UNIVERSITY OF CALIFORNIA, LOS ANGELES

The Smart Grid

Powering Our Future

Ray Avalos
Richard Abrantes
Wilson Lam
Ninh Le
Alan Yip

March 19, 2012

Instructors: Dr. Donald Browne & Dr. Gershon Weltman

Engineering 183EW

Contents

List of Figures

List of Tables

1 Executive Summary

The current base utility grid has been working for 100 years without change in the infrastructure. Most main components and equipments are getting old and outdated. Any failure to any portion of the grid can result in failure of the whole system because of the complex and interconnected characteristics of the current grid. It also leaves the grid open to cyber attacks. From another perspective, the growth of electricity demand is currently higher than the supply capability. The utility grid is obviously insufficient in fulfilling the energy needs of the 21st century. In order to solve numerous problems of the current utility grid, a new model of utility grids is required. Current developments are focusing on building a computerized grid system called the smart grid. Smart grids will be enhanced with sophisticated communication and sensing technologies to increase energy efficiency and reliability. The smart grid also offers a huge effect on enhancing employment of green energy, electric vehicles, smart home, and many more forms of technology, along with decreasing energy cost and pollution. However, we face multiple challenges technologically, monetarily, and socially in implementing the smart grid.

The actual construction of the smart grid is one of the most difficult technical issues to overcome when creating the smart grid. These technical issues stem from the technological advancement that the smart grid and relevant appliances must venture before it satisfies the requirements of the smart grid. Technology such as the Advance Metering Infrastructures (AMI), plug-in vehicles, electric vehicles (EVs), Home Area Network (HAN), and many more systems can create peak, cost, and risk issues unless the smart grid is able to manage information and electricity transfer correctly.

Advance Metering Infrastructure (AMI) technologies enable bi-directional communication between the utility grid and various grid technologies. The development of this technology enables the utility managers to create programs for consumers to participate in energy saving methods. Glendale Water and Power GWP, the pioneer of smart grid technology, has already implemented many types of AMI throughout Glendale, producing many foreseen benefits. Before AMI can provide these benefits, the fear that prevents AMI from moving forward in the smart grid includes technological risks and investments risks. Solutions to these risks can be eliminated if distributed among different investors and technologies that share these investments.

For electric vehicles to fully exploit the smart grid's bi-directional transfer of energy and data, special "grid tie inverters" must be made to convert direct currents to alternating currents to transfer electricity to the smart grid. With this grid tie inverter installed, consumers will be able to participate in electricity trade markets for EVs. The technical issue that comes with the EV's implementation into the smart grid is the peak issue that may cause blackout or brownout. To prevent peak issues, it is suggested that the smart grid be integrated with technology that manage charging and discharging time or create peak shaving techniques through incentives.

The Home Area Network (HAN) is a difficult piece of technology to execute. The issue here is equipping individual homes with technology that can communicate with the utility grid. The cost of installation, smart appliances, and wireless technologies are still unfeasible for most average consumers. These cost issues and technological improvements that companies need to overcome are not easy. The GWP has executed their AMI but now plans to install the HAN. Currently, solutions toward the HAN can only be seen in research to reduce cost and improve wireless technology or smart appliances.

The Unites States has officially announced a federal initiative in deploying the smart grid system. As development and improvements to the grid continues, speculations develop regarding the return of investment despite the cost of deployment. President Obama has announced that the United States would invest a total of $3.4 billion dollars into the smart grid initiative. It has been, however, estimated that the total cost of smart grid deployment would be $8 billion. The remaining funds will come from the Smart Grid Investment Grant program (SGIG) which is a group of organizations and various stakeholders dedicated in funding the smart grid initiative. This is the largest power grid modernization investment in United States history. Case studies have been conducted as to whether a national deployment of the smart grid would actually benefit the country in terms of efficiency, carbon emissions, and reliability. This, as a result, will be dependent on the available technology that can perform and fulfill the necessary requirements of the smart grid system. Case studies have shown if proper technology is selected to uphold the grid's functionalities, the nation will be benefitting enormously from its features while reducing carbon emissions.

The smart grid, itself, is a complex network of appliances, meters, and hardware all communicating with one another to send and receive data readings between the customer and utility provider. The most important aspect for the project's deployment is the ease of use for the consumer and its universal compatibilities with new appliances purchased. This universality will be created by a set of technological standards that the United States must decide on for appliance and other companies to begin manufacturing smart grid ready appliances.

