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Smart Grid Leadership Report: Global Smart Grid Implementation Assessment

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PRODUCT DESCRIPTION

Through its Smart Grid Demonstration Initiative, EPRI and the Galvin Electricity Initiative developed a survey to assess the development and deployment of Smart Grid projects worldwide. The survey identified leaders in Smart Grid advancement, key applications, drivers in developing a Smart Grid project, and lessons learned from Smart Grid initiatives, with emphasis on the integration of distributed energy resources with grid operation. Critical to Smart Grid success is coordination of Smart Grid research and demonstrations so that each effort can take advantage of the wide range of development and implementation activities throughout the world.

Results and Findings

This report will focus on the current progress of Smart Grid deployments, including definitions of the term Smart Grid, geographical scope, and functions addressed by Smart Grid projects. Based on the sample size responding to the survey, the majority of Smart Grid projects have been initiated within the past three to four years and are in developmental stages, specifically the proof-of-concept or business case development stage. The applications deployed within Smart Grid projects range from project to project. Advanced metering infrastructure (AMI) and enhanced fault detection were important to the majority of companies responding to the survey. These findings suggest that system communication, power quality, and reliability concerns are at the forefront of Smart Grid initiatives and advancement in Smart Grid technologies.

The report's next major focus is on the drivers prompting Smart Grid projects, including the effect of market research and regulatory agencies as well as benefits and beneficiaries. Respondents overwhelmingly indicated that internal operations were the driving force behind many Smart Grid projects. Challenges to research include funding and the implementation of new technologies. These findings provide a snapshot of the opportunities and barriers associated with Smart Grid project adoption.

The report's final focus is on Smart Grid leadership examples in areas such as asset management applications, consumer information transfer, dynamic pricing, wide area monitoring systems, integration of bulk and distributed renewables, energy storage, and the microgrid. Included are discussions of 20 Smart Grid projects from around the world along with project drivers. A second international Smart Grid survey sponsored by e8—a nonprofit international organization comprised of 10 world-class electricity companies—is included in Appendix C to support understanding project goals.

Challenges and Objectives

The primary goals for this report are to share knowledge of worldwide Smart Grid implementations, key incentives that stimulated leadership to deploy Smart Grid projects, and lessons learned as a result of Smart Grid initiatives. The study is designed to facilitate the international coordination of Smart Grid research and demonstrations.

Applications, Values, and Use

A smarter grid holds the promise of improved customer empowerment, greater system reliability, reduced costs, and decreased pollution. Many Smart Grid projects being deployed to date are research oriented, with a goal of quantifying the benefits of various Smart Grid technologies and applications. With the large number of similar projects being deployed by noncompeting stakeholders, the industry has a unique opportunity to share Smart Grid benefits assessments, lessons learned, and gaps identified. Collaboration of this type among utilities will help achieve Smart Grid goals in an effective manner so that results can be applied across the industry, taking into account unique factors within projects.

EPRI Perspective

While the Smart Grid will build upon the current electrical transmission and distribution systems, the grid's essential operational features will involve telecommunication and monitoring systems to enable two-way communication and interoperability as well as optimal integration of distributed energy resources (DER), including storage. The survey results described in this report can provide a framework for identifying key opportunities and obstacles facing Smart Grid projects around the world.

Approach

Survey respondents were selected based on a list of EPRI workshop, conference, research program participants, and Smart Grid Demonstration Initiative sponsors. The goal was to identify a group of experts from utilities and other organizations that could provide valuable insight into Smart Grid deployments around the world. Survey responses were requested from utilities representing a wide range of geographical locations. While the majority of respondents were from the United States, others were from South Africa, Japan, Ireland, France, and Italy.

EPRI deployed the Smart Grid survey via an electronic surveying tool sent to the respondent's e-mail address. The survey consisted of both open- and closed-ended questions. The survey also contained filter questions that would allow the tool to trigger a question based on responses to previous questions. Using filter questions eliminates respondents that would be unlikely to know about the topic or respond with a non-attitude. A pilot study was conducted prior to full-scale deployment of the survey to gain feedback on question structure and content. The final Smart Grid survey was divided into three question batteries that reflect overall project goals and objectives to determine the following:

- Key applications deployed by utilities and progress of Smart Grid implementations
- Key drivers that prompted leadership to deploy Smart Grid projects
- Key lessons learned from Smart Grid project development and implementation

Keywords

Smart Grid Demonstration Initiative
Galvin Electricity Initiative
Smart Grid Applications
Smart Grid Drivers
Smart Grid Lessons Learned

EXECUTIVE SUMMARY

This report examines international Smart Grid activities from the perspective of electric utilities actively planning or deploying Smart Grid projects. The goal of the report is to provide a global perspective on the key drivers for utilities to deploy Smart Grid projects and identify emerging trends in those deployments. The report provides the results of two surveys that EPRI facilitated along with industry knowledge based on our active research and involvement in Smart Grid activities around the world and examples of leaders in a number of Smart Grid applications.

The primary survey of this report was jointly funded by EPRI's Smart Grid Demonstration Initiative and The Galvin Electricity Initiative (GEI) to gain an understanding of different Smart Grid implementations around the world, supporting the goal of understanding deployment drivers, benefits, experiences, lessons learned and project status. The survey was offered to numerous international utilities, but the response rate was relatively low compared to the number of known smart grid projects and therefore does not allow for a complete observation of the state of the Smart Grid around the world. However, the responses that were collected still provide valuable insight into technologies and applications used as well as drivers that influence and benefits that result from current Smart Grid projects. To provide supporting content to the survey, Chapter 4 of this report provides 20 leading examples of smart grid projects around the world and key drivers the prompted investment in those Smart Grid Projects. Lastly, a second international Smart Grid survey completed in May 2010 that was sponsored by e8, a non-profit international organization composed of 10 world-leading electricity companies (www.e8.org), and was administered by EPRI is included in Appendix C. The public results of that survey are documented and are available online in the report "Smart Grid –Technology Innovation Group Report."[1]

The core drivers for Smart Grid deployments are primarily economic and policy based. The economic drivers are similar to those that have existed over the last century – having the most effective way to match electric supply with demand 100% of the time and cover many sub-categories. The newest driver is the rate at which emerging technologies are advancing, such as, communications, computing power, energy storage, and renewable generation. These technologies are creating new opportunities and innovative ways to match electric supply and demand. In addition, there are emerging drivers to understand potential business models where power sales do not drive profits. In many deployments, the economic driver includes the opportunity to leverage economic stimulus funding. One of the key findings of the survey is that Smart Grid pilots and demonstrations are being pursued to determine costs and benefits so that

[1] e8 Technology Innovation Group on Smart Grids "Smart Grid – Technology Innovation Group Report," http://www.e8.org/upload/File/0_4_2_2_att_-_smart_grid_group_outcomes_final_report_for_public_use.pdf

the extension of the smart grid applications for wide-scale deployment can be pursued in an educated manner and help to understand the factors that can affect the costs and benefits.

In addition, a key external driver is regulatory policy goals including Green House Gas (GHG), Energy Efficiency (EE), Reliability, and Renewable Portfolio Standards (RPS). For example the European Unions (EU) 20-20-20 target. In March 2007, EU leaders endorsed an integrated approach to climate and energy policy to combat climate change and increase energy security while strengthening the EU's competitiveness. To achieve these goals, a series of climate and energy targets to be met by 2020 are:

- A reduction in EU GHG emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving EE

Similar GHG, EE, Reliability and RPS goals exist in the United States on a state-by-state basis as well as other countries around the world.

The applications being deployed within Smart Grid projects range from project to project, but in the EPRI survey, Advanced Metering Infrastructure (AMI) and enhanced fault detection were selected by the majority of survey respondents. The most common Smart Grid applications being deployed include:

- Demand-side integration and empowering customers
  - Through price signals and through technology
  - The ability to integrate Distributed Energy Resources effectively
  - The capability of adjusting end-use load to match the available supply in near real time (e.g. through dynamic pricing signals and/or direct load control)
- Improving system performance and power flow and energy
  - Reliability through automatic reconfiguration, or "self-healing"
  - Power Quality improvement through better understanding and control of the operating power system
  - The ability to respond in real time to changes in load or line condition to improve efficiency and reduce losses
- Reducing Green House Gases
  - Deploying renewable generation and infrastructure to support integration of these resources along with integration of electric storage
  - Optimizing operation of centralized generation to avoid operating less clean generation.

These findings confirm that information and communication technologies are at the forefront of Smart Grid projects in order to enable integration of demand-side resources, power quality and reliability applications, and renewable generation penetration. A majority of respondents indicated “Internal Operations” improvement as a key driver that prompted their Smart Grid project. The response to this and similar questions highlight the complexity of Smart Grid projects and that there is no one-size-fits-all in regards to what is the single most important driver for all utilities.

An important survey result was that less than half of those who responded indicated that they have conducted market research for the Smart Grid project at their company and most companies indicated that their customers have very little knowledge of the Smart Grid. This is an indication that developing activities involving customer interaction, such as variable pricing programs, will be important to help educate customers about the Smart Grid.

A smarter grid holds the promise of improved customer-empowerment, reliability, reduced cost and reduced pollution. Many Smart Grid projects being deployed to-date are research oriented with a goal to quantify benefits of the technologies and applications. Collaboration among utilities will help achieve this goal in an effective manner so results can be applied across the industry taking into account unique factors within projects. With the large number of similar projects being deployed by non-competing stakeholders, the industry is in a unique opportunity to share benefits assessments, lessons learned and gaps identified. Leveraging this opportunity could contribute significantly to the effectiveness of the industry in its efforts to meet the needs of its customers and of society.

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1
BACKGROUND

1.1 Context

This report examines international Smart Grid activities from the perspective of electric utilities actively planning or deploying Smart Grid projects. The goal of the report is to provide a global perspective on the key drivers for utilities to deploy Smart Grid projects and identify emerging trends in those deployments. The report provides the results of two Smart Grid surveys that EPRI facilitated along with industry knowledge based on our active research and involvement in Smart Grid activities around the world. The primary survey that is the basis of this report was jointly funded by EPRI's Smart Grid Demonstration Initiative and The Galvin Electricity Initiative (GEI) to gain an understanding of different Smart Grid implementations around the world supporting the goal of understanding deployment drivers, benefits, experiences, lessons learned and project status. This survey was offered to numerous utilities around the world including the members of EPRI's Smart Grid Demonstration Initiative. A second international survey sponsored by e8, a non-profit international organization composed of 10 world leading electricity companies (www.e8.org) and administered by EPRI was completed in May 2010 and the results are considered in this report. The public results of that survey are compiled in the report "Smart Grid –Technology Innovation Group Report" and are in Appendix C of this report.

1.1.1 Goals and Objectives

The survey results described in this section can provide a framework for identifying the main opportunities and obstacles facing Smart Grid projects around the world. The primary goals for this report are to gain an understanding of different implementations around the world, the key incentives that stimulated leadership to deploy the project, and lessons learned as a result of the initiatives. The main objectives sought from this study are to facilitate the coordination of research and demonstrations so that each effort can take advantage of the wide range of developments and implementations around the world.

1.1.2 Geographical Scope

Survey respondents were selected based on a list of EPRI workshop, conference, research program participants, and Smart Grid Demonstration Initiative sponsors in order to identify a group of experts from utilities and other organizations that could provide valuable insight into Smart Grid deployments around the world. Survey responses were requested from utilities that represented a wide range of geographical locations. Figure 1-1 below provides a visual representation of the geographical scope of utilities who responded to the survey. The majority of respondents were from the United States, while others were from South Africa, Japan, Ireland, France, and Italy.

Figure 1-1
Visual Representation of International Response ***(Source: www.surveygizmo.com)***

The EPRI/GEI Smart Grid survey was deployed in May 2010, to 137 individuals from 70 different companies. A final response rate of 34.29% was achieved by the deadline (24/70 company's submitted surveys). The response rate of roughly 34% is relatively low and does not allow for a complete observation of the state of the Smart Grid around the world. However, the responses that were collected still provide valuable insight into technology trends and applications used as well as drivers that influence and benefits that result from current Smart Grid projects.

1.1.3 Methodology

EPRI deployed the Smart Grid survey via an electronic surveying tool sent to the respondent's e-mail address. The survey consisted of both open and closed ended questions. The survey also contained filter questions that would allow the survey tool to trigger a question if the respondent provided a particular response to previous questions. Using filter questions eliminates respondents who would be unlikely to know about the topic or respond with a non-attitude. A pilot study was conducted prior to full scale deployment of the survey to gain feedback on survey question structure and content. The final survey was divided into three question batteries that reflect the overall goals and objectives of the survey including:

- Key Applications Deployed by Utilities & Progress of Smart Grid Implementation
- Key Drivers that Prompted Leadership to Deploy the Smart Grid Project
- Key Lessons Learned from Smart Grid Project Development & Implementation

1.2 Key Findings

The key findings based on survey results will be analyzed in the following sections.

Section 2
Section 2 will focus on current progress of Smart Grid deployments, including definitions of the term Smart Grid, geographical scope and functions included in Smart Grid Projects. The majority of Smart Grid projects, based on our sample size, have been initiated within the past three to four years. The majority of respondents are also in the development stage of the project, specifically the proof of concept or business case development stage. The applications used within Smart Grid projects range from project to project. Advanced Metering Infrastructure (AMI) and enhanced fault detection were selected by the majority of companies that responded. These findings suggest that system communication and power quality and reliability concerns are at the forefront of Smart Grid initiatives and advancement in Smart Grid technologies.

Section 3
Section 3 will focus on the drivers that prompted Smart Grid projects, including the effect of market research and regulatory agencies as well as benefits and beneficiaries. Respondents overwhelmingly indicated internal operations as an important key driver that prompted their Smart Grid project. The main areas identified as challenges to research include funding and the implementation of new technology. These findings provide a snapshot of the opportunities and barriers to the adoption of the Smart Grid.

Section 4
Section 4 offers 20 examples of Smart Grid projects around the world and the drivers behind those projects. This section is split into resources that can be used in a Smart Grid such as Integration of Distributed Renewables, Energy Storage, and Microgrid, and then offers examples of utilities that are using that resource and their realized results.

2
SURVEY RESULTS - PROGRESS OF THE SMART GRID AND KEY APPLICATIONS DEPLOYED

The first section of questions in the Smart Grid survey involved the definition of the term "Smart Grid," the identification of companies surveyed who have initiated a Smart Grid projects, the current stage of their Smart Grid projects, and the major applications involved such as key assets, functions, and communication infrastructure. The following section will explore the results of the survey and explain what these findings say about Smart Grid development on a global scale.

2.1 What is a Smart Grid?

The term "Smart Grid" can be characterized differently across nations and utilities. The survey respondents were first asked to provide their company's definition of a "Smart Grid" so that results could be analyzed and a common understanding extracted. Figure 2-1 illustrates the most common descriptions of a Smart Grid based on the qualitative analysis of survey responses. The most commonly used term to describe a Smart Grid was the utilization of emerging/intelligent devices. Nearly 45% of respondents included this area in their Smart Grid definition. The next five most commonly used terms included: 1) Efficiency 2) Reliability and Power Quality 3) Improved Communications 4) Customer Experience/Involvement 5) Sustainable or Renewable Energy.

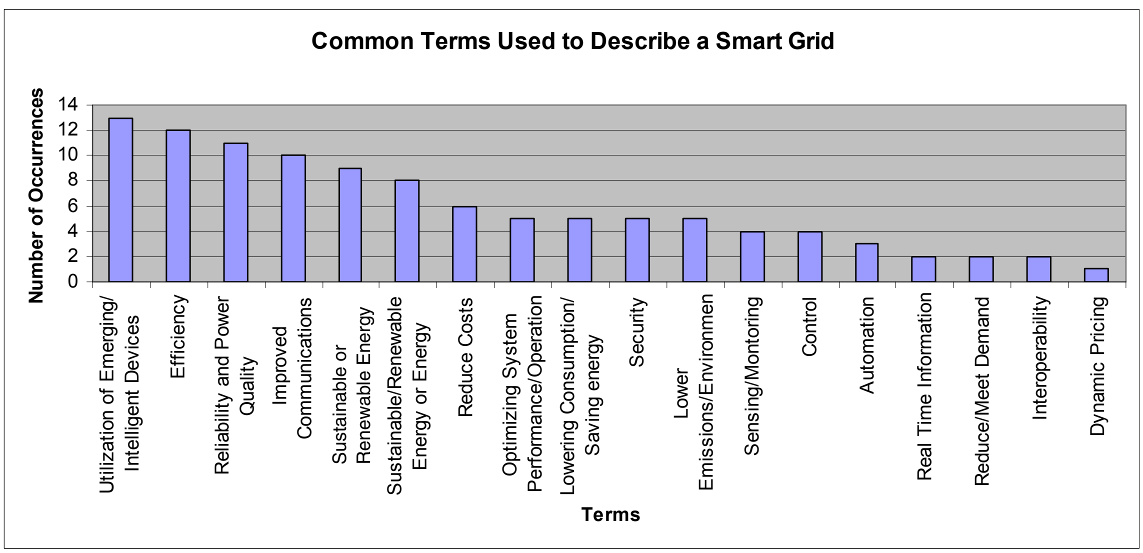


Figure 2-1
Common Terms Used to Describe a Smart Grid

Specific responses to this question are included in Appendix A of this report. The e8 Smart Grid –Technology Innovation Report members defined the Smart Grid as follows: **"The Smart Grid will be a customer-centered, interactive, reliable, flexible, optimal, economical, economically responsive and, ultimately, a sustainable and environmentally responsible electrical power generation and distribution system. Electric utilities must play a key role in its development."** The e8 definition went on to describe each of the attributes in more detail. Although no two definitions are exactly the same, they all have similar attributes and ultimately focus on the most effective means to leverage technology to link electric supply with demand considering internal and external factors.

As Figure 2-1 illustrates the majority, 83%, of the respondents indicated that they have a Smart Grid project at their company, while 17% did not. The geographical difference between those who responded yes versus no appeared to be insignificant based on our sample size.

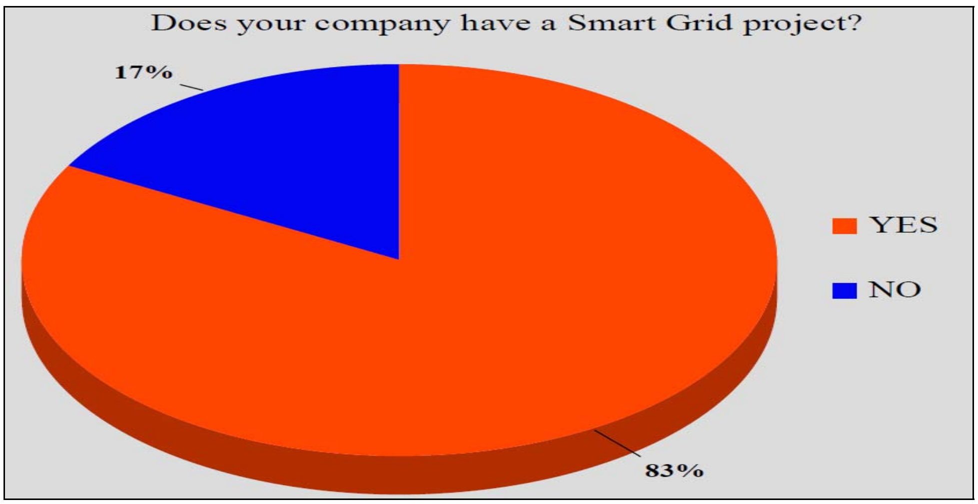


Figure 2-2
Measure of International Smart Grid Project Development

2.2 Smart Grid Projects Deployed

Section 2.2 analyzes Smart Grid projects in greater detail based on survey respondents who indicated that they have a Smart Grid project at their company. Figure 2-3 illustrates the increase in Smart Grid projects from 2005 to the present day. The figure also demonstrates a pause in Smart Grid initiatives from 2001-2003 followed by an increase and decrease between 2004 and 2005 although the relatively small sample size from the survey responses does not necessarily accurately reflect industry trends. The development of Smart Grid projects appears to maintain a steady increase from 2008 to the present.

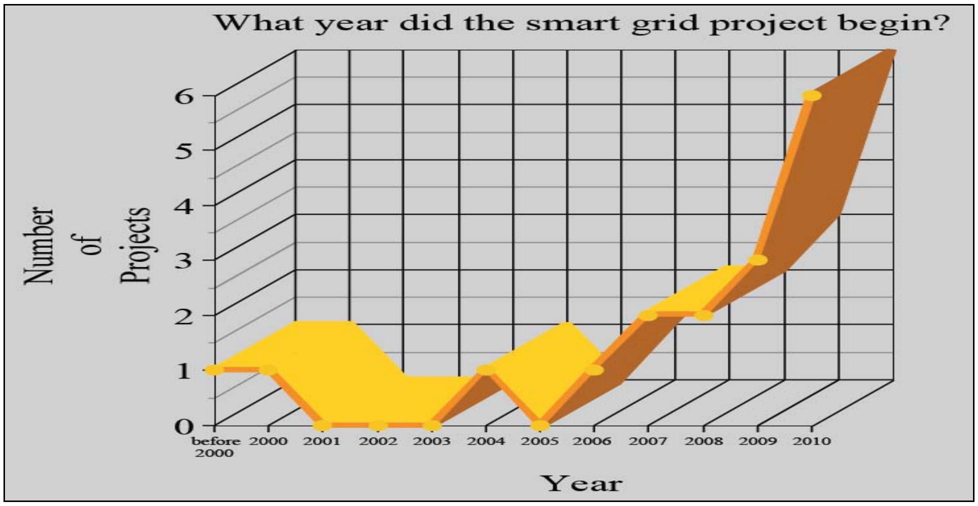


Figure 2-3
Year of Smart Grid Development Initiative

The location of Smart Grid projects represented in Figure 2-4 shows a high concentration of projects in the mid-west and eastern United States, but that is also where a majority of the responses came from – not necessarily indicating where the highest concentration of activities are occurring. Based on survey results, Wisconsin had the greatest concentration of Smart Grid projects followed by Texas, Mississippi, and Minnesota. Smart grid projects in western European countries such as France, Italy and Ireland were also identified. The sample of respondents was not high enough to necessarily provide a clear picture of the state-of-Smart Grid-deployments around the world and the survey also did not capture information related to the number of customers affected by the projects.

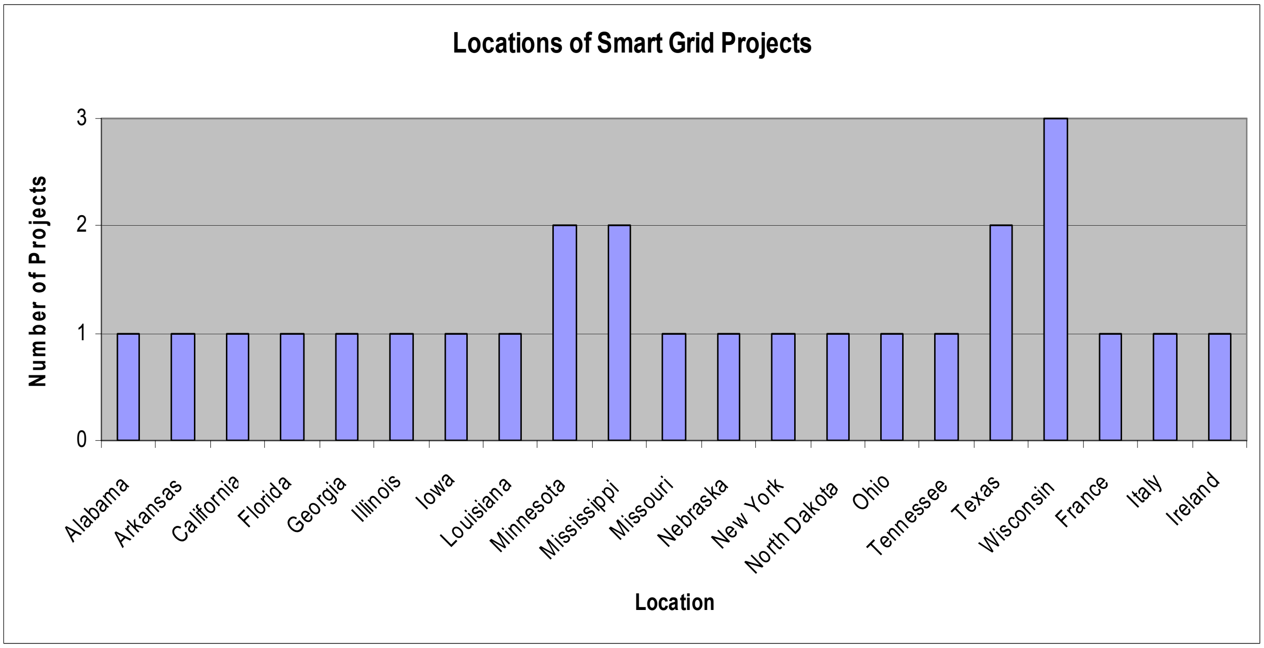


Figure 2-4
Location of Smart Grid Projects Based On Responses to Survey

Following the identification of the site of Smart Grid initiatives the respondents were then asked to identify the stage of development that most closely aligned with their company's project. Thirty seven (37%) percent of respondents indicated their project was categorized as a proof of concept and another thirty seven percent (37%) indicated their project was in the business case stage of development as illustrated in Figure 2-5.

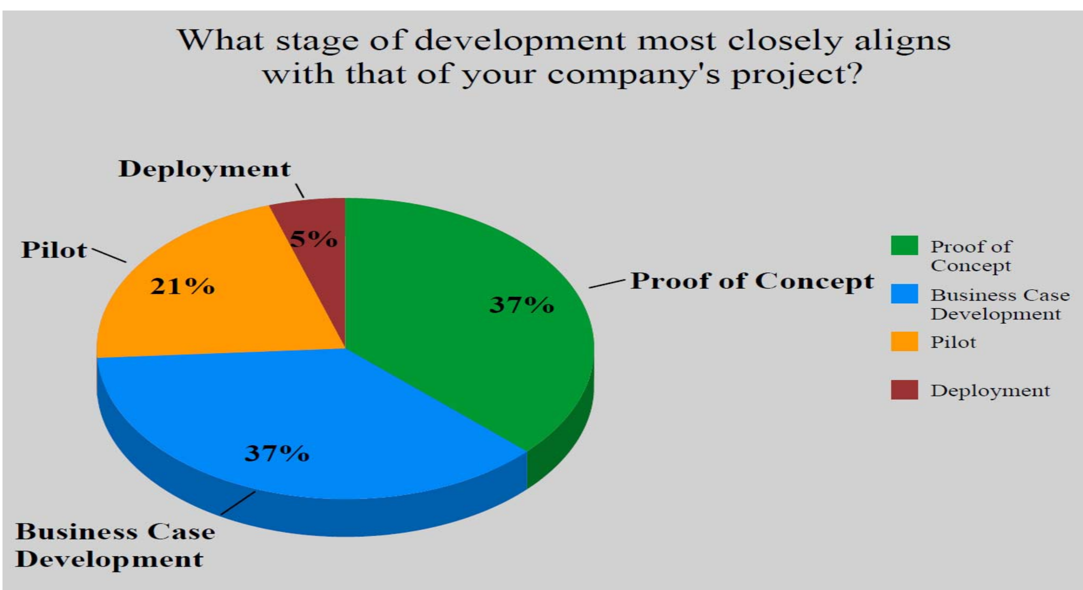


Figure 2-5
Smart Grid Stage of Development

The respondents indicating they were in the deployment stage were prompted to answer a follow up question regarding the percentage of the project in operation today. Figure 2-6 builds off the previous figure by illustrating the percentage of the deployed Smart Grid project complete to date. The deployed projects range from 10%-98% complete, but due to the small sample size of responses, is only representative of the survey responders, not necessarily the industry as a whole.

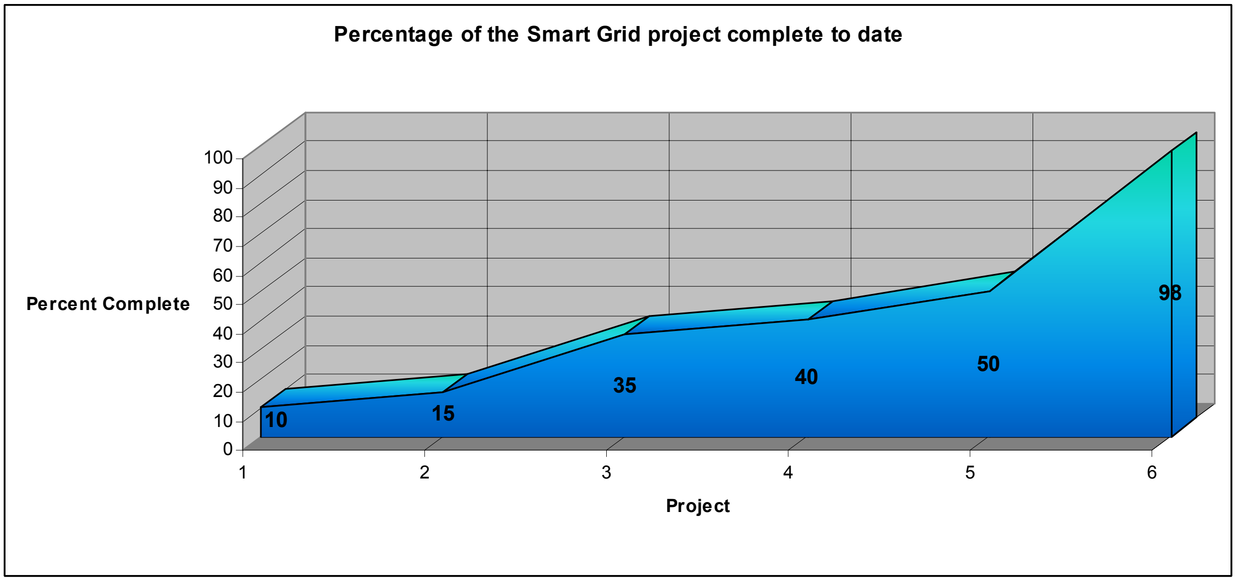


Figure 2-6
Percentage of the Smart Grid Project Complete To Date

2.3 Smart Grid Applications

Section 2.3 analyzes the common components that make up the Smart Grid projects. Specifically, the section will focus on the key assets, functions and communication infrastructure incorporated into the projects.

2.3.1 Key Assets

Figure 2-7 illustrates the key assets incorporated into these Smart Grid projects. The top three assets identified include: 1) Enhanced Fault Detection Technology 2) AMI / Smart Meters and 3) FACTS Devices.

