phase.
Driver	To comply with the 21st Century Energy Plan that has been submitted to state lawmakers
Next Steps	Next year, in 2010, the devices will undergo testing; if the pilot proves successful, in 2011 smart meters will be deployed throughout the state.

Duke Energy --- North Carolina	
Description	State regulators approved a Smart Grid project on March 9, 2009. Duke Energy will begin with a small project involving 200 customers in the southern part of Charlotte. Duke Energy will provide the 200 customers with meters, which will be connected to the system. The Smart Grid will include energy management services, home area network gateway, web-based applications, and tools to improve distribution. The project also involves the installation of a large storage battery and solar panels capable of generating 50 kilowatts of power. Through the use of the smart meters and storage batteries, Duke Energy will be able to determine the most efficient and effective way to use the system while improving the reliability of electrical service at the same time. For participating in the program, customers will receive rebates of up to $10 on each bill in addition to the savings generated by conserving energy. Duke Energy has not said how much the pilot program will cost. Duke Energy expects to report results of the program to the commission by the end of 2010.
Start/End Dates	March 2009–December 2010
AMI Solution/Product Used	R. W. Beck was retained to provide a strategic road mapping program for a "Utility of the Future." The deployment in Charlotte will utilize a combination of meter manufacturers, Echelon and GE, and other distribution devices connected with an RF mesh wireless network and digital cellular technology. Line sensors, substation equipment, and capacitors will be connected to the network.
Number of Meters	200
Driver	To test smart grid technologies as part of Duke's $1bn five year investment in smart grid equipment
Next Steps	Deployment and evaluation.

Progress Energy Carolinas, Inc. --- North Carolina	
Description	Over the course of 18 months, Progress Energy and Itron replaced 2.7 million electro-mechanical meters with Itron's AMR-equipped CENTRON® solid-state meter.
Start/End Dates	January 2006–May 2007 (AMR deployment)
AMI Solution/Product Used	R. W. Beck was retained to develop Technical AMI specifications, develop acceptance testing requirements, assist with the vendor selection process, and oversee installation processes. Itron CENTRON® solid-state meter
Number of Meters	2.7 million
Driver	To cut costs
Results and/or Lessons Learned	The meters were effective for the company, as it experienced a 50% reduction in meter-related billing complaints, and cost savings of approximately $21 million annually. The company is determining how to move forward with AMI technology deployment.

Duke Energy --- Ohio	
Description	Duke Energy is launching an AMI effort with a pilot program that calls for 480,000 smart meters to be installed in neighborhoods around Cincinnati and Northern Kentucky. While 60,000 smart meters have already been installed, the meters will not be fully operational until mid-2010 when the supporting technology is in place. Distribution assets will also be connected to the network and back office integration systems. Customers will be connected to an online portal where energy information gathered from the system can be delivered to shape energy usage.
Start/End Dates	April 2008–2009
AMI Solution/Product Used	GE and Echelon meters, communication systems from Silver Spring Networks, and digital cellular
Number of Meters	Number of endpoints: 50,000 electric, 42,000 gas; 146,000 additional intelligent electric meters and 48,000 additional intelligent gas meters in Cincinnati in 2009
Evaluation Process and Responsible Parties/Experts	Evaluation is being conducted by the Public Utilities Commission of Ohio. This AMI rollout is part of Duke Energy's "Utility of the Future" program, and results will also be evaluated internally.
Results and/or Lessons Learned	This AMI rollout is part of Duke Energy's "Utility of the Future" program; lessons learned will be identified at the end of the program.
Costs of Initial Deployment	$20–$25 million
Driver	NA
Next Steps	Continue deployment of intelligent electric and gas meters in Cincinnati

AEP (Columbus Southern Power Company and Ohio Power Company) --- Ohio	
Description	AEP has filed a pilot AMI proposal with the Public Utilities Commission of Ohio (PUCO) for 105,000 of its customers in central Ohio in the Columbus area. This AMI proposal is a multi-year initiative, and the company hopes to roll out full deployment of AMI ready meters by 2015, pending cost-recovery approval. The AMI pilot is part of AEP Ohio's gridSMART program. The gridSMART program involves a phase-in approach of several components, including AMI, Home Area Networks (HAN), and Distribution Automation (DA).
Start/End Dates	2009–2015
AMI Solution/Product Used	IBM will provide AEP with support services across the program, including program management, business process design, systems planning, and system interfaces.
Number of Meters	100,000 customers in first year, all 1.5 million Ohio customers by 2015
Costs/Benefits	Proposed net cost of $19.7 million of O&M and $89.2 million of capital investment.[26] Direct capital investment per meter ranges from $299–$348.[27] AEP hopes that its smartGRID initiative can automate meter reading, improve meter reading accuracy, improve the safety of AEP Ohio employees, help reduce outage events and duration, and increase restoration efficiencies.
Driver	New framework under state legislation SB 221 in 2008 that outlined a path for electric utilities to implement market-based pricing