In addition to the smart grid's enhancement of the current power grid in efficiency, performance, and cost savings, another attractive feature of the project will be to reduce carbon emissions from the consumption of fossil fuels. High emissions of carbon dioxide have led to global warming, leading to the Earth's experiential drastic climate changes, along with changes in ecosystems and ocean levels. The smart grid will be utilizing renewable energy in which electricity is generated from natural resources such as solar and wind energy. Although it is ideal for the smart grid to run completely from renewable energy, this is not feasible as a result of the limited availability of natural winds and solar sources. This is a challenge for developers as limited renewable energy can contribute to intermittency within the smart grid, pose more cyber-security risks, and create stability difficulties. The challenges in utilizing renewable energy are diminishing as a result of new methods in using renewable energy to sustain utility energy requirements.

The smart grid as a whole will be extremely beneficial to the environmental beyond the integration of renewable energy sources. Case studies have been conducted that have shown significant reductions in carbon emissions for the United States and the globe. With the implementation of the smart grid, the United States will be benefitting financially, economically, and environmentally that can dramatically change the way energy is utilized.

There are a number of ethical consumer concerns surrounding the smart grid. First, there is the issue of privacy. With the smart grid's two way communication feature, important data about any individual's habits and lifestyle will be readily available. Although this data is meant to help provide better service to the consumer, this data has the potential to fall into the wrong hands. To help prevent such incidents, proper regulations and security standards need to be established before the smart grid is installed. An active security system also needs to be deployed to help track, prevent, and repair against any malicious attacks. The consumers must also take an active role in understanding how their information will be used and what precautions they can take to protect themselves.

Second, there is the issue of fair pricing and availability. The smart grid allows greater variation in dynamic pricing relative to power costs and creates a more centralized control over power distribution. This can greatly impact the way people live as these pricing and availability adjustments may prevent some families and facilities from obtain their needed power to survive. However, dynamic pricing combined with protective legislation will actually be beneficial. It would allow the smart grid to achieve even greater savings and keeps utility companies from over charging.

Finally, there is a poorly known health risks attached to the smart grids. The immense amount of wireless devices that would be used if a smart grid is implemented would greatly increase consumer exposure to radio frequency (RF) radiation. RF radiation is linked with many health issues; however conclusive evidence has yet to surface. But the levels anticipated with the installation of the smart grid will greatly exceed those of any known studies (Levitt, 2011). Before the smart grid can be ethically and safely installed more conclusive studies must be done and strict standards should also be established.

As the smart grid system in the United States begins to conglomerate within the infrastructural workings of the community, the method by which to implement the smart grid, either through quick or thoughtful procedures, becomes an added controversial issue to the smart grid. The concept of building the smart grid quickly has two consequences: the United States, due to the ambitious push of the forefront, will become an international leader in smart grid technology with the downside of leaving firms or consumers in the wake of its progress. The main dilemma of quick implementation is that the problems that go alongside with the smart grid technology will naturally and abruptly develop. These issues will be left unattended or minimally addressed as a result. This is exemplified through numerous technological advancements that China has sought through its variation on the smart grid.

The contrast to this ambitious pathway is the route of building the smart grid with patience and consideration. Unfortunately, this form of insertion into society also has two consequences which are mere opposites to the method of building quickly: attending to the side effects of the smart grid helps appease the firms and citizens utilizing the smart grid, all the while surrendering to other countries' desire to maintain a winning notion about the smart grid. A country that has chosen to pursue this course of action is Korea. They have adopted an implementation plan that incrementally improves the smart grid in an attempt to allow its citizens to adjust as the smart grid is slowly implemented. This incremental improvement is also supplemented by a present test grid that allows technical issues of the smart grid to be addressed.

In reflection, the implementation of the smart grid requires its investors to be aware of duty ethics. According to Van de Poel and Royakkers, duty ethics is defined to be a morally correct action that adheres to the moralistic rule of the day. The leaders in United States have a duty that transcends from an expectation of government leaders: serving the people. This expectation becomes analogous to Korea's method of implementation and, therefore, should be followed by the United States in ensuring the welfare of its citizens.