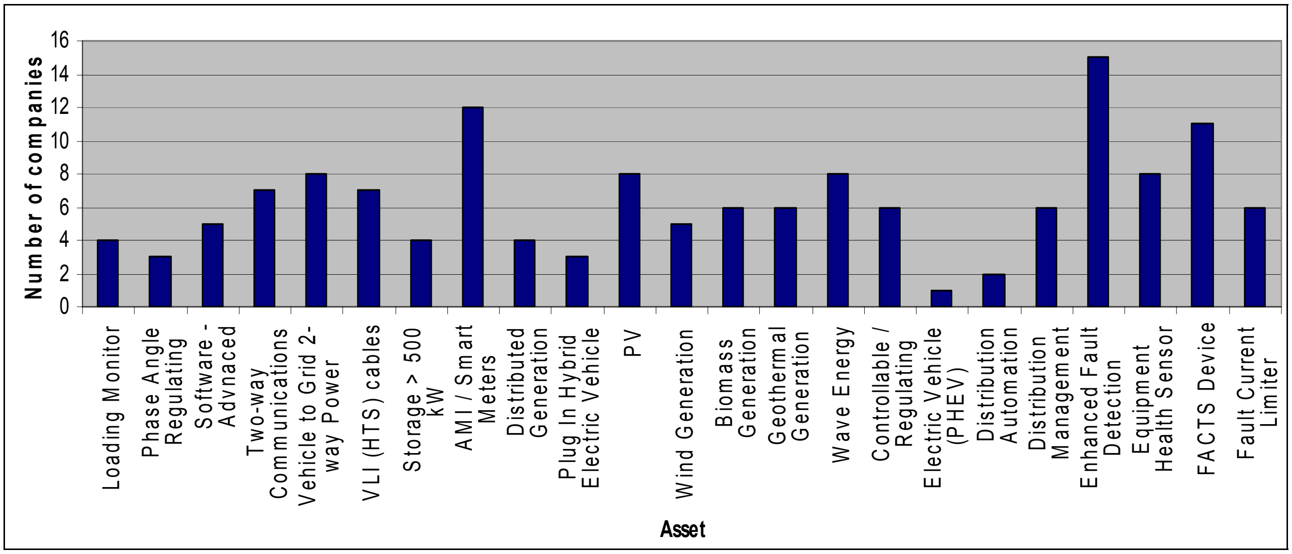


Figure 2-7
What are the key assets deployed in your company's Smart Grid project?

2.3.2 Key Functions

Respondents were asked which key functions were incorporated into their Smart Grid projects. The three most common functions identified in Figure 2-8 include: 1) Customer Electricity Use Optimization 2) Automated Voltage and VAR Control and 3) Automated Feeder Switching. Many respondents also checked the other category and listed further functions not identified in the response set. Figure 2-9 below lists these additional functions and the percentage of respondents who indicated them.

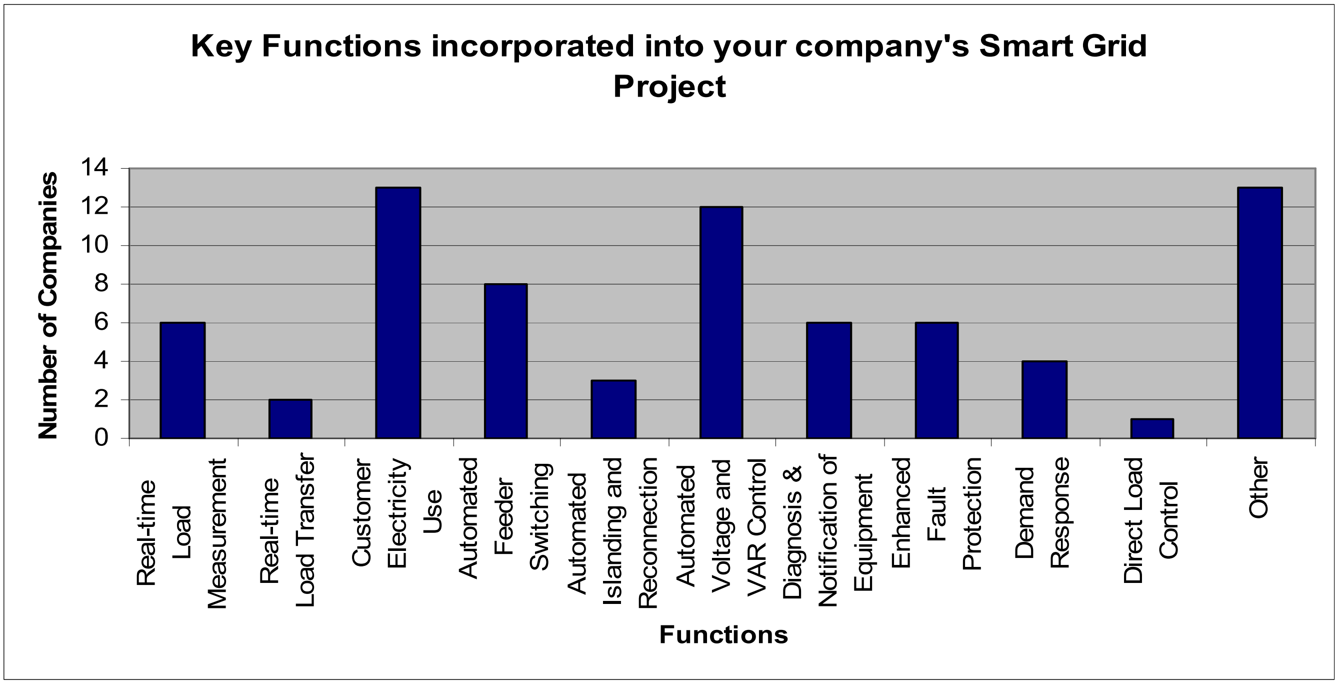


Figure 2-8
Key Smart Grid Functions

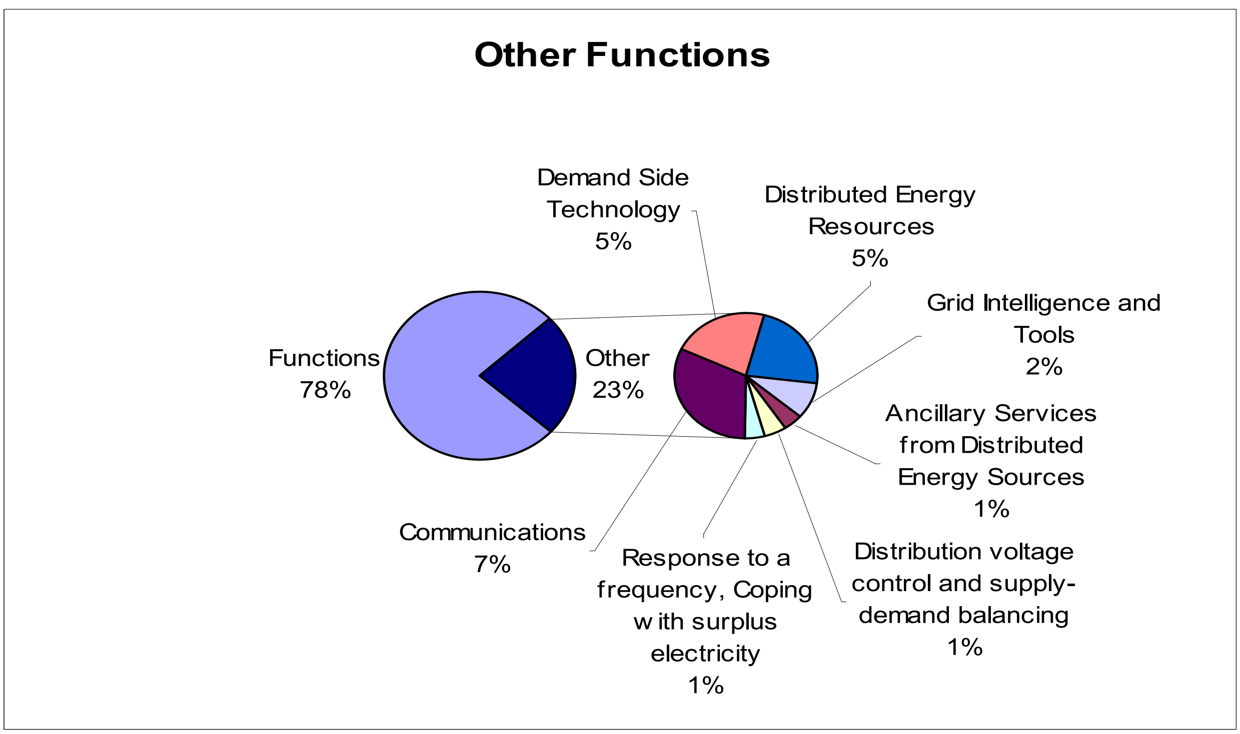


Figure 2-9
Other Smart Grid Functions

2.3.3 Communication Infrastructure

Figure 2-10 below shows the number of companies that employed various forms of communication infrastructure. The top three forms of communication infrastructure chosen by respondents include: 1) RF Tower 2) RF Mesh and 3) Cellular Based infrastructure.

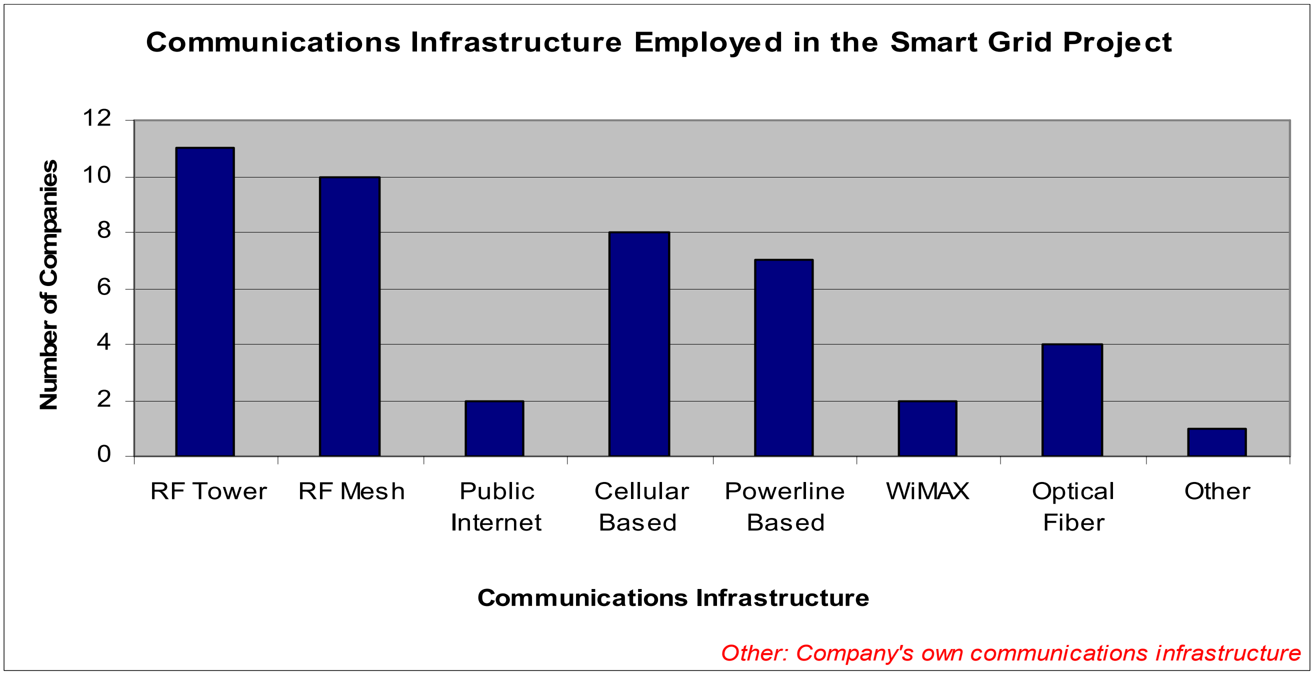


Figure 2-10
Communications Infrastructure Employed in the Smart Grid Project

3
SURVEY RESULTS - KEY DRIVERS, EXPERIENCES AND BENEFICIARIES

Section 3 will explore the key drivers that prompted Smart Grid leaders to develop a Smart Grid project at their respective companies, the experiences of companies deploying Smart Grid projects and the perceived beneficiaries of the Smart Grid as a whole. This section analyzes responses based on key benefit drivers, regulatory environments, policy needs, and customer related market research.

3.1 Key drivers that Promoted Smart Grid Project Development

The respondents were asked to rank the importance of various drivers that prompted them to develop a Smart Grid project. The majority of respondents ranked internal operations as an "Important Driver" that encouraged the development of the Smart Grid project; however, every variable had the highest response in the "Important Driver" category which shows that drivers vary by company and there is no one key driver that is the most important to everyone. Smart Grid projects are developed based on each company's specific needs and objectives.

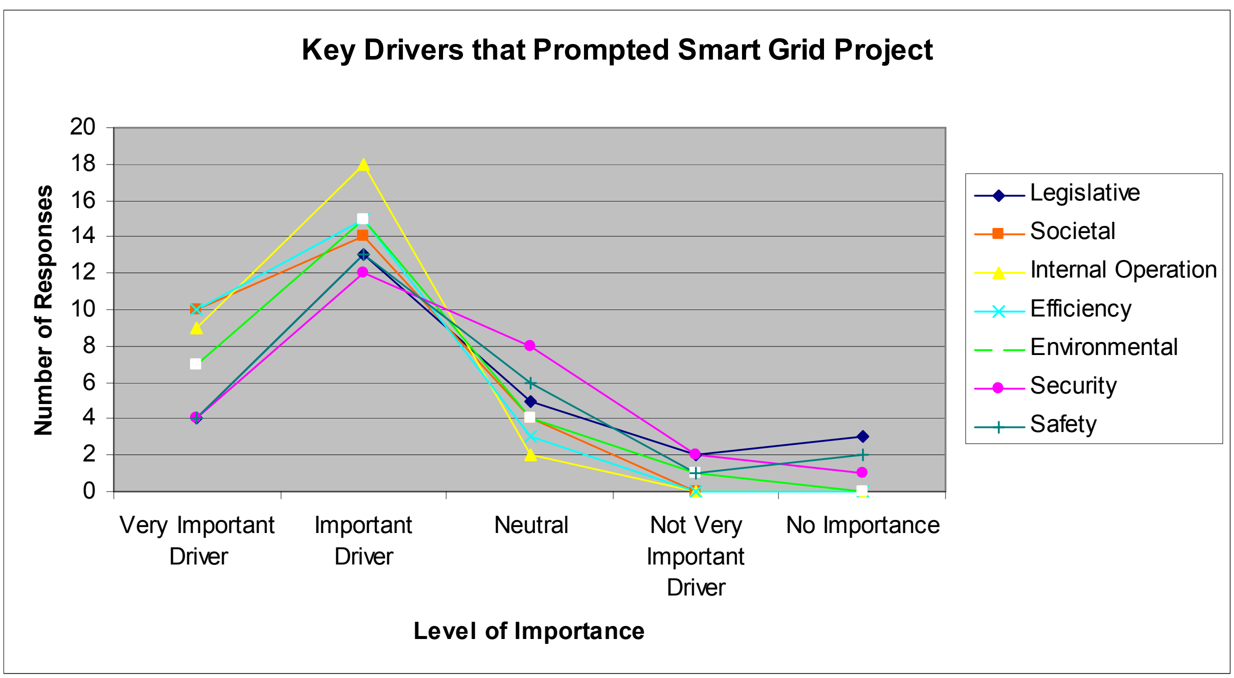


Figure 3-1
Key Drivers that Prompted the Smart Grid Project

3.1.1 Regulatory Relief for Smart Grid Investments

Figure 3-2 below illustrates that the majority of respondents (59%) indicated they have sought regulatory relief for their Smart Grid investments. This response prompted a follow up question for the respondent to list specific Smart Grid investments for which regulatory relief was approved and/or denied. Interestingly, 8 out of 11 companies who were approved for relief described projects that involved Advanced Metering Infrastructure (AMI).

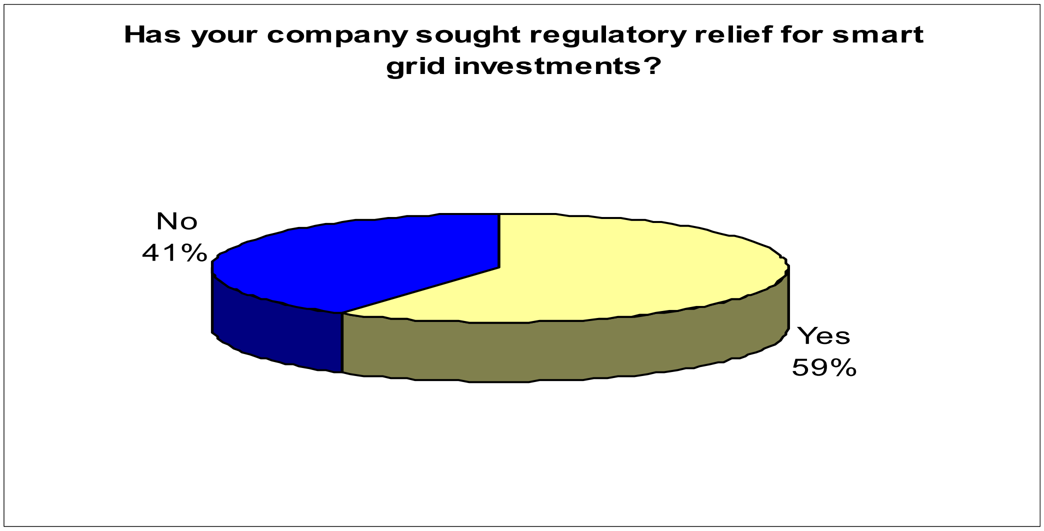


Figure 3-2
Regulatory Relief Sought

The respondent was then asked if their company had any Smart Grid efficiency targets. The majority (87%) indicated that they do not have Smart Grid efficiency targets at their company as illustrated in Figure 3-3.

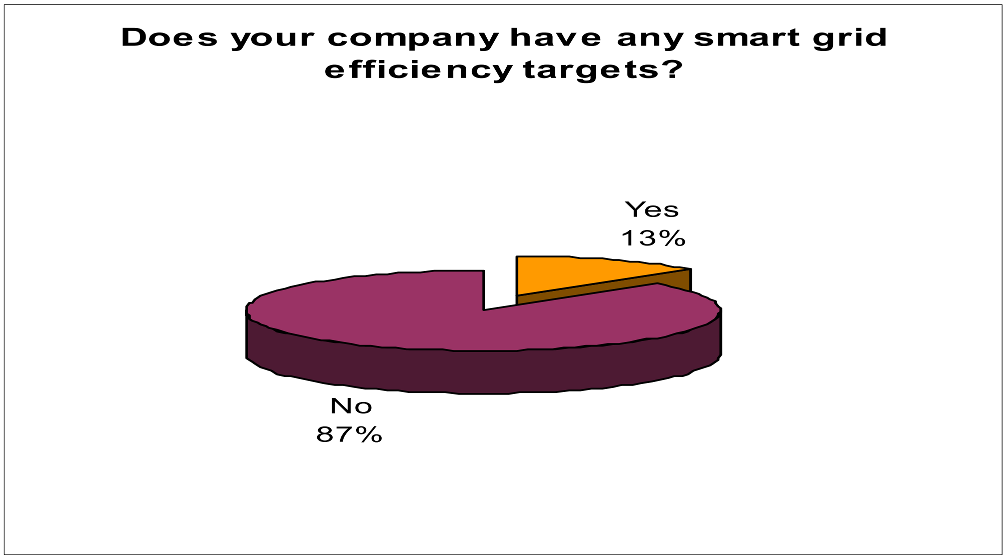


Figure 3-3
Efficiency Targets

Respondents were asked if their company had identified specific policy needs to enable their Smart Grid vision. Forty three (43%) percent of respondents indicated that they have identified specific policy needs. Those who answered yes were then asked to elaborate on these policy needs. The most frequently identified policy needs can be broken down into two categories as follows:

- Economic Policies:
  - Early Depreciation
  - Regulatory Recovery
  - Government Incentives
  - Strong Business Case
- System Operations / Technology Implementation

3.1.2 Consumer Research

The final half of the second question battery revolved around consumer research and consumer offerings provided as part of the Smart Grid projects. As Figure 3-4 illustrates fewer than half of those who responded indicated that they have conducted market research for the Smart Grid project at their company. Most companies indicated that their customers have very little knowledge of the Smart Grid. Those who had some knowledge either had little interest or were only interested in the personal benefits they could derive from the Smart Grid (ex: lower rates). However, with exposure through in-home displays or consumer education programs, consumer awareness of energy consumption increased and customer feedback was positive.

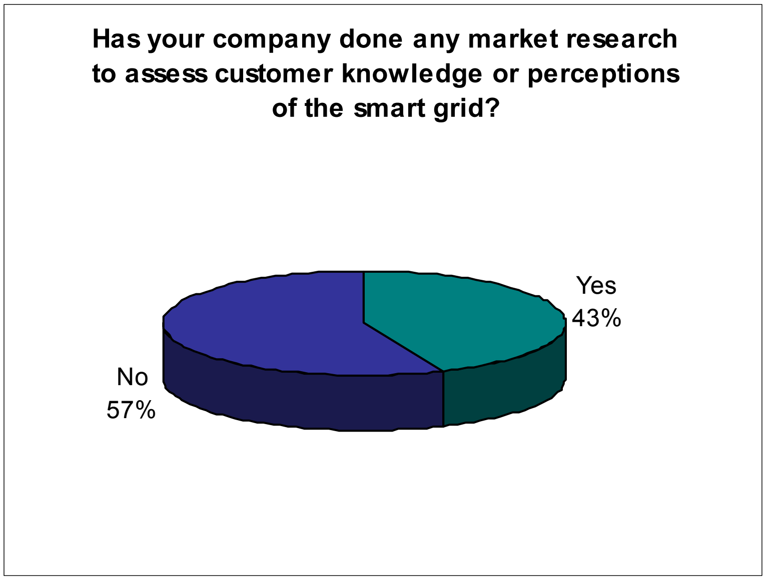


Figure 3-4
Market Research on Smart Grid Perceptions

The respondents were then asked to indicate if their company's Smart Grid project provided any of the consumer offerings listed in Figure 3-5. Companies that responded were very interested in understanding the customer perception of the new technology and feedback from customers who become involved with the new technology. Ninety four (94%) percent of the companies provided customer feedback opportunities and 41% of those that responded provided opportunities for customer empowerment and involvement. Companies were also interested in Load Control Services including Direct Load Control (65%) and Emergency Demand Response (41%).

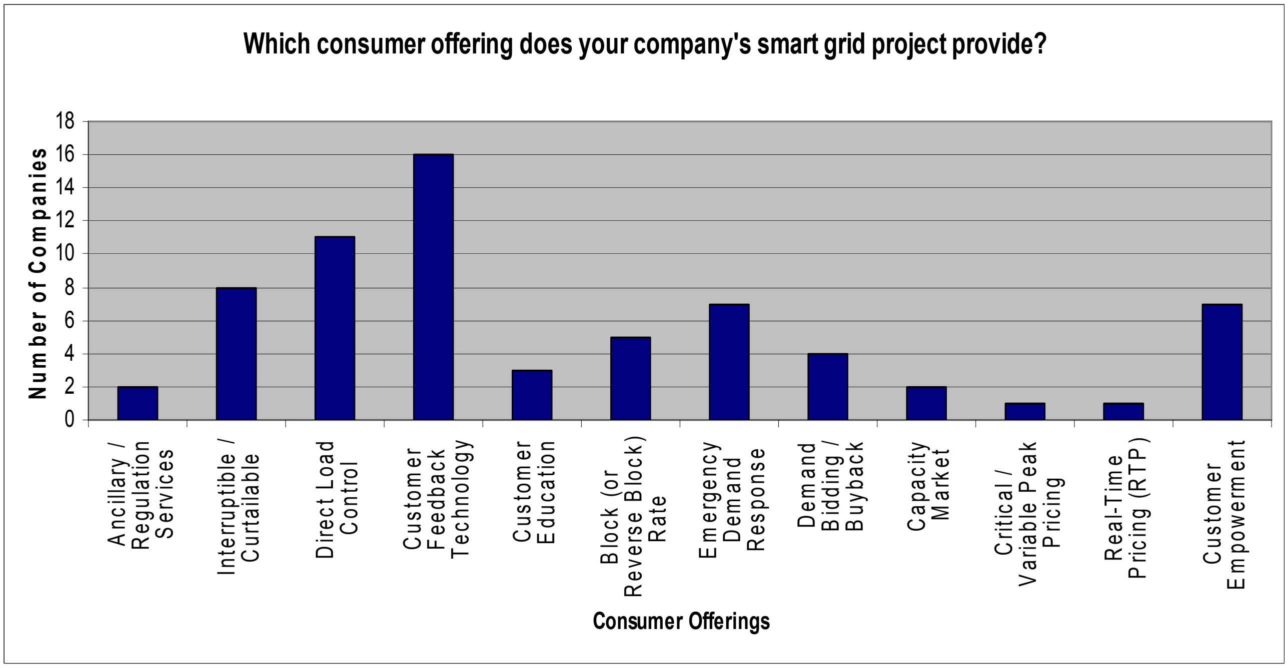


Figure 3-5
Consumer Offerings from Smart Grid Projects

3.2 Positive and Negative Experiences

The respondents were asked to describe the key positive and negative experiences related to their Smart Grid project. Following analysis of these results the most commonly mentioned topics can be divided into two main categories as follows:

- Funding
  - Identified as a crucial element, but getting funding and the DOE application was identified as a difficult undertaking
- Implementation of new technology
  - Fostered more interest of professionals, but many researchers and policy-makers do not understand the current abilities of these technologies
  - Technology has both positive and negative aspects: Usually it achieved the desired result, but there are problems with integration and implementation, maturity, and relationships with non-Smart-Grid vendors.

Many projects concerning distribution automation, different kinds of tariffs, volt/VAR control, AMI, and other aspects of the Smart Grid have just begun or have yet to be started; therefore, the benefits, lessons learned and experiences will be determined at a future date.

Financial Commitment

The financial commitment necessary for implementing a Smart Grid depends on the starting point of implementation. Some utilities already have implemented automation within their electrical systems to improve reliability while others have deployed Advanced Meter Infrastructure in limited quantities. Financial numbers from the e8 member utilities who have attempted to estimate the cost of full implementation range from $1 billion USD in one geographic region to $16 billion USD for an entire country. Smart meters in one region appear to show a pay-back time of about 4 years while substation automation at the medium and low voltage level has allowed one utility to avoid penalties and even receive a bonus from its regulators due to the improved reliability.

In a carbon market that assigns a monetary value for each ton of CO_2, the number of kWh saved may justify the deployment of Volt and VAR optimization (VVO) devices instead of millions of Smart Meters as the former may be much less expensive.

Examples of Successes

Improved distribution reliability through automation has already been demonstrated through astoundingly low interruption rates by those utilities that have completed implementation. The System Average Interruption Frequency Index, or SAIFI, value for some utilities in Japan is below 0.2 for the last eight years while the System Average Interruption Duration Index, or SAIDI, value is under five minutes. One utility in Europe reports SAIDI numbers less than 20 minutes and less than 17 minutes for the last two years respectively. By comparison, the SAIDI value for a neighboring country was 43.69 during the same time-frame while, for some regions in the United States without similar automation and considered otherwise above average in reliability, SAIDI numbers have exceeded 60 minutes for the last eight years and have even exceeded 100 minutes for six of those years. SAIFI numbers have exceeded 0.70 for the last five years and exceeded 1.0 for one of those years. Clearly, effective distribution automation allows for enhanced reliability.

Where AMI/Smart Metering has been implemented, utilities such as ENEL have reported improvements in transparency, meaning the customer may read his/her energy consumption, rates, and contract on the meter display. Billing is based on up-to-date meter readings. Customer inconvenience of on-site visits is eliminated by remote and fast contract changes (connections, disconnections, rates, voltage, subscription transfers etc.) performed by the contact center. Human error in manual meter reading is eliminated resulting in fewer complaints and disputes. ENEL has also reported reduction of power disruptions and repair time. Other benefits from using AMI include: real consumption reflected on energy invoices; reduced billing expenses; lower energy costs and reduced carbon-dioxide production through peak shaving and reduced load; improved customer satisfaction; and operational cost savings among others.

Examples of Challenges

The most serious impediments to implementing the Smart Grid, whether in total or in part, involve regulatory agencies and customers. Rather than assume that the public will understand

and accept the Smart Grid, utilities must present an appropriate business case or cases showing its value, and communicate the value effectively to regulators and customers. This helps both groups understand what the Smart Grid is and the service improvements it may accomplish. Likewise, the utility must educate customers and consumer groups about the benefits of the Smart Grid and how to realize them. Otherwise, the lack of effective communication regarding the new technologies and the Smart Grid may result in unanticipated resistance.

A specific challenge associated with Smart Grid investment is one of timing – all the substantive costs are incurred over a relatively short deployment period (including equipment and installation costs, IT and communication requirements, data and billing systems, etc.), while the consumer and utility benefits are realized over an extended period of time. Appropriate financial incentives will certainly spur additional investment in Smart Grid deployments and utilization of technology. Beyond the advanced recovery of costs, such incentives can take many forms including pre-approval of costs, advanced depreciation for replaced equipment, accelerated depreciation for Smart Grid equipment, enhanced rate-of-return, etc.

The technology currently available may not be at a sufficient level of development or cost. In the automotive industry, for instance, electric vehicles hold the promise of reducing automobile-produced CO_2 emissions dramatically; however, the state of battery technology required and cost compared to the present mature automobile technology prove to be a disincentive for many customers who would otherwise want to own an electric vehicle. In the power industry, energy storage and carbon sequestration technologies may currently pose similar problems.

Challenges posed by perception and misunderstanding may be overcome in large part through effective and continuous communication. Engaging policy makers, regulatory agencies, customers and consumer groups as well as technology suppliers throughout the process of approval and deployment will minimize the occurrence of surprise and opposition at the last moment. Effective demonstration projects will help convince regulators and customers that the benefits justify the costs.

3.3 Smart Grid Benefits and Beneficiaries

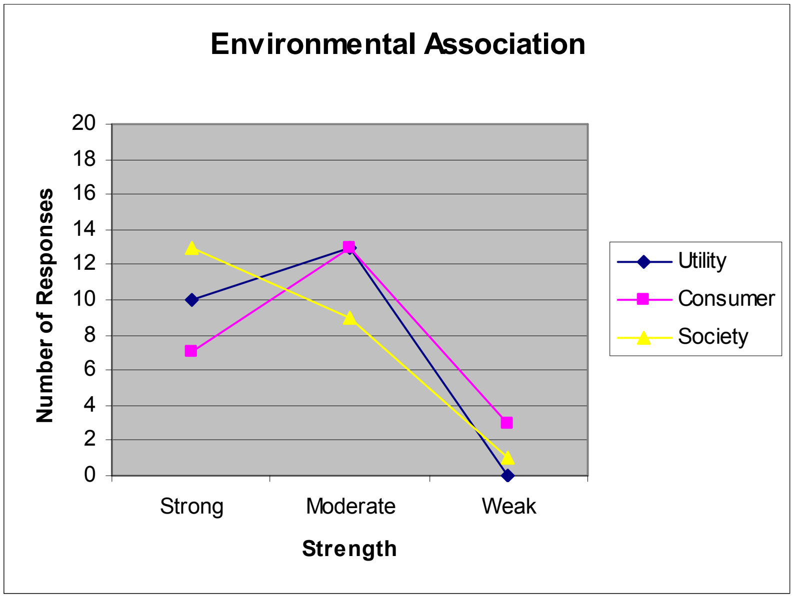
Identifying the benefits that provide the greatest value to utilities, consumers and society as a whole is a key aspect for the success of the Smart Grid. High-level categories of Smart Grid benefits include: Environment, Economic, Safety and Security, and Power Quality and Reliability. When asked to associate these benefits with the beneficiary (Utility, Consumer, and Society), an overwhelming majority of responses indicated that the benefits of Power Quality and Reliability are most strongly associated with all beneficiaries as compared to other benefit categories.

