GRIDWISE ALLIANCE Advocating for an Optimized Grid

Realizing the Value of An Optimized Electric Grid

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Prepared By:

QUANTA TECHNOLOGY

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EXECUTIVE SUMMARY

Today's electric grid is vital to our society and economy. It's fundamental to our education, manufacturing, retail, transportation, and financial systems. However, today's power grid is aging, inadequate for the new and increasing demands being placed on it, and outdated in many respects. The grid is being challenged to integrate new energy resources, such as wind and solar; and new demands, such as plug-in electric vehicles. In order to meet these challenges, the "business-as-usual" approach is no longer an option. Investment is needed to improve its material condition, to ensure adequate capacity, and to enable it to address the expectations of the modern customer. As we confront these challenges, it is necessary to recognize that the main beneficiaries of grid modernization are the energy customers and society as a whole. As such, we will need to build an intelligent, flexible, and sustainable grid that is both customer-centric and capable of balancing societal values, customer needs, and system operation constraints. In order to realize this vision and value of a modernized electric grid, all stakeholders must seek common agreement.

The GridWise® Alliance and Quanta Technology conducted research to report on the state of grid modernization and to quantify the benefits of a modernized electric grid. Detailed data was gathered through in the first-person interviews with selected industry representatives to discuss their experiences and results. Public information research of existing documents was also conducted by the research team. Based on the results from the interviews and research, the following six key technical domains that categorize smart grid implementation activities were identified:

Technical Domains:

- Renewable Generation and Distributed Energy Resources Integration
- Grid Control and Optimization
- Transportation Electrification
- Customer-Side Applications
- Workforce Effectiveness
- Communication Architecture and Integration

In addition, the following five major categories of key benefits and values of grid modernization were indentified:

Key Benefits and Values:

- Grid Reliability and Security
- Customer Energy Management Opportunity
- Asset and Resource Optimization
- Health, Safety, and Environment
- Productivity and Economic Growth

Grid modernization is still in its beginning stages. As such, much of the literature and discussions are based on expected benefits, but quantitative data is becoming increasingly available. Moreover, concrete examples of demonstrated benefits of grid modernization have been captured. They include examples of improvements to electric reliability, energy savings, and customer engagement among others.

This report contains case study examples and in these examples provided in Section 3, both quantitative and qualitative values have been captured. From these examples, a list of more than 20 different ways in which benefits can be and are being assessed were identified. These case studies demonstrate consistent realized or expected benefits across all of the technical domains and value categories. The assessment techniques used in this research are also being successfully used by utilities to demonstrate the benefits and progress of their grid modernization efforts. Some examples include:

- Oklahoma Gas and Electric has demonstrated energy savings improvements by implementing volt/VAR optimization on its electric system. Reducing voltage by 2% on an automated circuit has been shown to make a corresponding 1-2% reduction in demand/energy consumption. As a result of this smart grid investment in distribution automation and volt/VAR control, Oklahoma Gas and Electric has been able to delay the need to construct a new power generation plant to outside of their 10 year planning horizon.
- Southern California Edison has shown improvements in system reliability as a result of its advanced distribution system. As a result of distribution automation, Southern California Edison has achieved a 33 minute reduction in average Customer Minutes of Interruption. This represents a 47% improvement. Similarly, total Customer Minutes of Interruption were reduced by 18,949 minutes or approximately 17%.
- Pacific Gas & Electric launched its SmartRate program which is a critical peak pricing tariff option that requires internal meter data to implement. During the 2010 summer season, Pacific Gas & Electric Company called thirteen (13) Smart day events during which SmartRate participants reduced energy consumption by 14.1% on average. An analysis of the programs finds that 88% of the respondents experienced lower costs as a result of SmartRate participation.

It is believed that many customer and social benefits from smart grid can be realized through efficient deployment plans. As with most large scale investments and policy issues, it is necessary to find the right balance in sharing costs, benefits, and risks. In any case, to provide sustained momentum for utilities to continue smart grid deployment, regulatory support is required both from both a policy and a financial perspective. During our interview, two regulators, from the District of Columbia Public Services Commission and the Illinois Commerce Commission, respectively, provided their insights on the urgency and necessity of grid modernization.

From our research, several observations and challenges regarding successful grid modernization were identified, namely:

- Technology readiness;
- Market readiness and risks;
- Realization of potential benefits;
- Impacts of financial support; and
- Customer engagement.

As evident from the case study examples, many benefits of a modernized grid can be realized and the challenges overcome as technology is deployed and experience is gained. As we progress, it is imperative to transition grid modernization initiatives into "normal course of business." Our electric grid is a vital strategic asset that requires investment to bring it into 21st century technology.

Moving forward, the challenges we face and the issues raised in our observations should be addressed jointly by regulatory policymakers, utilities, and customers to ensure the successful implementation of grid modernization projects. The GridWise Alliance stands ready to facilitate this collaboration among stakeholders in order to achieve the important goal of transforming the electric system to achieve a sustainable energy future for the public good. Optimizing our energy resources, energy delivery, and energy consumption is made possible by modernizing the United States' electric grid.

1 INTRODUCTION

1.1 The Current State of the Electric Energy Industry

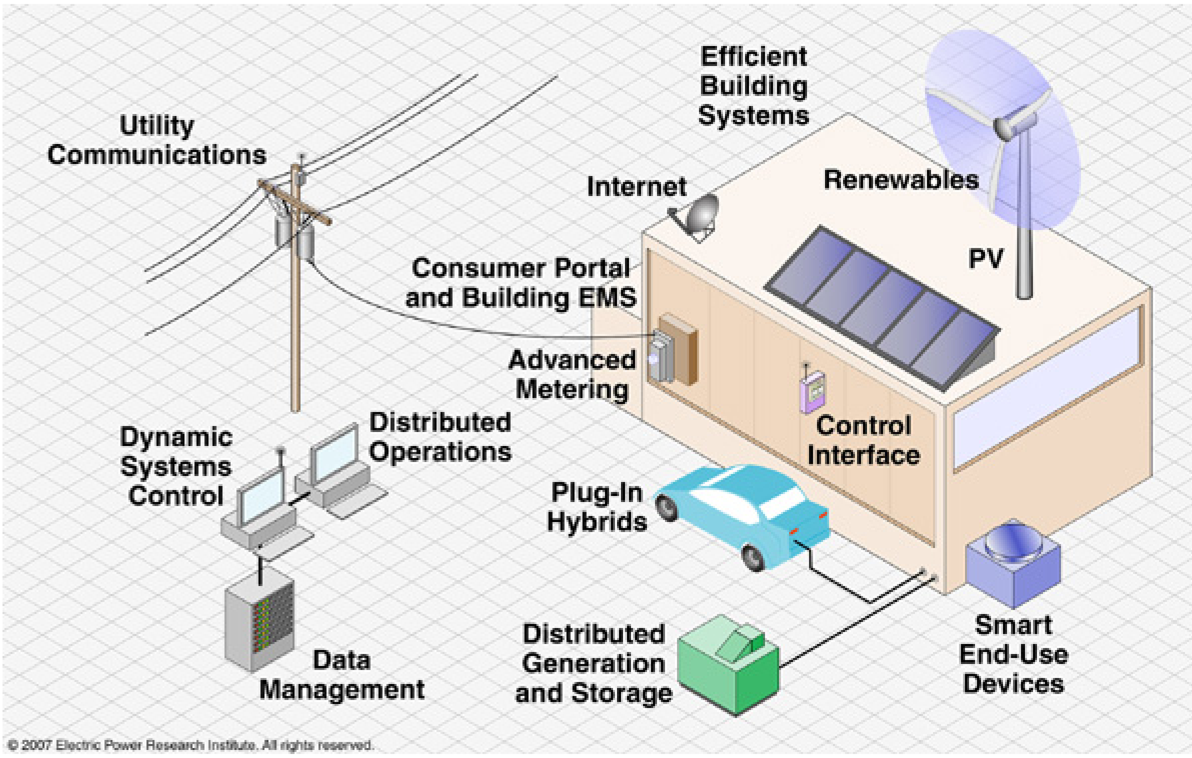
In the U.S., there are more than 142 million electric customers demanding over 4,200 billion kWh of electricity annually. Despite the recent economic downturn, the nation's customer base is expected to grow 16% over the next 20 years to more than 165 million customers, and increased demand to approximately 5,200 billion kWh [6, 9, 58]. Today's power grid needs to be upgraded because it is aging, inadequate for new demands being placed on it, and outdated in many respects. Investment is needed to improve its material condition, ensure adequate capacity, and enable it to meet modern customer expectations, such as service reliability, additional usage information, innovative energy management opportunities, etc. Even more challenging is the need to integrate new energy resources and demands. It is anticipated that approximately 200 GW of renewable energy generation, both centralized and distributed, will be added by 2020, primarily via wind turbine and photovoltaic systems [40]. Introduction of these generation resources creates challenges to grid operations due to the intermittent characteristics of these resources and the complexity of interconnection to the transmission or distribution system. On the demand side, adoption of plug-in electric vehicles (PEVs) is expected to increase dramatically, with an estimated 20 million PEVs in use by 2030 [40]. With each PEV requiring high demand of power for charging, this variable load, if left unmanaged as to when and where it occurs, could further stress an already-stressed grid.

The "business-as-usual" approach is not an option. High customer expectations with respect to power reliability and quality should be addressed by advanced automation, monitoring, and power protection technologies. Based on research conducted by the Electric Power Research Institute (EPRI), overall reliability can be improved by 40% through a fully automated distribution system [6]. The intermittency introduced by renewable generation can be mitigated by advanced energy storage or optimal profiling of solar and wind generation. The growth of energy demand requirements, including demands from PEVs, should be managed through effective demand response or other demand-side management programs, such as dynamic pricing, direct load control, and integration with customer home area networks (HANs). Based on Federal Energy Regulatory Commission (FERC) estimation, effective demand side management programs can cut peak demand by up to 20% within 10 years [15]. More grid modernization efforts should be conducted. As discussed in the recent International Energy Agency (IEA) report, "Smart Grid Technology Roadmap," the electric energy industry needs dramatic changes and widely deployed new technologies to modernize the grid in order to address the challenges it faces [41].

1.2 The Momentum of Smart Grid

The intention of "smart grid" is to modernize grid infrastructure and build in intelligence to power grids and delivery systems, and their interfaces to customer premises as illustrated in Figure 1. The perspectives range from an emphasis on infrastructure to an emphasis on new paradigm-shifting applications. The recent smart grid initiatives can be considered the single largest grid modernization investment in American history. Multi-billion dollar investments from both government and industry are fueling major activities over the next several years, providing the greatest momentum in transforming the energy industry in decades. With this investment in grid modernization research, development, and implementation, regulators and policymakers are trying to understand the costs and benefits of these efforts.

Figure 1: Diagram of Smart Grid Network



As smart grid development proceeds, it is necessary to understand that the final recipients of grid modernization benefits are the energy customers and society at large. In the long term, we will need to address how to build an intelligent and sustainable grid that is both customer-centric and capable of balancing multiple factors (e.g., societal values, customer needs, and system operation constraints). Policymakers and regulators are faced with the challenge of reconciling the large and complex investments required to modernize the electrical system and to develop a better way to connect the end customer to the electricity markets in a manner that allocates benefits and risks between customers and providers.

EPRI provides high level estimates of the costs and benefits of aggregate smart grid investment in the U.S [6]. As summarized in Table 1, the total benefit of all attributes for the smart grid is estimated to be between $1,294 billion and $2,028 billion for the period from 2010 to 2030. Based on EPRI's report, once all of the attributes and benefits of a smart grid are identified and analyzed, estimates of the total benefit may increase even more. It is estimated that the net investment in smart grid produces value that significantly outweighs cost, resulting in a benefit-to-cost ratio range of 2.8 to 6.0, based on the underlying assumptions discussed in the EPRI technical report. The report indicates an investment level of between $17 billion and $24 billion per year will be required over the next 20 years. These costs include the infrastructure to integrate distributed energy resources (DER) and to achieve full customer connectivity, but does not consider the cost of additional generation, the cost of transmission expansion to add renewable energy and to meet load growth, nor a category of customer costs for smart-grid-ready appliances and devices. In addition, renewable generation could also help society by reducing annual carbon emissions by between 60 and 211 million metric tons of CO_2, or equivalent to converting 14 to 50 million cars into zero-emission vehicles each year [7].