The national security of the smart grid also questions the importance of government involvement within the smart grid's infrastructure. The measure of government involvement in the market is worrisome for capitalistic proponents. The United States government is currently expected to maintain a laissez-faire stance in allowing the free-market-based economy to prosper. Their duty to oversee the livelihood of the economy is also embedded within that expectation.

The government has also encouraged the community to push its limits in the technological and scientific aspects as well. This instance is well cited in the development of the F-15's self healing system. The self-healing aspect of the system is also a well-defined parameter of the smart grid. The decision to completely restrict the government's involvement in the smart grid becomes nonsensical. The government's jobs are to resolutely maintain the country's free market economy by adhering to laissez-faire concepts and also help lead smart grid technology since the benefits of the capitalism allow government inclusion and participation in the smart grid venture.

The cyber security of the smart grid must also be ensured before the smart grid can be integrated as our main power grid. The centralized control of the smart grid makes it more convenient to use, but it also makes it convenient for attackers to access it. Once inside the system, attackers could wreck havoc across the nation by cutting off power to essential facilities or reconfiguring pricing and demand algorithms. The solution to this problem will require a more advanced detection and repair system than the ones that can be utilized for consumer privacy protection. Isolation of different parts of the grid will be pivotal in preventing a complete system failure. An adaptive and rapid anomaly detection system will also be needed to: 1) predict attacks, 2) stop attacks, and 3) adapt and evolve using the history of the system. Such a system would also be able to trace and record who is responsible for transactions across the grid. These will help ensure that all grid activity can be controlled and will help resolve many legal disputes.

1 Introduction

1.1 Methodology

To make a successful report we delegated specific topics to individuals and then compiled our findings later to make the final report. We followed the provided report outline and individual research topics were selected based on personal interests. The main division was between technological and ethical issues of the smart grid. Ray, Wilson, and Ninh took the technical aspects because they were already familiar with some of the technologies and wanted to do more research on those topics. Richard and Alan took to investigating ethical and societal issues of the smart grid. We utilized the first few weeks for each of us to do individual research. Alan set up a Dropbox (a free and easy to use online file sharing site) for the entire group so that we could rapidly share research and review each other's writings. During week 4 we started having weekly meetings to touch bases and make sure we were all moving in the same direction. Individual outlines were made during week 7 and tentative individual first drafts were done during week 8. The final report was compiled and edited during week 9 and 10. We also created the final presentation during week 9 and 10. The presentation was made in a similar fashion to the report itself. A summary of our schedule is provided in Table 1.1.

Table 1.1. Smart Grid Report Schedule.

Week	Assignment Due
1	Pick and delegate topics
2	Individual Research
3	Individual Research
4	First official group meeting, at least 5 sources per person, 8-10 min progress presentation
5	Individual outlines for specific sections, check with focus of overall report
6	Rough draft of individual sections for peer review (around 8 pgs each)
7	Finalize individual portions, plan introduction, conclusions, and executive summary, 10 min individual presentations
8	Team First Draft
9	Tentative Final draft, Format entire report with references, glossary, contents, executive summary, and cover
10	Finalize 35 minute presentation, 5 min for questions
3/19/2012	1 Bound Copy, 1 Unbound copy of Final Report

1.2 Contributions

Table 1.2. Individual Report Contributions identifies the final sections each individual was primarily responsible for. Many sections were a collaboration of multiple people's work such as the Executive Summary and Conclusion. Table 1.3 is the Responsibility Assignment Matrix (RAM) chart we used to delegate primary writing and reviewing tasks throughout the quarter.

Table 1.2. Individual Report Contributions.

Author	Sections
Ray Avalos	3.6 Cost vs. Return, 3.7 Consumer Technological Concerns, 5.1 Cost vs. Return Solutions, 5.2 Solutions to Consumer Technological Concerns, 6. Conclusion
Richard Abrantes	1. Executive Summary, 4.1 Building Fast vs. Right, 4.5.1 Government Involvement, 5.3 Building Fast vs. Right Solutions, 5.7.1 Government involvement, 7. Glossary, 8. References
Wilson Lam	1. Executive Summary, 3.1 Actual Construction, 3.2 Advanced Meter Infrastructure (AMI), 3.3 Plug in Hybrid (PHs) and Electrical Vehicles (EVs), 3.4 Home Energy Management Systems (HEMS) or Home Area Network (HAN), 3.5 Power Consumption with the Development of Smart Technology
Ninh Le	1. Executive Summary, 2. Background
Alan Yip	1. Introduction, 4.2 Consumer Privacy, 4.3 Pricing/Availability, 4.4 Health Concerns, 4.5.2 Cyber Security, 5.4 Consumer Privacy Solutions, 5.5 Dynamic Pricing, 5.6 Health Precautions, 5.7.2 Cyber Security, Final Report Formatting

Table 1.3. RAM Chart.