The four subsequent figures illustrate the strength of association between the benefit and beneficiary as identified by the survey respondents. The four benefits identified include:

- Environment
- Economic

- Safety and Security
- Power Quality and Reliability

Figure 3-6 illustrates the strength of benefit-beneficiary relationships as determined by responses to the survey. As can be seen in the first graph, the majority of respondents indicated that the environmental aspects of Smart Grid projects had a strong impact on society, but a moderate impact on the consumer and utility. The second graph in Figure 3-6 shows that safety and security resulting from the Smart Grid had a strong impact on utilities and a moderate impact on consumers and society. The economic association was identified by the majority of respondents as having a moderate impact on consumers. The final graph represents the association between power quality and reliability and the three identified beneficiaries. An overwhelming majority of responses indicated that the benefits of power quality and reliability are most strongly associated with all beneficiaries listed.



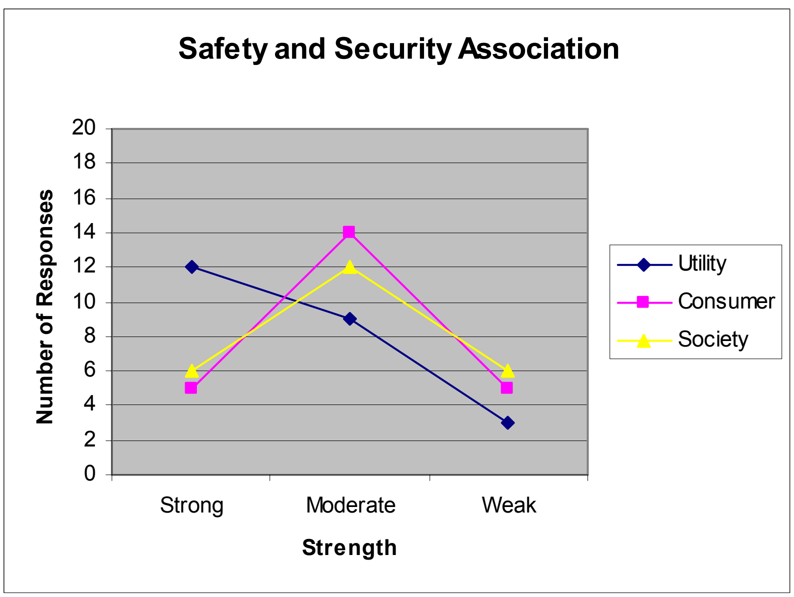
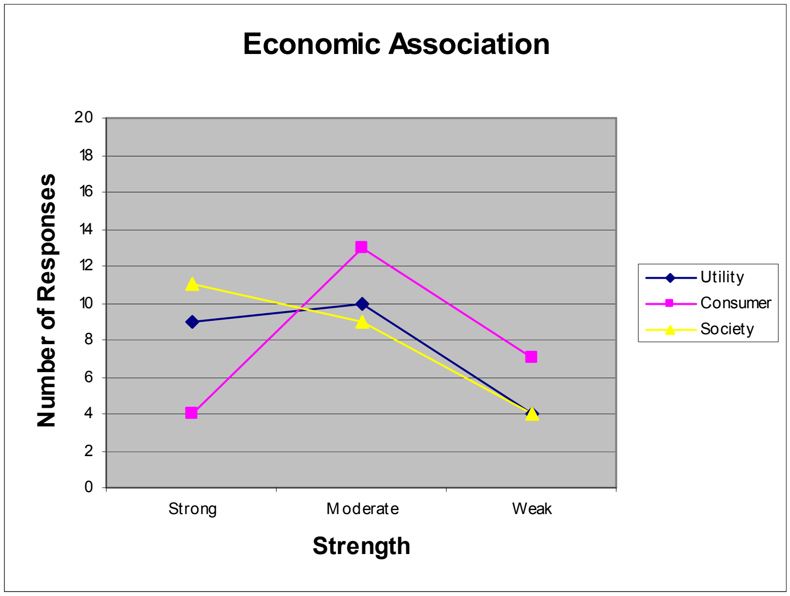


Figure 3-6
Strength of association between benefit and beneficiary



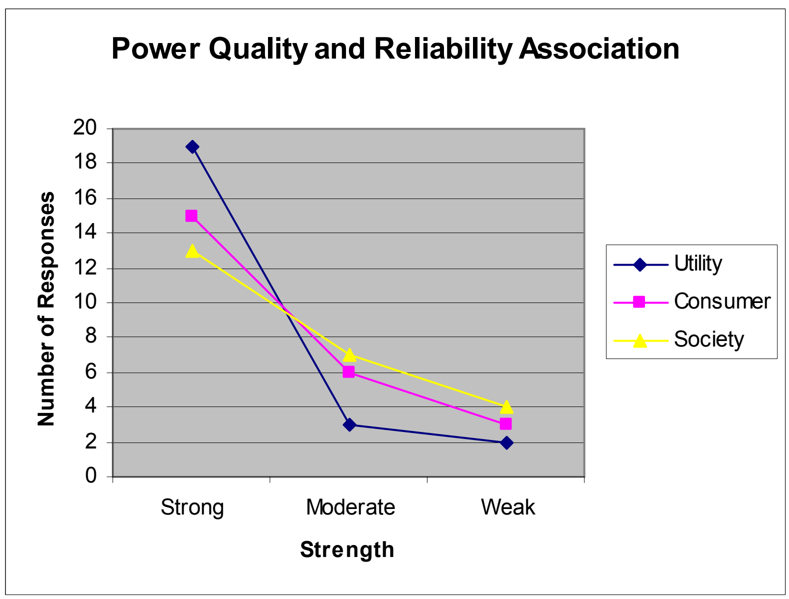


Figure 3-6 (continued)
Strength of association between benefit and beneficiary

4
SMART GRID LEADERSHIP EXAMPLES

This section provides examples of leaders in the industry that are deploying Smart Grid projects and the associated drivers that prompted those utilities to invest in the projects. The examples provided do not necessarily correspond directly to survey responders, but provide examples of leadership in that the projects are not widely deployed or are not considered a standard application within the electric utility industry. As shown in both the survey results and throughout this section, the drivers of each project vary based on the specific circumstances of the utility. Some projects are driven by government regulation and policy, some by older systems needing to be updated, and others are driven by a utility (and customers) pursuing reliable improvements. Though there is no universal motivation behind every Smart Grid project, having a broad base of examples to pull from can help other utilities in the planning and implementation of future Smart Grid projects.

4.1 Asset Management Applications

Asset Management is the systematic process to optimally operate, maintain and upgrade assets and manage their performance, risks and expenditures over their life cycle. Asset management is an emerging Smart Grid application as low cost communications, sensors and intelligence enable automated performance and condition monitoring to support this function.

National Grid, Leveraging PAS 55 – Optimal Management of Physical Assets

National Grid in the UK and US was actively involved in the development of PAS 55 and implementation within its electricity and gas businesses. PAS 55 – Optimal management of physical assets is a Publicly Available Specification (PAS) published by the British Standards Institution that provides guidance and a 28 point requirements checklist of good practices in physical asset management for utilities. Using the PAS 55 platform, a common language across different geographies and networks enabled efficient sharing of business practices and common methods. PAS 55's common language specification is used across non-competing businesses and is conducive to collaboration and provides a framework for continuous improvement for businesses.

Drivers

Asset Management was identified as one of three global areas of focus for National Grid along with field force management and customer focus efforts. The primary driver of asset management was to apply improved asset management practices to generate performance improvement and cost savings from a global perspective. This was an executive driven initiative lead by the Group Director of Transmission.

Electricité de France (EDF) – SmartLife: A European Coordination Project in Networks Asset Management

With EDF R&D acting as the coordinator with 25 additional European partners in Austria, Belgium, France, Italy, The Netherlands, Norway, Portugal, Spain and the United Kingdom, a two-year (2009-2010) coordination project called SmartLife relating to the asset management of distribution and transmission networks was launched. The two main objectives of SmartLife are to 1) Optimize management of aging and future assets and 2) Modernize current networks through innovation. The primary goals of this effort include:

- Identifying critical technologies of equipment and key factors influencing failure and aging mechanisms
- Targeting high value on-site diagnostic methods, lab expertise and aging methods
- Deducing methods reflecting the health index of equipment
- Identifying best practices and technological innovations

The goals will be accomplished by five user-groups focused on 1) Cables and Accessories, 2) Overhead Lines, 3)Transformers, 4) TSO asset management practices, and 5) DSO asset management practices.

Drivers

A significant portion of European networks were developed in the 1960s and 1970s and are now getting close to their expected lifetime. Because of the large amount of European assets at similar stages in life, a collaborative effort to better understand aging mechanisms, diagnostic tools and management processes is the most effective means to pursue the best solutions for all the members with this common issue.

Tennessee Valley Authority (TVA) – Substation-Wide Asset Monitoring through Networked Wireless Sensors

TVA has partnered with EPRI to investigate wireless mesh sensor network (WMSN) technology as an autonomous network of small low-cost wireless sensor nodes to support multiple applications including asset management. Such networks can be used for sensing a diverse set of signals over large regions for extended periods of time without human intervention. WMSNs can be installed quickly without costly and hazardous installation procedures. Although the processing and communication capabilities of individual sensor nodes are limited, the ease of deployment, possibility of autonomous configuration of hundreds of sensor nodes, and the benefits of on-site and distributed processing make WMSNs extremely attractive for substation monitoring applications. As this is an emerging technology, initial research is evaluating technology performance capabilities, power harvesting abilities, performance in a substation environment, and needs for future research. TVA's approach is focused on the design and performance of a WMSN deployed in a substation for monitoring the health of power subsystems such as circuit breakers, transformers and transformer bushings. The primary sensors are temperature based and solar powered with a high-power node capable of performing specialized computations adding necessary intelligence.

Drivers

TVAs application of WMSN technology is an example of leveraging technology to solve business problems as one of their core values – continuous improvement. TVA has a track record of strong research and development investment to support continuous improvement through innovation and new ideas.

4.2 Information to Consumers, Dynamic Pricing, Demand Response and Advanced Metering Infrastructure (AMI)

An important aspect of the Smart Grid is educating consumers and getting them information needed to help them manage their energy use in an environment where energy costs can vary based on either economic or reliability conditions. Understanding what information consumers respond to and what combinations of technology and tariffs are most effective supports Smart Grid goals of improving reliability and economically matching supply and demand.

Demand response generally refers to methods to shed consumer load or reduce demand for both reliability and economic reasons. Two primary approaches for demand response are "command and control" and "inform and motivate." Historically, the "command and control" method has been used more prominently for direct control of loads such as air conditioners and water heaters, but with advances in communication technology, standards development, sensor technology and intelligence, that is starting to change. With communications to homes becoming more ubiquitous and the promise of national standardized pricing and event messages to intelligence appliances and electric vehicles, the "inform and motivate" method for demand response is showing signs of wider adoption. Today, pricing motivation is resulting in manual control of demand-side resources, but as standards and the capabilities of appliances evolves, automated control based on consumer-defined settings is expected to be more prominent in the future.

Advanced Metering Infrastructure (AMI) refers to systems that measure, collect and analyze energy usage, and interact with electric meters through various communication media either on request (on-demand) or on pre-defined schedules. This infrastructure includes hardware, software, communications, consumer energy displays and controllers, customer associated systems, Meter Data Management Systems (MDMS), and network distribution business systems.

The network between the measurement devices and business systems allows collection and distribution of information to customers, suppliers, utilities and service providers. This enables these businesses to either participate in, or provide, demand response solutions, products and services. By providing information to customers, the system assists a change in energy usage from their normal consumption patterns, either in response to changes in price or as incentives designed to encourage lower energy usage use at times of peak-demand periods or higher wholesale prices or during periods of low operational systems reliability.[2]

Oncor – Smart Texas

Oncor is deploying an Advanced Metering System (AMS) scheduled for completion in 2012 and will include more than 3 million advanced meters. The project includes a comprehensive consumer education program that includes a Smart Texas Mobile Experience Center (www.smarttexas.com). In addition to tours, a portfolio of education materials is made available to consumers to support this goal. The state regulator in Texas has also developed a web-site (http://www.smartmetertexas.com/) to support statewide customer education. Oncor's AMS will provide consumers access to near-real-time information to help manage their electricity usage and enable retail electric providers to develop and offer new, innovative rate plans providing consumers additional ways for consumers to lower their bills. The new system will provide everyone in Oncor's service territory access to a Web portal to track energy consumption at 15 minute intervals on a "day after" basis even without an in-home display. Oncor's system has the capability of using in-home-displays to display how much electricity usage is being consumed in real- time, can convert that amount into a dollar amount to show how much consumers are spending and also display the carbon footprint based on current electricity usage. In home displays will be made available for purchase through the customers' retail electric provider or retail home specialty store.

Drivers

The primary driver for Oncor's advanced approach and system deployment is based on regulatory policy from the Public Utility Commission of Texas. Specific rules for advanced metering are outlined in the Advanced Metering Substantive Rules, chapter 25.130 (http://www.puc.state.tx.us/rules/subrules/electric/25.130/25.130ei.cfm) Because Texas has a deregulated electric market – meaning most Texas consumers can choose their own electricity provider, they have specific technical and functional requirements for metering to enable deregulation that will support competition between companies so consumers have choices to find ways to lower their electricity bills. Some of the regulatory requirements will include: automated or remote meter reading, two-way communications, remote disconnect and reconnect ability, ability to communicate interval data to independent organizations, ability to provide direct, real-time access to usage data, ability to provide 15 minute interval data on a "day after" basis, enable pre-paid retail pricing, ability for on-demand reads, capability to communicate with devices inside the premises including, but not limited to usage monitoring devices, load control devices and prepayment systems through a HAN in a non-proprietary format, and ability to upgrade these capabilities.

ESB Networks – Irish Electricity Customer Behaviour Trials (CBTs)

The project is designed to evaluate the ability to influence customer energy use with smart metering and new rate structures. The trials will ascertain the potential for smart metering

[2] http://en.wikipedia.org/wiki/Advanced_Metering_Infrastructure

enabled energy efficiency initiatives to effect measurable change in consumer behaviour in terms of reductions in peak electricity demand & overall energy use. ESBN is delivering the metering and data collection systems in response to the requirements of the Government, the Energy Regulator of Electricity.

The CBT includes both residential and small business customers with an experimental design of "control" and "test" groups to give an accurate indication of what would be expected in a national smart metering roll-out scenario and the results will thus inform the Smart Metering Cost Benefit Analysis. Experiments with test groups include evaluating performance with a combination of Time of Use (TOU) Tariffs, enhanced electricity usage and cost information via billing, web and in-home-display units, and financial incentives for overall load reduction (OLR) incentives. The experiment is designed such that results have a % reduction measure accurate to within 1% - persistence in modified behavior.

The two-year trial is underway with the benchmark period having ended in 2009 and the smart meter enabled new tariffs and stimuli continuing for the duration of 2010. The trial involves over 5,600 residential customers and 780 small businesses.

Drivers

The regulatory driver for this effort is the National Smart Meter Plan managed by the Commission for Energy Regulation (CER) in Ireland. The goal of this plan is to ascertain the potential for smart metering enabled energy efficiency initiatives to affect measurable change in consumer behaviour in terms of reductions in peak electricity demand and overall energy use.

Another driver for the CBT is leveraging it in combination with implementing much higher levels of wind generation. There is significant benefit aligning supply and demand in an environment with high penetrations of wind. ESB has a target of 40% renewable penetration by 2020 and understanding how to leverage consumer behaviour can facilitate higher penetration of wind generation and result in more efficient use of electricity in general.

ComEd – Customer Application Pilot (CAP)

The ComEd Customer Applications Pilot (CAP) will run between June 2010 and May 2011 and gather experimental and empirical evidence from a group of approximately 8,000 customers. This assessment will attempt to determine the relative benefits of various combinations of rate, enabling technology, and customer education/experience. This will allow ComEd to enhance assessment of its AMI options that will provide the best customer response at the lowest cost.

The structure of the assessment is comprised of 28 different combinations (or "treatment cells") of pricing programs, enabling technology and education applied to a representative subset of the 200,000 customers that are receiving AMI meters. ComEd has designed each treatment cell to test customer receptivity to a specific pricing and technology package, as well as estimate the likely change in the electricity demand and energy consumption resulting from customer adoption with the attendant decrease of greenhouse gas emissions.

Not only is this combination of breadth, complexity and approach unique in the industry, but participation is also in an "opt-out format" (customer is selected, and must choose to be excluded) which helps ensure that a truly representative sample of the population participates in the pilot.

The CAP is an opportunity to evaluate customer behavior based on combinations of:

- **Four technologies:**
  - Advanced web portal
  - Advanced web portal with basic in-home device (IHD)
  - Advanced web portal with advanced IHD
  - Advanced web portal with programmable communications thermostat (PCT) and advanced IHD
- **Five pricing programs:**
  - Increasing block rate (IBR)
  - Day-ahead real time price (DARTP)
  - Time of use (TOU)
  - Peak Time Rebate (PTR)
  - Critical Peak Pricing (CPP)
- **Education** (participants receive it or they do not)
- **Purchase** (participants in two treatment cells are required to purchase their own in-home equipment)

Demand response, load shifting, and load reduction are three areas expected to have significant data. In addition, the study will also yield substantial data regarding customer interactions with a third party call center. The customer enrollment process includes a call center where representatives are trained to handle the customer questions and issues. At the time of this report, the consumers exercising their "opt-out" option have been minimal (about 2%). The reasons given for the opt-outs are being tracked and categorized.

This project has broad stakeholder participation and input for reviewing not only the methodology design, but also the analytic assessment. Some of the stakeholders include the Illinois Attorney General, Citizens Utility Board (CUB), Illinois Commerce Commission, The City of Chicago, EPRI, and more.

Drivers

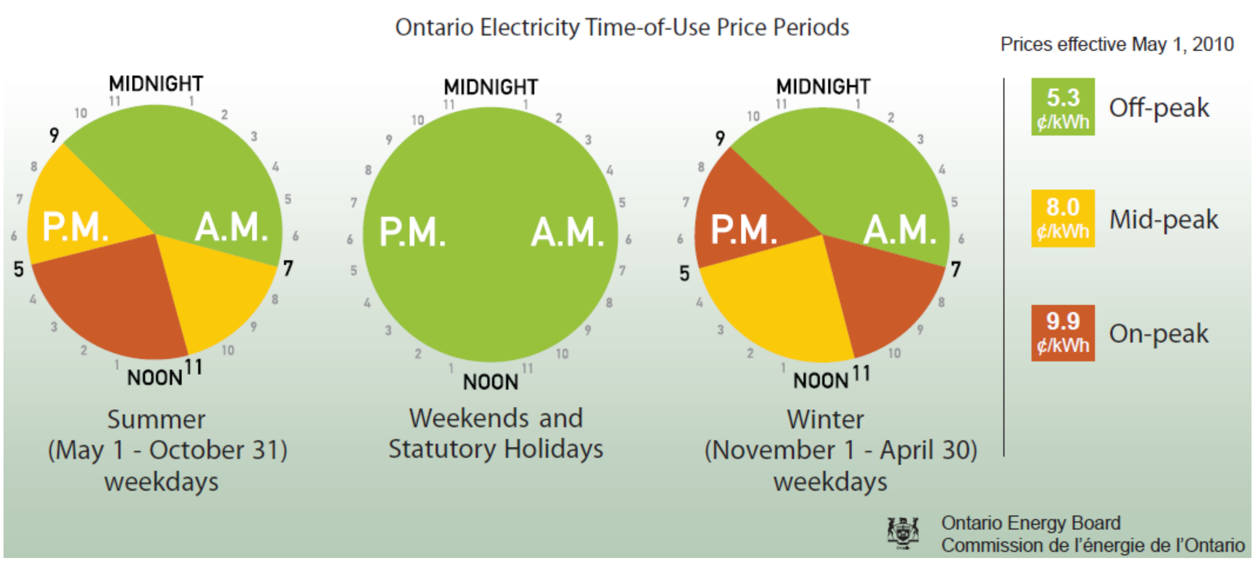
ComEd is taking a strategic approach in evaluating AMI functions and capabilities to most effectively understand technology and tariff scenarios that affect customer behavior. The right combination of technology and tariffs that provide the most effective results in reducing peak demand and overall energy usage is currently not well understood. A generally accepted expectation is a 3-5% energy savings from similar types of programs, but this approach will test a large number of tariffs, technology and education scenarios to better understand the impacts and what factors influence customer behavior. Understanding the associated benefits of various combinations of rate, enabling technology, and customer education/experience will benefit not only ComEd, but the entire family of Exelon companies when assessing AMI requirements for full-scale deployment. There are numerous examples of demand response applications with both rates and enabling technologies and the Com Ed approach provides a leading example of taking a scientific approach to understand the effects of demand response deployments

The stakeholder group is providing feedback in the methodology design and analytical assessment to ensure a broad range of stakeholder groups' needs are being addressed. Their feedback is an input into design and assessment of this project. The results of this project will not only provide information to support long-term strategic plans for ComEd, but public results will also help to advance the industry.

Ontario Energy Board (OEB) –TIME-OF-USE Rates[3]

By 2011, most consumers in Ontario will have made the switch to Time-of-Use (TOU) rates, where the price of electricity depends on the time it is used. This is just one part of the provincial government's plan to create a culture of energy conservation in Ontario. OEB sets rates for the distribution and transmission of electricity and the commodity price of electricity for consumers on the Regulated Price Plan (RPP) and TOU prices, but OEB does not regulate prices charged for competitive services such as contracts offered by electricity retailers.

The Ontario Energy Board (OEB) has developed daily and seasonal TOU periods with three periods: Off-peak, Mid-peak, and On-peak prices as shown in the following figure.



3 http://www.oeb.gov.on.ca/OEB/Consumers/Electricity/Electricity+Prices

The Ministry of Energy (Ontario) has arranged for the Independent Electricity System Operator (IESO) to support the smart metering initiative primarily performing the Meter Data Management / Repository (MDM/R) including all interfaces between the MDM/R and local distribution companies/ AMI and customer information systems.[4] Key initiatives under way in Ontario include:

- Introducing TOU pricing for electricity
- Smart Meters installed by the end of 2010
- Legislation to enable implementation of smart metering and conservation targets.

The government set targets to install smart meters in 800,000 households by 2007 and in all Ontario households by 2010. To date[5], over 1.5 million smart meters have been installed by Ontario utilities, and development of a data management entity is well underway. Consumers in a number of communities are already being billed using time-of-use rates established by the Ontario Energy Board. As utilities install smart meters for additional consumers, time-of-use pricing will be implemented in more communities across the province. Both installation of the meters and the change to time-of-use pricing will be accompanied by extensive information campaigns by local utilities, to ensure consumers are aware of what is happening in their communities.

Drivers

The government of Ontario, Canada mandated the installation of Smart Meters on all Ontario businesses and households by 2010 through the “Energy Conservation Responsibility Act in 2006.” An important driver of this act is that smart meters allow electricity distributors to track how much electricity is used by a consumer and what time of day that electricity is used. When combined with time-of-use pricing, this allows customers to reduce their overall demand for electricity and to shift their consumption to off-peak times such as at night and on weekends.

Smart meters are part of the Ontario government's broader energy plan to create a conservation culture, address rates and provide consumers with the tools they need to manage their energy consumption and costs. Smart meters also are an important tool for utilities in managing the electricity system with more efficiency and improved reliability.

ISO/RTO – Demand Response Markets in North America

Independent System Operator (ISO) and Regional Transmission Organization (RTO) markets in North America are some of the most advanced in enabling demand response to participate in markets that have historically only been allowed for bulk generation resources. The nine ISO/RTO’s in North America include Pennsylvania-Jersey-Maryland (PJM), ISO New England (ISO-NE), New York ISO (NYISO), Midwest ISO (MISO), Southwest Power Pool (SPP), California ISO (CAISO), Electric Reliability Council of Texas (ERCOT), Independent Electricity System Operator (IESO) of Ontario, and Alberta Electric System Operator (AESO).

[4] http://www.mei.gov.on.ca/en/energy/electricity/?page=smart-meters

[5] http://www.mei.gov.on.ca/en/energy/conservation/?page=conservation-faqs

The ISO/RTO's provide opportunities for demand response to participate in at least one and in most cases multiples of the following wholesale market product types:

- Regulation Reserve
- 10-Minute Spinning Reserve
- 10-Minute Non-Spinning Reserve
- 30-Minute Supplemental Operating Reserve
- Real-Time Energy
- Day Ahead Energy
- Capacity (long forward market facilitated by the ISO)
- Reliability Unit Commitment (RUC); also referred to as Residual Unit Commitment (RUC) in CAISO, and Reliability Assessment Commitment (RAC) in MISO.

The opportunities offered to Distributed Resources (i.e., both demand response and distributed energy resources) for provision of these products at different ISO/RTOs are not necessarily the same as those provided for conventional generation resources. In most cases, the minimum aggregated amount of load must be 100 kW to participate and in some cases the minimum amount is 1 MW and are used more so for system support rather than local support.

Drivers

Advances in technology have created an environment where smaller Distributed Resources, such as demand response and other DER, are now viable contributors to markets which historically have only interacted with bulk generation units. Distributed Resources now are beginning to provide clear cost savings. As an example of success of ISO DR programs during the August 2006 heat wave, PJM reported cost savings totaling US$650 million attributed to its DR programs. On just one day alone, Aug. 2, 2006, when PJM set a new peak load record of 144,796 MW, it reported DR savings of $230 million. These savings were based on incentives paid to DR program participants versus the cost of acquiring peaking generation, as determined by the market-clearing prices on that day. These (DR) voluntary curtailments reduced wholesale energy prices by more than $300/MWh during the highest usage hours.[6]

Florida Power and Light (FPL) – On Call® Program[7]

Using a portfolio of DSM programs, including interruptible rates for large power customers and a predominantly residential load-control program, FPL and its customers have successfully reduced demand for energy by 3463 MW – one of the largest Load Management Systems (LMSs) in the world. This reduction has allowed FPL to avoid building approximately 10 new 400-MW power plants. Of that total, 1000 MW of peak demand savings can be directly attributed to FPL's LMS. FPL's primary residential direct load control program is On Call®

[6] http://tdworld.com/customer_service/wholesale-markets-demand-response-program-200902/index3.html

[7] http://tdworld.com/distribution_management_systems/power_mega_load_management/

(http://www.fpl.com/residential/savings/oncall.shtml) and has more than 785,000 customers enrolled and over 800,000 load-control transponders. FPL pays residential customers incentives of $6 for controlling air conditioning and $3.50 for water heaters per month. Incentives are a major contributor to the ongoing cost of load-control programs.

Drivers

In the early 1980s, the Florida Public Service Commission (PSC) mandated that Florida-based utilities implement demand-side management (DSM) programs in response to the energy crisis at that time. As a result, FPL developed several conservation programs and implemented the LMS. FPL's regulatory filings with the PSC have consistently shown that the economic costs of building and operating new generating units are at least 20% to 30% higher than the cost of installing and operating the DMS program.

ENEL – Metering System and Telegestore Project[8]

ENEL's Telegestore project is an automatic meter management system (AMM) completed in 2006 with an investment of € 2.1 billion over a five year period with more than 30 million low voltage electricity meters connected to the Telegestore communication network. The endeavor's benefits shared by customers, power system and the utility, convinced the Italian Authority for Electric Energy and Gas to require all Italian customers to be equipped with automatic meter management by 2011.

In addition to its AMM system, ENEL has also introduced a set of innovative Smart Grid solutions, realizing the remote control of more than 100,000 Medium Voltage/Low Voltage (MV/LV) substations (i.e. 30% of the system) and the complete automation of most of them (with automatic fault clearing procedures), the Work Force Management system that represents a radical change in the crew management, the optimization of asset management policies based on a cartographic census of network assets and on a database of network events (power outage notification, fault detection etc), and the network investments optimization based on an ad hoc risk analysis.

Having already deployed Smart Metering, automation and control of MV network and Advanced Asset Management (methods and system support), ENEL is now focusing on advanced integration of Distributed Energy Resources (DER), developing a smart EV recharging infrastructure fully integrated in the grid and in the legacy ICT systems, and finalizing the "Smart Info" device, which represents the first step towards customer awareness and active demand, making available the data managed by the Smart Meters in the indoor environment, to allow the development of energy efficiency services.

Drivers

The liberalization of the Italian electricity sector in the early 2000's led to a competitive market in Europe enabling Italian customers to choose their electricity supplier. Eleven years ago, facing

[8] http://www.e8.org/upload/File/0_4_2_2_att_-_smart_grid_group_outcomes_final_report_for_public_use.pdf

this increased customer-centric commercial approach requiring differential tariffs, value added services and reduced services provisioning time, ENEL pioneered the Telegestore Project. In addition to supporting a competitive electric market, drivers for the project included reduced electricity theft and operating cost savings related to revenue collection, invoicing, remote connect/disconnect, remote meter reading, remote change in electric demand settings, remote change in billing plans (including prepay), and asset management.

4.3 Wide Area Monitoring Systems (WAMS) and Flexible Alternating Current Transmission System (FACTS)

Wide Area Monitoring Systems (WAMS) are used to improve power system reliability via a synchronized data measurement infrastructure for interconnected transmission systems. One of the primary technologies for WAMS is Phasor Measurement Units (PMUs). PMUs measure the magnitude and phase angle of sine waves of voltage and current. Phasor measurements that occur at the same time are "synchrophasors" along with the PMU devices that allow their measurement. Measuring the synchronized comparison of two phasors at different geographical locations on the grid can be used to assess the overall system conditions.

A flexible alternating current transmission system (FACTS) is a system of static equipment used for AC transmission of electricity. FACTS is defined by IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability." Many high voltage transmission systems operate below their thermal rating due to constraints such as stability limits. FACTS technology makes it possible to load lines, at least for some contingencies, up to their thermal limits without compromising system reliability.

State Grid Corp of China (SGCC) – West-East Electricity Transfer Project[9]

The SGCC West-East Electricity Transfer project includes three major west-east transmission corridors each with a capacity of 20 GW by 2020. As part of its plan, China is building a Wide Area Monitoring system (WAMS) and by 2012 plans to have PMU sensors at all generators of 300 megawatts and above, and all substations of 500 kilovolts and above. For reliable communications, SGCC is deploying an extensive private fiber-optic network throughout its high-voltage substations that amounts to over 1 million km of fiber-optic channels. All generation and transmission is controlled by the state, so standards and compliance processes enable rapid deployment.

Drivers

The key driver for the SGCC WAMS deployment is to ensure reliability in an environment of rapid infrastructure growth. Smart Grid technologies and applications are essential around the world to maximize efficiencies and they are especially important for China since they are actively building out its power distribution infrastructure which currently serves 26 Chinese

[9] http://www.sensorsmag.com/sensors-mag/news/frost-amp-sullivan-foresees-smart-grid-opportunities-china-5963

provinces with approximately 1.08 billion people. SGCC has made power grid construction its core business and a long-term strategic objective.