Table 2: Summary of Estimated Cost and Benefits of Smart Grid

	20-Year Total ($ Billion)
Net Investment Required	338 – 476
Net Benefit	1,294 – 2,028
Benefit-to-Cost Ratio	2.8 – 6.0

(Provided by EPRI Report 1022519: *Estimating the Cost and Benefits of the Smart Grid)*

1.3 Purpose of the Project

The GridWise Alliance engaged Quanta Technology to prepare this paper to better inform the public, federal and state policymakers, and regulators about the value and benefits of a more intelligent electric grid. The GridWise Alliance, founded in 2003, represents a broad range of the energy supply chain, including utilities, technology product and service companies, telecommunication companies, equipment manufacturers, academia, consultants and venture capitalists. The mission of the GridWise Alliance is to transform the electric grid to achieve a sustainable energy future for the public good. By helping policymakers and regulators to more clearly identify the value proposition, they will be better able to support prudent investments that will sustain and accelerate the transformation needed to modernize the entire energy ecosystem.

This paper documents the project team's findings from two parallel approaches:

- *Interviewing selected key industry participants using a set of prescribed topics for discussion*. The goal of the interviews was to gain insight from the participants, learning from their experiences, deployment results, and views on benefits that have been or may be realized through smart grid implementations.
- *Conducting a thorough review of publicly available information on the smart grid including technical reports, papers, press releases and presentations related to smart grid from utilities, independent system operators, R&D organizations, technology product vendors, service providers, and government agencies.* The research leveraged Quanta's expertise and knowledge.

This paper is organized as follows:

- Section 2 provides a summary on smart grid implementation and value proposition, which addresses drivers, technical domains, and key benefits.
- Section 3 summarizes case studies, observations, and challenges, from both interview and research results. Representative case examples are included in the Appendices.
- Section 4 summarizes concluding remarks.

2 SMART GRID IMPLEMENTATION AND VALUE PROPOSITION

There have been a great many activities relating to grid modernization efforts during the past several years. These activities range from customer-side applications to utility grid operations to renewable generation integration. Through the comments from interviewees and public research, certain key topics relating to smart grid implementation and its value proposition became evident in their importance to the electricity providers and regulators. These key topics include: (a) the key drivers for smart grid; (b) the technical domains that categorize smart grid implementation activities; and (c) the associated benefits that can result from smart grid efforts. These topics are discussed in the following sections.

2.1 Drivers of Smart Grid

Smart grid drivers have and will continue to determine the scope, allocation of resources, and priorities in the deployment and implementation of various smart grid technologies. These drivers can be not only initiated by utility business operation needs, but also by regulatory policies, economic considerations, and of course, providing benefits to customers.

Operational Drivers

The operational drivers that are propelling grid modernization in the United States include:

- *Service Reliability and Outage Prevention.* This is increasingly important in an information service-based economy. There have been five major blackouts in the last 40 years, three of which occurred in the last decade. The Northeast blackout of 2003 resulted in an estimated $7 - 10 billion in losses to the region [6]. A modernized grid will improve reliability.
- *Power Quality.* While less disruptive but more pervasive, power quality problems are estimated to now cost the U.S. $119 - 188 billion per year based on estimates from EPRI [6].
- *Electric Vehicle Integration.* With over 200 million vehicles on the road in the U.S. alone, a significant move towards the electrification of transportation requires grid modernization to take advantage of the environmental, financial and public policy benefits electric vehicles can provide.
- *Renewable, Alternative, and Distributed Generation.* Proliferation of new distributed energy resources, (e.g. the rapid adoption of rooftop-solar throughout the nation), will require grid modernization if we are to maintain existing levels of reliability and power quality.
- *Customer Empowerment.* Providing customers with more information, choices and engaging them to actively participate in grid operation from the demand-side introduces greater operational and market complexity.

Regulatory Drivers

Grid modernization initiatives were facilitated through two federal Acts: the Energy Independence and Security Act (EISA) of 2007 and the American Recovery and Reinvestment Act (ARRA) of 2009. ARRA made available grants totally $4.3 billing to one hundred companies with the expressed purpose of accelerating the modernization of the U.S. electric grid. Other federal and state initiatives that drive grid modernization include:

- *Smart Grid Interoperability Standards Facilitated Through National Institute of Standards and Technology (NIST) Activities*. While not necessarily a driver of grid modernization investment, these recommended standards facilitate smart grid deployment through lower deployment costs and more effective benefits realization.
- *Critical Infrastructure Protection (CIP) Cyber Security Standards*. These mandatory and enforceable standards are intended to ensure the protection of the critical cyber assets that control or affect the reliability of North America's bulk electric systems.
- *Demand Response (DR) Programs*. DR continues to gain ground through state legislative initiatives and utility regulation. FERC's "A National Assessment of Demand Response Potential – Staff Report"

from June 2009 and their staff report "National Action Plan on Demand Response" from June 2010, highlight the potential for DR as a load reduction means.
- *Renewable Portfolio Standards (RPS).* RPS have been established in 30 states plus the District of Columbia, stimulating rapid expansion of renewable technology and accelerating the need for smart grid technology for grid integration of these new renewable sources.
- *Federal Environmental Protection Agency (EPA) Rules.* New EPA rules, including the "transport rule," cover cross-state air pollution and the Mercury and Air Toxics Standards (MATS). These and future regulations which may emerge change the economics and planning of generation resources.

In addition to the federal initiatives, some states have adopted grid modernization related policies as part of their statutes. For example, California adopted its smart grid policy in 2009, with the approval of Senate Bill 17 introduced by Senator Alex Padilla. This codified various smart grid related policies and activities that the California Public Utilities Commission (CPUC) has already initiated. It gives proper latitude to CPUC in determining cost-recovery for smart grid investments as it deems appropriate. Moreover, it specifically addressed the approaches on regulatory as well as smart grid standards and protocols, and expectations on publicly-owned utilities and suggestions on rate-recovery. It establishes as state policy the modernization of the state's electrical grid to maintain reliable and secure electric service with infrastructure than can meet future growth in demand while achieving other objectives. It also establishes a regulatory approach for the California Public Utilities Commission (CPUC) and investor-owned utilities to follow in consideration and deployment of smart grid technologies [14]. Smart grid initiatives may also be structured to support compliance with a state's energy and environmental policies (e.g., Renewable Portfolio Standards (RPS), energy efficiency, demand response, and climate change).

Commercial Drivers

The grid modernization market has the attention of a multitude of vendors and investors. There is and will continue to be a significant technological upgrade to the electric system. As such, large technology, small technology, telecommunication, and software and service companies have focused efforts on smart grid.
- *Market Demand for Smart Grid Technologies*. Major technology companies have seen opportunities to participate in one of the most attractive business opportunities of the future. The smart grid market potential is viewed in terms of its trillion-dollar potential worldwide.
- *Venture Capital (VC).* VC is also entering the smart grid domain, drawn by the volume of market demand described above. Available private sector funding promises to bring faster and more concentrated technical innovation to the smart grid areas (e.g., smart metering, monitoring devices, data analysis software, communications and network technologies). More than one billion dollar in VC funding has been extended to key startups in North America [6].

2.2 Technical Domains

There has been a significant amount of discussion and activities regarding grid modernization during recent years. Based on interviews and research results, smart grid efforts can be categorized into the following six technical domains:
- Renewable Generation and DER Integration
- Grid Control and Optimization
- Transportation Electrification
- Customer-Side Applications
- Workforce Effectiveness
- Communication Architecture and Integration

These technical domains encompass the ecosystem of electric grid modernization and their interrelationships are shown in Figure 2.

A robust market place, innovation, new technologies and services for utilities and customers creates products, services, and jobs.

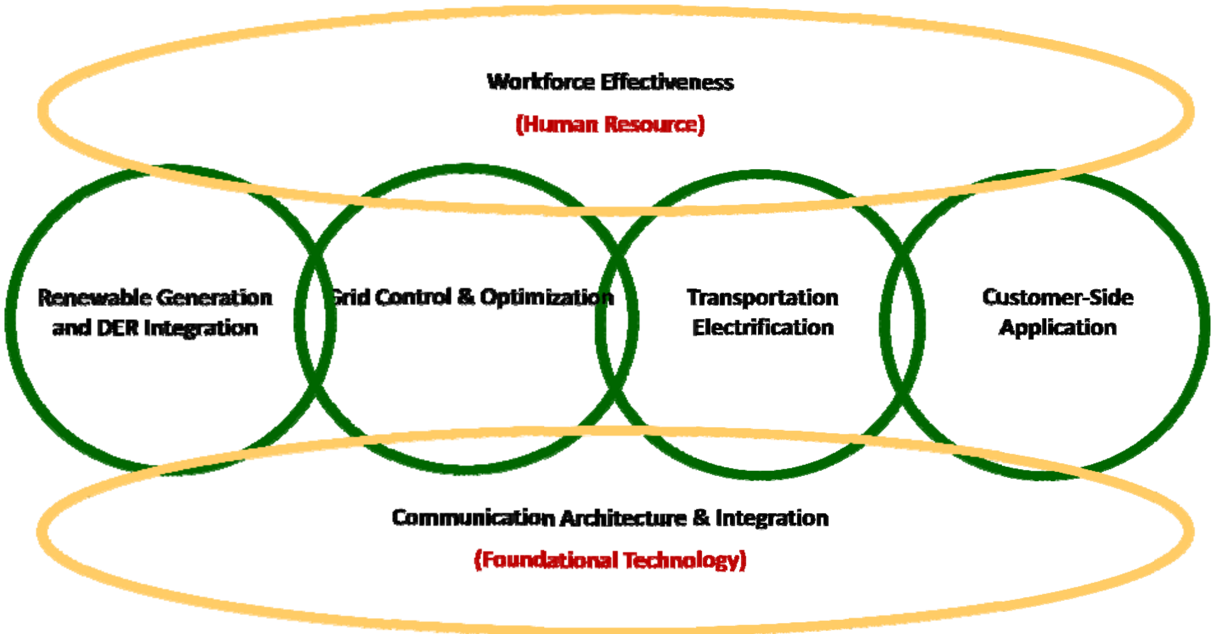


Figure 2: Technical Domains

<u>Technical Domain 1: Renewable Generation and Distributed Energy Resource (DER) Integration</u>
Integrate and manage new sources of renewable, storage, and other distributed energy supply.

Renewable Portfolio Standards (RPS) have been established in 30 states plus the District of Columbia. The specific location of bulk renewable generation resources presents fundamental challenges to power transmission. These resources are rarely located close to load centers, necessitating the construction of long distance transmission lines dedicated to their interconnection. The power output of such resources is variable by nature; and the power supplied may not coincide with system demand. Deployment of bulk renewable generation has become a core part of the smart grid effort.

In addition to bulk renewable generation, DERs are also becoming a new technical trend. Renewable generation and DER integration creates critical technology challenges due to the natural characteristics of these energy resources and the design and operation of the existing power grid. Grid stability issues caused by intermittent power output of renewable generation sources have to be addressed, both by individual renewable generators and power system owners/operators in a holistic manner, incorporating a system-wide complement of energy resources (e.g., considering energy storage and other volt/VAR control technologies and profiling solar and wind). While more research and studies are needed to fully understand the interactions of renewable and DER on the power grid, it is safe to conclude that advanced power electronic systems (e.g., inverters) will be essential to interconnecting and controlling these resources.

<u>Technical Domain 2: Grid Control and Optimization</u>
Improve capital efficiency and asset utilization with better intelligence and technology for optimal system planning and operation.