	Alan	Ray	Richard	Wilson	Ninh
Executive Summary	I	I	P	P	P
Introduction	P				
Problem/Background		D,I		D, I	P
Technological Issues	R	P	R	P	P
Ethical and Societal Issues	P	R	P	R	R
Recommended Solutions	D,I	D,I	D,I	D,I	D,I
Conclusion	D,I	P	D,I	D,I	D,I
References	I	I	P	I	I
Final Proofreading	P	I	I	I	I

2 Background

2.1 What are the Problems of the Current Utility Grid

The infrastructure and equipment of the current utility grid are old and outdated. The grid has been built and used for about a century without changing in technologies. During this computerized era, the utility companies' staffs still have to go from place to place to read meters, check for broken equipments, measure voltages (US Department of Energy); there are areas where power outage is only noticed when the somebody call the utility to report it (Office of Electricity Delivery & Energy Reliability). This aging system consists of other limitation from the old supervisory control and data acquisition system with slow data transmission rate, and limited bandwidth. These factors contribute greatly to managing and maintenance cost to the system. They also intimidate the reliability of the most important energy source of our country. However, the most important aspect affecting the reliability of the US electric power is the centrally controlled and interdependent infrastructure of the grid. Failure in some part may lead to other failure or even system shutdown. Recovering of the system always requires a lot of time for the technicians to manually find out and then fix the problem. Even though the grid has not been attacked before, it is very vulnerable to cyber attack or terrorism.

Electricity demand is always increasing while the supply capability cannot catch up. The transmission lines are always in over-scheduling condition, meaning there are more lines required to transport electricity than the number of available lines. They also operate at very close to the line's capacity. Exceeding capacity can cause major blackout due to line's failure. Blackout risk also increase due to increasing peak demand. According to industry standards, the minimum available electricity needs to be above peak demand. However, according to the 10 years forecast of increasing demand by North American Electric Reliability Corporation, the capability of supply is only 9.4% higher than peak demand (Figure 2.1) (South Mississippi Electric).

Due to this high demand, the electricity grid is, in fact, incapable of supplying energy during peak hours. Peak hours are the block of hours during the day when electricity demand is a lot higher than the rest of the day, as shown in Figure 2.2 (Decastro, 2008). To solve this peak demand problem, the utilities have been buying energy from private companies such as Reliant, AES, and Enron with astronomical rates during on-peak hours. Our pricing system is based upon average prices of on peak and off peak demand. Therefore, it does not reflect the actual consumption.