Bonneville Power Administration (BPA) – WAMS[10]

Synchrophasor measurements have gradually gained acceptance since developed in the 1980s when a system of computers locally recorded signals from transducers at substations. In 1993, EPRI initiated a project using PMUs installed at several utilities, including BPA, in the WECC (then called WSCC) for a wide area control action with successful installation of these units by the summer of 1996. BPA recorded data during the August 10, 1996 blackout that showed the growing oscillation as the system became unstable. The measurements from throughout the day also showed the increasing phase angle as the system weakened. In the aftermath of the event and subsequent analysis, BPA implemented many system improvements, one of which was improving the real-time phasor measurement system. The guiding philosophy in further development was to make the system reliable so data was always available, and make the data as accessible as possible. BPA's real-time phasor measurement applications run on standard PCs with data distribution by network using the IP protocol. This approach also simplified application and data distribution to anyone who needed it. This new system was successfully operating by May 1997 and has undergone many improvements and further developments, but the basic core system remains the same.

Interest in regional awareness has steadily increased. The 2003 blackouts accentuated the need for overall grid awareness, which is of critical importance to security monitors and ISOs. Data exchange between utilities extends the local WAMS to the whole grid. These applications provide value through the analysis, monitoring, and controls that can be done with them and are a building block for new generations of applications to improve reliability.

Drivers

Major blackouts have emphasized the need for better disturbance analysis and situational awareness. The current system at BPA (and other utilities) was implemented in response to a large blackout. The motivation was better situational awareness and dynamic analysis. Most of the value has come from event analysis. With centralized data access, determining a sequence of events and the likely causes can be done in minutes rather than hours and days. Moving forward, the primary drivers are to prevent large scale blackout events by allowing the early detection of system instability.

New York Power Authority (NYPA) – Convertible Static Compensator (CSC) Implementation and FACTS Training Simulator

NYPA has been a leader in deployment of FACTS technology. The deployment of the Convertible Static Compensator (CSC), the most advanced and complex electronic controller

[10] http://www.pacw.org/issue/autumn_2007_issue/cover_story/synchrophasors_for_wams/complete_article/1.html

developed under EPRI's FACTS initiative, is an example of its leadership.[11] This project at NYPA's Marcy substation provided the opportunity to develop and deploy a commercial scale CSC and implement it at a 345 kV substation (the highest voltage level at the time of the demonstration). This product provides the ability to both regulate voltage and control real and reactive power flow on two major transmission lines. With eleven possible configurations for the equipment, a truly flexible AC transmission system is realized.

For the Utility industry, the project was the most advanced demonstration both of the new power electronic equipment and of new system control methods to maximize the use of an existing transmission network. Although the concepts of the Static Synchronous Compensator (STATCOM), Unified Power Flow Controller (UPFC), Static Synchronous Series Compensator (SSSC) have been extensively studied in academic research, laboratory model demonstrations, and equipment already in service, this project included a number of first time developments.

The CSC consists of two 100 MVA inverters and each may be connected in shunt at the 345 kV bus or in series with 345 kV transmission lines, the highest voltage level at which this type of equipment has ever been connected. In total, eleven configurations of the equipment are allowed.

The dual STATCOM configuration is a first because both inverters are connected to the two secondary windings of the same main shunt transformer. The second phase of the project, the series transformers were installed and the remaining eight configurations (covering SSSC, UPFC, and Interline Power Flow Controller (IPFC) configurations) were commissioned. With completion of the second stage of the project the CSC was the most technically complex and flexible FACTS installation. The IPFC is a totally new and original control concept commissioned during the course of this project. A new control structure for the IPFC concept has been developed and extensively tested.

To complement its FACTS implementations, NYPA developed a flexible platform for a multifunctional voltage-sourced converter based FACTS Controller Operator Training Simulator[12], and customized it for use at the NYPA Control Center for operator training on the CSC facility at the Marcy substation. The Training Simulator allows an operator to adjust the FACTS Controller using the manufacturer's control screens and see the impact of the FACTS Controller reflected on the station one-line diagrams. The capability of the Training Simulator includes performing steady state rated capacity dispatch for various CSC configurations such as UPFC and IPFC. The training simulator is primarily a software development project and the FACTS Controller dispatch program contains many capabilities not found in other software packages. The simulator includes additional dispatch modes for shunt converters and series converters to support NYPA requirements. To accommodate new dispatch modes, the software incorporates a novel and efficient approach, in which the CSC shunt and series converters are modeled separately, so that for any shunt or series operating mode, only two equations need to be

[11] *Convertible Static Compensator (CSC) for New York Power Authority: Final Report,* EPRI, Palo Alto, CA, and New York Power Authority, White Plains, NY: 2003. 1001809
http://my.epri.com/portal/server.pt?Abstract_id=000000000001001809

[12] *Operator and Planner Training Simulator for Advanced Transmission Technology Concepts Status Report*. Electric Power Research Institute (EPRI), Palo Alto, CA, New York Power Authority (NYPA), White Plains, NY, and Rensselaer Polytechnic Institute (RPI), Troy, NY: 2007. 1013994.
http://my.epri.com/portal/server.pt?Abstract_id=000000000001013994

adjusted, thus simplifying the computer code. This effort included customizing the generic dynamic models in the existing software to represent the actual operation of the CSC hardware.

Drivers

For NYPA, FACTS technology offers a means of providing improved voltage regulation, real and reactive power flow control, and system reliability. The ability to more precisely control voltage and power flow at Marcy allows additional power to be dispatched along this transmission corridor with assurance that all system reliability standards are met.

The CSC project will both further develop control concepts for all the inverter based FACTS Controllers and also provide benefits to the New York Transmission system that allow additional system flow for a variety of loading patterns and contingencies. Transmission planning studies have shown that for many conditions the CSC could allow increases of 120 MW and 240 MW across the Central-East and Total-East interfaces respectively. In addition, the CSC has potential to improve system dynamic damping and operating flexibility. NYPA anticipates that continuing development of system control algorithms coupled with experience in the operation of the Controller will define additional benefits.

The development and installation of the CSC system at the NYPA Marcy Station is one of many projects included in its FACTS initiative. These projects demonstrate the feasibility of using controlled voltage sources in electric power transmission networks to regulate voltage and control power flow on transmission lines. They developed practical hardware that uses the largest commercially available electronic components to build systems commercially competitive with alternate methods of system compensation and control.

Using the training simulator, an operator can vary the controller configuration and the control mode and see the effect of the dispatch on the overall power system or disconnect transmission lines to emulate a contingency. An operator can then re-dispatch the FACTS Controller to reduce the impact of the contingency on the system. Power system planners can also use the training simulator to study advanced dispatch schemes and new control modes. The software is modular and enhancements can be readily added. A planner can work with the source code for new model and algorithm development. The new FACTS Controller dynamic models allow planners to perform stability analysis and controller design.

Such a training simulator, which can be used to dispatch the CSC in different configurations and in different modes, provide NYPA system operators with an off-line tool to gain experience in operating the CSC, which usually cannot be adjusted for training when it is dispatched for operation.

4.4 Integration of Bulk Renewables

Integration of bulk renewables is being driven primarily by large scale wind and solar photovoltaic (PV) installations. Climate policy is a key driver for deploying these resources and in many locations around the world, there are aggressive renewable penetration goals to support climate policy, achieve energy independence, improve national security and leverage natural resources. One of the key challenges with wind and PV is that they are intermittent and integration of bulk renewables must be managed to achieve supply and demand balance. Additional technologies such as storage and demand response combined with communications and intelligence are being leveraged to support balancing of energy.

DONG Energy – Wind Energy

Wind power provided 19.7 percent of electricity production and 24.1% of capacity in Denmark in 2007. DONG Energy has developed strong wind energy capabilities developing half of the world's ten largest offshore wind farms. Today, DONG Energy has approximately 500 MW of wind capacity and more than 1,000 MW in the development pipeline in Europe including Britain, Germany and Poland. With the large amount of penetration in Denmark, one challenge is when wind generation exceeds demand. Today, transmission and markets do not allow for the efficient export of wind generation and installation of additional transmission is an important step to expanding additional wind. Additional efforts to balance wind generated power include integration with electric vehicles as well as converting electricity to district heating. Because wind is intermittent, there is no way to avoid having large, flexible capacity generators to support the grid when no wind is blowing. Thermal power plants combined with hydroelectric are a good balancing resources.

Drivers

DONG Energy recognizes that renewable energy is a key to reducing CO2 emissions and is working to expand energy supplies based on renewable energy sources – such as water, wind, sun, biomass and geothermal energy. DONG Energy's "home" market of Denmark has one of the highest proportions of wind energy in the world and they are proud to have contributed to that metric. The early key driver for DONG Energy to deploy large penetration of wind grew out of concerns over global warming in the 1980s. Denmark found itself with relatively high carbon dioxide emissions per capita, primarily due to the coal-fired power plants built in the 1970s. Renewable energy became the natural choice for Denmark, decreasing both dependence on other countries for energy and global warming pollution. Denmark adopted a target of cutting carbon emissions by 22% from 1988 levels by 2005. In 1988, two years after the Chernobyl disaster, the Danes passed a law forbidding the construction of nuclear power plants. Today, almost half the wind turbines around the world are produced by Danish manufacturers and this local talent supports DONG Energy's business goals and needs.

4.5 Integration of Distributed Renewables

The integration of distributed renewable generation sources into the electricity grid poses a number of challenges for the industry. Utilities will be faced with issues of enabling high penetration of distributed generation into both existing and future distribution systems. Challenges that need to be addressed include a broad range of issues associated with a variety of strategies being considered for effective interconnection and integration of renewable and other distributed generation into a Smart Grid.

HECO – Renewable Energy Strategy

The Hawaiian Electric Company (HECO) and its subsidiaries, Maui Electric Company and Hawaii Electric Light Company have a three-pronged strategy for renewable energy:

1. Working to maintain existing renewable energy sources on its grids. At the same time there is a desire to pursue "here and now" renewable energy projects immeciately that can be cost-effective and commercial -- like biofuels, wind, solar, waste-to-energy, geothermal, ocean energy and seawater air-conditioning – where they are practical.
2. Working to make it easier for renewable energy developers to add existing and emerging "as available" renewable technologies by upgrading appropriate power lines, substations and other equipment and by taking steps to provide energy smoothing and storage for intermittent power.
3. Accelerating research, development, and demonstration (RD&D) of emerging technologies and resources (ocean thermal energy conversion, hydrogen and algae-for-biodiesel, for example) that are not available commercially or economically viable at this point– but that hold great promise for the future.

This strategy aims to ensure that HECO not only use as much renewable energy as is commercially and economically possible today, but also to help develop future sources. About 9% of the electricity sold to customers of HECO comes from renewable resources and have a portfolio approach to achieve RPS goals.

Drivers

Renewable Portfolio Standards (RPS) is a key driver for HECO and is strongly committed to achieving these goals for the state to reduce dependence on imported fossil fuels impacting security and the economy. In 2004, the Hawaiian legislature updated RPS levels and definitions such that Renewable Energy (RE) comprise of the following portion of electricity sales: 7% by end of 2003, 8% by 2005, 10% by 2010, 15% by 2015, and 20% by 2020. In 2009, HB 1464 increased the amount of RE generation required by utilities to 25% by 2020 and 40% by 2030. Hawaii's total production of greenhouse gas may be small, even on a per capita basis, but as an island state in a tropical hurricane path, they are among the most vulnerable places on earth to rising sea levels, more intense storms and even drought.

Southern California Edison (SCE) – Solar Program

For the second straight year (2008 and 2009), SCE topped the "cumulative solar megawatts" ranking in the united states with 515.6 MW-ac in 2009[13]. In addition, SCE ranked number one in "cumulative solar watts-per-customer" with 106.6 Watts-per-Customer. Another important ranking is the "annual solar megawatts where SCE was number two with 74.2 MW of solar

13 http://www.solarelectricpower.org/media/144950/2009%20utility%20solar%20rankings%20report%20version%201.1.pdf

installed in 2009 behind Pacific Gas & Electric with 85.2 MW. SCE saw an unprecedented 131% growth over 2008.

SCE is leading the United States in renewable energy, delivering approximately 13.6 billion kilowatt-hours of renewable energy to customers in 2009. This constitutes about 17 percent of the energy delivered to customers. SCE currently has sufficient contracts in place that, when delivered, will meet 20 percent or more of its customers' energy needs with renewable energy.

SCE also recently signed two wind-energy contracts. One agreement, with Puget Sound Energy signed in January, calls for 2 billion kilowatt-hours over the next two years. The projects are located in Columbia and Kittitas counties in Washington state. The other, with AES Mountainview, calls for 66.6 megawatts from a wind farm in the San Gorgonio Pass near Palm Springs. This 10-year contract was signed in November 2008.

In addition, SCE launched a Renewable Standard Contract Program which is available for all renewable technologies of 20 megawatts or less. This program is designed to help smaller renewable generators contribute to reaching California's aggressive renewable energy and environmental goals. It also provides a faster, simpler way for renewable projects with fewer than 20 megawatts to sell their power to utility customers.

SCE also recently celebrated “Milestone for a Major Renewable Transmission Project.”[14]

The first part of a major renewable transmission project capable of providing enough clean energy to serve about 3 million homes has been completed. When all phases are developed, the Tehachapi Renewable Transmission Project will include a series of new and upgraded high-voltage transmission lines capable of delivering 4,500 megawatts of electricity from wind farms, solar and other generation resources in Northern Los Angeles and Eastern Kern counties.

“Edison International is a leader in the development and delivery of energy from renewable sources,” said Theodore F. Craver, Jr., chairman and chief executive officer of Edison International. “The Tehachapi project recognizes the importance of tapping into renewable energy sources and exemplifies Edison’s commitment to help California meet its goals for a clean, green energy future.”

The Tehachapi project is the first major California transmission project built specifically to access renewable energy. It is an important infrastructure project for SCE and one of 11 new transmission lines regulators say are needed to help California reach its ambitious renewable energy goals.

During the next five years, SCE forecasts that it will invest $21.5 billion to expand, green and strengthen the region’s power grid. A total of $5.5 billion, or 26 percent of this investment, is directed toward the transmission grid.

[14] http://www.edison.com/pressroom/pr.asp?id=7390

Drivers

The primary drivers for renewable integration are to meet renewable energy goals. California lawmakers are currently developing legislation to increase the current 20% by 2010 Renewables Portfolio Standard (RPS) to 33% by 2020. The California Public Utilities Commission (CPUC) and California Energy Commission (Energy Commission) have endorsed this change and it is a key greenhouse gas (GHG) reduction strategy in the California Air Resources Board's (ARB) Assembly Bill (AB) 32 Scoping Plan.

4.6 Smart Distribution

Automating the distribution system provides one of the most cost-effective ways to improve distribution reliability. It is critical to understand the benefits that can be achieved compared to alternatives, the technology required to achieve those benefits, and the overall economics.

New technologies will be critical to future Smart Grid operation. These technologies will include advanced sensors for understanding conditions in real time, power electronics technologies to improve performance and provide fast response to system changes, and new protection and switching technologies that facilitate automation. The distribution management system (DMS) will be the centerpiece of the smart distribution system in the future. The future Smart Grid must integrate widespread distributed resources as part of the normal operation of the system. The distribution management system, automation systems, protection systems, planning tools, and more must all be designed to accommodate this new paradigm.

Research is required to provide not only technology development and assessments in these areas, but also standards to ensure interoperability and industry deployment opportunities for Smart Grid technologies.

WE Energies – Distribution Vision 2010 (DV2010)[15]

WE Energies (New Berlin, Wisconsin), led a national organization with nine electric utilities in the formation of new consortium called Distribution Vision 2010, LLC (DV2010) in 2000. Their goal was to accelerate the development of new advanced technologies to improve the reliability of the distribution system through automation and bring new automation technologies to the market faster. Bringing Distribution Automation (DA) to another level so it is automated and it virtually corrects itself without human intervention. The basic idea is to take high-speed, fiber-optic based communications systems, overlay them on the distribution grid, and develop intelligent devices that can do the switching and adjustments remotely, using more than one pathway for the electricity -- in effect "dynamic reclosing."

WE Energies is testing the concept in their premium operating district (POD) concept in a commercial area of New Berlin, Wis. This pilot project will demonstrate a four-tier level of new switching, designed to make the district virtually outage proof. The system uses three different

[15] http://www.energypulse.net/centers/article/article_display.cfm?a_id=1410

feeder lines to the district, thus incorporating the concept of a "matrix" so that if one feeder is interrupted, the system automatically switches to another. The switching is designed to occur within four cycles of current. The four-tier system also ensures that each "end" of the traditional radial distribution system is treated as though it were the front instead of the back of the system. The POD was placed into service on March 30, 2006.

With New Berlin POD is fully operational, DV2010 already is bearing fruit in terms of greater system reliability there and in other parts of the country. DV2010 represents a concerted effort by utilities to move electric distribution up another major level to the point where automated systems use high-speed communications to automatically switch power flow, reroute around problems and use multiple feeders in a matrix-like configuration to provide virtually uninterruptible power to customers.

Drivers

The goal of DV2010 is to deliver less than one minute of qualified outages to customers per year, or 99.9998 percent available service. New technology in commercial and industrial processes have created an environment where some customers have zero tolerance for any type of power interruptions, where a one-second outage may just as well be a one-hour outage because their critical processes have tripped off-line and product is lost at a significant cost. Reliability goals are attained by reducing response times to system problems and performing partial feeder restoration as soon as practicable. In 2000 WE Energies vice president of distribution operations challenged the engineering department with the question: "What can we do to improve our system reliability? If you were to start over, what would the distribution system of the future look like?"

"We did some self-examination and found that the practical limit of U.S. distribution systems is four nines of quality," says Russell P. Fanning, principal engineer, distribution automation, for WE Energies. "Customers equate reliability to electric service availability. Radial feeder electric distribution systems deliver levels of perceived reliability that are typically in the range of 99.98 percent available service." That equates to about 100 minutes of annual outage time on a given system, as indicated by SAIDI (system average interruption duration index).

To answer this challenge, WE Energies engineers brought together their peers from other major utilities to form DV2010.

4.7 Energy Storage

Energy storage systems may be essential when managing large quantities of variable renewable generation as well as peak loads. By enabling wind integration, energy storage can help utilities reduce greenhouse gas (GHG) emissions. Distributed storage systems can create value to utility business operations by improving management of peak loads and mitigating outages, which can improve relationships with end use customers. Storage technologies include large-scale, bulk storage options such as pumped hydro, nonfuel, adiabatic compressed air storage as well as many types of battery storage technologies such as sodium-sulfur (NaS), lithium-ion (Li-ion), zinc-air (Zn-Ar), zinc-bromine (ZnBr), and other emerging flow battery systems.

Tokyo Electric Power Co. (TEPCO) – Sodium Sulfur (NaS) Battery[16],[17]

One solution to the problem of supplying peak loads is electrochemical batteries, which store electricity in the form of chemical energy. After performing long-term research, TEPCO has succeeded in developing and commercializing high-capacity, long-life sodium-sulfur (NaS) batteries. Already connected and in operation on the utility's distribution network, the NaS battery systems offer the same operational capabilities as pumped storage hydroelectricity.

Furthermore, the high-speed load-following capabilities of NaS batteries can serve as a countermeasure against infrequent power disturbances such as momentary outages and voltage sags. NaS batteries are expected to not only improve power quality, but also to play important roles in stabilizing the operation of independent small-scale networks and using renewable energy resources such as wind and solar power.

TEPCO/NGK (NGK Insulators Ltd.) consortium declared their interest in researching the NaS battery in 1983, and have become the primary drivers behind the development of this type ever since. TEPCO chose the NaS battery because all its component elements (Sodium, Sulphur, and Ceramics) can be found in abundance in Japan. The first large-scale prototype field testing took place at TEPCO's Tsunashima substation between 1993 and 1996, using 3 x 2 MW, 6.6 kV battery banks. Based on the findings from this trial, improved battery modules were developed and were made commercially available in 2000. The performance of the commercial NaS battery bank is as follows:

- Capacity : 25–250 kW per bank
- Efficiency of 87%
- Lifetime of 2,500 cycles (at 100% DOD - depth of discharge), or 4,500 cycles (at 80% DOD)

As of 2008, sodium-sulfur batteries are only manufactured by one group, the NGK/TEPCO consortium, which is producing 90 MW of storage capacity each year.

There is currently a demonstration project using NGK Insulators' NaS battery at Japan Wind Development Co.'s Miura Wind Park in Japan. Japan Wind Development has opened a 51 MW wind farm that incorporates a 34 MW sodium sulfur battery system at Futamata in Aomori Prefecture in May 2008.

Drivers

Supply and demand balancing is a primary driver for large scale energy storage. Wholesale and retail markets are creating opportunities for energy storage to charge when energy prices are lower or even negative and discharge to the grid when energy prices are higher (arbitrage).

Renewable Energy Control Load leveling is affected by operating the TEPCO NaS battery system automatically on a daily cycle of charging at nighttime and discharging during the

[16] http://en.wikipedia.org/wiki/Sodium-sulfur_battery

[17] http://www.freerepublic.com/focus/f-news/2544593/posts?page=3

daytime. This operation mode is performed by configuring an output pattern for each time interval corresponding to the difference in tariff rates applicable during the day and night periods. Automatic operation is typically conducted on a programmed basis scheduled a year in advance.

The load-leveling operation was performed at each customer's site, and the combined performance during 2006 was an annual discharge of 200 GWh, which equates to the output of a small hydroelectric power plant. Similarly, in the summer of 2007, the recorded discharge output was 160 MW during the peak-load daytime period (1 p.m. to 4 p.m.), effectively shifting the peak demand on TEPCO's distribution network.

These statistics confirm that NaS battery systems can store excess off-peak energy at diverse locations on the distribution network, and release or discharge the stored energy during the peak-load daytime period. In addition to the load-leveling function, the NaS battery system can improve network reliability by supplying stored electrical energy during outages and power quality by mitigating voltage sags.

From TEPCO's perspective, the attributes of NaS battery technology include:

- Financial benefits from mass production as raw materials are abundant and high-volume ceramic manufacturing is a proven technology.
- NaS batteries require about one-third of the space required by alternative commercial options such as lead-acid batteries.
- NaS Applications on Distribution Networks Because a NaS battery does not self-discharge, the loss of charge during storage and periods of standby is minimal.
- NaS batteries have a long life span of about 15 years and superior life-cycle characteristics, with about 4500 daily discharge cycles.
- Load Leveling
- The batteries are 70% to 80% energy efficient, and the hermetically sealed cells release no emissions.
- Minimal maintenance is required as there are few auxiliaries and no moving parts.

4.8 Microgrids

Microgrids are modern, small-scale versions of the centralized electricity system. They achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction, established by the community being served. Like the bulk power grid, smart microgrids generate, distribute, and regulate the flow of electricity to consumers, but do so locally. Smart microgrids are an ideal way to integrate renewable resources on the community level and allow for customer participation in the electricity enterprise. They form the building blocks of the Perfect Power System.[18]

[18] http://www.galvinpower.org/microgrids

BC Hydro – Intelligent Microgrid[19],[20]

A microgrid on the Burnaby campus of the British Columbia Institute of Technology (BCIT) in Vancouver, British Columbia, Canada is sponsored by BC Hydro and funded by the British Columbia government's Innovative Clean Energy (ICE) fund and the Canadian government's Western Diversification Fund. BCIT's Intelligent Microgrid will be a test bed where communication technologies (wired, wireless (RF), and Power Line Communication (PLC) also known as Broadband over Powerline (BPL)), smart metering (one phase and three phase), power generation (thermal turbine, photovoltaics (solar), and wind), and even smart appliances are integrated to measure the merits of different solutions, show off the capabilities, and speed up the commercialization of BC made solutions and technologies for the Intelligent Grid. The validation and qualification of architectures, models and protocols will be guided, supervised and scrutinized by BC Hydro and BC Transmission Corporation (BCTC).

To turn BCIT's campus into an Intelligent Microgrid, a network of smart meters and other control components is required. These components need to be fitted with communication modules to enable them to communicate with data aggregation units in substations. These substations need to be equipped with Intelligent Agents to monitor consumption, demand, usage profiles, and distribution yields. The networking of these substations is achieved through their inclusion in BCIT's Internet Engineering Lab (IEL)[21] which includes servers to allow tests on the resiliency of different network topologies, architectures, and protocols for substation networking. Localized power generation plants (solar, wind, and thermal) will be integrated into the microgrid to allow for the development of command and control models for distributed generation and integration of such alternative energy sources into the future Intelligent Grid of British Columbia.

The BCIT Intelligent Microgrid will be rolled-out using different communication technologies such as RF, PLC, etc. The Microgrid will be able to utilize and work with many different technologies which could become available in the future, and the architecture will be open and non-vendor specific. The BCIT Intelligent Microgrid network integrates the following 7 components:

Smart Meters: Capable of measuring multitudes of consumption parameters (e.g. active power, reactive power, voltage, current, demand, etc.) with acceptable precision and accuracy. Smart Meters should be tamper-proof and capable of storing the required data for a number of billing cycles.

Smart Displays: Capable of measuring consumption profiles and displaying that in an easy-to-understand form to end-customers. Smart Displays are part of how the utility companies communicate to the end-customers to keep them informed of up-to-the-minute trends in power consumption.

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[19] H. Farhangi, "The Path of the Smart Grid" IEEE Power & Energy Magazine, vol. 8, no.1, pp. 27-28, Jan/Feb 2010
[20] http://www.bcit.ca/microgrid/
[21] http://www.bcit.ca/appliedresearch/tc/facilities/iel/index.shtml

Communication Modules: Enabling each meter to communicate with adjacent meters, or with mobile/stationary data aggregators. The communication channel has to be extremely robust, secure and low-cost. Multiple technologies will be employed, with wireless (RF) and Power Line Communication (PLC) being the top contenders.

Access and Networking Middleware: To allow the setup and management of a secure meshed network comprising smart components in the same neighborhood, together with their assigned data aggregator. Encryption and security technology for secure access is paramount!

Data Aggregation Unit (DAU): Capable of exerting command and control over a meshed network of slave meters. A DAU is capable of accessing each and every node in its assigned network.

Smart Appliances Control: Capable of exerting command and control over Smart Appliances to adjust/control their performance and service level based on user and/or utility requirements. The software for doing this will involve a lot of embedded technologies.

Aggregator Application Software: To allow authentication and hand-shake with each node in the network. It is capable of identifying each termination, querying them, exchanging data and commands with them and storing the collected data for scheduled and/or on-demand transfer to Utility Servers.

Key deliverables of BCIT's Microgrid project, over three consecutive phases, are:

Construction of a Smart Grid test bed

- Provisioning methods for smart termination points (meters, data aggregators, appliances, sensors, controls, etc.)
- Integration solutions for alternative sources of energy (wind, solar, thermal, etc.) with the electricity grid
- Innovative network architecture and topology for Smart Grid

Operational Analysis and Qualification of grids

- Resilience, reliability, security and scalability
- Data collection and distributed command and control methods
- Emission standards for wood waste boilers and methods for achieving such standards with optimum efficiencies

Qualification of interface protocols and models

- Interface with Utility back-office tools (billing, load management, service provisioning, outage restoration, etc.)
- Seamless end-to-end deployment, operation and maintenance
- Easy and intuitive human interface for operators and customers

Drivers

An intelligent grid will help to balance power generation with demand, reducing the potential for blackouts. It will also be able to integrate current energy sources such as hydro or natural gas with alternative energy sources such as biomass, solar, and wind plants.

Benefits/Drives to BCIT:

- Reduced carbon footprint and reduced energy cost
- State-of-the-art educational opportunities for students
- Modern Energy Management System & Facilities
- Leadership position among Canadian post-secondary institutions
- International recognition through collaborations with Gridwise

Economic Benefits/Drivers

- The BCIT Intelligent Microgrid project will create the infrastructure required to develop additional skills, equipment, software and services in BC.
- This unique infrastructure will enable all local BC stakeholders to showcase their expertise to global customers in this emerging industry.
- Domestic and export sales will be generated, employment will be created, and the tax base will be increased.
- Implementation of Intelligent Grids by electrical utility providers will decrease their operational costs, improve the services provided to customers, and increase the revenue they generate.
- Electrical theft detection can be enabled over an Intelligent Grid. This is a global problem that desperately needs addressing for both economic and environmental reasons.

Environmental Benefits/Drivers

- Giving electrical utility providers the ability to manage their electrical infrastructure remotely and more efficiently will result in significant emission reductions through decreased travel requirements alone. Related applications include: Automatic Meter Reading; Distribution Automation; Transformer Evaluation and Monitoring; Power Quality Monitoring; Remote Control Load Balancing to maximize efficiency, Asset Management, SCADA, Advanced Network Management with GIS and Mapping, Fault Detection, Surveillance, and Security.
- Most utility providers in North America have to perform thousands of "truck rolls" a year simply to turn customers on and off. The emissions generated by their vehicles are significant and the associated cost of doing so is millions of dollars annually. Intelligent Grids give utilities the ability to perform these actions from their command and control centers. Therefore this environmental issue and associated costs could be avoided altogether.
- The potential future benefits include delaying or eliminating the need to build new power generation facilities in the future due to:

  - more efficient energy transmission capabilities through applications such as Peak Load Management and Distribution Automation,
  - more efficient energy use through applications such as Time of Day Billing, Automatic Meter Reading, Load Balancing, etc.
  - more efficient energy transmission capabilities through applications such as Peak Load Management and Distribution Automation,
  - more efficient energy use through applications such as Time of Day Billing, Automatic Meter Reading, Load Balancing, etc.

Smart Metering combined with in-home display indicators to provide feedback to consumers on their energy usage is a key element in effective long-term behavioral change and making consumers aware of their carbon footprint. Implementing such technologies in many homes throughout the province will significantly reduce the residential electricity consumption and the corresponding greenhouse gases produced. A paper published at Oxford University, titled "The Effectiveness of Feedback on Energy Consumption", determined that "savings from direct feedback immediately from the meter or an associated display monitor, range from 5-15%". Given BC's rising consumption levels, such savings could prove to be quite significant in the long run.

Commercialization Opportunities/Drivers

- The skills, products and applications generated by BCIT's Microgrid project will be commercialized and sold globally.
- The market for Intelligent Grid related technologies, applications and services is significant:
  - The total value of utility providers' assets in the US is estimated to exceed one trillion dollars.
  - It is estimated that at least 60% of these assets need to be changed and/or upgraded in the next 10 years.
  - That is a US$60 billion market a year for the next 10 years.
  - The US Utility Market is a one-quarter of the Global Market, showing how large the international market could be for BC made Intelligent Grid products, services and solutions.

4.9 Standards

According to Section 1305 of the Energy Independence and Security Act of 2007[22], the development of protocols and standards to increase the flexibility of Smart Grid equipment and systems was required. The interoperability framework “shall be flexible, uniform, and technology neutral” and “align policy, business, and technology approaches in a manner that would enable all electric resources, including demand-side resources, to contribute to an efficient, reliable electricity network.” It calls on the National Institute of Standards and

[22] http://www.smartgrid.gov/sites/default/files/pdfs/eisa_2007.pdf

Technology to take a leadership role in coordinating the "development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems."

Tennessee Valley Authority (TVA) – Integrating IEC 61850 at TVA Bradley 500kV Substation[23]

TVA has embarked on a program to dramatically reduce the cost of building, refurbishing, operating and maintaining transmission substations with a standards based approach leveraging IEC 61850. At the same time, the project hoped to advance protection, control, monitoring and automation capabilities within its transmission system. To date, the Bradley 500kV Substation includes 34 Intelligent Electronic Devices from five manufacturers, selectively connected to redundant fiber optic networks. Project scope includes SCADA support, four distribution protection schemes, CB condition monitoring, transformer monitoring and a publish/subscribe server for multiple department access to data and functionality.