[26] http://www.pickocc.org/about/rfps/rfp_2009-05.pdf
[27] AEP. "AEP's 'gridSMART' Project Ohio Roll Out Strategy PUCO Staff Workshop." December 2007. www.puco.ohio.gov/emplibrary/files/media/CMSFiles/WebcastRelated/275/Ohio%20Workshop_Cost_Benefit_final.ppt

AEP (Columbus Southern Power Company and Ohio Power Company) --- Ohio	
Next Steps	If PUCO approves cost recovery for AMI implementation for all of AEP Ohio, all meters will be converted to AMI by 2015.

Other Notable Smart Grid/AMI Deployments

Xcel – Boulder SmartGridCity™ --- Colorado	
Description	Xcel Energy is leading a $100 million venture to turn Boulder, Colorado, into a smart-grid city. 15,000 homeowners and businesses in Boulder received smart meters in the summer of 2008 with the intention of helping them monitor their energy usage and make choices based on price and the type of fuel used, such as coal, natural gas, or wind. The smart grid aims to allow some plug-in hybrid electric cars to feed power to the grid and even serve as backup generators for homes. The smart grid also will allow the utility to integrate solar and wind power to specifically serve Boulder.
Start/End Dates	March 2008–August 2010
AMI Solution/Product Used	Landis+Gyr[28]; the primary means of communication will be broadband over power lines (BPL); CURRENT Smart Grid™. SmartSynch is responsible for the delivery of commercial "smart meters" and energy management software to Boulder businesses.[29]
Number of Meters	15,000[30]

[28] "Smart Grid City Design Plan." Xcel Energy. http://smartgridcity.xcelenergy.com/media/pdf/SmartGridCityDesignPlan.pdf

[29] Brautigam, Jane et al. "Memorandum to Mayor McGrath and members of City Council: Update on Xcel Energy's Smart Grid." October 22, 2008. http://www.bouldercolorado.gov/files/City%20Council/Study%20Sessions/2008/10-28-08/m-smart_grid.ss.10.28.08.final.pdf

[30] "Smart Grid City Design Plan." Xcel Energy. http://smartgridcity.xcelenergy.com/media/pdf/SmartGridCityDesignPlan.pdf

Xcel – Boulder SmartGridCity™ --- Colorado	
Evaluation Process and Responsible Parties/Experts	Accenture, Current Group, GridPoint, Schweitzer Engineering Laboratories, and Ventyx are partners in the Smart Grid Consortium. Partners will provide guidance and products and services for Xcel's Smart Grid. Descriptions of the roles of each partner are as follows:[31] **Accenture**: Accenture is managing the integration and management of data flow, including automating processes, transmission and distribution of electricity. To develop the Smart Grid, Accenture will integrate diagnostic software, intelligent distribution assets and outage management software into Xcel Energy's existing IT infrastructure and will be building a lab-like environment for testing power outages, reliability, and potential impacts to the grid. **Current Group**: Current Group is using their fully integrated CURRENT Smart Grid™ solution that combines advanced sensing technology, two-way high-speed communications, 24/7 monitoring and enterprise analysis software, and related services to provide location-specific, real-time data. The solution provides consumers information and control over their energy usage and enables the widespread deployment of renewable energy sources. **GridPoint**: GridPoint uses their SmartGrid Platform™ to apply information technology to the electric grid to provide an intelligent network of distributed energy resources that controls load, stores energy, and produces power. The platform enables Xcel to evaluate technology and system capabilities such as advanced demand management, supply management, solar photovoltaic integration, PHEV smart charging, online energy management, instant backup power, performance monitoring, and customer support. **Schweitzer Engineering Laboratories (SEL)**: SEL's work in SmartGridCity™ will focus on the "smart substation" effort. **Ventyx**: Ventyx supports SmartGridCity™ by providing work management solutions for deploying Smart Grid technologies; maintenance, repair, and operations (MRO) management for work and service requests triggered by the Smart Grid; and planning and analytics for price and load forecasts and decision support for connecting customer actions to trading and investment decisions in real time. **Spirae**: Spirae was hired by the City of Boulder to help conduct an independent analysis of the Smart Grid plan by Xcel.[32]
Results and/or Lessons Learned	At the end of the initial SmartGridCity trial period (determined by Xcel to be the end of 2009), the city of Boulder will determine whether the project has delivered increased system reliability as measured against pre-determined metrics. Boulder city council staff will report back to council with proposed metrics as part of the SmartGridCity check-ins in 2009.
Costs/Benefits	Estimated costs of $100 million for the Consortium to deploy the trial project. It is estimated that the costs will be $17 million for Xcel Energy. Funding of the SmartGridCity™ project is a shared-risk model with contributions from multiple partners, primarily provided in exchange for a testing platform for their products or services.[33]