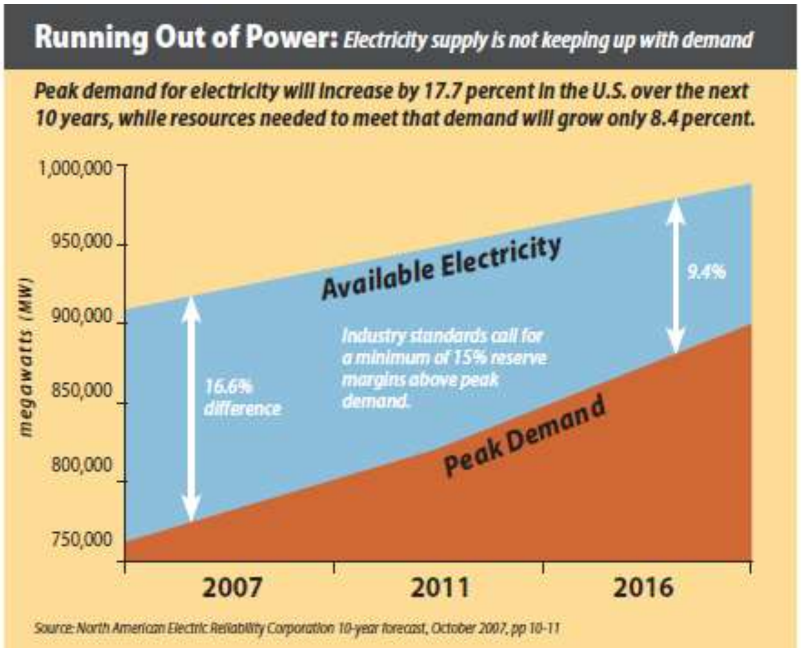


Figure 2.1. Available Electricity vs. Demand

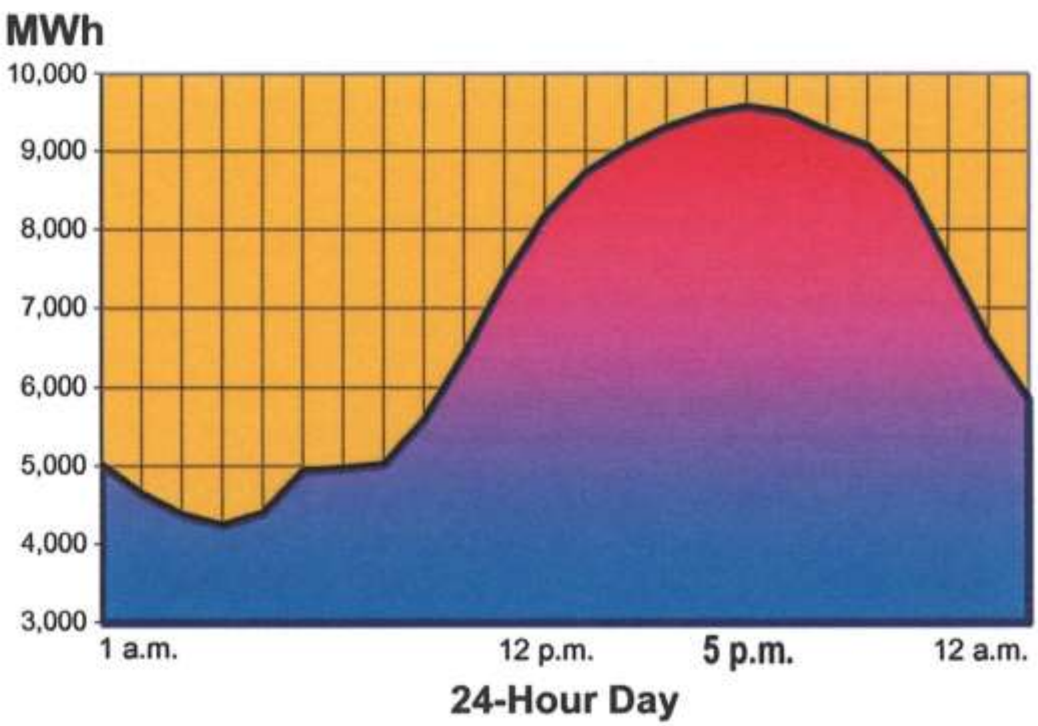


Figure 2.2. Peak Hour Demand. (Decastro, 2008)

2.2 What is the Smart Grid

In order to keep up with the 21st century electricity demand, the new model of utility grid, smart grid, needs to be put into operation. Smart grid is an automated and remote controlled computerized-system with advanced electricity transmission and generation, and automated and remote controlled information metering, monitoring, and management. According to the US department of energy's vision for smart grid, the smart grid must have the following functional characteristics: self-healing; motivating demand response by consumer; resisting from cyber and physical attack; providing power quality for 21st century needs; accommodating all generation and storage options; enabling markets; optimizing assets and operating efficiently (US Department of Energy).

Self-healing: The system can detect problems using digital sensors, locate these problems and fix them automatically or manually.

Demand respond: The current grid only allows electricity to transmit from the grid to customers. Smart grid should enable two-way flow of energy which would allow customers to both receive and send electricity to the grid.

Resisting attack: the centrality characteristics of the current grid make it vulnerable to attack. Once attacked, the whole interconnected and centrally controlled system could be shut down. Smart grid structure is localized and capable of deterrence, prevent and repair from failure

High power quality: smart grid will balance the load and supply electricity at different grades with different pricings to satisfy the consumers' needs

Accommodating all generation and storage options: smart grid need to improved interconnection standards to enable a large variety sources of generation and storage such as wind, solar, hybrid vehicles.