Drivers

While the cost of refurbishment of primary equipment (breakers, transformers, LTC's, etc) at existing substations will remain expensive, there may be compelling reasons/advantages to the wholesale refurbishment of the secondary system (monitors, relays, RTU's, controllers, etc) with the new IEC 61850 standard. The IEC 61850 communications standard provides the means to integrate communications, information and applications into a coherent, flexible and very powerful framework for the substation secondary system.

Southern California Edison – Edison SmartConnect™- Industry Resource Center[24]

SCE utilized systems engineering in its approach to identify business needs and develop systems requirements for its smart metering program, Edison SmartConnect. The first step in this approach is to develop use cases. SCE partnered with EPRI to use the IntelliGrid Use Case framework as the starting point for SCE's independent development of use cases. EPRI then translated the SCE use cases back into the IntelliGrid repository for industry use.

What is a use case? A use case results from the application of a rigorous method for identifying necessary functionality and vendor product requirements. The use cases developed by SCE for its AMI project placed particular emphasis on how the advanced metering system will be used when deployed.

SCE made deliberate effort to not only a standardized methodology to determine requirements, but to also make them publicly available to provide a contribution to the industry.

Driver

Open Innovation - SCE is interested in encouraging the open development of smart meter/Smart Grid uses and related technology, so that we can better meet the needs of customers and improve

[23] http://www.ruggedcom.com/pdfs/news/tva_bradley_iec_61850_project.pdf
[24] http://www.sce.com/CustomerService/smartconnect/industry-resource-center/use-cases.htm

operational efficiency and safety. It is in this spirit of open innovation that SCE is providing the AMI use cases to other utilities, for their potential use.

A
SMART GRID SURVEY RESPONSE

The information below contains the unedited Smart Grid survey responses for questions that had narrative responses.

1. Please describe your company's definition of a Smart Grid.

7 principal characteristics related to functions of Smart Grid; see Smart Grid Implementation Strategy documents
We use the DOE definition of smart grid.
A grid in which devices can communicate efficiently to provide better situational awareness for operations staff.
A Smart Grid is a seamless, telecommunication enabled T&D system that automatically sends, receives, and utilizes data from Intelligent Electronic Devices in order to optimize system performance, reliability, and the customers experience
A Smart Grid is an electrical power system that has sensing, controls, and process capability that enables operations and planning functionality of substantially greater degree than traditional substation-based SCADA and Relaying systems.
An electrical grid in which the system dispatch model incorporates real time demand at the retail meters and allows participation thru lowering consumption. This is done in cooperation with the consumer and price points are established at a threshold price that both parties agree upon.
A Smart Grid delivers electricity from suppliers to consumers using digital technology to save energy, reduce costs and increase reliability.
The overlay of communications technology and distributed intelligence onto the transmission and distribution system for purposes of improving reliability, operating efficiency, and asset optimization. Ultimately this will allow interested customers to use other data and technology for purposes of more actively participating in their own energy decision-making.
Electricity networks that can intelligently integrate the behavior and actions of all users connected to it - generators, consumers and those that do both in order to efficiently deliver sustainable, economic and secure electricity supplies. (EU technology platform)
We define Smart Grid at present as follows; countermeasures for the penetration of renewable energy such as PVs, technology for the maintenance and reinforcement of power quality, and technology for the efficient use of electricity and energy saving.
The concept of a smart grid has many definitions and interpretations dependent on the specific country and industry stakeholders key drivers and desired. The Smart Grid European Technology Platforms (comprising European stakeholders, including the research community) defines smart grid [as] an electricity network that can intelligently integrate the actions of all users connected to it generators, consumers, and those that do both, in order to efficiently deliver sustainable, economic and secure electricity supply
Efficient use of assets and resources, to the benefit of customers and company in enhancing and leveraging the asset and controlling investment
Combining communications with intelligent devices to provide power system automation, monitoring, and remote control which transform all aspects of system operations and enable new services to consumers.
Utilizing technology to improve the reliability and efficiency of the electric system. Involving customers in better management of their energy consumption.

A Smart Grid is a means to an end rather than an end in itself, and comprises the integration of ICT in Grid operations as well as the use of more technologically developed network components (such as High Temp Lo Sag Conductor) to achieve the long term results of lower emissions, increased fuel security(through reduction in fossil fuel usage) and development of the network for future needs in an economic, efficient and effective manner
The primary goal for smart grid for my company is to deliver the optimal amount of information and load control for customers, distributors, and grid operations to change behavior in a way that reduces system demands and costs, and increases energy efficiency. Smart grid promotes societal benefits like reduced emissions, lower energy costs, and greater flexibility to accommodate new renewable distributed energy sources.
We define the smart grid as an increasingly intelligent and highly automated electric power system that utilizes technology advancements in telecommunications, information, computing, sensing, controls, materials, in addition to other grid technologies. The smart grid will be able to better meet customers energy demands, while also seamlessly integrating new sources of energy and delivering power over a network that is increasingly interoperable, efficient and resilient.
The tool to realize a future low carbon society based on electricity technology through smart use of electricity
An Electric / gas distribution infrastructure which securely incorporates information and communications technology into all aspects of energy supply, delivery and consumption to enable energy markets, improve system reliability and customer service, reduce operational and customer costs, improve efficiency and minimize environmental impacts.
A smart energy approach to the distribution and customer service activities that may include two way communication network which supports products and services capable of providing real time information, time differentiated pricing, and capabilities to perform distribution and operations functions.
The installation of intelligent devices broadly across the electric delivery system that enables continuing enhancements in the operation, reliability, adaptability, flexibility, utilization, planning, and design of the electrical grid. Enabling Smart Grid technologies also include ubiquitous and high speed communication network(s), as well as the back office IT systems that support of integration of data from these various intelligent devices, leading to actionable information.
A system enabling dynamic monitoring, control, and understanding of the transmission, distribution, and customer systems.
Integration of the electrical grid with intelligence infrastructure
A fully integrated system which provides a smart interface between the customer and the supplier, as well as between the system and its components throughout the value chain
A future power delivery grid that will enable active participation by consumers, accommodate electricity storage, enable new products services and markets, provide adequate power quality, optimize energy efficiency and asset utilization, optimize reliability, and be secure.
We are currently working on defining this specifically for our company. Basically we believe it is comprised of many different facets with in the company. This would include doing more with the data we currently have and sharing infrastructure across different business units, for example, communication infrastructure.
Our definition of smart grid is to realize high efficiency, high quality and high reliability transmission and distribution system without losing present stability of power supply by using new technologies such as storage battery, ICT in order to enhance customer service and to realize low carbon society.

15. Please describe the efficiency targets and identify the mandating body.

A key driver for the development and the deployment of the Smart Grids is represented by the EU Climate and Energy Package. In March 2007 the EU's leaders endorsed an integrated approach to climate and energy policy that aims to combat climate change and increase the EU's energy security while strengthening its competitiveness. They committed Europe to transforming itself into a highly energy-efficient, low carbon economy. To kick-start this process, the EU Heads of State and Government set a series of demanding climate and energy targets to be met by 2020. These are: â€¢ A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels â€¢ 20% of EU energy consumption to come from renewable resources â€¢ A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency. Collectively they are known as the 20-20-20 targets.
1400MW of peak reduction by 2012; 50% clean and renewable generation (energy) by 2030. Mandating body: self-inflicted

16. Please add any other details about your company's regulatory environment that you believe are relevant

3 states, each with very different regulatory environments. One very supportive and encouraging smart grid investments. One that is unconvinced, but is open to the possibility if a customer centric business case can be made. The third is somewhat in the middle, encouraging smart grid projects to be brought forward, but not tied exclusively to achieving only customer benefits.
Regulatory interest in smart grid technology in Missouri has been benign and a bit slow in developing.
Nothing specific yet.
PUCO is supportive and forward thinking
Good relationship with Regulator which has been established on the basis that we have very detailed business case for every investment. On Maintenance the summary is 200 pages, and divvies all assets into 12 classes, with each class divvied into 5 subclasses with a description of expenditure in each, and in detail, and down to specific stations. This is the summary. Backing this is a detailed cost benefit analysis of each specific case. On the capital Investments side every circuit from MV to 110kV and every substation 38/MV, 110/MV, 110/38kV has been individually examined under load scenarios and an investment case made - two reports of about 5" each. In addition every investment at MV has had an Investment Appraisal written justifying it's net benefits.
Nothing specific yet.
California's leadership in response to national policy directives imposes more ambitious standards on California's electric utilities than energy providers in other states. For example, California's Renewables Portfolio Standard (33% renewables by 2020) calls for greater amounts of cleaner and greener generation options like wind and solar, which increases the amount of variable generation and distributed energy resources on the power system requiring fundamental change in how the system is designed and operated. This additional load on the system is exacerbated by greater demand for electricity as a cleaner, alternative transportation fuel. Further, policy goals such as the California Solar Initiative and California's Carbon Reduction Law (AB 32) will require implementation of smart grid technologies at all levels of the utility supply chain.
State reluctant to pursue smart grid initiatives particularly in the AMI arena.
Currently the company is capped on amount of hydro power we are allowed to use toward our renewable portfolio.

18. Please elaborate on the identified issue(s) and how they differ from current practices.

Clear rate recovery guidelines Clear business case treatment Clear early depreciation rules
Regulatory recovery mechanism required for smart grid investments.

Unbottling wind and increased use of transmission assets.
Recovery of early depreciation of retired legacy meters with current book life of 30 years. Where rate recovery is based on backwards looking test years, need some means to assure recovery of smart grid investment costs will be allowed.
A strong policy commitment at the governmental and regulatory level supporting Smart Grids is very important in order to enhance economical incentives to invest in Smart Grids Research, Development and Demonstration (RD&D) projects to develop and test new solutions and successively deploy these at full scale.
Safety Policy reviewed and Live line working procedures
TOU and real time pricing
Deployments will be made when assured adequate regulatory recovery
Ensure that SmartGrid pays it's way and is developed in such a manner that it does not cannibalize earlier SmartGrid investments e.g. if reclosers reduce impact of earth faults but SmartNeutral eliminates occurrence of earth faults then overinvestment now in advance of smart neutral would not be wise. Also not to use Smart technology for the sake of using Smart when a better result could be obtained from simply being smart about how the network is developed e.g. if EV's impact on network can be controlled by a timeswitch no need to have elaborate DSM
Positive regulatory outcome
NYS 45 by 15 plan to add 30% renewables and reduce load by 15% by the year 2015 - new DER installations create a challenge for the utility to deliver reliable and stable service
Integration to system operations through ICCP and retail meters integration to MDMS

20. Please write a brief description of the main conclusion(s) concerning customer knowledge or perceptions of the Smart Grid.

Customers generally don't have much knowledge of what smart grid is, and they seem to be growing more suspicious of it given what's been in the press regarding a number of smart meter deployments. Of those who have a realistic picture, very few (at least in MO) will be interested in using data and technology to change their energy behaviors - they just want lower rates.
Realized, through a consultancy society, a market test in order to assess the customers awareness increase of their energy consumptions, thanks to the usage of a display placed within their premises that shows the meter's data. Referring to the sample population analyzed, the test has outlined in synthesis that: the customers awareness, without the in-home display, is not very strong using the in-home display the energy consumption awareness has been improved in a relevant manner most of the customers involved in the test have expressed a positive opinion about the effectiveness of the use of the in-home display for achieving awareness about their energy consumptions â€¢ most of the customers suggested to show on the display, not only the meters data, but also the energy prices (for this purpose, in a fully unbundled market, also retailers have to be involved).
Not with this project but with Smart metering project
Deep study of consumer programs resulted in extensive consumer education plan
Customers are not familiar with smart grid and its benefits.
Customer's initially do not understand smart grid, but are interested in personal benefits they may be able to derive.
Sent out a survey to customers and internal employees - most stated that they knew little about smart grid or saw little benefit
Market research in-flight. scoped to discover nature of residential demand response, including reaction to incentives and information
Not available yet.
We are currently involved in a project called iCanConserve. Through this project we hope to learn more about the customer experience as it relates to adoption of new technologies to help with energy efficiency and knowledge.
Now processing, so it is difficult to answer it.

21. Please describe the key positive experiences related to your company's Smart Grid project identified to date, if any.

Recently received funding from DOE. Also have found interest in further demonstration and research efforts by industry professionals as a result of DOE funded project.
New opportunities to manage load through demand response programs
Less than 0.4% of AMI metered accounts are estimated on a monthly basis.
Pretty much just getting started and developing deployment strategies in all areas we intend to pursue. However, we're very mature in areas of substation SCADA, capacitor control, Outage Analysis and Automated Meter Reading.
Our smart grid field tests are now under implementation.
The Smart Grids program already implemented has given the following results: Thanks to the AMM solution (32 Mill Smart Meters deployed in the year 2006) Customers benefits: invoices based on actual energy consumption remote contract management and significantly reduced customer home intrusion tailored tariffs and possibility to provide value added services Power System benefits: power peak demand shaving energy efficiency and CO2 emissions reduction commercial and technical losses reduction Utility benefits (same benefits are experimented by Utilities adopting the Telegestore): significant savings in operating costs (Opex - â,¬/customer) o customer satisfaction and reduction of customer claims number investments focused on core Utilities business . Thanks to automation and remote control systems, from 2001 to 2007: o Quality of service increased (e.g. SAIDI index decreased from inception to the present by around 60%) Relevant reduction in annual Opex has been achieved
Improved supply quality and continuity
Well accepted by customers High value of performance data
Improved reliability in Distribution Automation pilot areas
Getting better value for money from investment made - e.g. from Smeter pilot last year we are about to review average loading per house design and also get representative 'model samples' for use in Network analysis
We are in the planning stage and have not had any "experiences" yet.
Our smart grid field tests are now under implementation.
Better understanding of how to integrate intermittent renewable resources; Importance of open innovation and broad collaboration with all stakeholders; Importance of rigorous testing and technology evaluation; Lessons learned from increased knowledge of actual grid operations.
Success in capturing monthly billing reads and remote connect and disconnect.
educational, relationship building
Customer response is very positive
Reliability has been much improved by introducing DAS.

22. Please describe the key negative experiences that have been identified regarding your company's Smart Grid project, if any.

DOE application processing very burdensome.
Still working to improve Read Interval Success performance to allow billing of time based rates using strictly interval usage data, and not register reads.
None to date
Problems for implementation typify introduction of any new technology
Masses of academic and other literature which places no emphasis on the economics of Smart Grid and parrots assumptions on why Smart Grid is needed without having critically reviewed real requirements.
We are in the planning stage and have not had any "experiences" yet.
Disconnect between technology providers and actual capabilities; Maturity issues associated with emerging technologies; Disconnect between policy mandates and technology maturity.
change, new territory with distribution customers acting as a supplier (load as a resource), internal change, financial and economic challenges
Some vendors feel threatened by the potential redundancy of their technologies
We do not have any idea.
getting government funding is not easy

24. Other Comments.

We are considering multiple smart grid efforts, and have one or two small related items in pilot stage. But basically, we are at the business plan/planning stage.
We are developing a comprehensive 5 to 10 year Smart Grid roadmap for phased deployment based on prioritization against various business drivers.
Simple technology not reliant on communications infrastructure will enhance supply conditions for rural customers
It is quite difficult to describe total percentage of the smart grid project process, because it depends on the component.

B
SMART GRID SURVEY

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EPRI Smart Grid Survey

=======================================

The Electric Power Research Institute (EPRI) & the Galvin Electricity Initiative (GEI) have developed the following survey to analyze the development and deployment of smart grid projects around the world.

Survey respondents will be invited to a webcast to discuss the results of the survey. The results gained from this survey are critical to smart grid research for international coordination of smart grid efforts. The survey is focused on the integration of distributed resources (including consumers) with the operation of the grid. The goals and objectives of the survey are to gain an understanding for different smart grid implementations around the world, identify the key drivers that stimulated leadership to deploy the smart grid projects, describe the lessons learned, experiences, business drivers, and internal/external factors that had an effect on deployment. The survey should take about 10 minutes to complete.

Please complete and submit the survey by Wednesday May 26, 2010 and if you have any questions please contact: Christina Haddad at chaddad@epri.com

===

Key Applications Deployed by Utilities & Progress of Smart Grid Implementation

===

1. Please describe your company's definition of a smart grid.

    ____

    ____

2. Do you have a smart grid project at your company?

    ( ) Yes

    ( ) No

3. Please provide a name and description of the smart grid project(s)

    ____

    ____

4. What month and year did the smart grid project begin?

    Month/Year ________________

5. Please list the country(s) and state(s), if applicable, where the smart grid project is located ____

6. Please identify the stage that most closely aligns with the progress of your company's smart grid project(s)

    ( ) Evaluating Business Case

    ( ) Planning Phase - (Decision to Deploy Project Made)

( ) Technology Evaluation Phase - (Pilot/Demonstration)
( ) In Process of Full Deployment
( ) Deployment Complete - (In Operation)

7. If the project is in the deployment stage, approximately what percentage (%) of the smart grid project is complete to date?
____

8. Please select the key asset(s) deployed in your company's smart grid project, if any.

( ) Advanced Interrupting Switch
( ) AMI / Smart Meters
( ) AMR / Interval Meters
( ) Controllable / Regulating Inverter
( ) Customer EMS / Display Portal
( ) Distribution Automation
( ) Distribution Management System
( ) Enhanced Fault Detection Technology
( ) Equipment Health Sensor
( ) FACTS Device
( ) Fault Current Limiter
( ) Loading Monitor
( ) Microgrid Controller
( ) Phase Angle Regulating Transformer
( ) Phasor Measurement Technology
( ) Smart Appliances and Equipment (Customer)
( ) Software - Advanced Analysis / Visualization
( ) Two-way Communications (high bandwidth)
( ) Vehicle to Grid 2-way Power Converter
( ) VLI (HTS) cables
( ) Storage > 500 kW
( ) Storage < 500 kW
( ) Thermal Storage
( ) Distributed Generation
( ) Plug In Hybrid Electric Vehicle (PHEV)
( ) Electric Vehicle (EV)
( ) Photovoltaic (PV)
( ) Wind Generation
( ) Biomass Generation
( ) Wave Energy
( ) Other

9. Please mark the key function(s) incorporated into your company's smart grid project.

( ) Wide Area Monitoring and Visualization
( ) Dynamic Thermal Circuit Rating
( ) Flow Control
( ) Adaptive Protection
( ) Automated Feeder Switching
( ) Automated Islanding and Reconnection
( ) Automated Voltage and VAR Control
( ) Diagnosis & Notification of Equipment Condition
( ) Enhanced Fault Protection
( ) Real-time Load Measurement and Management
( ) Real-time Load Transfer
( ) Demand Response
( ) Direct Load Control

( ) Smart Charging for Electric Vehicles
( ) Permanent Peak Shifting
( ) Customer Electricity Use Optimization
( ) Other

10. Please select the communication infrastructure employed in the smart grid project, if any.
( ) RF Tower
( ) RF Mesh
( ) Public Internet
( ) Cellular Based (1xRtt, GPRS, EVDO, CDMA, etc)
( ) Powerline Based
( ) WiMAX (IEEE 802.16)
( ) Other

===
Keys Drivers That Prompted Leadership to Deploy the Smart Grid Program
===

11. Please identify the key driver(s) that prompted your company to deploy the smart grid project.

	Very Important Driver	Important Driver	Neutral Driver	Not Very Important Driver	No Importance
Legislative	_____	_____	_____	_____	_____
Societal	_____	_____	_____	_____	_____
Internal Ops	_____	_____	_____	_____	_____
Efficiency	_____	_____	_____	_____	_____
Economic	_____	_____	_____	_____	_____
Environmental	_____	_____	_____	_____	_____
Security	_____	_____	_____	_____	_____
Safety	_____	_____	_____	_____	_____

12. Has your company sought regulatory relief for smart grid investments
( ) Yes
( ) No

13. Please list specific smart grid investments for which regulatory relief was approved and/or denied

____
____

14. Does your company have any smart grid efficiency targets?
( ) Yes
( ) No

15. Please describe the efficiency targets and identify the mandating body.

____
____

16. Please add any other details about your company's regulatory environment that you believe are relevant

____
____

17. Have you identified specific policy needs to enable your smart grid vision?

( ) Yes
( ) No

18. Please elaborate on the identified issues(s) and how they differ from current practices.

____
____

19. Has your company done any market research to assess customer knowledge or perceptions of the smart gird?

( ) Yes
( ) No

20. Please write a brief description of the main conclusion(s) concerning customer knowledge or perceptions of the smart grid

____
____

21. Please indicate if your company's smart grid project provides any of the following consumer offerings.

( ) Price Based Rates
( ) Real-Time Pricing (RTP)
( ) Day-Ahead Pricing
( ) Critical / Variable Peak Pricing
( ) Time of Use Rates
( ) Block (or Reverse Block) Rate
( ) Incentive Based Rates
( ) Emergency Demand Response
( ) Demand Bidding / Buyback
( ) Capacity Market
( ) Ancillary / Regulation Services
( ) Interruptible / Curtailable
( ) Direct Load Control
( ) Customer Involvement
( ) Customer Education
( ) Customer Feedback Technology
( ) Other

===

Key Lessons Learned from Smart Grid Program Development & Implementation

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22. Please describe the key positive experiences related to your company's smart grid project identified to date, if any.

____
____

23. Please describe any negative experiences that have been identified regarding your company's smart grid project, if any.

____
____

24. Please indicate the strength of association between estimated benefits of the smart grid project and the potential beneficiaries listed below (utilities, consumers and society at large).

	Economic	Environmental	Power Quality & Reliability	Safety & Security
Utility	_____	_____	_____	_____
Consumer	_____	_____	_____	_____
Society	_____	_____	_____	_____

25. In the space provided below please list further comments you would like to add, if any.

____
____

Please list contact information for the key smart grid contact at your company.

===
Thank You!
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Thank you for taking our survey. Your response is very important to us.

C
SMART GRID – TECHNOLOGY INNOVATION GROUP REPORT

The Smart Grid—Technology Innovation Group Report was developed at the request of the e8 Leadership team. The scope of work assigned to the group developing the report was to examine member company experiences in Smart Grid deployment and develop recommendations that could help accelerate the deployment of Smart Grid across e8 members and the world in general. The group evaluated regulatory, financial, technical, policy and public communication/education issues that can accelerate or inhibit deployment of smart grid. We attempt to share participant company experiences and challenges in a succinct fashion in this report

Participating e8 members:

- American Electric Power
- Duke Energy
- Electricite de France (EDF)
- Ente Nazionale per l'Energia eLettrica (Enel)
- Hydro-Quebec
- Kansai Electric Power Company
- RWE AG
- Tokyo Electric Power Company

Electric Power Research Institute (EPRI) supported document development through aggregation of information and compiling the final report.

1 INTRODUCTION

Ancient peoples knew of strange phenomena involving amber ("Elektra" in ancient Greek) and lodestones, phenomena we call electricity and magnetism. By the mid-1800s, electrical pioneers such as Andre Ampere, Allessandro Volta, and Georg Ohm had provided the scientific knowledge concerning electrical phenomena that made the first efforts at large-scale electrical generation possible in the 1880s and 1890s. Since those first developments of practical electrical power generation and distribution, the alternating current (AC) electrical generation and distribution system as it exists today has evolved from separate and disconnected entities to a vast interconnected system of power providers and users. While electricity primarily powered electric lighting in the beginning, today a seemingly limitless array of machinery and appliances operate using grid-supplied voltage and current.

Throughout the world, people in developed nations such as those represented by utilities in the e8, benefit from economical electricity. However, while those entities that generate and transmit electrical energy strive to become ever more efficient and pollute less, the sheer scale of electrical demand – one that continues to grow each year despite current economic strains – would be expected to cause increasing pollution and put an increasing strain on the electrical system meant to accommodate that demand. In some, but not all parts of the world, fixed electric rates enjoyed by the residential population – regardless of the actual cost of generation at time of day – contribute to ever larger peak and extreme peak loads and may serve to exacerbate the need for new construction.

A balancing act ensues with many actors – electricity providers, regulatory bodies and users – pulling and pushing according to their view of the situation, one that differs by region. On the one hand, electricity providers see the need for more generating capacity while regulatory bodies may not want the rise in rates that the new construction would require. All the while, the people using the electricity may not be aware of their own role in the balancing act. In many parts of the world, these people have never before had to be concerned with their electric consumption.

Fortunately, advances in computer controls, communications, alternative energy and other components have enabled a method of using the existing transmission and distribution structure to provide power more efficiently throughout the day. This method may also result in less pollution through the integration of cleaner distributed resources, and, through two-way communication with customers, may help moderate electrical demand at critical points during the day or night, beyond the capabilities of the transmission system alone. This is known as the Smart Grid.

Current State of the Electrical Grid vs. the Smart Grid

After a hundred years or so, the state of electrical generation and distribution in developed nations is considered mature. In the United States, for instance, the electrical grid infrastructure, representing more than $1 trillion in asset value, consists around 450,000 miles of transmission, 5 million miles of distribution and 22,000 substations and serving well over 100 million customers and at least 283 million people. Meanwhile, Canadian utilities invested $2.4 billion in 2007 in high-voltage transmission infrastructure numbering over 45,000 miles and $1.7 billion in distribution infrastructure. An electric utility company may monitor and control hundreds of grid devices as they operate their part of the grid. Investments in generation, transmission and distribution for developed regions have largely been made with maintenance or replacement of same being the greater concern. Figure 1-1 illustrates the basic structure of the current grid for typical voltages in the United States operating at 60Hz.

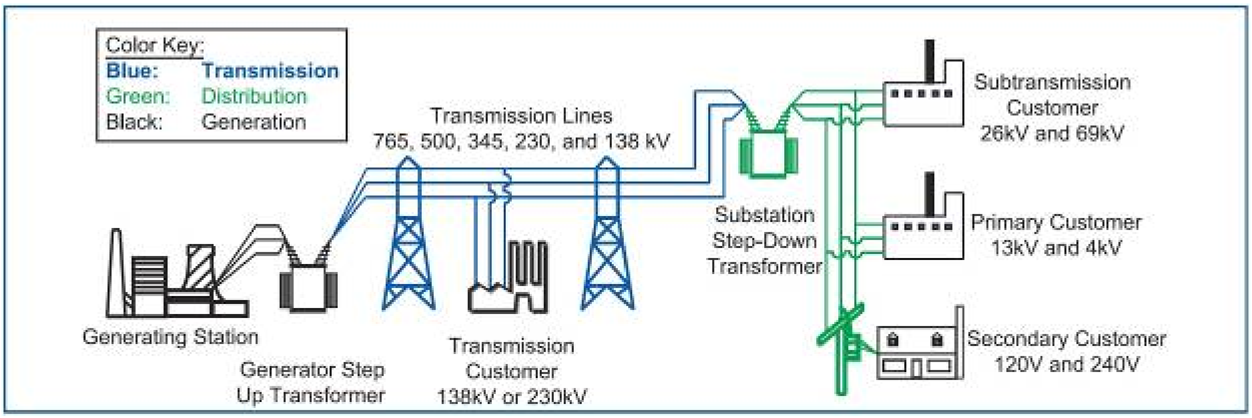

Figure 1-1
Basic Structure of Electrical Generation and Distribution [1]

In Europe, there is a system of interconnected Transmission System Operators (TSOs) organized as the European Network of Transmission System Operators for Electricity (ENTSO-E – formerly UCTE – Union for the Coordination of Electricity Transmission). This organization in the EU spans 34 countries with 42 TSOs sharing a synchronous transmission grid [2]. Figure 1-2 shows the extent of ENTSO-E in Western Europe, which is completely interconnected and operating at 50Hz, although specific voltage levels will differ for some European nations. Figure 1-3 illustrates transmission and distribution voltages typical for Germany.

Figure 1-2
Detail of ENTSO-E Map Showing Western Europe [3]

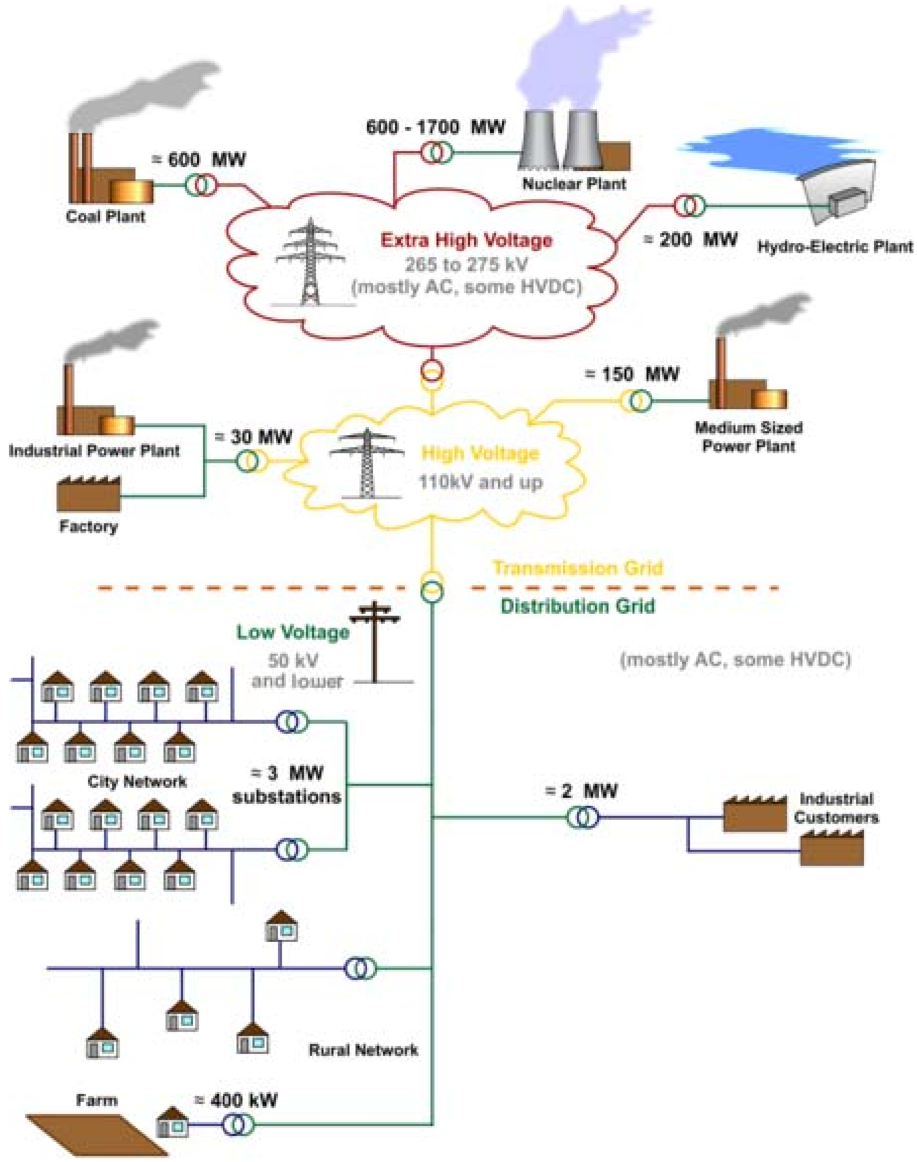

Figure 1-3
Electrical Grid Schematic – Germany and other European Nations [4]

While the Smart Grid will build upon the current electrical transmission and distribution systems, it will have features essential to its operation that will involve telecommunication and monitoring systems to enable two-way communication and interoperability, as well as the optimal integration of distributed energy resources (DER) including storage. Thus, with Smart Grid capabilities, the current framework shown in Figure 1-3 will more resemble that shown in Figure 1-4.