The aging grid infrastructure is being replaced or upgraded, providing significant opportunities for smart grid applications. Such opportunities exist for both the transmission and distribution systems. The end result is improved capital efficiency and asset utilization using better intelligence and technology for optimal system planning and operation. Examples on the distribution side include: distribution automation (including volt/VAR control, fault location, isolation, service restoration, etc.), advanced distribution management systems including monitoring and control of Distributed Energy Resource (DER), such as Demand Response (DR), electric vehicles, energy storage, etc., and condition-based maintenance, etc. On the transmission side, one of the major trends is Wide-Area Monitoring, Protection and Control (WAMPAC). WAMPAC is becoming a key component in grid optimization and control, through the provision of situational awareness tools, to help prevent large scale cascading outages of interconnected power systems. More advanced application tools using real-time information from phasor measurement units (PMUs) need to be developed and implemented as part of WAMPAC applications, while including appropriate security to comply with NERC CIP requirements.

Technical Domain 3: Transportation Electrification
***Enable effective, efficient and reliable Plug-in Electric Vehicle (PEV) integration to the power grid*.**

PEVs offer alternative fuel for transportation, not only reducing the dependency on oil, but also reducing combustion emissions and carbon-related environmental impacts. Adoption of PEVs is likely to be driven by state and federal policies, as well as customer preferences. PEV integration capability should provide a seamless experience for customers who chose to buy PEVs, while safely and cost-effectively integrating vehicle charging with grid operations. While PEVs offer tremendous potential, they also create unique challenges through uncertainty about how much, where, and when charging will increase demand on the utility system. As customer adoption of PEVs increases, the potential to adversely impact system reliability increases as does the potential to create substantial coincident peak loading. This would lead to overloaded network elements, failures, and system outrages. With forecasted increases in the number of PEVs and the resulting energy demand if PEV load is left un-managed, additional costs will be incurred in areas primarily related to: (a) system energy or wholesale generation procurement; and (b) distribution infrastructure upgrades or replacements. PEV readiness involves not only upgrading the power grid, but also the communication network.

Technical Domain 4: Customer-Side Applications
Empower customers to become "active" participants in the energy supply chain by managing their own energy consumption.

This is facilitated through programs supporting demand-side management (DSM), including demand response (DR) and energy efficiency. Enhanced customer engagement will enable customers to optimize their energy usage by providing them with sufficient information about their own power usage, the rates or true prices associated with that power usage, and the motivation and technological means to make rational economic decisions. Examples of enabling applications include: implementing effective and efficient Advanced Metering Infrastructure (AMI) or other systems to establish two-way communications with customers; developing portals to enable customer's participation in improving grid efficiency and reliability; interfacing utility systems with Home Area Network (HAN) and programmable and communicating in-home devices; and facilitating the safe and reliable customer adoption of solar and PEV technologies. Future technologies could potentially permit active participation in energy markets through DR and electric transportation.

Technical Domain 5: Workforce Effectiveness
***Maximize workforce productivity, effectiveness and safety; and prepare human resources though education programs and on-the-job training*.**

Human resources and workforce effectiveness is an essential domain to support the other technical domains of grid modernization. As a utility deploys smart grid technologies and systems, a variety of workforce challenges will be encountered, including managing an increasingly complex infrastructure, replenishing an aging workforce, and leveraging an increasing amount of field data, all while maintaining a focus on safety. One-half of the 500,000 to 600,000 utility workers will be eligible to retire in the next five years and will need to be replaced with a trained and motivated workforce [56]. Introducing smart grid technologies requires employees with different skills to support the implementation, maintenance and operation of the systems. Accomplishing this, in an environment where it is already difficult to get highly skilled employees with technical experience, will be challenging. To ensure the success of technology deployment, comprehensive on-the-job training, as well as academic education programs, should be established to support the smart grid efforts.

Technical Domain 6: Communication Architecture and Integration
Establish effective, secure communication infrastructure and technology architecture to support scalability, flexibility, and interoperability for data and information exchange.

The communications infrastructure is the foundational technology "glue" that holds together all of the other technical domains. Success results from establishing effective and unified communication infrastructure and technology architecture across the grid supply chain, from generation to the customer, to support scalability, flexibility, and interoperability for data and information exchange. The capabilities that these smart grid networks must support vary widely in their needs regarding bandwidth, latency, reliability, and security. This poses new security challenges and risks that must be addressed. Utilities, consumer groups, and vendors must collaborate in developing secure software, hardware, security tools, and new standards that are appropriate for the smart grid environment. The evolving grid modernization regulatory landscape is also an important factor, requiring adequate technology margins for scalability, flexibility and interoperability.

2.3 Key Benefits and Values

It has become an essential topic recently to identify benefits and values of smart grid implementation. After reviewing all of the smart grid strategies, roadmaps, and deployment plans from the interviewees and public research results, five key themes emerged in support of the grid modernization value propositions:

- Grid Reliability and Security
- Customer Energy Management Opportunity
- Asset and Resource Optimization
- Health, Safety, and Environment
- Productivity and Economic Growth

In the following subsections, these five themes and their assessment parameters are briefly discussed. Then, in the Section 3, case studies are used to describe how these values can be demonstrated through utility smart grid projects. While the list of assessment parameters is only an example based on our research, a comprehensive list of metrics and value streams should be and is being derived through a consensus-building process among all stakeholders.

Theme 1: Grid Reliability and Security
Deploying smart grid applications can maintain and enhance grid reliability and security while adapting to new sources of supply and demand.

New sources of supply include renewable generation and DER. New variables on the demand side include DR, electric vehicles, and customer-side applications. These sources and variables will have an impact on maintaining grid reliability and security. Smart power transmission and distribution grids, together with an effective and efficient communication network, can support system reliability and security under these scenarios.

The electric generation, transmission, and distribution system is an extremely complex machine that needs to be constantly monitored, synthesized and balanced. System operations have certain tools available to them now but with a smart grid their ability to assess, monitor, analyze and control increases significantly. New tools such as Phasor Measurement Units (PMUs) on transmission networks, smart switches and smart sensors throughout the distribution networks, and smart meters at homes and businesses increase situational awareness and system control. It is akin to the advancement made in medicine as doctors moved from relying only on a stethoscope to utilizing x-rays, CT scans, and Magnetic Resonance Imaging to diagnose and treat patients.

Overall, the smart grid will provide greater monitoring and control across the entire power delivery system, enabling quick, and often automated, response to outages or events of system instability. In this environment where increasing demands are placed on an aging electricity system, simply maintaining existing levels of grid reliability and security will not suffice.

Examples of assessment parameters for grid reliability and security:

- Reliability indices:
  - System Average Interruption Duration Index (SAIDI)
  - System Average Interruption Frequency Index (SAIFI)
  - Momentary Average Interruption Frequency Index (MAIFI)
- Outage duration (minutes, hours)
- Outage loss ($)
- Renewable resources integrated (MW)
- Renewable resources integrated (%)
- Peak load reduction (MW)
- Peak load reduction (%)

Theme 2: Customer Energy Management Opportunity

Smart grid customer-side applications can empower customers' energy decisions through insight, choice, and control.

Empowered customer energy management opportunities result in benefits across several domains in terms of reduced peak demands and associated costs, increased conservation, increased system reliability, enhanced customer service, and integration of demand-side resources with wholesale markets. With the readily accessible and reliable information regarding energy usage, customers are empowered to manage their own consumption. The modernized grid can empower customers through better information and give them both the tools and the incentives to support grid operations. The ultimate benefits of smart grid related to customer participation, should customers choose to participate are: (a) customers are enabled to optimize their energy usage according to their preferences and values; and (b) utilities obtain customer active participation in grid operation to mitigate peak load and other critical issues.

Examples of assessment parameters for customer energy management opportunity:

- Smart meter installation (total number)
- Smart meter installation (% of customers)
- DR / Load control participation (MW)
- DR / Load control participation (%)
- Overall energy consumption reduction (%)
- Energy efficiency saving (GWh)
- Energy efficiency saving (MW)
- Energy efficiency saving (Therms)

Theme 3: Asset and Resource Optimization
Smart grid can efficiently optimize capital, both human and financial, and improve the use of natural resources.

By optimizing grid operations and planning, coupled with energy efficiency measures through demand-side customer applications, a net reduction of energy consumption can be realized. Effectively integrating renewable generation and DERs can improve usage of natural resources in energy delivery. Overall, these will in turn reduce the need for generation with carbon by-products, and facilitate the use of sustainable resources, such as wind and solar, through efficient generation. The overall effect is improved use of these natural resources. Furthermore, the smart grid efforts in the Workforce Effectiveness domain promote training and education of human resources. This can prepare the existing and future workforce for smart grid applications and maximize the benefits of advanced technologies.

Examples of assessment parameters for asset and resource optimization:

- Reduced/avoided O&M cost ($)
- Reduced/avoided capital cost ($)
- Energy theft detection (incidence per year)
- Remote (e.g., Microgrid) distributed resources (MW)
- Remote (e.g., Microgrid) distributed resources (%)

Theme 4: Health, Safety, and Environment
Smart grid advances sustainability by mitigating impacts on health, safety, and environment.

Sustainable energy supply and delivery is the provision of energy that meets the needs of today's customers without compromising the ability of future generations to meet their needs. A modernized grid promotes sustainability because it can better handle the intermittent nature of renewable generation such as solar photovoltaics and wind generation. Successful implementation of smart grid applications should not result in any net increase in risk introduced by the technologies. Renewable generation and DER integration can significantly improve sustainability of energy supply. Effective deployment of renewable generation can also reduce greenhouse gas (GHG) emissions and stabilize energy production costs. Smart grid projects in grid optimization will adopt more automation that can improve power delivery efficiency and safety.

Examples of assessment parameters for health, safety, and environment:

- GHG (e.g., CO_2/NO_2) reduction (ton)
- Monetized GHG reduction ($)
- Customer and employee safety metrics (number of incidences per year)
- PEVs enrolled in smart charging program (number)

Theme 5: Productivity and Economic Growth
Successful implementation of a modernized grid can improve productivity and competiveness, as well as support economic growth.

From the utility business point of view, all grid modernization applications improve effectiveness of grid operation and automation, and hence improve productivity. From the societal point of view, the recent smart grid incentives and funding from the government and private sectors have created short-term job growth during the construction phase. Moving forward these investments in new energy technologies, communication infrastructure, intelligent electronic devices, etc., will pave the way for continued development and successful growth of the technology industry.

Examples of assessment parameters for productivity and economic growth:

- Reduced operation and maintenance (O&M) cost ($)

- Jobs created (number)
- Training programs developed (number)

Moreover, efficient and reliable delivery of electricity is a fundamental building block to any productive economy. Our manufacturing, finance, service, and information technology sectors cannot grow without corresponding growth or improvement in reliable electricity.

2.4 Technical Domains and Supporting Benefits

The five themes discussed above support the benefits resulting from implementation of six technical domain applications. Table 2 below shows their relationship.

Table 2: Mapping between Technical Domains and Value Proposition Themes

Technical Domain

Value Theme	Renewable & DER Integration	Grid Control & Optimization	Transportation Electrification	Customer-side Application	Workforce Effectiveness	Communication Architecture
Grid Reliability & Security	Secondary Benefit	Primary Benefit	Secondary Benefit	Secondary Benefit	Primary Benefit	Primary Benefit
Customer Energy Management Opportunity	Secondary Benefit	Secondary Benefit	Primary Benefit	Primary Benefit	Secondary Benefit	Primary Benefit
Asset and Resource Optimization	Primary Benefit	Primary Benefit	Secondary Benefit	Secondary Benefit	Primary Benefit	Secondary Benefit
Health, Safety and Environment	Primary Benefit	Secondary Benefit	Primary Benefit	Primary Benefit	Secondary Benefit	Secondary Benefit
Productivity and Economic Growth	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit

Supporting Value Themes to a Technical Domain are categorized as either a primary benefit or secondary benefit. Primary benefits are those that directly relate to an improvement within a technical domain. For example, customer energy management opportunities are direct benefits offered by customer side applications. Secondary benefits are more of the “softer” benefits that will be derived from implementations of projects in the technical domains over time or in the aggregate. For example, customer-side applications can result in additional benefits in asset and resource optimization, e.g. reduced load, dollar savings, or deferred generation similarly by providing education and training through workforce effectiveness projects, economic growth and better productivity from smart grid implementations. While these are worthy benefits to make a more productive work force, it tends to be difficult to actually place a dollar value on them.