Enabling markets: it opens to real time pricing system and enhances both wholesale and retailing the market.

Optimizing assets to operate efficiently: with the advanced measuring and sensing technology, the smart grid will be able to reduce cost and assets in both utilities' and customers' sides.

2.3 Potential of the Smart Grid

Smart grid will offer a wide range of improvement to the grid; as a result will benefit the utilities, consumers and the society in multiple ways. Smart Grid will meet new capacity requirements by incorporating electricity generation capacity and advanced distribution system. Energy transmission and distribution will become a lot more efficient. A localized distribution mechanism will minimize energy lost. The system can also quickly isolate outage, island or curtail certain loads as needed for critical places such as hospital or emergency services. Since the grid would not be the only energy generation source, during emergency conditions or disasters, energy can be generate within residential area and supply to important places. Capital cost to manage the lines and equipment also reduce significantly with the automated and remote control meters and equipments. The management will also have a more thorough view of the system to ensure maintenance quickly and precisely. The operational efficiency of the grid can generally increase. The utility can manage peak load more efficiently with the incorporation of a large number of consumers or the so-called new partners. The need for building new power plants will also decrease. This will also ease low electricity price pressure to the grid and state government. The price should reflect the true value of electricity that serves the benefit for both utilities and consumers. By actively participating in this market, consumer will be able to manage electricity to maximize their profit. Energy conservation therefore will become strengthen as a collaboration of the whole community.

Smart grid will open to an enormous amount of new technologies and applications in house appliances and electric vehicles. House appliances can be easily monitor and control with digital technologies. They can be adjusted to desirable load mode which can be energy conservation during on-peak hours or maximum capacities during off-peak hours. Safety of house appliance will increase because they can be turned on or off remotely or automatically.

To the environment, smart grid promises to give a boost in reducing pollution and our exploitation of natural resources. Since implementing renewable energy is one of the main features of smart grid, electricity will be less dependent on fossil fuel. Carbon emission from fossil fuel electricity production therefore will reduce significantly. When constructing new power plant is not a need, land resources and natural landscape will also be conserved. Wireless operation in smart grid will also save a huge amount of metal wiring and other materials in grid construction. Smart grid when implemented will be the greatest revolution in energy technology that is capable of offering countless benefits to the community and pushing forward the development of all other technologies.

Upon implementing the smart grid and changing the operation of the largest interconnected machine on Earth, we are facing a lot of challenges in technologies, monetary and society. A certain level of technology has to be established before smart grid can become nationally applied. A huge investment is required for research, and the actual construction of smart grid. Smart grid, in the developing period, has raised multiple societal concerns in health, personal privacy, regulation, security, or negative environmental impacts... Do the pros outweigh the cons vs. the current system? Can everyone be convinced? These issues will be addressed in the following sections.

3 Technological Issues

3.1 Actual Construction

To actually build the smart grid, technology such as Advance Metering Infrastructure (AMI) must be built for bi-directional flow of information. Without AMI a smart grid will not be much different from the current rigid grid. Technologies such as electric vehicles (EV), Home Area Network (HAN), etc. also play important roles in the development of the smart grid's reliability in its function of electricity distribution and information transfer. Depending on the smart grid management of these technologies in information and electricity transfer technological issues can arise; therefore, it is vital to smart grid survival that these issues that might arise be addressed before the smart grid is fully executed.

In building the smart grid, technology such as Advance Metering Infrastructure (AMI) is a must to advance further in the field of smart grid technology. The construction cost has already received billions of dollars in research and development from various governments and investors (Jeff, 2009). In Jeff article he stated that the Department of Energy (DOE) alone in the United States has already given 3.4 billion dollars toward smart grid investment grants for companies and researchers for smart technology installations and research.

This will not only mean further research to improve the reliability of the smart grid but also pull in private investors as Jeff has stated. In a sense once a trigger is set, the possibility of going forward is much more certain. These huge pushes toward investments for the smart grid are due to possible future technology such as plug in hybrid, electric vehicles (EVs), advanced metering infrastructure (AMI), home energy management systems (HEMS) or home area network (HAN), etc.