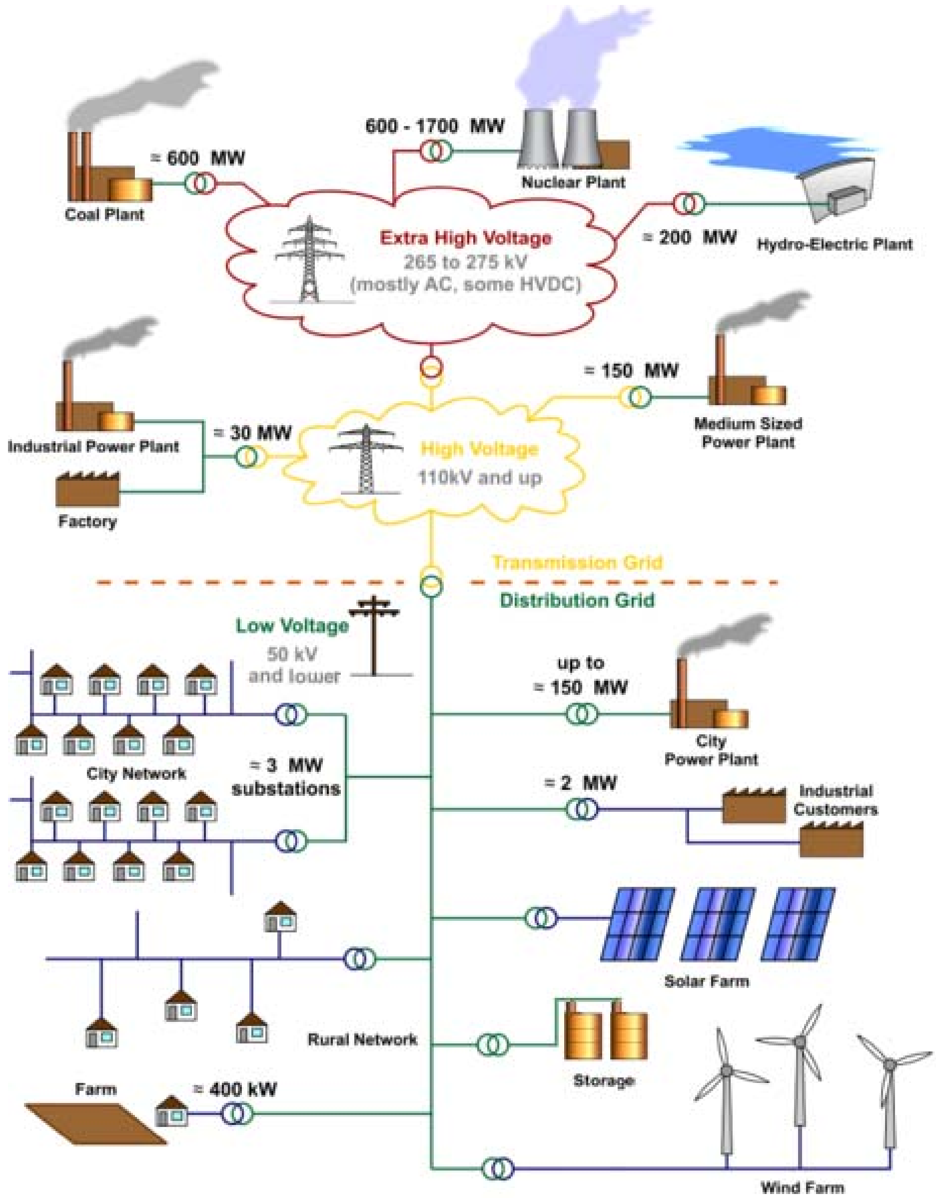

Figure 1-4
Smart Grid Example [5]

With the exception of large-scale energy storage, most of what is pictured in the previous figure exists in some regions of Europe. The main difference will be that instead of merely being *connected* to the grid, all components will be *integrated*. In essence, rather than simply being a passive collection of parts associated with power generation and distribution, the Smart Grid will be an active system engaged in optimizing itself. [6]

The island nation of Japan has a grid system operating at 50Hz on the eastern regions of the island while the western regions operate at 60Hz. Transmission-level voltages may be seen in Figure 1-5.

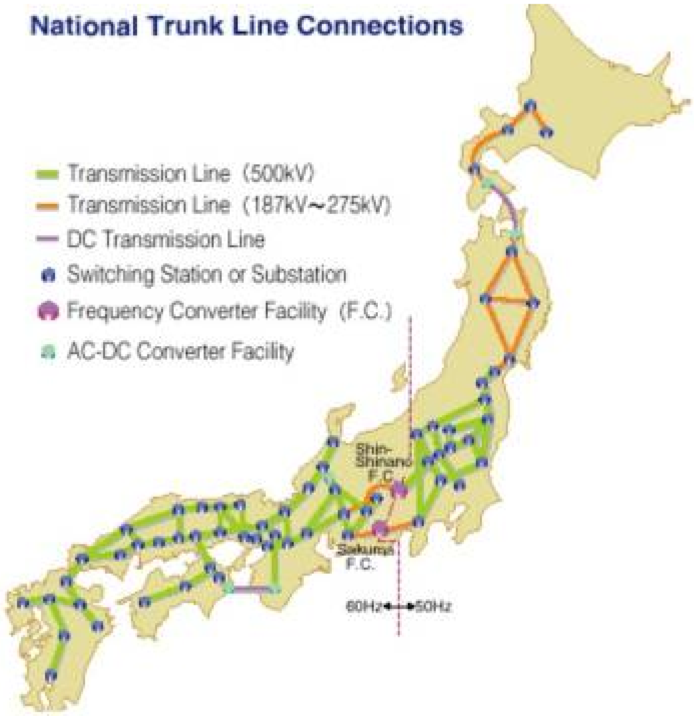

Figure 1-5
Transmission Trunk Line Connections – Japan [7]

2
WHAT IS A SMART GRID?

The state of the current electric power delivery system as compared to the Smart Grid may be compared to today's winged aircraft: the basic design of the airplane is the same as forty years ago, yet, to be operated, modern aircraft must have very sophisticated controls and sensors. The Smart Grid will use the basic design of the electrical system in use today – probably the same major components that exist in the field today; however, the Smart Grid must have many more monitors, sensors, switching devices and sophisticated communication systems that will allow it to be a highly automated power delivery system.

The electrical grid of today and for the last hundred years or so has consisted of centralized generation, transmission and distribution. As shown earlier in Figure 1-1, electrical generation has consisted of one or more large sources of power at a given voltage, stepped up to a much higher voltage level for transmission, and then stepped down for distribution to all end-users, essentially flowing one way from the beginning to the last load in the circuit. Figures 2-1 and 2-2 illustrate the interconnected electric grids spanning North America, Europe and Western Asia. While modern electrical generation and distribution technology is well-established and mature, many constraints, mandates, developments, and demands in the modern world now push power providers in a new direction.

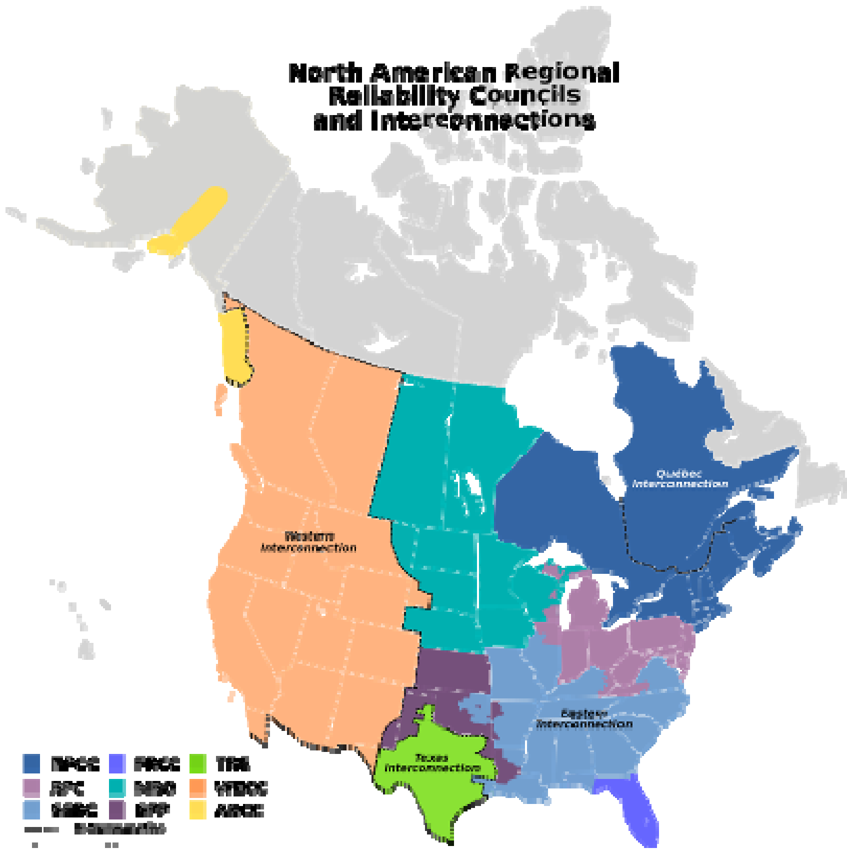

Figure 2-1
Interconnections of North America [8]

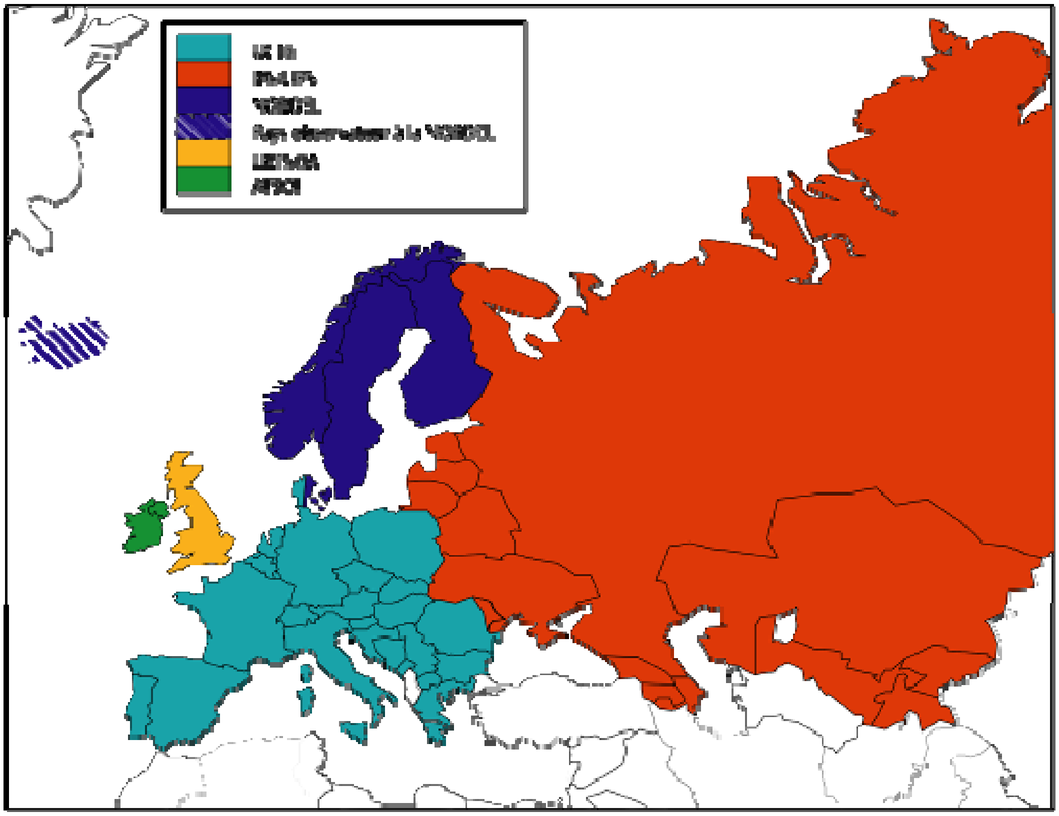

Figure 2-2
Interconnections of Europe and Western Asia [9]

The Smart Grid, rather than the top-down relationship indicated by Figure 1-1, may be considered an interconnected set of domains as in Figure 2-3, consisting of various actors with similar objectives. The actors in each domain may be organizations, devices, computer system or software applications that make decisions and exchange information. Each domain will have secure communications connections with the other actors, whereas the electrical connections will be between Bulk Generation, Transmission, Distribution and Customer as with the current framework – the main difference being that the customer may also be an electrical supplier. [10]

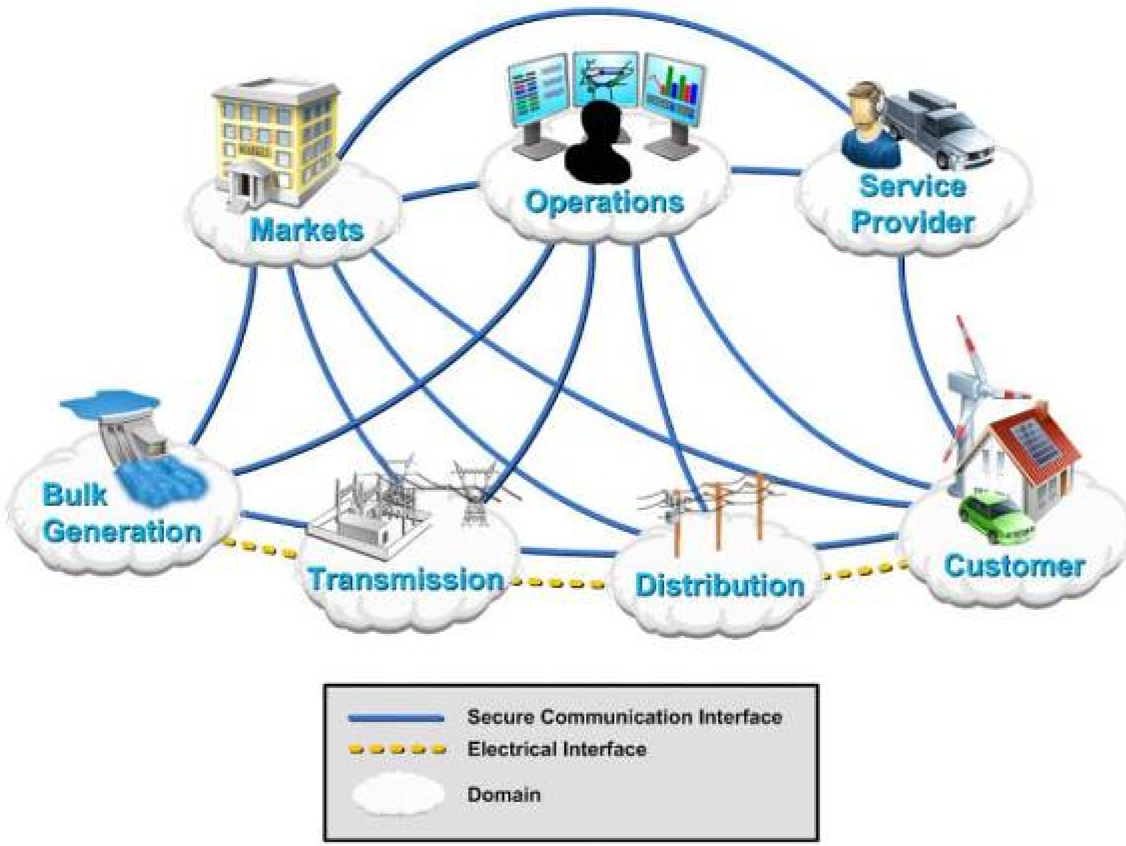

Figure 2-3
The Smart Grid – a Conceptual Model [11]

In the United States, The American Recovery and Reinvestment Act of 2009 (also known as the federal stimulus program) in response to the recent world-wide economic downturn has targeted Smart Grid development. Figure 2-4 illustrates the breakdown of projects targeted by this funding. “Integrated systems” in the figure refers to “Integrating and Crosscutting across Different ‘Smart’ Components of a Smart Grid”.

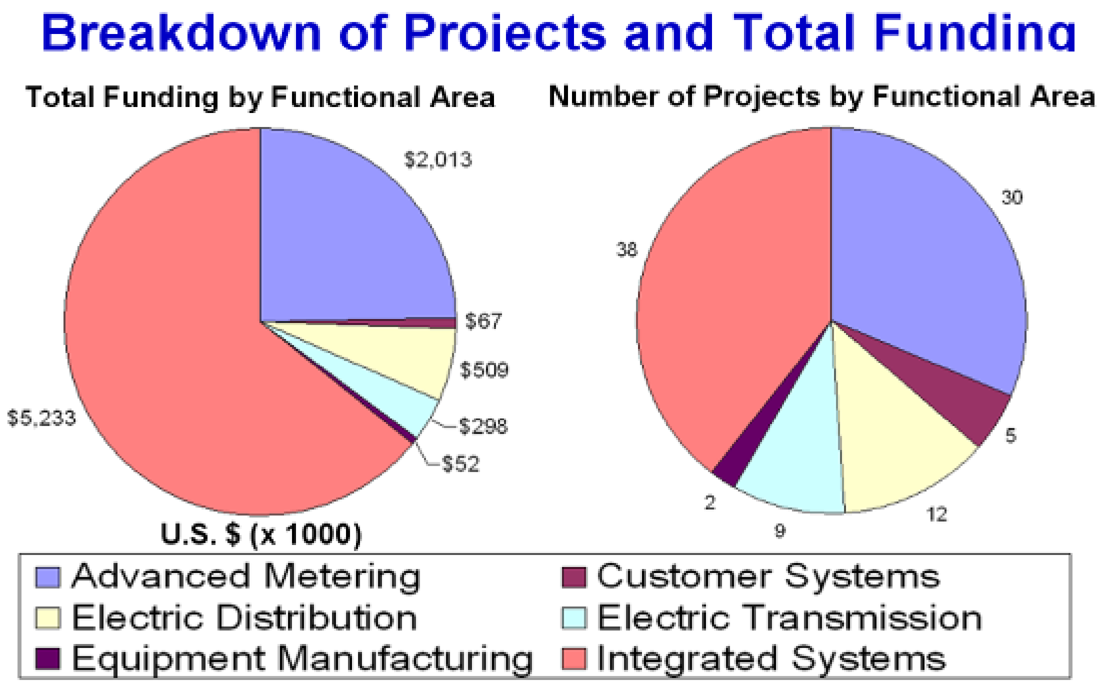

Figure 2-4
United States Federal Stimulus Funding [12]

At the present time, the various components for the Smart Grid continue to develop globally without a definite destination or even definition of what this new direction will become. One common component, the Smart Meter, for instance, may be considered a necessary part of a Smart Grid; however, meter deployments alone will not fulfill its vision. This report, in part, seeks to provide a reasonably accurate definition as well as a destination along with suggestions concerning a path that e8 members may use to achieve a Smart Grid.

The Smart Grid: A Definition

The Smart Grid will be a customer-centered, interactive, reliable, flexible, optimal, economical, economically responsive and, ultimately, a sustainable and environmentally responsible electrical power generation and distribution system. Electric utilities must play a key role in its development.

Customer-centered: The customer may determine – using real-time or near real-time information as to cost of generation, as well as cost to the environment at time of use – his or her most economical and/or most environmentally-friendly use of energy. By enabling the implementation of enhanced dynamic pricing and the use of advanced IT, the Smart Grid will empower the customer by providing him real-time price signals, while optimizing costs for the utilities. At the same time, the Smart Grid will enable the customer to become an electricity producer as well, and thus have the opportunity to be rewarded for electricity generated and admitted into the system.

Note: The customer-centered definition may not cover all countries/companies. For example, the time of use (TOU) works very well in Japan; the system divides 24 hours into several segments with each segment having a different price menu, which brings huge benefits to both customers and power suppliers as well.

Interactive: An intelligent system with two-way communication in real time between utilities, generation systems, transmission systems, distribution systems and customer/end users concerning the state of the power systems, cost of generation and cost of consumption at time of day.

Reliable: With more monitoring devices as well as automation control of the transmission and distribution grid, a far greater capability of both responding to and adjusting grid conditions in real time will become possible. This will yield a more robust, reliable and secure system.

Flexible: Power may come from a variety of sources in different geographic locations including large-scale and small-scale new renewable power sources as well as conventional generating sources.

Optimal: The Smart Grid will allow for the implementation of demand-response programs that will improve matching of load and power supply at any point in time and at least cost, thus optimizing the use of available energy resources. This will also reduce the need for capital investment in constructing excess expensive peak-load capacity.

Economical: Improved operational efficiency, reliability and sustainability will allow the cost of generation and distribution to be kept as low as possible so that the cost to the customer and effects on the environment may also be kept low.

Economically responsive: At any time, relying on the best allocation of resources and merit order of generation capacities, the Smart Grid will enable the utility and customers to improve cost efficiency by using detailed information and data. This data will determine the right price signal and thus will keep the cost of energy generation and use as low as possible, to enable the use of decentralized storage when competitive, decentralized renewable generation if available, and thus, by enabling the 'smart use' of energy. As a result, the need for expensive peak or extreme peak generation will eventually be minimized if not eliminated.

Sustainable: By both reducing the need for building more generating capacity and reducing adverse affects on the environment, the Smart Grid may conserve money and resources, and will, through what may be termed the 'smart use' of electricity, continue to provide adequate electrical power into the future. Moreover, the Smart Grid will foster innovation - allowing new markets and opportunities not possible with the traditional grid.

Environmentally responsible: With its ability to connect sources of energy both locally and from different geographic locations that release fewer or no pollutants into the air or water, the Smart Grid will enable customers to choose cleaner sources of energy. Thus, the need to use those sources of energy that produce more pollution will be minimized. In this way, the Smart Grid has the potential to become the basis for a world-wide, low carbon society.

Through its flexibility – over and above most existing generation and transmission infrastructures today – the Smart Grid makes possible all the objectives above. Moreover, utilities in all parts of the world may pursue all or select only those objectives that relate specifically to their own business objectives and situation whether regulatory, political, economic, or environmental. The Smart Grid will be capable as well of accommodating new and existing technologies.

In the pursuit of a more efficient and economical distribution grid, one possible outcome of Smart Grid developments may be that individual customers will use less power or they may use more of less costly generated power. These changes in consumption patterns may require new or modified business models for utilities. The question emerges: Why should power providers choose to spend money to sell less power? In the future, individual users are likely to use less power through more efficient appliances; however, the Smart Grid will enable many more uses for electricity – e.g. for industry and domestic uses such as electric vehicles – such that power providers will very likely sell more power.

Drivers to Adopt the Smart Grid

The answer to the previous question involves several factors already mentioned – in particular, in developed and developing areas worldwide, electrical power generation is expected to increase over time. The Energy Information Agency (EIA), offers worldwide energy statistics divided into those countries in the Organization for Economic Cooperation and Development (OECD) and those not in that organization (non-OECD). Information from the EIA shown in Figure 2-5 illustrates this expected increase – less dramatic for nations in the OECD but far more dramatic for non-OECD nations. The recent economic conditions in countries such as the United States, for instance, have made for a smaller yearly power generation increase than in previous years according to EIA statistics. It may be seen as well that much of this increased generation, typically baseline, is expected to come from burning coal. The greenhouse gas effect expected from the carbon dioxide (CO_2) released by using coal as a fuel concerns many nations around the globe.

One of the most serious conditions for power providers is electrical usage at times of peak and extreme peak loads. This type of generation must start quickly when needed and may only be needed for a short period of time. Typically, these facilities use more expensive fuel.

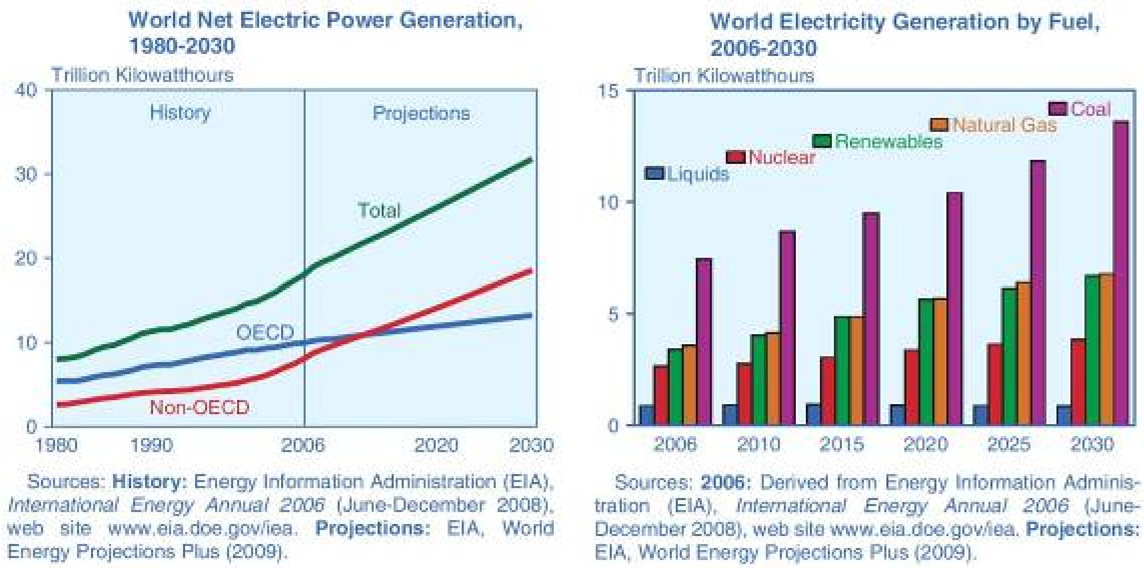

Figure 2-5
Electric Power Generation – History and Projections [13]

Eventually, the increasing load will necessitate new and ever more expensive generation to handle the increase as well as upgrades in infrastructure to carry the load. All of these efforts, if allowed by regulators, would likely result in increased usage rates (called tariffs) charged to customers. However, regulators or policymakers tend to be wary of allowing such increases. Meanwhile, pollution from centralized generation facilities will steadily increase from all but nuclear and hydro; both may be limited by public sentiment or geography – the NIMBY syndrome can sometimes occur as a hindrance to the building of new centralized facilities while most suitable rivers in many developed nations may already have been utilized for hydroelectric generation (although upgrades to existing facilities continue to increase capacity). Coal-fired facilities, then, tend to be the least expensive and most expedient new, large-scale source of electricity to construct. Even so, the public in those regions may oppose any construction of new, central generation facilities – especially those that contribute CO_2, SO_2 and other pollutants to the air and ash waste to the land.

Less-polluting sources of generation developed over the years, known as renewable energy resources, include technologies that use wind and tides, the sun, geothermal and other sources. According to Figure 2-4, the use of these technologies may be expected to increase also. However, these renewable resources are variable to such an extent that power providers may not, as a matter of course, rely on them and yet may in some regions be required by law to accept output from these sources. Another promising source of clean generation that emerged from programs in Space Exploration is the fuel cell. Unfortunately, while producing practically no pollutants (assuming hydrogen as the fuel) and a steady output, the sheer cost of this application along with problematic technical issues make it impractical at the present time for large-scale implementation.

In many developed regions, mounting concern for the effects on the environment from all sources of pollution has made a priority of cutting pollution and CO_2 emissions specifically – particularly in Europe where all EU member states have a mandate to do so.

In 2007, the Electric Power Research Institute (EPRI) outlined a plan for reducing CO_2 emissions in the United States from electrical generation that became known as the Prism, shown in Figure 2-6. Extrapolating from those 2007 levels, CO_2 emissions are expected to increase significantly due in part to increased generation of electrical power. However, by increasing efficiency, using many less-polluting technologies that already exist, and upgrading existing facilities, CO_2 emissions from electrical generation may be reduced well below current levels by 2030. The goals of greater efficiency and reduced production of pollutants and CO_2 may be facilitated by the Smart Grid. Indeed, the Smart Grid may foster the 'smart use' of electricity such that electricity may replace fossil fuels entirely in many residential, transportation and industrial applications. In this way, 'smart use' of electricity may become the basis for a low-carbon society.

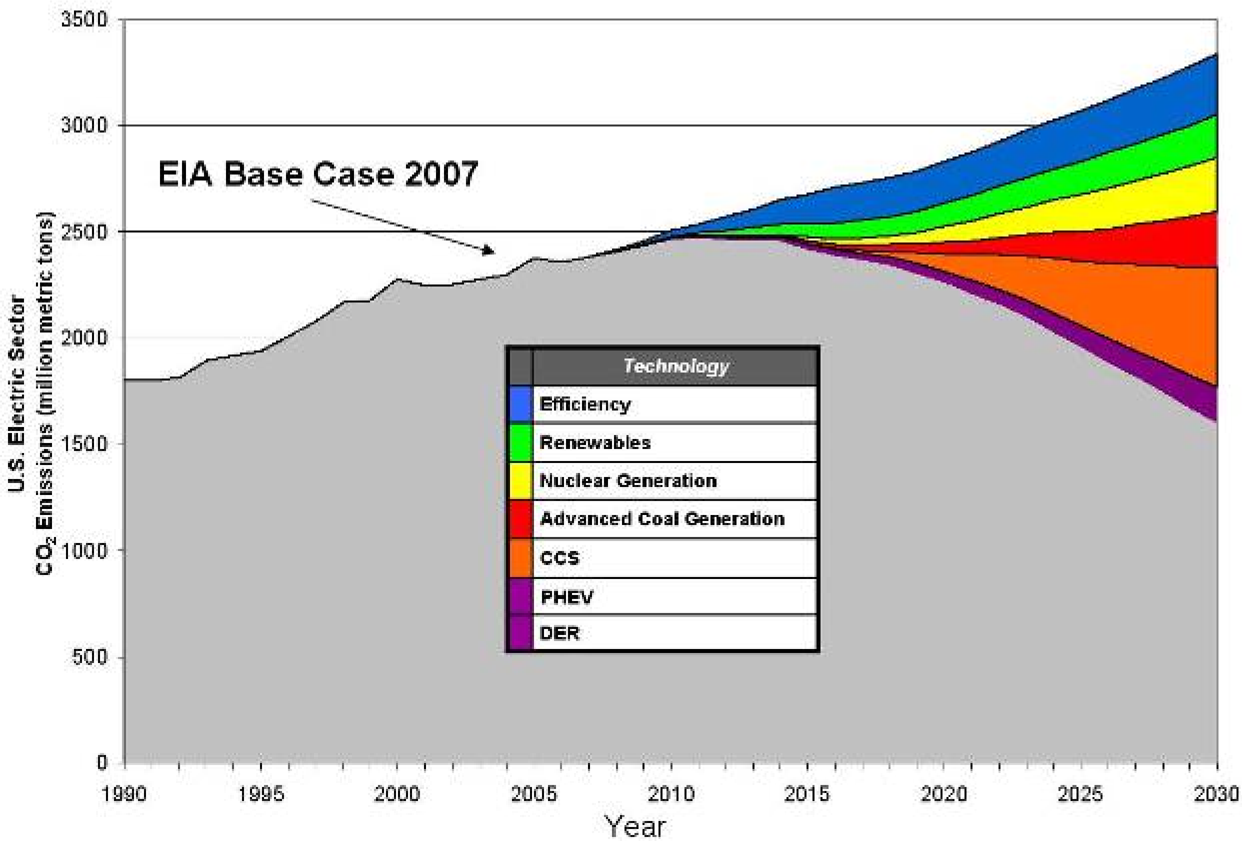

Figure 2-6
The Prism [14]

The advent of vehicles using electricity rather than petroleum will raise new challenges for utilities and customers alike: drivers cannot simply fill up a tank to operate the vehicles and large numbers of electric vehicles charging from homes or workplaces will add entirely new loads to the grid. Slow-charging operations performed overnight may present a lesser challenge to the grid compared to fast-charging techniques executed randomly during the day. At the same time, large numbers of electric vehicles connected to the grid offer a possible source of power for the system if needed. The Smart Grid, controlling the process of "Smart Charging" may be the best way to integrate electric vehicles – both as load and as source – into the electric distribution system.