3 CASE STUDIES

Deployments of smart grid technologies are occurring across the United States. Some utility companies have been aggressive with their grid modernization roll-out plans, while others are taking a slower approach. This section includes both interviews and extensive public research results of grid modernization efforts.

A benefit assessment is summarized in Section 3.1 and represents the key finding from the research of case studies. The supporting examples from utilities and solutions vendors are included in the Appendices A.1 and A.2. Please note that some smart grid projects or efforts may cover multiple domains, resulting in multiple value themes. The reported benefits, as well as how they fit into the five value proposition themes, are discussed in each example in the Appendices.

Regulatory perspectives, supported by two interviews with regulators, are included in Section 3.2. A summary of these two interviews is included in Appendix A.3.

A summary on our key observations is included in Section 3.3.

3.1 Summary of Benefit Assessment

Smart grid implementation is still in its beginning stages. Most of the interviews and literature review completed for this research found that many smart grid benefits are still expected to occur in the future. However, early results of grid modernization efforts do demonstrate significant benefits are being achieved. Moreover, these early results do reinforce that the expected benefits are in fact achievable. Many of the benefits cited by the companies were similar in nature and can be categorized by the five themes previously identified. Among the examples, there were some quantitative benefits values provided, while some only described the value proposition of smart grid in a qualitative manner. Table 3 summarizes how the assessment parameters were used by utilities to demonstrate the benefits or progress of smart grid projects in the case study. Most of the benefit examples in the table are "expected" benefits unless specifically indicated in the table as "demonstrated."

Table 3: Benefit Assessment Examples

Assessment Parameter	Expected or Demonstrated Benefits
Overall energy consumption reduction (%)	▪ Demonstrated reduction of 1-2% due to distributed automation volt/VAR control (Oklahoma Gas and Electric) ▪ Demonstrated reduction of 16.9% through SmartRate program (Pacific Gas and Electric) ▪ Demonstrated reduction of 20% through energy efficiency programs (Pacific Gas and Electric) ▪ Demonstrated reduction of 9% through demand response program (Oklahoma Gas and Electric) ▪ Reduction of 20% by 2016 through SmartBuilding program (Duke Energy) ▪ Reduction of 18% by providing customer with real-time energy information (Federal Energy Regulatory Commission)
Energy efficiency saving (GWh) Energy efficiency saving (MW) Energy efficiency saving (Therms)	▪ Demonstrated saving of 2,060 GWh, 357 MW, and 16.8 million Therms through energy efficiency programs (Pacific Gas and Electric) ▪ Saving of 6,000MWh/yr (Burbank Water and Power)

Reliability indices: SAIDI, SAIFI, MAIFI	▪ Improvements of 13% in SAIFI, 19% in SAIDI, 7% in CAIDI (Pepco Holdings Inc.) ▪ Reduction of 100,000-175,000 (out of 850,000) customer interruptions (Commonwealth Edison) ▪ Improvement of overall reliability by 40% through distribution automation (Electric Power Research Institute)
Outage duration (minute, hours) Outage loss ($)	▪ Demonstrated reduction of 33 min (47%) to average Customer Minutes of Interruption (CMI) and 18,950 minute reduction of total CMI per circuit from distribution automation (Southern California Edison) ▪ Reduction of $50K/yr loss (Burbank Water and Power) ▪ Estimation of $1,600-$4,700/MWh loss for residential and $7,000-$50,000/MWh loss for C&I (Pepco Holdings Inc.)
Peak load reduction (MW) Peak load reduction (%)	▪ Reduction of 5% peak load (Burbank Water and Power) ▪ Reduction of 1.2% in Eastern MAAC and 3.6% in SE MAAC through demand side management programs (Pepco Holdings Inc.) ▪ Reduction of 6-20% critical peak load in PHI service area (Pepco Holdings Inc.) ▪ Reduction of 20% peak demand nation-wide through DR (Federal Energy Regulatory Commission)
DR / Load control participation (MW) DR / Load control participation (%)	▪ Savings of $612 million/yr through a 500MW increase in demand response participation (ISO New England)
Reduced/Avoid Operations and Maintenance (O&M) cost ($)	▪ Demonstrated avoided 582 utility service call back to customers or truck rolls at Delmarva Power after Hurricane Irene (Pepco Holdings Inc.) ▪ Saving of $74M in operation, 15 yr net present value (Pepco Holdings Inc.) ▪ Saving of $4M in O&M due to automation (Oklahoma Gas and Electric) ▪ Saving of $523K/yr from advanced metering infrastructure (Burbank Water and Power)
Reduced/Avoid capital cost ($)	▪ Saving of $95-314M from demand response, 15 yr net present value (Pepco Holdings Inc.)
Renewable resources integrated (MW) Renewable resources integrated (%)	▪ Achieving renewable portfolio standard (RPS) goals ▪ Reduction on environmental impact
Green house gas (GHG) (e.g., CO_2/NO_2) reduction (ton)	▪ 29% reduction in 10 years (NV Energy) ▪ 0.7-5.4 million tons reduction 2011-2020 (SDG&E) ▪ Reduction of 1 million tons CO2 and 215 tons of NO2 (Pacific Gas and Electric) ▪ Reduction of 220,000 tons of green house gases through SmartBuilding program (Duke Energy)
Monetized green house gas (GHG) reduction ($)	▪ $10-550M saving 2011-2020 (SDG&E)
Jobs created (number)	▪ Estimations of 280,000 new positions across various categories (Electric Power Research Institute)

The most compelling results are those that demonstrate an overall reduction energy consumption. Notably, Pacific Gas & Electric achieved 16.9% and 20% reduction in energy consumption thoughts its Smart Rate and energy efficiency program. Oklahoma Gas and Electric realized a 9% energy reduction as a result of its demand response program. These are all very impressive results. These results occurred due to new technology being available (i.e. a modernized and optimized grid) and change in customers' behaviors.

Equally impressive is the 1-2% annual energy reduction achieved by Oklahoma Gas and Electric by using voltage/volt-ampere reactive (Volt/VAR) control. The significance of a 2% reduction is that it is achieved without any customer involvement. System operations achieved these savings merely by utilizing smart grid technologies made available to them through grid modernizations efforts. OG&E's experience highlights the potential energy savings if utilities across the country could achieve similar results with volt/ VAR programs, however, it is understood that actual results will vary due to different utility service areas and operating conditions.

While the above highlights some concrete benefits and outcomes, other measures of grid modernization advancement are important to track and understand. Smart meter installation (e.g., total number or percentage of customers) is reported by several utilities to indicate their progress in deploying AMI at various stages. And, through AMI, many utilities believe that the benefits resulted from energy theft detection (e.g. incidence per year) can be significant, but no specific numbers are reported. Similarly, the number of PEVs enrolled in smart charging program (if available) can be used to describe the result of promoting PEV readiness efforts. Other assessment parameters, such as "worker safety measure," "training programs developed," etc. are also discussed by several utilities as possible benefits measures.

3.2 Regulatory Perspectives

The Board of Directors of the National Association of Regulatory Utility Commissioners (NARUC) developed a resolution in summer 2011 to endorse foundational principles relating to smart grid deployments. Its purpose was to educate NARUC members and identify issues of concern and interest to state regulators, federal government, and others. NARUC concluded that effective and constructive regulatory oversight with respect to smart grid investment was important in protecting the public's interest. Close coordination between regulators, utilities, and customers is critical to any grid modernization effort. To facilitate the discussion, utilities have and continue to develop smart grid deployment plans and schedules that demonstrate how they plan to address an evolving and increasing number of mandates/demands, while at the same time providing safe, reliable and reasonably priced service. Of course such discussions would not supplant the need for formal rate setting proceedings.

Many benefits from smart grid, for utilities as well as for customers, are to be realized through efficient deployment plans. Technology readiness, risk mitigation, and customer engagement are key successful factors. From a regulator standpoint, Commissioner Richard Morgan from the District of Columbia Public Service Commission believes that technology is still evolving and is expected to continue to evolve. However, that does not mean that technology cannot deliver benefits to customers now. Commissioner Morgan notes that there are a lot of unrealized benefits that need to be explored and captured. He acknowledges that some smart grid benefits cannot be easily quantified. Also, Commissioner Morgan thinks that customers are not given enough credit for changing, and customers will be interested when given the opportunity to experience benefits. There is a need for substantial efforts in customer education and customer engagement.

It is imperative to understand that grid modernization is not an option. Commissioner Sherman Elliott from the Illinois Commerce Commission believes that smart grid is not an option, it is inevitable. He also believes that there needs to be a sense of urgency and a "go slowly" approach is not the correct way.

Similar to Commissioner Morgan's point of view, Commissioner Elliott believes that while smart grid technology readiness may be good, the market readiness still needs work. This again indicates the importance of "customer outreach." However, in many states, outreach activities have been limited because of issues related to "ownership" of the messages, and who should participate financially. Going forward, this will be a challenge that the three parties, i.e. utility, commission, and customer, must resolve together.

3.3 Challenges and Observations

Smart grid technologies offer unprecedented challenges to regulators in encouraging and adjudicating decisions regarding smart grid investments. In the following sections, several observations and identified challenges from our research are discussed.

3.3.1 Technology Readiness

While most of those interviewed for this project felt that generally available technology was ready for the smart grid market, there were concerns regarding interoperability. National Institute of Standards and Technology (NIST) interoperability and cyber security standards are being finalized. As pointed out by the National Regulatory Research Institute [19], it is reasonable for vendors to accept risk associated with ensuring their systems will meet future standards, and it is unreasonable to burden ratepayers with the risk that smart grid assets could be prematurely made obsolete or become stranded when forthcoming standards are established. Somewhere a risk trade-off among vendors, utilities, and markets will need to be addressed.

New technologies that must be embraced include security and telecommunications network management. The smart grid will incorporate new networking technology, as well as sensors and controls that enable real-time, energy information exchange between utilities and customers, as well as monitoring and control of grid operations. To network these technology components, consideration of both interoperability and cyber security needs to occur.

Furthermore, a major concern in the area of customer-side applications is "ease of use", which is also related to interoperability issues. For example, the advanced devices introduced to demand response (DR) and home area networks (HAN) will become available for mass consumer markets. These devices are expected to be "plug-and-play" ready to be adapted by customers. As Secretary of Energy, Dr. Steven Chu, has said to assuage customers who are resistant to changing their habits, saving energy in the home has to be incredibly simple, much like a point-and-shoot camera that lets customers simply push a button to take a photograph, although the device is embedded with the ability to do much more.

3.3.2 Market Readiness and Risks

In general, the interviews suggest that, while certain aspects of grid modernization (most notably smart meter implementation) are either ready for public adoption or already in production, many other aspects will develop in parallel to be dependent upon further development with the regulatory and customer environment. A successful smart grid project implementation requires, among other aspects, market acceptance and adoption. Not only does the customer community need to be ready for new technologies and new applications, but also the energy market needs to develop supporting rules and tariffs to enable new market participants and products. Furthermore, new market entrants can help with innovative products and services that leverage smart grid investments, thus providing further value and choice to customers.

Deployment of smart grid includes risks when considering technology readiness and market readiness. Glendale Water and Power's (GWP's) risk management plan [34], summarized in Table 4, outlines the potential difficulty (and cost) of gaining broad-based customer support. GWP notes that, while some level of public opposition is inevitable, the key is to anticipate and mitigate such risk. To this end, GWP and other companies have focused on maintaining clear communication with the customer and actively responding to concerns, including offering free meter testing at the customer's request.