3.2 Advanced Meter Infrastructure (AMI)

The purpose of the smart grid is to have efficient communication throughout the whole utility grid and its surrounding. This requires the importance of correctly employing Advanced Metering Infrastructure (AMI) to the consumers: business, factories, and homes (Steiger, 2012). The goal of the AMI is to manage, collect, store, and transmit data between the consumers and the providers. This bi-directional flow of information requires careful planning and technologies to manage such vital information. This is when AMI comes into play. AMI can benefit the smart grid by efficiency managing the flow of information and create the possibility for automatic demand and response as professor Gadh has described. The issue with AMI comes to the surface once implementation begins to take place. The implementation of AMI technology requires a wide scale adoption of wireless technology (wireless technology is prefer over wired technology as Steiger stated). To implement wireless technology and communication protocol huge financial investments must be made. The technical problems with this technology come in term of technological risk and investment risk.

Glenn Steiger, the CEO of Glendale Water and Power Company (GWP), stated that during the start of smart grid execution investment risk is a huge issue that a utility company needs to overcome. The huge investment risks come from the development of communication systems and its appliances. The smart grid main component is communication which requires wireless AMI technologies. Gadh stated that Wi-Fi was put up for consideration since it is so wide spread now, but Wi-Fi proved to be a huge consumer of energy and other technological innovations were needed. This requires research and development of other wireless technology such as Zigbee to replace Wi-Fi.

Investments were made by certain companies and research groups to develop lower energy wireless technology like Zigbee. Due to this investment for smart grid bi-directional communication system technological risks arise. The possible benefits that can be achieved with this technology are viewed as the solution or reasoning to further invest in AMI for bi-directional communication.

The installation of AMI technologies into homes and new infrastructures will create the possibility of communication between homes and the utility grid companies. This will give these companies more real time response toward their smart grid. This means that the smart grid will become a better and more efficient network. The benefit for installing AMI will give the utility companies the ability to pinpoint blackout locations quickly. Besides pinpointing blackouts easily, the Glendale Water and Power's CEO explained that their smart grid with AMI implemented now has the capability to reduce cost, self-heal, and self-manage. AMI also eliminates the unnecessary cost to hire workers for manual meter reading. These benefits are viewed as the financial gain and solution needed to outweigh the financial risks during smart grid implementation.

The main solution for AMI implementation during recent year is improvement of wireless technology, equipment cost, and installation cost. One technical issue is the bi-directional network service between the utility grid and consumers. There were limited technologies that would enable transfer of data at a low cost from every home. Having a cellular provider for every home was not feasible due to high cost of cellular network. The technological solution for this is a mesh network which was suggested and then executed in the Glendale Water and Power Company to eliminate the network high cost problem. A mesh network as described by Gadh is a network system that relays information to each neighboring system until it finally reaches its destination. This information continues to be sent and collected with encryption until it reaches a main tower where it is sent to the utility company. Since the main tower is the only one connected to the cellular tower technology costs can be reduce by having multiple home data sent at once. With the mesh network setup technical issue for AMI wireless communication was basically reduced or eliminated.

The benefits Steiger explained that AMI comes with are the ability to monitor data from smart grid to detect system health, alarms and events, and leak detection. Steiger presented to a class stating that system health includes application and database health, network health, and meter read rates. The network information is monitor by the AMI systems continuously through the day and if there is a disturbance reports will be sent back through the wireless network indicating an issue (Steiger, 2012).

As electricity is stolen or tampered within the utility grid a mismatch in data reading or data information allows the Glendale Water and Power to detect the issue right away. These stolen and tempering issues were extremely difficult to deal with before stated Steiger. Before the installation of the advance monitoring systems into the smart grid, the monitoring of the metering system was through a manual process which takes place approximately once a month. Steiger explains that the tampering of the meter or meters by consumers to steal electricity during those months goes undetected in a manual meter. This relates to lots of cost for utility companies such as GWP to fix those manual meters (Steiger, 2012). On the other hand, with AMI or Meter Data Management System (MDMS) installed the ability to detect these issues as they arise becomes much easier as data is continuously collected from various sites throughout the day.