To address these and other conditions and concerns, the Smart Grid offers an effective means of empowering customers, improving system performance, and improving system power flow and energy.

Leading the world to a low carbon society

Using the Smart Grid, electric utilities may contribute to building a low-carbon society by taking action on both the supply and demand sides, and coordinating policies and technologies.

On the supply side, this would involve shifting to zero-emission power sources in the long term (i.e.; Nuclear, Renewable, etc.), introducing energy-efficient technologies, reducing transmission loss, and so forth.

According to the International Energy Agency (IEA), 19,854,871 gigawatt hours (GWh) of electricity were produced in 2007 while just over 13 million terajoules (TJ) of heat were obtained through the burning of coal, oil, gas, and biomass – processes that release toxic pollutants as well as CO_2 [15]. These statistics hold a significant opportunity for the Smart Grid. As illustrated in Figure 2-7, on the demand side, utilities may encourage the use of energy-efficient equipment such as heat pumps over resistive technologies for heating and cooling residences and buildings – the "Smart Use of Electricity" – to save primary energy. Electricity may replace the combustion of fossil fuels for transportation and heat generation with greater efficiency – a cross-sector feature – and thus reduce CO_2 emissions. In the case of a restaurant, a completely electrified kitchen will require a much smaller sized air-conditioning or ventilation system since the electric appliances, producing no hot exhaust gases, will require less volume for ventilation. Cost reduction, conservation of primary energy, and reduced CO_2 emissions may thus be achieved. This one example shows how shifting to electricity may have a variety of favorable results.

Therefore, not only is it desirable but also practical and effective to seek a low carbon society through electricity-based technologies on both the supply and demand sides. To ensure the integration of more renewable energies, and to promote the smart use of electricity, the platform required to connect both suppliers and customers is the Smart Grid, forming the basis of a future low-carbon community.

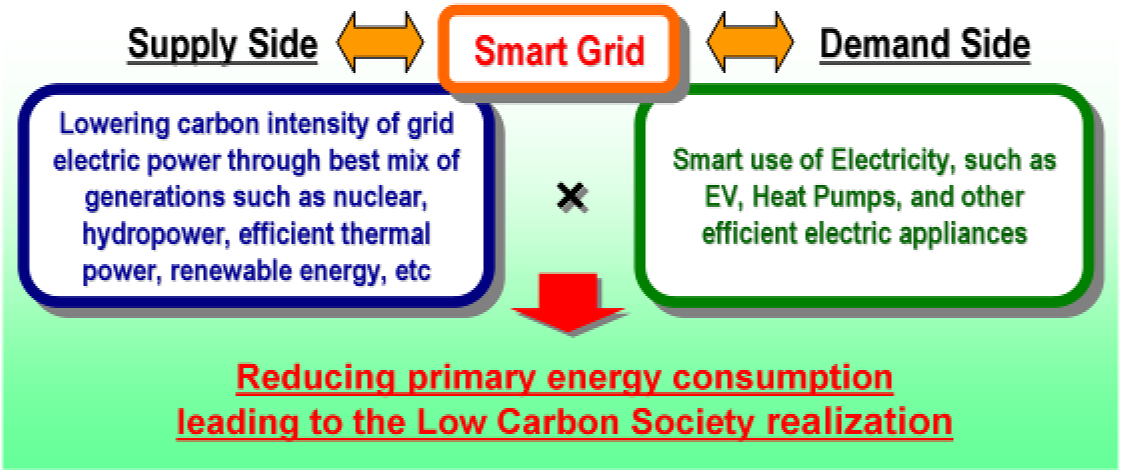

Figure 2-7
Supply-side and Demand-side Integration Using the Smart Grid [16]

Empowering the Customer

The Smart Grid may offer the customer the choice of paying for less-polluting power sources such as wind, solar, etc. described earlier. Furthermore, the Smart Grid may be used to interact directly with appliances now being developed that will allow customers to monitor their energy usage and to turn them on or off remotely using wireless technologies. In a similar manner, then, utilities could turn such loads off during times of peak loading, or communicate the real price for the energy to the customer that the appliances will use so that the customer may choose to allow those appliances to run or not at that time.

Improving System/Network Performance

Reliability

In his testimony before the United States Congress, on May 5th, 2007, Mr. BirnBaum of CURRENT, LLC indicated that "…existing grids are one-way systems for the delivery of electricity without the self-healing, monitoring and diagnostic capabilities essential to meet demand growth and new security challenges facing us today." Further, he described the blackout of the previous year in Queens, New York that left 100,000 customers without electrical power for several days while the utility, using the standard outage detection methods used at the time, diagnosed and responded to the outage. The extent of the blackout was astounding: 40 million customers affected in eight states with an estimated financial loss of $6 billion [17].

Other blackouts have occurred worldwide: Western Europe on November 4, 2006, where five million people were without power for 30 minutes, Greece on July 12, 2004, Italy on September 28, 2003, affecting 57 million people, and Australia on March 14, 2005, among others. The interconnected nature of the European grid heightens the possibility that an overload or outage in one country will have severe effects in neighboring countries – the aforementioned outage in

Italy originated from a transmission line in Switzerland that had come in contact with a tree (It should also be noted that these interconnections allow for a quick recovery as well) [18].

At times of peak load when utilities must decide whether or not to start up peak generation facilities or more drastically, to shed loads, the residential customer may be alerted to this situation through the Smart Grid and may respond by choosing either to pay for the more expensive power anyway, or to turn off those appliances that use large amounts of power until later – perhaps allowing the utility not to require the more expensive energy in the first instance, or to prevent overload conditions in the second instance. An overloaded system can become unstable to the point of complete loss of power or blackout lasting perhaps hours or even days at the present time.

Through Distribution Automation, the Smart Grid will also allow automatic reconfiguration of systems where a short-circuit condition or "line fault" has occurred. Called "self-healing," grid devices activate to isolate the area(s) directly affected by the fault and thus maintain power distribution to adjacent circuits. Where line accidents have caused loss of power, utility crews may respond quickly to the exact location of such outages. Further, the utility crews would know from line instrumentation that power has been either lost or restored to an area rather than having to drive through neighborhoods or the rural countryside either to identify where damage has occurred and power lost or to confirm that power has been restored to those locations. Hydro-Quebec and EPRI have developed precise distribution fault location systems based on wave shape analysis that could serve in this way as Smart Grid applications. ENEL uses fault detectors in its medium and low voltage substations and is investigating, as are other utilities, the use of Smart Meter information for this purpose

Power Quality

Utilities must conform to standards regarding harmonic distortion, over- and undervoltage and other factors. However, "power quality" represents a problem over and above network harmonics and voltage level. It remains a problem largely for the customer at the present time. Utility line operations, for instance, that switch various loads or customers that operate large motor loads at random intervals may produce power quality variations in the distribution system that upset sensitive industrial devices or equipment. In many areas currently, the industrial customer – sometimes with the help of the utility – must solve these power quality problems. The Smart Grid may allow active power quality improvement through customer services that offer real-time power quality monitoring and remediation of variations such as momentary outages and voltage dips.

Improving System Power Flow and Energy

Losses in the power system due to line and equipment resistance reduce system efficiency. These losses result in part from additional load current needed to supply reactive power (VARs) as illustrated in Figure 2-8 using the Power Triangle. Typically, inductive VARs – the vertical line of the triangle – are due to the magnetizing current required for inductive loads to operate multiplied by the voltage across the load (i.e., volt-ampere reactive or VAR). To supply the real power (Watts) that produces the actual work associated with a load (e.g. heat), the utility must also transmit extra current to supply the VARs. This extra current produces additional losses that are a function of resistance times the square of the total current, or I^2R. In the figure, the angle of VA with respect to W is known as the power angle; the cosine of the power angle is the power factor. As the power angle *decreases* (green line), the power factor more closely approaches the value of 1.0, the cosine of 0˚. At unity power factor, VA and W are equal – the ideal condition at which point no VARs are present. The quantity of watts will not change (assuming the same load) as the power angle changes. The value of VARs and VA will change – both increasing with the increasing power angle (decreasing power factor).

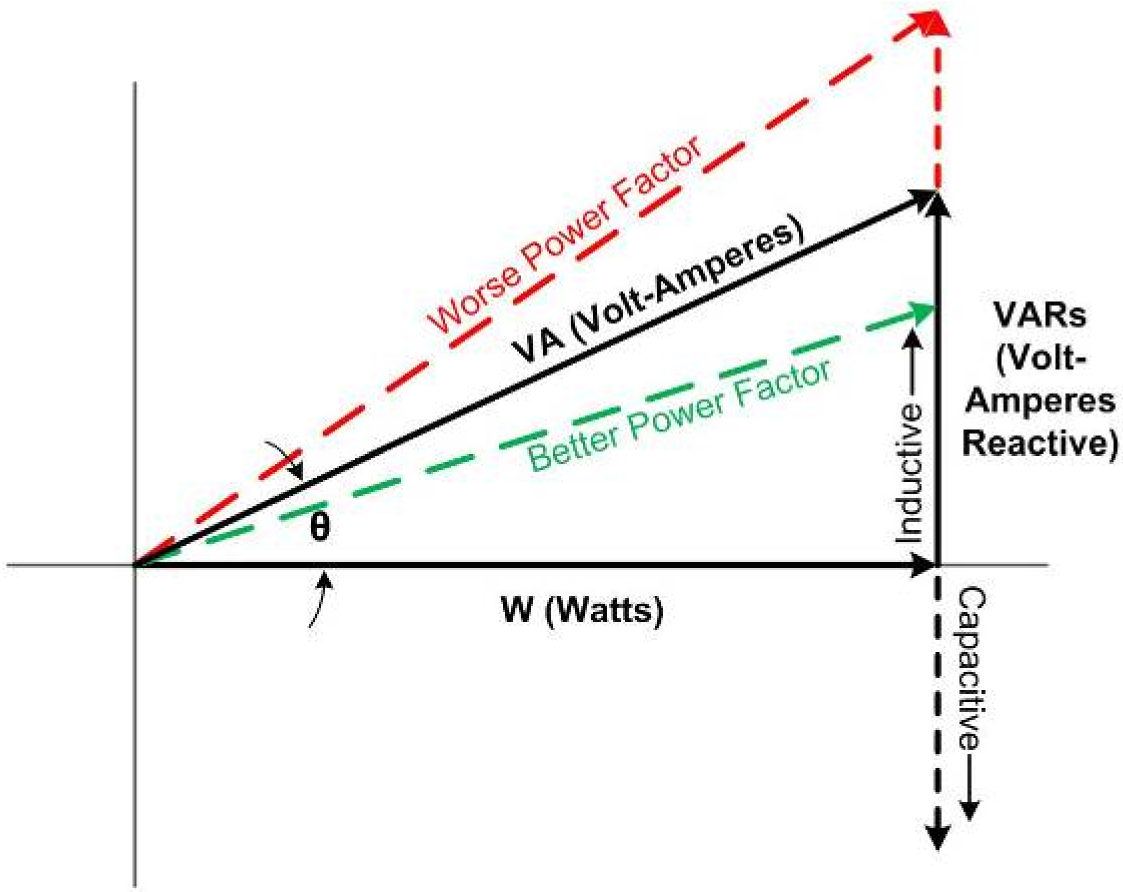

Figure 2-8
The Power Triangle [19]

The figure also indicates that capacitive VARs counteract inductive VARs; therefore, the power angle may be reduced and the power factor may be increased (approaching 1.0) by connecting capacitors to the power system. In this way, line current may be reduced, line voltage may be reduced and system efficiency may be increased – less power need be transmitted to support the same load. While utilities have long employed line capacitors with discrete controls (e.g. time clock) to accomplish this task, the Smart Grid, using Volt and VAR optimization (VVO), could respond in real time to power factor conditions and changes thus keeping the system voltage as low as possible and the grid as efficient as possible. In addition, reducing the voltage supplied to the load (end-use customer) has been shown to also reduce the end-use energy consumption (kWh). *In a carbon market, each kWh saved may have a monetary value*.

In Summary

These drivers for the adoption of the Smart Grid may thus be summarized:

- Empowering the customer
  - *Through price signals and through technology (Integration of electric storage, e.g. through electric vehicles)*
  - *The ability to integrate Distributed Energy Resources effectively*
  - *The capability of adjusting end-use load to match the available supply in near real time (e.g. through dynamic pricing signals and/or direct load control)*
- Improving system performance
  - *Reliability through automatic reconfiguration, or "self-healing"*
  - *Power Quality improvement through better understanding and control of the operating power system*
- Improving system power flow and energy
  - *The ability to respond in real time to changes in load or line condition to improve efficiency and reduce losses*
- For carbon markets, the Smart Grid may also enable reduction of CO_2 emissions through improved efficiency and enhanced integration of intermittent DERs
- Resource constraints
  - Finding sites for central generation facilities
- Global Climate Change

The Smart Distribution System described above is a continuity of what utilities have been doing for several decades (improving performance and power flow) by applying new computerized and telecommunications technologies and developing modern applications to increase performance and power flow. These applications represent challenges that depend on each utility's context (customer satisfaction on reliability and PQ, legacy systems, geographical situation for telecommunication access, etc.).

Barriers to Adoption of the Smart Grid

Implementing the Smart Grid will involve new investments in various components and technologies that will enable real-time communication and control at multiple points of the grid. Some existing equipment that functioned adequately in the old grid may not fulfill the demands of the Smart Grid making premature replacement necessary. Regulatory agencies in various regions may not have experience with the Smart Grid concept or understand its potential and therefore may be reluctant to allow its adoption. Consequently, without buy-in from these agencies, utilities may be reluctant to proceed with Smart Grid initiatives on their own as they may not be allowed to recover their new investments or those previous investments in existing equipment rendered obsolete by the Smart Grid.

Although companies currently design equipment for the future Smart Grid, no standards exist to guide the development of such devices. This absence of a generally-accepted standard may prove to be a barrier.

The Smart Grid will greatly change the way many residential customers have always used electrical power as they would have to consider the actual cost that power at TOU. These customers may prefer the convenience of the old way, to keep to the way things have always been done – especially if, compared to the old way, the new way has the potential to cost them more money should they lose track of their energy usage. To use the telecommunication industry as an example, many customers have discovered to their shocked surprise and consternation that a family member using their chosen cell phone plan (one of many confusing plans) has, through texting, internet access or some other function accomplished using the cell phone, caused a month's charge to number in extra hundreds or even thousands of dollars!

The access to and information available from customers through the telecommunications technologies that will be used will also cause concern for data privacy and cyber security.

The technologies required to realize the Smart Grid in all of its functionality may not yet exist along with the skilled workforce to implement and maintain it.

These barriers to the adoption of the Smart Grid may thus be summarized:

- Regulatory uncertainty
- Economic disincentives
- Reluctance to change the existing system
- Data privacy and cyber security
- Available technology and required skills

3
ACHIEVING A SMART GRID

The Smart Grid may be envisioned as a complex, interconnected set of power sources and users with the potential for two-way communication and interoperability. Figures 3-1 and 3-2 illustrate this idea. Many new technologies, devices and systems will be required to build the Smart Grid of the 21st century.

Figure 3-1
A Smart Grid Concept [20]

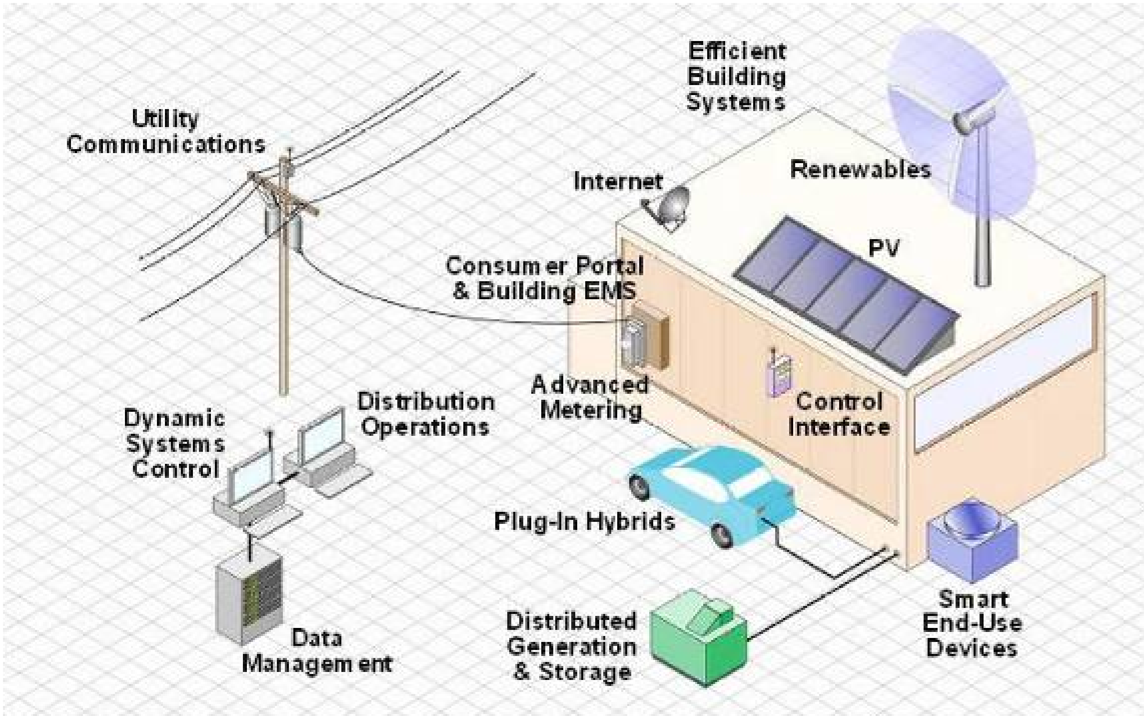

Figure 3-2
A Home Area Network (HAN) [21]

Applicable Components

The physical components of the Smart Grid may fall generally into two categories seen earlier: those that empower the customer and those that improve system performance and power flow:

- Empowering the customer
  - Meter technologies
  - Telecommunications technologies
  - Demand-side technologies (including hyper-efficient appliances and home automation)
  - Distributed energy resources (DER)
- Improving system performance and power flow
  - Telecommunications technologies
  - Grid Intelligence and Tools
    - System monitoring
    - Data management system
  - Energy efficiency tools
    - Predictive tools coordinated between generation, transmission, distribution and the customer side

For customers as well as utilities, the Smart Grid, through the above components, will provide better information on consumption, will allow tailored tariffs, increased quality of supply and service, and increased customer choice. For the network operator, the Smart Grid will allow savings in operating cost, increased lifespan of existing infrastructure, and greater customer satisfaction. For the electric power system as a whole, the Smart Grid will enable greater energy efficiency, demand management, peak shaving, increased DER capacity and integration, increased EV hosting capacity and CO_2 reduction.

Although the Smart Grid does not yet exist as such, certain aspects of what will become the Smart Grid appear in some e8 countries already. Moreover, specific devices or techniques may already exist commercially and/or may be part of pilot projects currently underway in various geographic regions. A description of these technologies follows.

Meter Technology

Advanced Metering Infrastructure (AMI) offers definite advantages and opportunities over the conventional power meters currently in use around the world. With the old-style non-communicating meters, a person must travel to every meter location (in some areas, *inside the residence*), then translate and manually record the information registered on the meter dials. AMI devices, however, may be read remotely – perhaps using wireless technology, perhaps using dedicated communication lines or a combination of both. Thus, tremendous savings in labor may be achieved with this technology alone. Because manual meter reading increases the likelihood of misreading, AMI devices will ensure accuracy as well. The addition of two-way communication through the Smart Meter enables real-time transfer of information such as price signals, thus enabling the customer to adjust energy usage accordingly. AMI technologies already exist; e8 members already using them seem satisfied with the results.

Telecommunications Technologies

Utility Operations

More advanced communication for utility operations combined with sensors will allow for better operation and maintenance of distribution networks as well as quick identification of outage location and repair. These sensors will serve to monitor for power quality variations as well.

Utility to Consumer

Advanced communication will allow for the remote reading of meters thus allowing more accurate and dependable billing. Where this has been applied, e8 members report considerable savings over manual reading.

Consumer Operations

Advanced communications will enable users of electricity to manage their own consumption day by day – perhaps even in increments of hours or minutes – rather than only to react to the subsequent bill for actual use of energy one month or so after the fact.

Demand-side Technologies

On the customer side, the Smart Grid will make possible such things as Smart Appliances for the home or smart manufacturing equipment for industry that may turn on or turn off according to information on real-time pricing or carbon-dioxide impact, where applicable, for the power being received. Buildings or communities that store electricity (consistent with the Net-Zero concept*) may as well store and later release energy into the grid according to such information. Developments continue with Smart Appliances and some e8 members think this technology may be mature in 5 to 10 years.

* The building may be autonomous from the electrical grid and does not contribute carbon emissions

Distributed Energy Resources (DER)

Although regulations and requirements for DER differ from region to region, the communication capabilities of the Smart Grid will better enable the integration of these diverse power sources – some of which require further development to be practical.

Renewable Generation – photovoltaic, wind, and other decentralized energy sources. PV and wind generation are available today and the technologies continue to improve in terms of energy output and cost.

Energy Storage – battery, pumped water storage, compressed air, electric vehicles and others. Battery technology requires further development – perhaps 10 years – before it may be considered mature enough for economical deployment. However, these technologies will be essential to moderate the variable effects of PV and wind.

Fuel Cell – PEM, Solid Oxide and others that convert fuel to electricity electrochemically with no combustion. These technologies continue to improve, yet remain too expensive for massive deployment.

Combined Heat and Power – non-utility sources where industrial processes produce heat or power or both.

Grid Intelligence and Tools

Perhaps one of the most significant outcomes of the Smart Grid for Utilities is that it will provide detailed information in real time concerning the state of the grid both overall and at specific locations. This information, in both detail and timeliness, will allow for quick action in adjusting grid conditions that might otherwise result in power interruptions.

System Monitoring

With large numbers of sensors deployed throughout the electrical grid, utilities will be able to ascertain exactly where problems are developing rather than waiting for a call from a customer without power. Power providers may access a wide range of system data using different types of sensors designed to measure different parameters such as voltage, current flow, temperature, power quality and others. Thus, the Smart Grid will enable a power provider to support its particular goal(s) such as power quality monitoring or real-time monitoring for volt-VAR optimization. The Smart Grid will enable the integration of system sensors with AMI as well. While some e8 members already have transmission systems with much improved system reliability, the technology for allowing system monitoring may take another 3 to 5 years to reach maturity. Compared to the transmission system, far fewer sensors have been deployed on the distribution system. Since most Smart Grid technology will be implemented on the distribution system, the integration of data from the smart distribution system with that from customer installations – through AMI or other technologies – should result in further improvements in efficiency and reliability.

System Operation/Management

Real-time information about the state of the grid may allow common system operations to become automated on both the transmission and distribution systems. The Smart Grid could thus enable automatic system configuration, fault location or predictive maintenance based on wave shape analysis.

Planning

Historical information recorded from sensors may be used for demand forecasting and refining load curves at both high and low voltage levels. Time-sequenced information and penetration levels of various Smart Grid resources may be modeled and simulated to better understand system impacts and benefits prior to mass deployment of such resources. Through analysis of the system's parameters and subsequent billing, energy theft could be quickly recognized and the location identified.

Customer Offers

With its communications technology, the Smart Grid will enable utilities to tailor rates to suit individual customers – especially residential customers – by offering incentives to purchase "smart appliances" to home management systems featuring bill management, appliance monitoring and other services. The utility may even partner with other providers of services such as cable television and security services.

Recent trials in Europe as well as parts of the United States indicate both the challenge and opportunity presented by customer offers if the customer must choose. The United Kingdom has offered an “Economy 7” TOU tariff for several years for much cheaper power used between 1 AM and 8 AM – only around 15% of households have opted for this tariff. Similar results have occurred in the state of Texas in the United States. A similar reception may be awaiting a dynamic tariff perhaps because customers have no easy method of determining their benefits vs. costs. Therefore, the power provider must meet this challenge by providing as much information to the customer as possible concerning the price of power at time of use as well as strategies for customers to use energy most economically. [22]

Policy and Regulatory Needs

Current policies and regulations in many regions reflect the intent to govern the mature electrical grid of the past as well as related technologies – not the developing platform that will characterize the Smart Grid for perhaps a decade or more. Moreover, such policies and regulations vary between countries, states and regions. Some countries seek to promote the Smart Grid while others have taken no action; some countries mandate carbon reduction while others mandate DER integration; others may have no real policy on carbon or DER. Conflicting government policies and regulatory bodies render attempts to implement the new Smart Grid more difficult.

In all countries, a clear policy commitment at the governmental level supporting Smart Grids would allow regulatory rules to change – specifically those regarding cost reimbursement. Currently, the Smart Grid is evolving and is likely to continue to do so for some years. Today’s technology or even the next generation may be obsolete well before their investment has been recovered. Accelerated cost recovery, then, would allow utilities to make investments now and later as technology improves. Furthermore, for the Smart Grid to allow for the more efficient use of transmitted electrical power, tariffs must take into consideration the actual cost of providing that power at time of use rather than an arbitrary or average rate.

One strategy available to utilities regarding policy-makers applies to transmission and distribution (T&D): policy-makers may not be able to mandate dynamic tariffs for residential customers; however, dynamic T&D tariffs for the power suppliers may be possible. Thus, the actual cost of power production would be passed on to the customer. In this way, customer behavior may be modified and incentive for adopting dynamic tariffs in the long term may be established. [23]

Financial Commitment

The financial commitment necessary for implementing a Smart Grid would seem to depend on the starting point. Some e8 members already have implemented automation within their electrical systems to improve reliability while others have deployed Advanced Meter

Infrastructure alone in limited quantities. Financial numbers from those e8 members who have attempted to estimate the cost of full implementation range from $1 billion USD in one geographic region to $16 billion USD for an entire country. Smart meters in one region appear to show a pay-back time of about 4 years while substation automation at the medium and low voltage level has allowed one utility to avoid penalties – even receiving a bonus from its regulators due to the improved reliability.

In a carbon market that assigns a monetary value for each ton of CO_2, the number of kWh saved may better justify the deployment of VVO devices over millions of Smart Meters as the former may be much less expensive.

Plan/Process

At the beginning of the process of Smart Grid implementation it may be advisable – perhaps even imperative – to engage with as many groups having an interest in the project as possible besides the regulating agencies controlling the area of implementation. Members of e8 who have succeeded thus far with their current efforts partnered with consumer groups, commissions as well as vendors of the technology to be used. Past demonstrations for regulators helped educate them about the technology, its purpose and benefits. Several members have on-going or planned demonstration or pilot projects. The success of these projects will aid greatly in convincing those agencies of the merits of the Smart Grid.

Each e8 member has its own approach and focus depending on the current state of development for each with regards to the Smart Grid. For instance, e8 members in Japan already have very stable grid systems and are more directly concerned with creating a low-carbon society. One member in Northern Europe is concerned with DER integration due to their abundance of wind energy. Europe in general is driven by an initiative called “20/20/20” that members hope to achieve in part through the use of the Smart Grid. Meanwhile, in North America, relatively small pilot projects have been undertaken by e8 members in the United States and Canada regarding AMI, distribution automation and line optimization. The Italian e8 member, focusing on the issues set by the European 20-20-20 proposal, seems to be well on its way to achieving a “smarter” grid. In addition to improved reliability, installed smart meters provide two-way price and contract communication at the meter.

Major Successes

Improved distribution reliability through automation has already been demonstrated through astoundingly low interruption rates by those e8 members who have implemented it. System Average Interruption Frequency Index, or SAIFI, value for e8 members in Japan are below 0.2 for the last eight years while System Average Interruption Duration Index, or SAIDI, value falls under five minutes. One e8 member in Europe reports SAIDI numbers less than 20 minutes and less than 17 minutes for the last two tears respectively. By comparison, a the SAIDI value for a neighboring country was 43.69 during the same time-frame while, for some regions in the United States without similar automation and considered otherwise above average in reliability, SAIDI numbers have exceeded 60 minutes for the last eight years and have even exceeded 100 minutes for six of those years. SAIFI numbers as well have exceeded 0.70 for the last five years and exceeded 1.0 for one of those years. Clearly, effective distribution automation allows for enhanced reliability.

Where AMI/Smart Metering has been implemented, utilities such as ENEL report improvements in transparency – the customer may read his/her energy consumption, rates, and contract on the meter display. Billing is based on up-to-date meter readings. Customer inconvenience of on-site visits are eliminated by remote and fast contract changes (connections, disconnections, rates, voltage, subscription transfers etc.) performed by the contact center. Human error in manual meter reading is eliminated resulting in fewer complaints and disputes. ENEL also reports reduction of power disruptions and repair time. Other benefits from using AMI include: invoices for energy reflect real consumption; billing expenses are reduced; peak shaving and reduced load also allow for lower energy costs and reduced carbon-dioxide production; improved customer satisfaction, operational cost savings and others.

By working with regulators and other interested parties, other members such as Duke Energy have experienced success in being allowed fairly large-scale Smart Grid pilot projects.

Many other pilot projects of e8 members concerning distribution automation, different kinds of tariffs, volt/VAR control, AMI, and other aspects of the Smart Grid have just begun or have yet to be started; therefore, the benefits and lessons learned will be determined at a future date.

Major Challenges

The most serious impediments to implementing the Smart Grid, whether in total or in part, involve regulatory agencies and customers. Rather than assume that the public will understand and accept the Smart Grid, utilities must present an appropriate business case or cases showing its value, and communicate the value effectively to regulators and customers. This helps both groups understand what the Smart Grid is and the service improvements it may accomplish. Likewise, the utility must educate customers and consumer groups about the benefits of the Smart Grid and how to realize them. Otherwise, the lack of effective communication regarding the new technologies and the Smart Grid may result in unanticipated resistance.

A specific challenge associated with Smart Grid investment is one of timing – all the substantive costs are incurred over a relatively short deployment period (including equipment and installation costs, IT and communication requirements, data and billing systems, etc.), while the consumer and utility benefits are realized over time. Appropriate financial incentives will certainly spur additional investment in Smart Grid deployments and utilization of technology. Beyond the advanced recovery of costs, such incentives can take many forms including pre-approval of costs, advanced depreciation for replaced equipment, accelerated depreciation for Smart Grid equipment, enhanced rate-of-return, etc.

The technology currently available may not be at a sufficient level of development or cost. In the automotive industry, for instance, electric vehicles hold the promise of reducing automobile-produced CO_2 emissions dramatically; however, the state of battery technology required and cost compared to the present mature automobile technology prove to be a disincentive for many customers who would otherwise want to own an electric vehicle. In the power industry, energy storage and carbon sequestration technologies may currently pose similar problems.