Table 4: Risk Management Plan (RMP) Summary

Risk Identifier	Risk Title	Risk Description	Likelihood of Occurrence % Prob.	Cost/Schedule Impact	Risk Consequence	Handling strategy and Mitigation
RM01	Strong Public Opposition	Strong public opposition to the deployment of smart grid technology and the perceived invasion of privacy.	30%	8 to 12 month project delay.	Could result in the premature termination or significant delay of the project.	Create and maintain two way communications with stakeholders and respond to stakeholder questions.
RM02	Moderate Public Opposition	Moderate public opposition to the smart grid concept with perceived security issues and unnecessary costs.	50%	Up to $1M added costs and 4 to 6 month project delay	Can result in project delays and added costs.	Respond to stakeholder questions and concerns promptly.
RM03	Slight Public Opposition	Slight public opposition to the smart grid concept due to a lack of understanding of the technology and benefits.	90%	Cost and task activities are included in the current budget and schedule.	Will raise issues that may delay project tasks or require adjustment to deployment approaches	Provide customers with the knowledge needed to take full advantage of the benefits afforded to them by the AMI Smart Grid

(Provided by Glendale City AMI-Smart Grid Initiative, November 2010)

Smart grid deployments require a commitment to a fully complete rollout to ultimately realize all benefits. However this does not imply that deployment must be "all at once" with no logical sequencing plan in place.

To minimize risk in deployment, key implementation milestones should be developed as phases to confirm conditions remain within plan for system and benefits improvement. It is important to note that there are different paces of implementation for different parts of the country, depending on the local regulatory environment. Also it may be beneficial to implement certain key functions first that can offer more obvious payback. For example, deploying an outage management system (OMS) may be a better initial focus to demonstrate operational benefits. OMS is a function that could easily be implemented in smaller investments and in phases and can benefit customers almost immediately.

3.3.3 Realization of Potential Benefits

In some cases, societal benefits may have conflicting implications to utility business operations. Utility regulation approaches may need some adjustment to address these conflicts. For example, new regulatory and business models are being considered which would offer a greater incentive for utilities to engage in energy efficiency. If not appropriately implemented, promoting energy efficiency may result in lost revenues and an unsustainable business model for utilities.

Another challenge is for all parties to understand the incremental value of grid modernization investments. Smart grid technologies are typically implemented in stages due to budgetary or resource constraints, or customer demands, with each stage requiring a business plan for regulators to approve. In many cases, the overall benefits of numerous smart grid efforts may come from the synergistic applications of a portfolio of smart grid technologies, with the benefits not being significantly realized until the final stages of full deployment.

Pacific Gas & Electric Company's (PG&E) benefits table [45] (see Table 5 below) is a good indication of the difficulty in quantifying grid modernization benefits. In an effort to gain regulatory approval for smart grid projects, it is often necessary for utilities to demonstrate the positive effects of the projects. As shown below, however, a number of realizable benefits cannot realistically be presented in a quantifiable manner. As a result, the benefits attached to smart grid projects may appear to be less than they actually are.

Being unable to quantify smart grid benefits presents a challenge, if the customer cannot see a direct link to the stated benefits. Benefits that cannot be quantifiable in measurable numbers generally fall in two categories: "soft" benefits that provide value to recipients as a whole, but are difficult to measure (i.e. customer satisfaction, career development opportunities), and benefits that aren't visible to the customers, but are necessary to sustain operations nonetheless. For instance, trying to explain the value to the residential customer of a utility investment in synchrophasor technology and wide area situational awareness is difficult to do in quantifiable terms. It needs to be done with simple statements that highlight not only energy cost savings but the more common benefits such as improvements in "keeping the lights on" or making sure large-scale blackouts are not suffered as a consequence.

Customer acceptance of grid modernization is undoubtedly critical to the success of a large number of smart grid projects. However, it is difficult to gain customer support when some of the benefits are not easily quantified. Where benefits of smart grid are identified that can be quantified for customers, such as demand response and dynamic pricing, regulators can help facilitate customer involvement by combining smart meter capabilities with rate and tariff offerings that will reward customers for changing their energy use behavior to reduce peak loads.

Table 5: Smart Grid Benefits Quantification and Allocation Framework

Benefit	Quantifiable	Monetizable	Recipient		
			Customer	Utility	Society
Promotes Public Safety			X	X	X
Avoided Energy Costs	X	X	X		
Increases Customer Empowerment			X		
Maintains or Improves Reliability	X		X		
Improves Customer Service			X		
Promotes Electric Market Efficiency			X		
Improves Utility Operating Efficiency	X	X	X	X	X
Avoided Capital or O&M Costs	X	X	X	X	
Enables Compliance				X	
Reduces GHG Emissions	X		X		X
Improves Environmental Footprint	X		X		X
Improves Energy Independence					X
Promotes Sustainable Economic Prosperity					X
Promotes Employee Safety				X	
Improves Work Processes				X	
Provides Career Development Opportunities				X	

(Provided by PG&E Smart Grid Deployment Plan, June 2011 CPUC Filing)

3.3.4 **Impacts of Financial Support**

Foundational tools that affect grid modernization technology investment are regulatory levers of incentives (and disincentives) for investment in smart grid. These levers are at the forefront of smart grid technology deployment. Traditional utility ratemaking inherently incentivizes capital investment in order to earn a return on investment. The question becomes how financial support from government and private sectors can facilitate successful grid modernization deployments. As we know, ARRA funding, although limited to a maximum 50% match of total project funding, helped propel some smart grid deployments. This infusion of funds also fueled vendor and supplier offerings and industry efforts in interoperability.

To keep the momentum going, regulators' support for grid modernization is critical. Recent regulatory orders have linked benefits achievement to the potential for recovery of smart grid project expenditures, such as CPUC Decision (D.) 10-06-047 which established the requirements that each of the investor-owned utilities (IOUs) must address in seeking approval of their Deployment Plan.

It is recognized that there is a need for new cost recovery mechanisms to be in place to continue grid modernization deployments in the United States. Just as utilities are updating the electric grid, it is equally important to update the models and the regulatory rate process. That means that regulators, utilities and customers have to build consensus and develop mechanisms for cost recovery in an environment where the energy usage may be reduced.

3.3.5 **Customer Outreach and Engagement**

A study released by Ovum finds that most ongoing efforts by utilities to gain customer acceptance of smart meters have been inadequate. Ovum concludes that unless utilities are able to better educate customers about the long-term benefits of smart meters, they may revert to old consumption habits, thereby rendering grid projects ineffective. The report indentifies early-stage customer acceptance and long-term customer behavioral change as two integral areas of customer engagement. [59]

Our interviews and research reaffirms that the one thing that can help move installations of smart meters forward and help progress on the smart grid overall, is informing and educating customers. According to a new Market Strategies International E2 (Energy + Environment) Study, 79% of Americans know little or nothing about the smart grid, and 76% don't know anything about smart meters. The survey shows that after having the technologies explained to them, 75% feel that the smart grid, complete with smart meters, should be a priority over the next 1-5 years, and 67% support their utility company in installing the technologies. [64]

Most companies realize that customer acceptance of smart grid innovations is critical to the long-term success of grid modernization efforts. Many aspects of grid modernization directly depend on active customer participation, and it is critical that customers understand and accept the technology. To this end, most of the companies are, to some extent, attempting to engage customers regarding smart grid progress and functionality. Community outreach programs and advertisements in local news mediums are helpful tools to raise awareness of smart grid programs, and monetary incentives provide customers with a positive reward for participation.

As to the methodology, Oklahoma Gas & Electric Company's (OG&E) approach is to ensure a careful and focused smart grid information campaign. Pilot programs, such as Duke Energy's Envision: Charlotte project or PG&E's SmartRate program, are also helpful tools to build community support. The Smart Grid Customer Collaborative (SGCC) report, "Excellence in Consumer Engagement," concluded that the most successful customer outreach strategy is to keep the message simple, and clearly state the benefits to encourage enrollment. The analysis indicated that customers respond positively to a staged series of benefits, where benefits can be seen in a 3-6 month time period [52].

Ovum believes that early stage customer acceptance and long-term customer behavioral change are the two integral aspects of customer integration. These critical targets cannot be achieved solely through the use of advertising campaigns or open communication. Rather, demonstrable savings and ease of use may be the key to engaging customers, thereby ensuring the longevity of the smart grid.

4 CONCLUDING REMARKS

Our nation depends on a robust and reliable electric grid to power our economy and society. The electric system is fundamental to our quality of life and it is a critical component of many industries such as financial services, transportation, construction, manufacturing, retail, and education. It is imperative to modernize the power grid to its next generation now. The first phase toward achieving this goal was developing a common understanding of what the smart grid would be, and what its applications and benefits are. Not that long ago, a number of people equated smart grid with AMI or smart meters. While smart meters are a component, they are just a small piece in an overall optimized electric network.

It has become apparent that smart grid requires a holistic approach addressing all technical domains and broad coverage of benefits themes, as described in this paper. Grid modernization has now moved to a second phase, namely deployment, as documented through a large number of implementation projects supported by multi-billion dollar investments. Consistent benefits, both realized and expected, can be seen in all of these projects, either quantitatively or qualitatively. This deployment phase will continue in the next few years as applications and associated benefits are clearly demonstrated from the results of the projects.

Success of these deployment projects will set the direction for further steps in developing the grid of the future. For example, most Smart Grid Investment Grant projects in the U.S. will be completed by mid-2013, resulting in major implementation of smart grid technology and benefits that will create a framework for how the grid will be designed and operated going forward. As a result, the next smart grid phase should encompass transitioning more and more grid modernization initiatives into "normal course of business." In addition, results achieved and smart grid infrastructure deployed will uncover new applications and benefits that may not have been considered before. As is evident from case examples, many more potential benefits can be identified and realized as technology is implemented and experience is gained.

Building an optimized grid does not happen in a vacuum. Engineers and system operators clearly see the value of grid modernization. However, there are significant policy and financial issues that must be addressed prior to engineers building this technically advanced, flexible and optimized system. As with most policy issues, the key is to find the right balance in sharing costs, benefits and risks. The responsibility for achieving this balance lies with regulators and, in some cases, legislators, but must include input from all stakeholders. To provide momentum for utilities to continue smart grid investment, regulatory support is required, both from a policy perspective and financial perspective. To this end, a thoughtful deployment plan that includes cost benefit analysis or a successful pilot project that confirms expected benefits is an important component of the evaluation. Furthermore, to accelerate to the next grid modernization level, customer outreach and engagement is an essential success factor.

The business case for smart grid is positive. Benefits and success stories are being captured. A "business as usual" or "slow go" approach is not in the nation's best interest. Moving forward, the challenges faced by all stakeholders in the electric energy ecosystem and the issues raised in our observations should be addressed jointly by regulatory policymakers, utilities, and customers to ensure the successful implementation of a modernized electric grid for the United States and its prosperity.

APPENDICES

A.1 Examples of Utility Smart Grid Activities and Benefits

Appendix A.1 contains more information on the case studies presented in Table 3. The examples are organized by Technical Domains. Please note that some smart grid projects or efforts may span multiple domains, resulting in multiple values themes. The reported benefits, as well as how they fit into the five value proposition themes, are discussed in each example. The efforts related to Workforce Effectiveness are sometimes addressed as a supporting activity in smart grid projects. Similarly, the Communication Architecture and Integration is very often identified as a foundational technology that enables smart grid applications.

Technical Domain 1: Renewable Generation and DER Integration

1. ***San Diego Gas and Electric (SDG&E): Borrego Springs Microgrid Demonstration Project [65]***

   Theme 1: Grid Reliability and Security
   Theme 2: Customer Energy Management Opportunity
   Theme 3: Asset and Resource Optimization
   Theme 4: Health, Safety, and Environment
   Theme 5: Productivity and Economic Growth

   SDG&E, owned by Sempra Energy, is a regulated public utility that provides natural gas and electricity to San Diego County and southern Orange County in southwestern California, United States.

   SDG&E currently has two Microgrid projects located in Borrego Springs, California, allowing for active customer participation to support the community's energy needs and address standards, integration and interoperability challenges [65]. A Microgrid, consisting of a group of energy generators (wind, solar, portable generation, battery storage, etc.) and customer loads within a clearly defined area, can be controlled to act as a single entity with respect to the larger electric grid. Accordingly, a Microgrid may have the ability to connect or disconnect from the main grid in the event of a system disturbance, enabling it to ride through outages by disconnecting from the main grid and operating in an islanded mode and balancing the local load and generation resources. SDG&E notes that Microgrid is a smart grid alternative service delivery model.