[31] "Smart Grid City Design Plan." Xcel Energy. http://smartgridcity.xcelenergy.com/media/pdf/SmartGridCityDesignPlan.pdf

[32] Brautigam, Jane et al. "Memorandum to Mayor McGrath and members of City Council: Update on Xcel Energy's Smart Grid." October 22, 2008. http://www.bouldercolorado.gov/files/City%20Council/Study%20Sessions/2008/10-28-08/m-smart_grid.ss.10.28.08.final.pdf

[33] Brautigam, Jane et al. "Memorandum to Mayor McGrath and members of City Council: Update on Xcel Energy's Smart Grid." October 22, 2008.

Xcel – Boulder SmartGridCity™ --- Colorado	
Driver	Xcel wanted to construct the first smart grid city in the country to serve as a cornerstone for its strategy to address environmental and global energy challenges.
Next Steps	Trial period will conclude, followed by a determination of the success of the program. Xcel will also seek regulatory approval for a tiered electricity rate for Boulder residents later this year and implement it in early 2010.

Austin Energy --- Texas	
Description	The City of Austin, Austin Energy, the Environmental Defense Fund (EDF), and the University of Texas have launched a Smart Grid initiative plan called the Pecan Street Project. The project brings together stakeholders to determine the interrelated issues surrounding a Smart Grid deployment, and seeks to utilize the city of Austin, TX, as a laboratory for pilot and long-term projects. The project currently has two planned stages: **Stage 1**: End of January–Beginning of August 2009: Teams comprised of representatives from stakeholders will get together and think about the interrelated issues and the challenges the utilities will face when implementing a Smart Grid. They will provide their recommendations to Austin Energy, and determine which projects should be piloted and what projects should be researched further. Essentially, Stage 1 is laying out the problem, suggesting short-term solutions, and roadmapping a long-term model. **Stage 2**: No set timeline: The City of Austin and its partners will commence implementing projects that can be implemented, i.e., conducting research, and launching pilot projects. **Future Stages**: The Consortium, as it exists now, is something that may or may not continue in the future. If the corporate partners are interested, they can form a more long-term consortium, similar to Sematech—the consortium of U.S. semiconductor companies. They would like to have the companies continue research in Austin. For its AMI deployment, Austin Energy is scheduled to finish deploying all of their smart meters this summer, and this project is far beyond just smart meters.
Start / End Dates	The governance stakeholders met in October 2008 to draw up an outline.
AMI Solution / Product Used	Austin Energy has a Cellnet+Hunt RF mesh communications network. Austin Energy has utilized a Cellnet+Hunt fixed-network advanced metering solution for approximately one-third of its customers since 2002. Austin Energy has integrated GE Energy's distribution management system technology into its existing outage management system. These applications will work in combination with the geospatial information system-essentially, a GPS for the grid to help notify the utility when a portion of the grid goes down (or is in danger of doing so), which maximizes power reliability.[34]
Number of Meters	Austin Energy has 234,000 residential and C&I meters; however, not all are included in the city of Austin Pecan Street Project.
Evaluation Process and Responsible Parties/Experts	The Consortium and evaluation process is structured with a three-tiered system. **First Tier**: The first tier members are the non-profit and local entities that initialized the project. This is the governance group that has the ultimate decision making for shaping the recommendations. Entities in this group are

http://www.bouldercolorado.gov/files/City%20Council/Study%20Sessions/2008/10-28-08/m-smart_grid.ss.10.28.08.final.pdf

[34] "Austin Energy Launches Smart Grid Deployments." Renewable Energy World, September 24, 2008. http://www.renewableenergyworld.com/rea/news/article/2008/09/austin-energy-launches-smart-grid-deployments-53658

Austin Energy --- Texas	
	Austin Energy, City of Austin, EDF, University of Texas, UT Austin, Technology Incubator, and Austin Chamber of Commerce. **Second Tier**: The second tier is comprised of a member of each of the governance entities, as well as representatives from corporate partners. This group is considered the "day-to-day" project managers. Corporate partners include Applied Materials, Cisco, Dell, Freescale, GE, Gridpoint, IBM, Intel, Microsoft, Oracle, and Sematech. **Third Tier**: The third tier consists of action teams populated by all of the entities listed above, plus other participants that may have a part in the process. There are 12 action teams that cover topics such as distributed generation, technology, energy efficiency, demand response, network storage, water conservation, systems integration, developing a business model, customer interfaces, legislation and regulatory changes, workforce training, and assessing environmental benefits and costs of new technologies.
Results and/or Lessons Learned	Most "lessons learned" will not occur until after Stage 2.
Costs/Benefits	Most "costs" will not occur until after Stage 2.
Driver	NA
Next Steps	Finishing Stage 1