Challenges posed by perception and misunderstanding may be overcome in large part through effective and continuous communication. Engaging policy makers, regulatory agencies, customers and consumer groups as well as technology suppliers throughout the process of approval and deployment will minimize the occurrence of surprise and opposition at the last moment. Effective demonstration projects will help convince regulators and customers that the benefits justify the costs. Examples follow:

EDF (France)

EDF is focused on full integration of all the electricity system's elements a single, efficient, customer-oriented system that will allow the customer to manage consumption and that will enhance cost-effectiveness for utilities. Currently, a test deployment of 350,000 smart meters in Lyons and Tours will allow remote interruption, two-way communication, various price signals, and information on load curves and supply quality.

Accomplishments to date include real-time generation and transmission system and middle voltage to 20kV operation, real-time diagnosis and restoration on very high and middle voltages, real-time price signal and load shedding for industrial customers as well as real-time electronic metering with automatic switching and billing.

Current challenges include integration of intermittent renewables, real-time data management in low-voltage grids below 20kV and supply-demand balance in real time.

AEP (US)

AEP's initiative in Smart Grid deployment is called gridSMART^{sm}, an integrated system involving 10,000 customers in South Bend, Indiana. This system explored direct load control (DLC) and uses GE I210 smart meters that allow time of use (TOU) pricing and serve as a customer web portal. Successes to date include very positive feedback from customers concerning the project. Web-based energy information provided consumers information on their individual usage.

Challenges involved communication between devices involving Zigbee compatibility.

KANSAI (Japan)

The focus of KANSAI is to achieve a low carbon society. Already having an extremely- reliable grid system, KANSAI is working to achieve an efficient, high-quality and reliable power system with efficient generation and to transmit and to use electricity by applying ICT and other new technologies such as storage batteries. Increasing photovoltaic generation and use of electric vehicles is seen as an important step in the direction of reducing CO_2 emissions. The challenge remains of effectively integrating DER into the grid.

TEPCO (Japan)

Working with KANSAI, and also having a system with similar reliability, TEPCO has implemented a field test program using smart meters for roughly 1000 of TEPCO and KANSAI customers. The goal is to evaluate the effects on load levelling from visualizing energy consumption, peak pricing, real-time pricing, and direct control of air conditioners. The project is currently being evaluated.

Future efforts will develop the next generation of generation distribution and demand-side technologies for balance and voltage control.

RWE (Germany)

A step-wise modernization undertaken to increase the flexibility of its grid has been the focus of RWE with consideration that both new and replacement construction be upgradable to incorporate Smart Grid technologies in the future. Therefore RWE set up several projects with the government and several partners (universities, industry, etc.) to research the functionality and integration of SmartMeter (AMI) and E-Mobility into the Smart Grid strategy. In the Project "Mühlheim zählt" –for example- 116,000 meters will be installed by the end of 2011 and backed by a comprehensive accompanying research.

RWE focuses also on investing in solutions for integrating renewable energy sources regarding storage for highly variable DER. The variability of DER remains one of the more difficult challenges of electric grids around the world but especially for places with lots of wind at one point in time and then little or no wind at another. RWE is investigating various methods and tariffs that will aid in this integration as well as "Smart Home" applications.

Hydro-Québec (Canada)

Hydro-Québec is fortunate to have a large amount of hydro-electric generation at its disposal. (36 810 MW – 98 % hydraulic). Because of Québec's specific context, which is characterized by long transmission lines, harsh weather, and customers' reliance on electricity for their heating needs, very high standards and various mitigation plans have been used in the system design to ensure the transmission system reliability.

Smart Grid projects are now focused primarily on the distribution system.

To improve the reliability of its distribution system, H-Q is implementing remote control of 3750 MV switches and breakers on 1000 feeders. So far, with roughly half of the switches and breakers remotely controlled, reliability is improving.

A Volt and VAR Control project at the distribution level is targeting to save annually 2 TWh. Hydro-Québec will install equipment at the end of 1000 feeders to monitor and control the voltage and VARs. Field measurements from pilot project have confirmed thus far the benefits of this approach.

Pilot projects currently underway seek to increase operational efficiency by eliminating manual meter reading through the use of AMI. An additional benefit will be to take advantage of AMI deployment to facilitate the gradual implementation of additional Smart Grid components and strategies.

Duke Energy (US)

Working with stakeholders and groups who have different perspectives and concerns has proven to be a major Smart Grid implementation challenge. Duke Energy worked with roughly eleven Ohio stakeholder groups that were understandably skeptical about Smart Grid. However, through effective communication with its stakeholder groups, pilot programs, and a strategic choice to develop the most adaptable platform possible with regards to the evolution of technology, Duke Energy received approval to start its program. Duke Energy produced educational/persuasive videos and constructed an "Envision Center" exhibition space where stakeholders and political representatives could witness firsthand the benefits of Smart Grid.

Lessons learned from the effort have largely to do with communication: public perception is important and the company process should be transparent to stakeholders. Smart Grid deployment is complex. We may therefore be better served by breaking project information into smaller, more manageable "bites."

ENEL (Italy)

The liberalization of the Italian electricity sector in the early 2000's led to one of the most competitive markets of its kind in Europe. Nowadays Italian customers may choose among many possible suppliers. The process has triggered growing competition between energy providers and continuous performance improvements in terms of service reliability and quality to satisfy customer demand. Eleven years ago, facing this increased customer-centric commercial approach requiring differential tariffs, value added services and reduced services provisioning time, ENEL pioneered the **Telegestore** Project, an automatic meter management system (AMM), completed in 2006 with an investment of € 2.1 billion over a five year period. The endeavor's benefits shared by customers, power system and the utility, convinced the Italian Authority for Electric Energy and Gas to require all Italian customers to be equipped with automatic meter management by 2011.

In addition to its AMM system, ENEL has also introduced a set of innovative Smart Grid solutions, realizing the remote control of more than 100,000 MV/LV substations (i.e. 30% of the system) and the complete automation of most of them (with automatic fault clearing procedures), the Work Force Management system that represents a radical change in the crew management, the optimization of asset management policies based on a cartographic census of network assets and on a database of network events (power outage notification, fault detection etc), and the network investments optimization based on an ad hoc risk analysis.

Having already deployed Smart Metering, automation and control of MV network and Advanced Asset Management (methods and system support), ENEL is now focusing on advanced integration of Distributed Energy Resources (DER), developing a smart EV recharging infrastructure fully integrated in the grid and in the legacy ICT systems, and finalizing the "Smart Info" device, which represents the first step towards customer awareness and active demand, making available the data managed by the Smart Meters in the indoor environment, to allow the development of energy efficiency services.

4 RECOMMENDATIONS

The Role of the Utility Industry

The process of designing and implementing the Smart Grid requires leadership. The failure of the utility industry to embrace this responsibility would likely result in a missed opportunity to guide Smart Grid development – or prevent it from occurring at all. Moreover, utilities not working *together* to guide Smart Grid development will risk a future hodge-podge of conflicting device and software technologies between regions due to the lack of standards. If the Smart Grid holds the promise of greatly improved customer-empowerment, reliability, reduced cost and reduced pollution, some entity somewhere is likely to take control of it leaving utilities to adapt their efforts, or worse, abandon earlier efforts to align to a new direction.

Therefore, utilities – being experts in systems-oriented drivers such as reliability, power quality and system energy efficiency – must take the leading role in the development of the Smart Grid by actively engaging with and providing their broad expertise to all interested parties and stakeholders including government policy makers, regulatory agencies, standardization organizations, consumer groups, customers, equipment manufacturers and research institutes. Such engagement will require commitment both in time and resources in the coming years. Likewise, the aforementioned stakeholders should realize that utilities possess significant knowledge and experience with in the power industry and must be included in all aspects of the Smart Grid.

Research and Development/Technology Needs

One important aspect of the Smart Grid development involves standards. Prior to the broad implementation of television broadcasting, for instance, standards had been written so that broadcasting technology and receiving technology would be compatible. The technological aspects of a Smart Grid require intercommunication and compatibility. Currently, no generally-accepted standards for the Smart Grid or its components exist although several organizations such as NIST and EPRI currently are working with standards organizations such as IEC, IEEE, ANSI, ISO, CEN as well as industries involved in an effort to develop them. The IEC 61850 series, for instance, involves interconnectivity of monitoring resources that would be useful for Condition-based Maintenance – that is, replacement of equipment based on its present condition rather than a prescribed schedule or after it fails. The Smart Grid would enable the monitoring of equipment for predictive maintenance in this way.

With or without an accepted standard, products are currently being manufactured to be used with the Smart Grid. The technology and system performance of various parts of the Smart Grid must be validated with component and subsystem testing and modeling/simulation or pilot testing prior to mass deployment. Therefore, the utilities should bring all such groups together – standards organizations and manufacturers – and provide to these groups their expertise in power systems engineering, telecommunications, energy markets and other areas.

The utilities will deploy these products and will be greatly affected by adopted standards – particularly those regarding information transfer, interoperability, cyber security and data privacy – and utilities should be engaged by these groups in order to coordinate all such efforts to assure that standards and equipment designed to those standards support Smart Grid deployment as well as operations and management.

Policy and Regulations

The danger inherent in legislative actions regarding the electrical grid is that the right policy does not emerge to support Smart Grid deployment. Likewise, policy decisions regarding the Smart Grid made too early may inadvertently hamper its future development – changing such policies after the fact tends to happen slowly. Legislation should accommodate innovative technologies, how grid organizations evolve, the need for greater flexibility and the need to ensure economic development, greater competitiveness, job creation and high quality security of supply [24]. Therefore, utilities must keep policy makers informed and policy makers should work with utilities to ensure that overall public policy will allow the Smart Grid vision to continue to evolve.

While policy decisions normally occur at the national level, regulatory decisions occur at the state level. In Europe, overlapping and/or complementary policy *and* regulatory decisions occur at both the member-State (national) *and* European (EU Commission and/or EU Council and Parliament) levels. Regulatory bodies from different areas may approach the Smart Grid differently. For utilities, a major regulatory issue may be the assurance of regulatory recovery of investments. Normally, utilities must prove the benefit of any project using business cases that demonstrate the benefit to customers and the Smart Grid will require the same approach – as a concept as well as for the individual systems that will comprise the physical Smart Grid.

Customer-side Recommendations

Some e8 members have used cash incentives to bring customers into a pilot program. Eventually, customer offers enabled by the Smart Grid for residential energy users will move away from a single rate and be based on TOU or real-time pricing. Other offers may provide incentives to purchase smart appliances and heat pumps technologies or promote Residential Energy Management Systems (REMS). Load-shedding for households will become possible to address peak demand conditions. In short, offers more similar to those for industrial and commercial customers will become possible with the Smart Grid.

Therefore, utilities should actively engage with customers to explain how TOU pricing can bring more benefit to the customer in lowering bills than the flat rates they generally expect to lower their bills.

Business Models or Opportunities

Due to various communications technologies that will be connected to the Smart Grid, new business models for utilities will become possible. One observer compares the changes to the utility industry with those to the telecommunications industry as a result of IP communications developments [25]. Some new activities may or may not be allowed by regulators in a given area. At the present time, utilities mainly act as energy providers, with a rate-recovery mechanism for infrastructure on a straight kWh rate. Future rate recovery mechanisms may come from offering energy efficiency solutions to the customer allowing the utility to become an energy service provider.

AMI will open opportunities in the area of information technology due to the sheer amount of data made possible and the need to store and analyze it. Other opportunities will arise around communications technologies due to the necessity for wireless and fiber-optic means of transmitting large amounts of data. Home area networks (HAN) and home energy management systems (HEMS) will involve devices such as smart thermostats that will communicate with the Smart Grid. Energy storage technologies will enable utilities to more efficiently connect variable sources such as wind and solar generation. All these will create new opportunities for utilities and for the customer [26].

In trying to improve efficiency and reduce CO_2 and other greenhouse gas emissions, the new business model for utilities may be that of simultaneously seeking the least cost to the customer and the most profit for the utility. For instance, utilities may be able to meet renewable electricity requirements where applicable by installing their own energy storage on properties and photovoltaic equipment on roof-tops that they rent for those purposes. In this way, the utility would pay the homeowner for the stored or generated power in exchange for using the power according to the utility's need. Emission-offset credits may also be possible. On the other hand, long-term contracts with renewable-energy providers would free the utility from financing such projects on their own. Demand response programs could be outsourced to third parties or kept within the utility [27].

As indicated earlier, federal stimulus funding in the United States had made Smart Grid development opportunities available that previously did not exist. While this funding may be considered temporary in nature, it could aid utilities in developing important parts of a Smart Grid.

The Smart Grid will make business models and opportunities for utilities possible that have never before existed. Therefore, utilities must consider what these possibilities may be, what their regional policies and regulators will allow, and then plan for the kind of energy service provider that they can become.

Stakeholders

Regulatory bodies, financial institutions, customers, suppliers and others hold a stake in the Smart Grid. These entities may appear to have compatible or conflicting roles in its functioning. In order to support the needs of all stakeholders, utilities must understand those needs and strive to educate all groups concerning the benefits of the Smart Grid and the utility's approach. Keeping these groups informed and engaged in the process of adopting a Smart Grid will best assure their acceptance of it. To accelerate Smart Grid deployment, we must encourage stakeholders to invest in its implementation. Revenue models and incentive schemes have to be defined and supported at political, regulatory and financial levels.

Utilities must engage their consumers such that sustainable participation becomes "second nature" and they must inform environmental groups of the positive greenhouse gas impacts of the Smart Grid.

Each stakeholder has its own primary interests and needs that utilities must consider and then determine how best to educate those stakeholder groups concerning how the utility may meet those needs.

Table 4-1
Stakeholder Groups

Stakeholder & Role	Primary Interest	Education Focus
Consumer	- Pay less - Protect the environment	- TOU pricing suits can lower your bill - Load shedding helps the environment
Policymakers	- Climate Change mitigation - Consumer Protection - Ensure a sustainable development of the Country	- Smart Grids enable enhanced integration of intermittent DERs, network losses reduction, energy efficiency etc - Load shedding can lower utility bills - Smart Grids enable electric mobility (Electric Vehicles)
Regulators	- Security of energy supply - Consumer protection	- Smart Grids enable peak shaving and reduces the need for new peak load generation capacities - Improved quality of service and demand-side management.
Financial Community	- Utility profitability	- Investment in Smart Grids makes utilities more profitable through: - Emergence of new services - New and smart use of electricity leading to increased sales (substitution of electricity for fossil fuels in industry and domestic customers e.g. EVs) - Better management of capacities and of distribution networks - More efficient billing.
Environmental	- Climate Change mitigation - Management of natural resources	- Smart Grids enable enhanced integration of DERs... - ... and reduced investments in new generation capacities for peak load, thus reducing pressure on availability of coal, gas, etc.

Public-private partnerships

Partnerships between utilities and other entities are needed to deploy the Smart Grid. This includes telecommunications, IT and IP companies in the communications domain. Partnerships are also needed with developers of devices and systems such as energy storage, alternative energy generation, distributed generation technologies, charging structure for electric vehicles, and others who will emerge to develop new applications and products for the Grid [28].

One such partnership already possible where AMI deployment has occurred could involve cable entertainment services. Another could involve security monitoring services. Just as the cable industry offers bundling of services to reduce the cost of each to the customer separately, the utility industry could offer cable and security services along with electricity. Partnership between vendors may be possible as well.

Public authorities around the world may partner with utilities to provide loan guarantees and subsidies – matched by the private sector – that may enable, among other things, the design of the most optimal devices for smarter transmission networks. These incentives could also further the development of photovoltaic generation and wind deployment. The all-electric vehicle will require some connection to the utility. Companies are already designing and marketing charging stations for these vehicles. The public sector has an interest in these developments; therefore, partnerships around this endeavor will be beneficial for Smart Grid deployment as well.

All such partnerships – private-private and public-private – allow the expertise of each member to be leveraged for the benefit of all members. Table 4-2 is a partial listing of these possible partnerships.

Table 4-2

Public-Private Partnership	Benefit
Government -utility	Loan guarantees and/or subsidies
University-utility	Research and testing capabilities
Public Organization-utility	Broad base of knowledge along with research and testing capabilities; standards development
Private-Private Partnership	
Utility-vendor	Collaboration on device or service deployment
Vendor-vendor	Collaboration on device or service development

Addressing developing nations

While the e8 may represent many different stages of development for the Smart Grid of the twenty-first century, each nation has as a basis the well-developed grid of the twentieth century. Developing nations may not have any such basis upon which to build. According to the World Energy Outlook for 2009 published by the International Energy Agency, around 71% of the populations of sub-Saharan Africa – close to 590 million people – have no access to electricity.

Figure 4-2 illustrates the extent of world population currently and in the year 2030 without access to electricity. In its reference scenario, IEA envisions a 30% electricity demand growth in OECD countries between 2007 and 2030 (from 9245 to 11596TWh), while countries outside the OECD will see electricity consumption multiply by 2.7 within the same period (from 7183 to 17334TWh). India's consumption alone will multiply by 3.6 (from 544 to 1966TWh). [29]

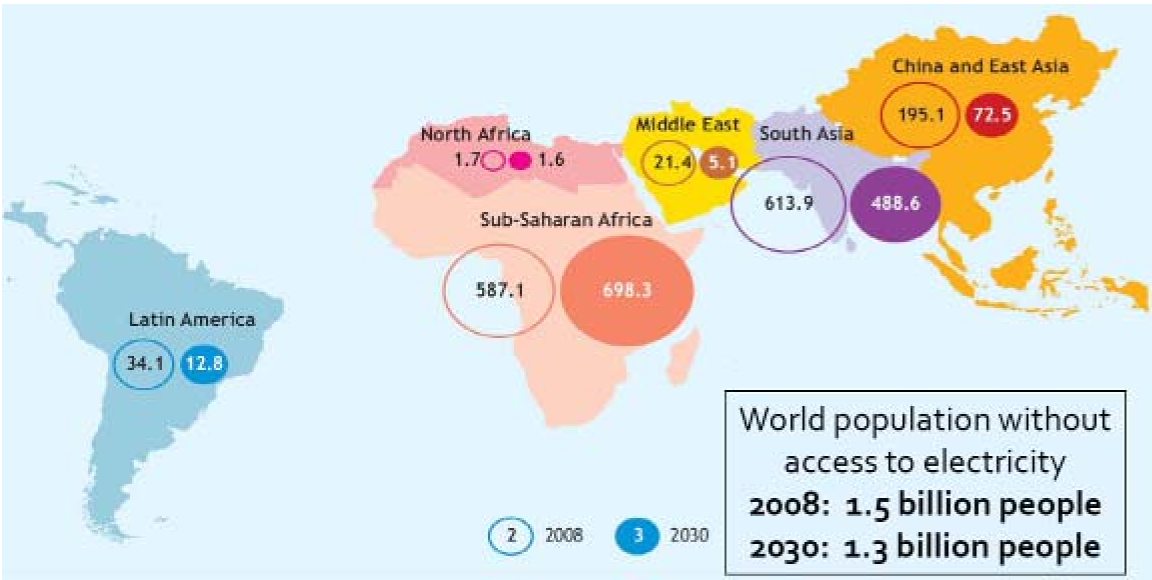

Figure 4-1
Populations without Access to Electricity [30]

A minimal or nonexistent infrastructure may or may not be a hindrance to Smart Grid efforts in those regions as, not having already spent resources to build a 20th century electric grid, developing nations may be able to jump directly to the 21st century Smart Grid. One clear indication of the urgency of working with developing nations may be seen in electrical generation and generation by fuel projections in Asia from the Energy Information Administration (EIA). Figure 4-3 indicates that not only will electrical generation increase in Eurasian regions, but that energy generated from burning coal is likely to increase dramatically as well.

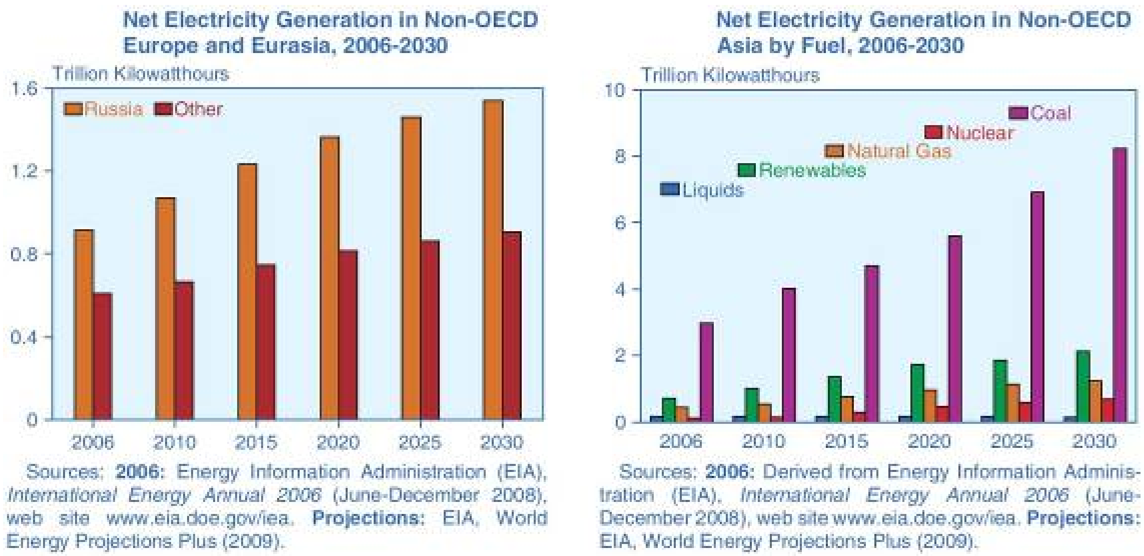

Figure 4-2
EIA Projections for Europe and Eurasia [31]

Yet this outcome need not be inevitable. In addition to the massive deployment of low-carbon generation capacities (nuclear, large hydro, clean coal, wind, etc.) needed to address predicted growth in electricity demand, the Smart Grid may be the engine of change in developing countries that – while paying for itself – allows cleaner generation, efficiency, reduced costs and improves the quality of life for every citizen wherever they live. To do so, however, developing nations must have adequate access to capital, effective prioritization, plus little or no opposition to change from government institutions, regulatory bodies and the populace. As with developed nations, effective engagement and communication will be essential in order to bring the Smart Grid to developing nations. One important issue for promoting the Smart Grid in developing countries involves technology and knowledge transfer between developing and developed countries while another involves determining the appropriate technologies to apply.

The e8 is ready to support developing countries by supplying experts to accelerate capacity-building and help determine the business cases that best represent the context for the Smart Grid in each country. These business cases could then be used as the basis for choosing Smart Grid technologies for deployment.

Becoming Smart in Stages

The Smart Grid will be a huge undertaking and a single, best path to the Smart Grid may not exist. Prior to focusing on a specific technology, one of the first tasks may be to address how the technology or technologies best suited for deployment may be selected. Therefore, both developed and developing nations may find their own way best by focusing on business objectives specific to their country, utility, and/or customers rather than on technology alone. On their path to the Smart Grid, for instance, some developing countries may want to concentrate on implementing DER (PVs, wind, biomass, etc.) to meet energy demand and thus avoid the use of coal or hydrocarbon fuels.

More developed countries may find improving system efficiency to be a better beginning path to the Smart Grid. For example, reducing the voltage on existing systems may be a low-cost method of reducing greenhouse gas emissions. Other countries may choose to concentrate on demand response or on reliability.

To select appropriate technologies for Smart Grid deployment, one e8 member developed a three-stage approach. The first stage consists of identifying business objectives such as system performance, power flow and energy efficiency. In the second stage, applications such as remote control of equipment, volt/VAR control, fault location, and load management are identified. In the third stage, technologies are selected to provide the desired data, as illustrated in Figure 4-3. This approach serves as an example for consideration and merely represents one possible way for pre-deployment analysis.

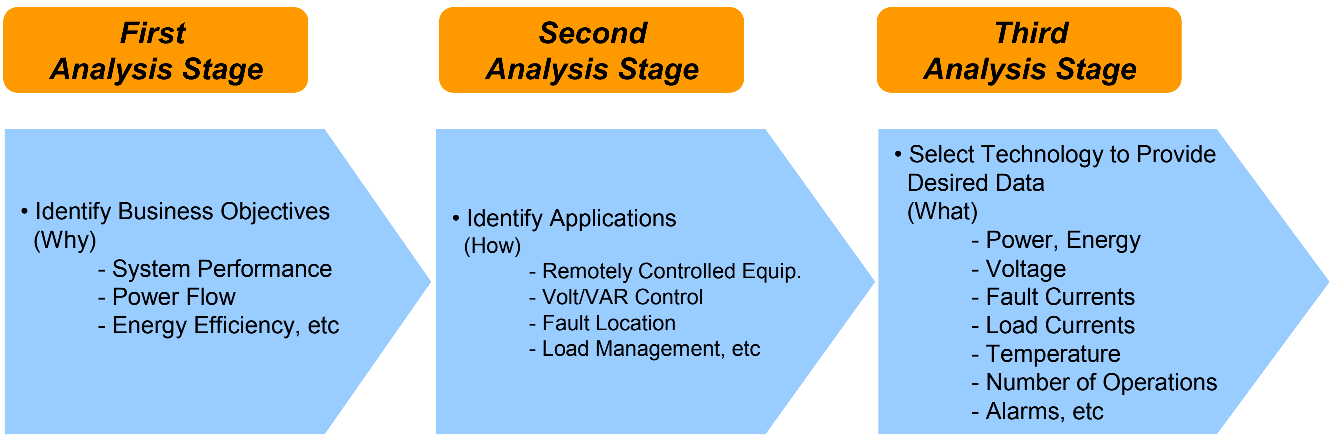

Figure 4-3
Becoming Smart in Stages – One Possible Pre-Deployment Analysis Approach [32]

Once the best technologies and time frame for the deployment stages have been determined, the next task is implementation.

Another e8 member has adopted a three-stage pilot plan – some of which has been accomplished – for implementing its version of the Smart Grid illustrated in Figure 4-4. This plan, while specific to one country, may offer a representative sequence of events for others, both in developed and developing nations, in implementing the Smart Grid.

The first stage for grid implementation may involve Smart Meter deployment, high and medium voltage remote operation, and medium and low voltage substation automation/remote operation. For the e8 member, the last two reduced SAIDI numbers from inception to the present by around 60%. These successes should build confidence in the overall direction of the Smart Grid among customers, policymakers and regulators.

The second stage may involve wireless IP-based communications infrastructure with MV/LV substations and remote meter management system in order to realize an integrated communication infrastructure enabling all Smart Grid applications, providing “smart info” to customers (who already have the “smart meters”) to achieve awareness, Electric Vehicles recharging infrastructure enabling large scale electric mobility, and active control and demand response of DER for renewables integration.

The third stage (still being planned for the e8 member) may involve active demand management for low voltage customers, integration with Smart Homes (HEMs and/or HANs), and perhaps even Smart Cities as these technologies evolve.

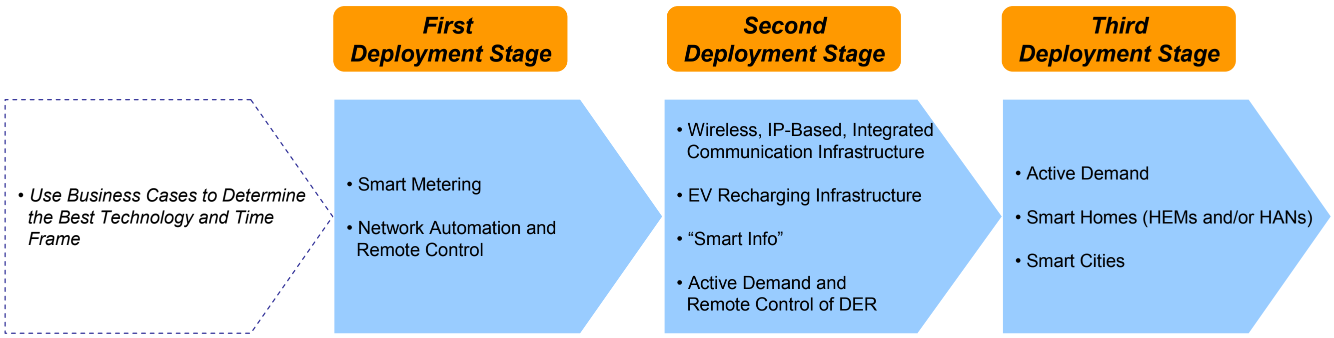

Figure 4-4
Becoming Smart in Stages – One Possible Deployment Approach [33]

The preceding sequence, meant purely as an example, serves to illustrate one possible approach to implementing a Smart Grid over an unspecified period of time with respect to the technology involved – it does not represent a road map to achieve a Smart Grid. Utilities in different areas may prefer entirely different approaches; however, the most important activity, using appropriate business cases to determine the best technologies and time frame, should be undertaken first.

5 SUMMARY

The Smart Grid will be the culmination of approximately 120 years of development in electrical generation, transmission and distribution. Power in the old electrical grid basically flowed one way from generation though the last load. The Smart Grid will allow two-way transfer of information between power provider and customer and even power transfer to the grid from users capable of providing electrical generation. Advanced Metering Infrastructure will allow greater efficiency and accuracy in billing operations while eliminating error and significant labor costs involved with manual reading. The communications infrastructure can also enable new advanced functionalities such as, for instance, smart home appliances, electric vehicle recharging data acquisition systems, etc. Smart grid deployment will have direct impacts on greenhouse gas emissions through more efficient operation of the grid and optimal integration of distributed energy resources. Additionally, Smart Grid deployment will sensitize customers to their consumption, which has been demonstrated to result in an overall reduction in consumption.

In the event of electrical problems that would otherwise cause electrical outages for wide areas, effective distribution automation and interoperability will allow the Smart Grid to, in effect, "heal" itself. The services that the Smart Grid will enable will create business and partnership opportunities for utilities that never before existed. While the transition and investment to arrive at the Smart Grid may seem a risky undertaking, doing nothing may prove even more risky in the end as economic and political pressures combine with technological advances push society in this direction.

While the regulatory situation varies in each region, the Smart Grid, thanks to the potential of its interconnectivity, will enable business and partnership opportunities never before possible. More than electrical power providers, utilities may become energy solutions providers and more – if the right business model(s) may be identified.

The challenges utilities face with the Smart Grid involve what has been done before, what must be done now, and what must be done in the future. Regulatory mechanisms and policies in place now relate to what the grid has been up to the present time. The groundwork for the Smart Grid, regarding policy and regulation, reliability, interoperability, cost recovery mechanisms, and possible business models and opportunities must be carefully considered and put in place now so that the Smart Grid achieves its full potential.

Many drivers both for and against will influence how this new system develops; however, to do this successfully, utilities must collaborate with *each other* as well as all the other stakeholders having a controlling interest to guide and bring about this new creation called the Smart Grid. To overcome common barriers faced by all countries and accelerate the development and the deployment of Smart Grid, the global partnership of e8 can play a key role.

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Acronyms

AMM	Advanced Metering Management
DSM	Demand Side Management
EV	Electric Vehicles
fy	fiscal year
HAN	Home Area Network
HEM	Home Energy Management
ICT	Information and Communications Technology
IT	Information Technology
IP	Internet Protocol
PLC	Power Line Carrier or Programmable Logic Controller
PV	Photovoltaic
REN	Renewable Energy Network

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