2. ***SDG&E: Societal and Environmental Benefits [46]***

   Theme 1: Grid Reliability and Security
   Theme 2: Customer Energy Management Opportunity
   Theme 3: Asset and Resource Optimization
   Theme 4: Health, Safety, and Environment

   SDG&E collaborated with the Environmental Defense Fund, a leading environmental non-governmental organization, in an attempt to quantify the societal and environmental benefits of its smart grid deployment plan, in particular those that are expected from the integration of centralized and distributed renewable resources and PEVs. Their results are displayed in Table 6.

Table 6: Societal and Environmental Benefits 2011 – 2020

Societal /Environmental Benefit Sources	Benefit Range	Estimated tons of CO2 Avoided
Estimated Avoided Emissions from Energy Reductions and Peak Load Shifting	\$12 MM - \$83 MM	~ 0.7 million
Estimated Avoided Emissions Reduction by Integrating Centralized Renewable Energy	\$85 MM - \$612 MM	~5.4 million
Estimated Avoided Emissions Reduction by Distributed Generation	\$10 MM - \$79 MM	~ 0.7 million
Estimated Avoided Net Emissions Reduction by Integrating Electric Vehicles	\$284 MM - \$550 MM	~ 0.9 million

(Provided by SDG&E Smart Grid Deployment Plan, June 2011 CPUC Filing)

3. ***PJM Interconnection: Smart Grid Investment Grant (SGIG) Wide-Area Situation Awareness Project for Renewable Integration* [60]**

Theme 1: Grid Reliability and Security ***Theme 3: Asset and Resource Optimization***
Theme 4: Health, Safety, and Environment

PJM a Regional Transmission Organization (RTO) which is part of the Eastern Interconnection grid operating an electric transmission system serving all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. PJM is currently the world's largest competitive wholesale electricity market.

PJM expects that the benefits of its Department of Energy (DOE) smart grid projects will include "improved grid reliability and security, fewer service interruptions, lower costs, cleaner energy, more integration of renewable energy, demand response opportunities and a means to bring greater energy independence to customers". Specifically, the PJM and Midwest ISO are working together to jointly implement synchrophasor technology project (also known as phasor measurement units - PMUs) to improve the reliability of the power supply system across the Midwest and eastern United States. These two regional transmission operators are sharing the real-time synchrophasor measurements for improving operator wide area situation awareness, improving the system reliability and facilitating the integration of highly-variable, renewable sources of power such as wind and solar. [42]

4. ***NV Energy: Integrating Renewable Generations [57]***

Theme 1: Grid Reliability and Security ***Theme 3: Asset and Resource Optimization***
Theme 4: Health, Safety, and Environment

NV Energy is a Las Vegas-based company that produces, distributes and sells electricity in southern part of Nevada.

The company signed its first contract for geothermal power in 1983, and this past year, they surpassed the renewable energy threshold of 1 GW under contract. NV Energy's longstanding renewable energy commitment has resulted in one of the most diverse and extensive renewable energy portfolios in the United States. To date, over 1,200 projects totaling more than 19 MW have been installed at homes, businesses, public buildings, and schools. NV Energy generates the majority of its electricity using fossil fuels, which emit GHG, including CO_2. In keeping with its commitment to sustainability, and in light of increased legislative scrutiny and federal regulations, NV Energy has chosen to voluntarily reduce its emissions on a per customer basis. By 2010, NV Energy reduced GHG per customer by 29% from 2000 levels, surpassing their goal of 20% reduction.

Technical Domain 2: Grid Control and Optimization

5. ***Pepco Holdings Inc. (PHI): Improved Operational Benefits [3, 10,63]***

Theme 2: Customer Energy Management Opportunity ***Theme 3: Asset and Resource Optimization***
Theme 5: Productivity and Economic Growth

PHI is a holding company that distributes electricity to customers in Washington, DC, Delaware, Maryland, and New Jersey through its subsidiaries Potomac Electric Power Company (PEPCO), Delaware Power and Atlantic City Electric. In 2007, PHI filed its Blueprint for the Future program with local regulators. This program incorporated several key smart grid initiatives. PHI estimated that the smart grid projects would have the following benefits:

- $74M in operational benefits (15–year NPV)
- $95M to $314M DR benefits (15-year NPV)
- 13% improvement in SAIFI
- 19% improvement in SAIDI
- 7% improvement in CAIDI

Prior to Hurricane Irene, Delmarva Power, a PHI Company, had approximately 290,000 AMI meters activated. As a result of the meters feedback, 582 call back to customers or truck rolls were eliminated in the areas affected by Hurricane Irene.

In addition, PHI's minority-owned subcontractor Scope Services, Inc., is recruiting and training local workers to install "smart meters" in Prince George's and Montgomery counties through the end of 2012.

6. ***Southern California Edison (SCE): Advanced Distribution Automation [48]***

Theme 1: Grid Reliability and Security ***Theme 5: Productivity and Economic Growth***

SCE is the largest subsidiary of Edison International and is the primary electricity supply company for much of Southern California, USA. It provides 14 million people with electricity.

SCE's distribution and automation focus requires a support infrastructure to provide an integrated platform that enables DG programs, enhances outage response and service restoration, and improves power quality while making the distribution grid more efficient. The Advanced Distribution Automation System will provide increased reliability through the continuation of SCE's circuit automation progress, while allowing for future deployment of self-healing circuits. Circuits automated between 1993 and 2004 resulted in a 33-minute reduction in average Customer

Minutes of Interruption and an 18,949-minute reduction in total Customer Minutes of Interruption (CMI) per automated circuit. Three years prior to automation the average Customer Minutes of Interruption was 70 minutes and total CMI per circuit was 108,318 minutes. Three years after automation, these figures had dropped to 37 minutes and 89,368 minutes, respectively. This increase in reliability, based on circuits automated between 1993 and 2004, provides a basis for the potential benefits that may be realized with further automation programs. This represents a 47% improvement to average Customer Minutes of Interruption (CMI), as well as a 17% reduction in total CMI per circuit.

7. *Oklahoma Gas & Electric (OG&E): Distribution Automation [18]*

Theme 2: Customer Energy Management Opportunity ***Theme 3: Asset and Resource Optimization***
Theme 5: Productivity and Economic Growth

OG&E is a regulated electric utility company that serves over 750,000 customers in Oklahoma and western Arkansas.

OG&E has demonstrated improvements through volt/VAR optimization. Reducing voltage by 2% on an automated circuit has been shown to make a corresponding 1-2% reduction in demand/energy consumption. Through DA and volt/VAR optimization OG&E has been able to delay the need to construct a new power generation plant to outside their 10 year planning horizon.

To obtain Commission support, OG&E guaranteed that its customers will benefit from the smart grid deployment. The benefits are actually subtracted from revenue requirements, with the net difference subject to recovery. A total of approximately $22 million in fixed reductions in annual revenue requirements is projected. Included in the savings are $4 million in O&M costs, and reduction of losses due to fraud and theft. The cost of the project is $366 million (35% from ARRA funds) over a 3-year deployment period. The cost for the average OG&E residential customer is estimated to be $1.94 per month over the 42-month duration of a smart grid recovery rider, until OG&E's next rate case in 2013.

8. *Burbank Water and Power (BWP): Smart Grid Program [36]*

Theme 1: Grid Reliability and Security ***Theme 2: Customer Energy Management Opportunity***
Theme 3: Asset and Resource Optimization ***Theme 4: Health, Safety, and Environment***
Theme 5: Productivity and Economic Growth

BWP services 45,000 households and 6,000 businesses in Burbank, California, with water and electricity. BWP expects a number of benefits as a result of their smart grid program. While many benefits are associated with the reduced cost due to automation, a number of other benefits relate to the reduction in emissions, the effect of peak load reductions, and the increased reliability as a result of the enhanced grid. A summary of some of BWP's main expected benefits are as follows:

- An annual benefit of $523,000 through the elimination of meter readers, calculated as a $52,157 annual meter reader cost plus 40% in benefits x 7 meter readers plus $11,533 in annual mileage reimbursement expenses.
- A $120,000 annual benefit from reduced cost of energy supply resulting from a shift in up to 5% of peak demand to off peak periods (230 MW x 5% x 2 hours per day x 365 days x 5 days per week x $20 price difference). Further, BWP expects a reduction in emissions of 6,000 MWh of generation per year.
- An annual benefit of $50,000 as a result of a reduction in lost revenue due to faster restoration of service, and an additional $7,500 annually from not having to investigate outages.

9. *Black & Veatch Report on Commonwealth Edison (ComEd): Benefits From Operational Improvements [31]*

Theme 2: Customer Energy Management Opportunity ***Theme 3: Asset and Resource Optimization***
Theme 4: Health, Safety, and Environment ***Theme 5: Productivity and Economic Growth***

ComEd is the largest electric utility in Illinois, serving the Chicago and Northern Illinois area. ComEd is a unit of Chicago-based Exelon Corporation, one of the nation's largest electric and gas utility holding companies.

ComEd's 5.4 million customers are estimated to save $2.8 billion on their electric bills over the 20-year life of the smart meters, with an investment of $1.7 billion. This savings results from operational improvements. The estimation was developed as a result of evaluating the one-year smart meter pilot approved by the Illinois Commerce Commission (ICC). The cumulative customer benefits will be generated by:

- Virtual elimination of manual meter reading, more accurate bills, and fewer service visits and calls to the Customer Call Center. Also, fewer truck rolls and thus less CO_2 emissions will result.
- Improved electricity theft detection and quicker sign-up of new customers, minimizing energy losses.
- Enhanced disconnection and reconnection of electric service, minimizing collection costs.

These savings are in addition to any savings customers would see by using smart meters to manage their own energy usage. It was noted that if a smart grid had been fully operational during the July 11, 2011 storm that struck Northern Illinois, the technology would have allowed faster identification of outage locations, and quicker dispatch of crews to restore service. ComEd estimated that with a smarter, more modern grid, of the 850,000 actual customer interruptions that occurred during the storm, approximately 100,000 to 175,000 customer interruptions would have been avoided.

10. *New York ISO (NYISO): Deployment of Smart Grid Technologies to Support Smart Grid Drivers [44]*

Theme 1: Grid Reliability and Security ***Theme 2: Customer Energy Management Opportunity***
Theme 3: Asset and Resource Optimization ***Theme 4: Health, Safety, and Environment***
Theme 5: Productivity and Economic Growth

New York Independent System Operator (NYISO) is a non-profit agency which operates New York's bulk electricity grid, administers the state's wholesale electricity markets, and provides comprehensive reliability planning for the state's bulk electricity system.

According to the NYISO Smart Grid whitepaper issued in September 2010, "the development and integration of smart grid technologies offer potentially significant benefits for New York customers by empowering electricity customers, reducing power costs, improving the reliability of the power system, and facilitating integration of renewable resources." The optimal deployment of the smart grid technologies will enhance the reliability and efficiency of the power system by improving grid operators' situational awareness and control. The smart grid technologies will help meet the challenge of reliably connecting renewable energy resources to the grid and economically integrating them into the wholesale energy markets. Another major benefit of allowing customers to participate in the wholesale markets by taking advantage of hourly variable pricing is that the true economics of distributed renewable resources will be visible to customers, encouraging increased customer adoption of more efficient distributed resources. NYISO has been working with the utilities in New York State on a $74 million smart grid project, which is partially funded by a $37 million DOE Smart Grid Investment Grant (SGIG). Effectively implementing the broader regional markets initiative will provide New York with approximately $190M in annual savings.