National Grid	
Description	National Grid has submitted a proposal to the Massachusetts Department of Public Utilities (DPU) to build and operate a Smart Grid pilot in Worcester, Massachusetts. The pilot will involve approximately 15,000 customers. The pilot will take place over two years, and it will cover more than 1% of its Massachusetts customer base. The area covered includes a wide variety of customers—single and multi–family and small business—from urban, suburban, and rural settings with variable electricity usage. Customers will be given the opportunity to choose among three potential new Basic Service rate alternatives ("Smart Grid Pricing"): Critical Peak Pricing Program, Peak Time Rebate, and Hourly Pricing Program. The pilot will also integrate plug-in hybrid electric vehicles ("PHEV"). For the proposed pilot, National Grid has obtained the use of a Ford PHEV and is developing a program for demonstration and testing in anticipation of the arrival of the PHEV in the third calendar quarter of 2009. National Grid's strategy overlays the electric grid with a two-way communications network with speed and capacity sufficient to enable advanced metering, home energy automation and management, and distribution automation and management; and to support distributed generation and storage functions. In addition, National Grid has submitted a proposal to the NY PSC for two pilots in NY.
Start / End Dates	The proposed timeline is to conduct the pilot for 31 months.
AMI Solution / Product Used	The vendor selection process has not yet been completed by National Grid. However, the utility has determined that existing meters will be replaced with advanced digital smart meters; additionally, in-home energy management technologies will be made available to customers who choose to use them.
Number of Meters	Initially, 250 meters will be installed in 2009. Beginning in September or October of 2010, meter replacements will ramp up (500 – 1st month, 1,000 – 2nd month, 5,000 – 3rd month) until approximately 15,000 smart meters are installed, replacing current meters.
Evaluation Process and Responsible Parties/Experts	Doug Houseman of Capgemini CTO will oversee security compliance for the pilot. The evaluation of the technology will be internally undertaken.

National Grid	
Costs/Benefits	The overall pilot cost is estimated at $56.4 million. This includes costs for hardware, software, and services. The cost on a per meter basis is $3,760; however, the Pilot description document indicates that this number is not representative of the costs of an overall deployment, and that the cost of a full-scale deployment would be lower when acquiring the equipment and software at a mass deployment scale.
Driver	American Recovery and Reinvestment Act of 2009, Massachusetts Green Communities Act
Next Steps	Receive approval by the Massachusetts DPU to launch the Smart Grid pilot.

Appendix A. Maryland's Electric System

The following data describe the electric resources in the State of Maryland at this early stage of the Smart Grid initiative.

Table A-1. Maryland Electric Utility Data (approximate values)

Total # of meters	2 million[1]
Total # of transformers	353,000[2]
Miles of transmission lines	2115[2]
Miles of distribution lines	37,500[2]
Total # of substations	415[2]
Annual consumption (2007)	63,430 MWh[3]
Peak demand (2007)	15,000 MW[3]
Projected annual load growth	0.97%[3]
Baltimore Gas & Electric customers w/Direct Load Control	25%[4]

Notes:
[1] EIA 2007
[2] www.bge.com; prorated for number of customers in state
[3] ACEEE, "Energy Efficiency: The First Fuel for a Clean Energy Future," February 2008
[4] FERC, "Assessment of Demand Response and Advanced Metering," August 2006

Table A-2. Maryland Electric Generation by Fuel Type (2006)

Coal	61%
Nuclear	28%
Natural Gas	4%
Hydro	4%
Petroleum	1%
Renewables	1%
Other	1%
Total Generated	**49,000 GWh**

Note:
Source: EIA, 2007

Appendix B. Sources

Smart Grid deployment activities referenced in this report include those recommended in the following references. Significant cost and benefit information on demand response programs, distributed generation, and renewable supply is included in these sources.

- Governor's Energy Summit Proceedings, July 25, 2007
- Maryland Strategic Electricity Plan, January 14, 2008
- Energy Efficiency: The First Fuel for a Clean Energy Future (ACEEE), February 2008
- Maryland Public Service Commission Administrative Docket PC-12, May 22, 2008

Other sources include:

- Research on the Characteristics of a Modern Grid: Optimizes Asset Utilization and Operates Efficiently
- Smart Building Technology Moves to the Home
- Web Interfaces Will Fuel the Emergence of the Smart Grid
- Research on the Characteristics of a Modern Grid: Self Heals
- "Visions for a Sustainable Energy Future", by Mark Gabriel, The Fairmont Press