Technical Domain 3: Transportation Electrification

11. SCE: PEV Integration [48]

Theme 1: Grid Reliability and Security ***Theme 2: Customer Energy Management Opportunity***
Theme 3: Asset and Resource Optimization ***Theme 4: Health, Safety, and Environment***

Federal and state policies and California's Alternative Fuels Plan are driving adoption of an estimated 100,000 vehicles in SCE's service territory by 2015. Based on recent forecasts, SCE expects to see approximately 450,000 PEVs in its service territory by 2020. If left unmanaged, PEV charging may cause critical overloading conditions which would result in in-service equipment failure and consequent customer outages. These impacts are even more pronounced when customers charge on-peak or when PEVs cluster on aging circuits ill-equipped to accommodate this new load. Managing PEV load to reduce the on-peak charging of these vehicles through TOU rates or future DR programs, will decrease coincident peak loading and avoid system energy costs. PEV integration will also help to avoid localized reliability impacts associated with incremental PEV load. PEV integration thus provides substantial benefit by helping to mitigate overloading of distribution infrastructure, avoiding subsequent outages, and maintaining adequate levels of reliability as PEV adoption continues to increase in SCE's service territory.

12. SDG&E: Enabling PEVs [46]

Theme 1: Grid Reliability and Security ***Theme 2: Customer Energy Management Opportunity***
Theme 3: Asset and Resource Optimization ***Theme 4: Health, Safety, and Environment***
Theme 5: Productivity and Economic Growth

Cost-based time-differentiated PEV rates can be an effective way to encourage PEV charging during off-peak hours, and may yield system benefits resulting from a more efficient use of the grid. It is estimated that after 2012, thousands of PEVs will be owned by SDG&E's customers, making the SDG&E's service territory a region with one of the highest concentrations of PEVs in the U.S. This creates a timely opportunity to utilize smart grid technology to efficiently integrate these loads with SDG&E's electric distribution system. "Smart Charging" applications have the potential to enable the integration of greater numbers of PEVs while helping to maximize distribution system efficiencies. SDG&E continues to build capabilities to serve these loads in compliance with state and federal laws and the California Public Utility Commission. SDG&E's "Electric Clean Transportation" program provides outreach, education, and information to all customers regarding the environmental and fuel savings benefits of PEV, including off-peak charging and incentive rates for PEV customers, as well as information regarding charging facilities and home charging. This effort is needed to support the rapid growth of PEV.

13. PJM: PEV as Storage (Theme 3 and Theme 4)

Theme 3: Asset and Resource Optimization ***Theme 4: Health, Safety, and Environment***

In an interview with PJM, it was reported that they are working on an R&D project in conjunction with the University of Delaware to communicate with electric vehicles to have the electric vehicle provide a regulation service to PJM. In the R&D project, a signal is sent to a battery in a car to provide electricity back to the grid, or be charged by the grid. This concept is also being applied with General Motors to test a fleet of Chevrolet Volts. The intention is to learn how to optimize storage to support grid requirements. As an example, electric school buses that sit idle in the summer could actually be a power source for the grid when charged in off-peak hours. To move from the R&D stage will most likely require aggregators to provide the aggregation services.

Technical Domain 4: Customer-Side Applications

14. *Brattle Report (PHI): DSM Programs [1]*

Theme 1: Grid Reliability and Security ***Theme 2: Customer Energy Management Opportunity***

The Brattle Group's report on quantifying benefits resulting from PHI's proposed DSM programs predicts that peak load could be reduced by 1.2% in Eastern Mid-Atlantic Area Council (MAAC) and by 3.6% in Southwest MAAC in 2013 as a result of the DSM programs. In the Brattle Group's "delayed supply response" scenario, the programs could increase reserve margins from 11.5% to 12.9% in Eastern MAAC and from 5.8% to 9.9% in Southwest MAAC. DSM could prevent low reserve margins with probable blackouts and could allow the system to operate more reliably. The Brattle report cites several studies that have quantified the value of lost load at between $1,600 and $4,700 per megawatt-hour for residential customers and between $7,000 and $50,000 for small commercial and industrial (C&I) customers. As such, it follows that even an incremental increase in reliability is of great economic value.

15. Brattle Report (PHI): Peak Demand Reductions Due to Dynamic Pricing [1]

Theme 1: Grid Reliability and Security ***Theme 2: Customer Energy Management Opportunity***
Theme 3: Asset and Resource Optimization

The ability to apply dynamic rates to all distribution customers as a result of AMI deployment is expected to yield significant reductions in peak demand beyond those that could be achieved through energy efficiency and direct load control programs. Brattle produces an estimate of expected average critical peak reductions based on analysis of a variety of assumptions, including: rates of $0.83/kWh during critical peak hours (representing a surcharge of $0.70/kWh over the current all-in rate of $0.125/kWh) and a $0.013/kWh discount during all other hours; 12 critical days during the summer season, with each critical event lasting four hours (totaling 48 critical hours); and average load shapes for residential and C&I customers. Brattle estimates an average critical peak reduction of up to 19% of the approximate critical peak in PHI services areas.

16. *Pacific Gas and Electric (PG&E): SmartRate Program [55]*

Theme 2: Customer Energy Management Opportunity

PG&E provides natural gas and electricity to customers in most of the northern two-thirds of California.

PG&E launched its SmartRate Program, a critical peak pricing tariff option that requires interval data to administer, in 2008. This program empowers customers to manage energy usage on hot summer days when SmartDay events are triggered (when temperatures surpass a preset threshold). At the start of the summer season, there were approximately 24,500 active residential participants. In the 2010 season, from May 1 through October 31, PG&E called 13 SmartDay events, during which SmartRate participants reduced energy consumption by 14.1%, on average. An evaluation of the program finds that 88% of respondents experienced lower costs as a result of SmartRate participation.

17. PG&E: Energy Efficiency (EE) Programs [45]

Theme 2: Customer Energy Management Opportunity   Theme 4: Health, Safety, and Environment

PG&E offers a diverse portfolio of EE programs that includes a mix of rebates and financial incentives, training and education, and support for commercializing new and emerging technology, as well as other activities, such as advocacy for stronger building codes and appliance standards.

PG&E exceeded Commission goals in 2009, with savings of 1,593 GWh, 273 MW and 25.3 million therms. In 2010, PG&E also exceeded Commission goals, with savings of 2,060 GWh, 357 MW and 16.8 million therms, resulting in customer savings of over $332 million on their energy bills. They also avoided emissions of more than 1 million metric tons of CO_2 and nearly 200 tons of nitrogen oxide (NO_x). Going forward, a new California-wide program will reward customers for adopting "whole house" energy-saving retrofits. The aim of this program is to reduce energy use by 20% in 130,000 homes through the end of 2012 through energy-saving steps.

18. Oklahoma Gas and Electric (OG&E): Customer Empowerment [18]

Theme 2: Customer Energy Management Opportunity   Theme 3: Asset and Resource Optimization
Theme 5: Productivity and Economic Growth

The scope of the OG&E smart grid projects is to implement system-wide AMI and distribution automation by the end of 2012, along with a private wide-area network (WAN) of wireless and microwave radios. Deployment is focused in the areas of:

- AMI/smart meters: OGE is unique in its deployment in that each customer is "smart grid ready" at the time of smart meter installation, rather than waiting for the full deployment to be completed. This allows incremental benefits to be realized.
- Full voluntary opt-in of demand response: program is based on variable peak pricing rates, offered in pricing "tiers" based on current conditions such as weather/temperature, power market pricing, etc.

Through remote connect and disconnect functions with the AMI system, a significant number of truck rolls have been eliminated, with a 99% success rate on connect/disconnect orders. Currently OG&E's DR program has a customer base of 6,000 and customer reaction to the DR program has shown a large customer acceptance. In 2012, OGE plans to increase the DR program to 30,000 participants which will have a greater mix of customers and will be a good test of the DR program's continued success. OG&E estimates a 9% reduction in energy consumption from DR programs by 2018.

19. Duke Energy: Envision: Charlotte & SmartBuilding Advantage [38]

Theme 2: Customer Energy Management Opportunity   Theme 3: Asset and Resource Optimization
Theme 4: Health, Safety, and Environment

Duke Energy (Duke), headquartered in Charlotte, North Carolina, is an energy company with assets in the United States, Canada and Latin America.

Duke's Envision: Charlotte project is intended to improve overall sustainability inside Charlotte, North Carolina's I-277 loop. By leveraging digital smart grid technologies to aggregate energy usage and display it as an overall community number, Duke hopes to reduce energy usage 20% by 2016, thereby avoiding 220,000 metric tons of GHGs.

Duke's SmartBuilding Advantage project is an end-to-end pilot program that implements smart grid technology to gain energy efficiency in commercial buildings. Early participants have averaged 27% annual savings with payback periods of 2 to 4 years.

20. Oncor: Smart Meter Deployment [65]

Theme 2: Customer Energy Management Opportunity

Oncor, headquartered in Dallas, TX, operates the largest distribution and transmission system in Texas, delivering power to approximately 3 million homes and businesses and operating approximately 117,000 miles of distribution and transmission lines in Texas.

In August 2011, Oncor installed its two-millionth smart meter, completing two-thirds of its planned advanced meter development, which started in 2008. Oncor's smart meters, coupled with Texas' Smart Meter Texas web portal, allows customers to review daily and cumulative energy usage. In-home monitors and other HAN devices allow customers to review their usage information, including their carbon footprint and prices per kWh, in near real time. Based on current consumption patterns, Oncor predicts that its customers could collectively save up to $250 million annually.

21. ISO New England (ISO-NE): Demand Response Program [24]

Theme 2: Customer Energy Management Opportunity

ISO-NE is an independent, non-profit Regional Transmission Organization (RTO), serving Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.

ISO-NE is one of the pioneers of the implementation of demand response program. According to the ISO-NE DR analysis, a reduction in electricity use by five percent during peak hours (through conservation and energy efficiency) would save customers $580 million annually, and a 500-MW increase in demand response participation would cut wholesale costs by $32 million – a total of $612 million annually.

22. McKinsey and Company Report: The Smart Grid and the Promise of Demand Side Management [27]

Theme 2: Customer Energy Management Opportunity

This McKinsey report suggests that demand-side management could translate into $59 billion in societal benefit by 2019. McKinsey estimates that by 2020 the United States could cut end-use energy consumption by 9.1 quadrillion BTUs, over one-fifth of its total projected demand. FERC estimates that demand response programs could cut peak demand by up to 20 percent within 10 years. Pilots have shown that real-time access to information provided through smart grid networks can cut energy consumption by up to 18%.

A.2. Examples of Smart Grid Vendor Community Activities

In Appendix A.2, example discussions with three vendors are included. Many technology vendors have developed a smart grid product development roadmap. As part of this project, only a small number of representative vendors were interviewed.

Among those vendors, ABB, an international manufacturer of electric systems infrastructure and systems, takes an expansive view of the smart grid, defining it by its capabilities and operational characteristics to support utility operations and processes, rather than by the use of any one particular technology. ABB believes that information technology and communications are enablers of several key applications. For example, AMI, distribution grid management, asset health management, mobile workforce management, transmission technologies, and DERs such as PEVs, energy storage, distributed generation, and demand response are all applications. ABB sees the growing convergence between operational technologies and information technologies as a smart grid driver.

Another example is General Electric (GE). GE, also an international manufacturer of electric infrastructure and systems, worked with utilities to learn key business drivers, and developed solutions based on those drivers. GE views market potential as segmented into the six areas of utility drivers: (a) distribution optimization; (b) transmission optimization; (c) demand response; (d) asset optimization; (e) smart metering; and (f) workforce and engineering design optimization. In addition to the requirement of cost/benefit and payback, other business case drivers identified by GE include impact on reliability, reducing SAIDI/SAIFI, and impact on environment (CO_2 reduction). Distribution case solutions have been found to be the biggest business case justification. Typical payback has been realized at six times the cost returned in three years. Cases include volt/VAR optimization, fault location, and fault isolation.

Verizon, a communications service provider, is active in the smart grid market. Verizon's vision encompasses the realm of "smart energy," of which smart grid is a key component. Verizon sees opportunities in smart meters, distribution automation, the enormity of data generated by a smarter grid, and the provision of demand/response services. Verizon is also applying its experience with cyber security and its role as part of the nation's critical infrastructure to the security challenges confronting the smart grid. Looking beyond the grid, Verizon provides smart-home and smart-building solutions and telematics and telemetry for electric vehicles, which comprise markets adjacent to the smart grid. The company offers a home monitoring and control service that enables customers to remotely access, control, and monitor doors, thermostat controls, and appliances and to view home-energy use in near real time—all via smart phones. Significantly, Verizon Home Control service includes installation of an energy reader for whole-house energy-use data. While Home Control is designed to communicate with smart meters and smart-grid technologies if available, Verizon offers Home Control independently from smart-grid deployments, as the service is not dependent on smart grid technologies.

A.3. Examples of Regulators Comments

In Appendix A.3, two important interviews with utility regulatory commissioners are included. Many of the case study interviews highlighted regulatory concerns as did many of the industry papers reviewed in conjunction with this report. This report sought to collect some actual views from regulators who have been involved in evaluating smart grid deployment. Two example comments are included in the following sections: Commissioner Richard Morgan from the District of Columbia Public Service Commission (DC PSC) and Commissioner Sherman Elliott from the Illinois Commerce Commission (ICC).

DC PSC

Commissioner Richard Morgan of the DC PSC provided insight into the smart grid environment in DC. In DC they have had success with a dynamic pricing response pilot test of 900 customers, conducted from 2008-2009, known as PowerCentsDC. It was designed to study how customers respond to dynamic pricing, facilitated by smart metering technology. Results of the pilot showed that the technology was feasible, and the vast majority of participants did respond to pricing options. Participants reduced their peak load as well as saved money. When asked after the test concluded, customers desired to stay on the dynamic pricing structure by a margin of 14 to 1. Based on pilot results, the decision was made by the DC Council to allow utilities to go forward with the smart meter deployment. By early 2012, smart meters will be installed at all DC customer locations.

From a regulator standpoint, Commissioner Morgan offers his views on smart grid:

- Technology is still evolving and is expected to continue to evolve. That doesn't mean that technology cannot deliver benefits to customers now. There are a lot of unrealized benefits that need to be explored and captured.
- Smart grid is not widely understood or accepted by customers. However, customers are not given enough credit for changing, and customers are interested when given the opportunity to experience benefits.
- There are significant potential benefits of dynamic pricing. It remains a matter of how to capture and quantify the benefits. It is also understandable that some of smart grid benefits cannot be easily quantified.
- There is a need for substantial efforts in customer education and customer engagement. To make this happen, there has to be a collaborative effort.

ICC

Commissioner Sherman Elliott believes that while smart grid technology readiness is good, the market readiness still needs work. There is not a lot of knowledge in the customer marketplace. An education process is needed to express the value propositions. From his point of view, there are two areas of value proposition where utilities are involved: (a) traditional operational benefits; and (b) customer benefits. The challenge in quantifying benefits is that an upfront investment is required, but benefits stream in over time. The difficulty is how to get the Net Present Value (NPV) of benefits stream to offset the cost of investment over time. Whatever quantification method is used, the estimation technique utilized needs to provide a high level of confidence.

Commissioner Elliott believes that with all the pilot tests and studies that have been conducted throughout the country and world, there should be sufficient results to develop models to determine elasticity of demand for various pricing structure options to help monetize the benefits of dynamic pricing. He would like to see some results or analysis that makes inferences on benefits from the customer side, especially dynamic pricing.

“Customer Outreach” is an important aspect of the smart grid. In Illinois, outreach activities have been limited due to issues with “ownership” of the message, and who should participate financially. The ownership issue stems from the supply chain in the smart grid service, which ranges from utility to EV provider, appliance manufacturer, sensor manufacturer, telecom provider, and so on. Depending on where you are in the supply chain, there is a different message to send.

Commissioner Elliott’s key messages on smart grid are:

- Sense of Inevitability: Smart grid is not an option. It is an inevitability. The question is just a matter of “when.”
- Sense of Urgency: The longer the delay in smart grid deployment, the less we are able to gain productivity and efficiency sooner.
- The “go slowly” approach by regulators is not the correct way to approach smart grid deployment.

GLOSSARY

AB	Assembly Bill. A proposed law introduced by a state legislature.
AMI	Advanced Metering Infrastructure. The full measurement and collection system that includes meters at the customer site, communication networks between the customer and a service provider, and data reception and management systems that make the information available to the service provider.
ANSI	American National Standards Institute. An organization that oversees the creation, promulgation and use of thousands of norms and guidelines that directly impact businesses in nearly every sector including energy distribution. www.ansi.org
ARRA	American Recovery and Reinvestment Act of 2009. Legislation passed by the U.S. Congress in 2009 in support of retaining and creating jobs, economic activity and investment in long-term growth.
CAIDI	Customer Average Interruption Duration Index. A reliability index commonly used in the electric power industry indicating the average outage duration experienced by customers, or average restoration time.
CAISO	California Independent System Operator. The regional transmission and market system operator of the state of California. www.caiso.com
CBM	Condition Based Maintenance. An application of sensors, monitoring systems, and processes to support maintenance of equipment in service as the need arises.
CEC	California Energy Commission. California's primary energy policy and planning agency. www.energy.ca.gov
CIP	Critical Infrastructure Protection. A concept that relates to the preparedness and response to serious incidents that involve the critical infrastructure of a region or nation.
CMI	Customer Minutes of Interruption. The number of minutes of interruption a customer encountered. The customer-minutes of all interruptions are then summed to determine the total customer-minutes for a customer during a specified time period.
CPUC	California Public Utilities Commission. Entity that regulates privately owned electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies. www.cpuc.ca.gov
CSI	California Solar Initiative. The solar rebate program for California consumers that are customers of the investor-owned utilities - Pacific Gas and Electric, Southern California Edison, San Diego Gas & Electric. www.gosolarcalifornia.org
DA	Distribution Automation. A family of technologies including sensors, processors, communication networks, switches and applications that can perform distribution automation functions to improve reliability, service quality and operational efficiency.
DC PSC	District of Columbia Public Service Commission. An independent District Government agency established to regulate the electric, natural gas, and telephone companies in the District. www.dcpsc.org
DER	Distributed Energy Resources. Electric energy sources that typically include distributed generation and energy storage and may be interconnected with the power system at transmission or distribution level voltages.

DG	Distributed Generation. Active energy sources such as a micro-turbine, diesel backup generator, or other standby generation that may be interconnected with the power system at transmission or distribution level voltages.
DMS	Distribution Management System. A control system to manage distribution power operations through a combination of communications with field equipment and hierarchical control algorithms.
DOE	U.S. Department of Energy. The federal agency whose mission is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions. www.energy.gov
DR	Demand Response. Similar to dynamic demand mechanisms to manage customer consumption of electricity in response to supply conditions, for example, having electricity customers reduce their consumption at critical times or in response to market prices.
DSM	Demand Side Management. Programs that consist of the planning, implementing, and monitoring activities of electric utilities that are designed to encourage consumers to modify their level and pattern of electricity usage.
EE	Energy Efficiency. Efforts to reduce the amount of energy required to provide products and services.
EMS	Energy Management System. A system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation and/or transmission system. The monitor and control functions are known as SCADA; the power system analysis and optimization applications are often referred to as "advanced power system applications".
EPRI	Electric Power Research Institute. An independent, non-profit company performing research, development and demonstrations in the electricity sector for the benefit of the public. www.epri.com
FERC	Federal Energy Regulatory Commission. An independent agency that regulates the interstate transmission of electricity, natural gas, and oil. www.ferc.gov
FLISR	Fault Location, Isolation, and Service Restoration. An application that leverages the distribution automation, SCADA equipment, and advanced algorithm to automate the outage restoration process before the service crews arrive.
GHG	Green House Gas. A gas when in high concentrations in the atmosphere contributes to the greenhouse effect.
GPS	Global Positioning System. A space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites.
GWh	Gigawatt-hour. A unit of measurement of energy equal to one billion watt hours.
HAN	Home Area Network. A residential local area network (LAN) used for communication between digital devices typically deployed in the home.
IEC	The International Electrotechnical Commission. This organization prepares and publishes international standards for all electrical, electronic and related technologies. www.iec.ch
IED	Intelligent Electronic Devices. A term used in the electric power industry to describe microprocessor-based controllers of power system equipment.

IEEE	Institute of Electrical and Electronics Engineers. A professional engineering association for electrical, electronic, and other engineers. www.ieee.org
ICC	Illinois Commerce Commission. www.icc.illinois.gov
IOU	Investor-owned utility. An IOU is a business organization, providing a product or service regarded as a utility (often termed a public utility), and managed as private enterprise rather than a function of government or a utility cooperative.
IRC	ISO/RTO Council. Comprised of 10 Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs) in North America, it works collaboratively to develop effective processes, tools, and methods for improving competitive electricity markets across North America. www.isorto.org.
ISO	Independent System Operator. A regional system operator responsible for the reliable operation of the bulk electric transmission system in its FERC-approved geographic territory.
kW	Kilowatt. A unit of measurement of power equal to 1000 watts.
kWh	Kilowatt hour. A unit of a unit of energy equal to 1000 watt hours or the equivalent to one kilowatt (1 kW) of power expended for one hour (1 h) of time.
MAIFI	Momentary Average Interruption Frequency Index. MAIFI is a reliability indicator used by electric power utilities. MAIFI is the average number of momentary interruptions that a customer would experience during a given period (typically a year).
MVA	Megavolt ampere. A unit used for the apparent power in an electrical circuit.
MW	Megawatt. A unit of measurement of power equal to one million watts.
NARUC	National Association of Regulatory Utility Commissioners. The national association representing the State Public Service Commissioners who regulate essential utility services, including energy, telecommunications, and water. NARUC members are responsible for assuring reliable utility service at fair, just, and reasonable rates. www.naruc.org
NERC	North American Electric Reliability Corporation. An organization whose mission is to ensure the reliability of the North American bulk power system. www.nerc.com
NIST	National Institute of Standards and Technology. A measurement standards laboratory which is a non-regulatory agency of the United States Department of Commerce. www.nist.gov
OMS	Outage Management System. A computer system used by operators of electric distribution systems to assist in restoration of power.
PCT	Programmable Communicating Thermostat. A term used by the California Energy Commission to describe programmable thermostats that can receive information wirelessly.
PEV	Plug-in Electric Vehicle. Any motor vehicle that can be recharged from any external source of electricity and the electricity stored in the rechargeable battery packs drives or contributes to drive the wheels.
PMU	Phasor Measurement Unit. A PMU is a device which measures the electrical waves on an electricity grid, using a common time source, such as GPS, for synchronization.
PQ	Power Quality. A broad term used to describe the measurement of electrical power performance. Variations in voltage, frequency, wave shape (harmonics) and other

aspects of power may make the power delivered to equipment less than ideal, creating compatibility problems. Electronic equipment may be especially sensitive to power quality problems.

PV Photovoltaic. A method of generating electrical power by converting solar radiation into direct current electricity.

RPS Renewable Portfolio Standard. A regulation that requires the increased production of energy from renewable energy sources.

SAIDI System Average Interruption Duration Index. A commonly used reliability indicator by electric power utilities. SAIDI is the average outage duration for each customer served in a given period.

SAIFI System Average Interruption Frequency Index. A commonly used reliability indicator by electric power utilities. SAIFI is the average number of interruptions that a customer would experience in a given period.

SCADA Supervisory Control and Data Acquisition.

SGIP Smart Grid Interoperability Panel. A broad group of smart grid stakeholders organized by NIST to provide an open process for participation in the coordination, revision, acceleration and harmonization of smart grid standards. Members of the SGIP develop and review use cases, identify requirements, and propose action plans.

T&D Transmission and Distribution. The power delivery system used to supply electric power at voltage from 765 kilo volts to 120/240 volts.

VAR Volt-Ampere Reactive. A unit of reactive power.

WECC Western Electricity Coordinating Council. A regional forum that promotes electric service reliability in the Western United States and Western Canada. www.wecc.biz

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