The ability to detect leakage is an extra installation that comes to benefit the GWP instantly stated Steiger. To do this a wireless water meter needs to be connected to a smart meter that is able to send data back and forth through the AMI. Since water meters are able to monitor the water usage and send the information to the smart meter, a huge increase in water usage will give the utility and water companies a warning. With this warning the water companies will be able to quickly respond to the leak detected at the site of the wireless water meter. Steiger states that consumers in the same way can be able to detect such leaks with the installation of both smart meter and wireless water meter. Currently those smart meters and water monitoring systems are implemented and fully functional in the Glendale Water and Power district which is the city of Glendale. This dual implementation of water and electric monitoring devices is possible because of the cooperation of both the utility and water companies.

The Glendale Water and Power CEO explain that the difficulties behind this technology are the huge investments that need to be made before the GWP Company becomes self-growing. Steiger states that GWP was one of the first to receive$20 million dollars investments from the government. Later GWP also receives $1 million more grants from the government to continue their smart grid technology. The high cost for installation is the greatest technological drawback for the smart grid (Steiger, 2012).

The government officials that were interested in the smart grid during that time gave funding to GWP (Steiger, 2012). Due to this GWP is now able to execute many operations within its district. Glendale being a smaller city enables GWP to quickly implement their smart grid system Steiger points out. With the smart grid fully functional Steiger explains that GWP will actually be reaping the benefits and incomes within a few years. The technological solutions to these issues discussed were all through research and development of new technologies as well as method of network implementation for AMI to be successful.

3.3 Plug in Hybrid (PHs) and Electrical Vehicles (EVs)

The spontaneous growth of the smart grid during this recent decade prompted many different technological advances. One such advancement is the car industries' introduction of plug in hybrids and electric vehicles (DeForest, 2009). The choice for electricity as the next replacement comes into view for many consumers as gasoline prices skyrocket stated DeForest. With the development of smart grid side by side with the electric vehicles and other devices it is essential for both the smart grid and the electric vehicles to be in perfect synergy. The function of the smart grid is to manage data that comes from appliances. EVs, being the appliances for this case, need to be strictly monitored by the smart grid to prevent technical issues such as peak, frequency, voltage, and phasor problems.

The basic definition of an EV from the U.S, Department of Energy is a vehicle that could "draw electricity from a battery with a capacity of at least four kilowatt hours and (…) is capable of being charged from an external source." The maximum benefit can only be achieved by having both the EVs and smart grid working together side by side as many articles appear to point toward this conclusion. From DeForest's technical paper their analysis of grid to vehicles (G2V) and vehicles to grid (V2G) implementation can be a huge technical issue if left unmanaged.

Technical issues arise for EVs if management of the demand and response systems for EVs at the utility level is not well organized. However, DeForest stated that there are technical solutions for these issues through programs that can be created for consumers to participate in. The incentives behind such participation are discount on electrical bills and other discount offers made only available to consumers in the program(s) (DeForest, 2009).

3.3.1 The Implementation of Plug in Hybrid and Electric Vehicles

The technology of plug in hybrid and EVs enable these vehicles to plug in directly to the utility grid and recharge their battery from the grid. The developments of these technologies are underway in many car industries and are already commercialized like the Nissan Leaf or Chevy Volt. This direct plug-in into the grid enables transfer of electricity and information. The problem that quickly arises with EVs implementation into the smart grid is the peak issues. Technical issues that can result from EVs are peak issues. Peak issues occur if electricity consumption by consumers rise sharply during certain time of the day resulting in utility grid having to meet the demand by producing excess electricity.

Gadh (personal communication, 2012), as well as from various articles, at times discuss the transfer-of-electricity method's main goal is to help stabilize the grid technical issues we are encountering today such as peak problems, blackout, voltage, phasor, and frequency issues alike. These technical issues which shall be addressed, all are already being researched on as the smart grid continues to develop along with EVs. The technical issues with EVs only occur if they are left unmanaged. The straightforward solution that comes out of this is a management system for EVs.

The first of widely feared problems that many utility grid companies anticipate is peak issues that are already occurring and the fact that EVs might further push the demand of electricity pass the current peak (DeForest, 2009). As Gadh (personal communication, 2012) has stated, peak issues come from the high demand of electricity at certain time of the day where insufficient electricity provision occurs and therefore electricity must be supplied through other means beside power plants (which are much more expensive). These peak issues normally occur slightly after the afternoon time when most people are using electricity. This can be confirmed from the CAISO CAMX (California Independent System Operator for the California- Mexico Power Area) graph (Figure 3.1). The black line on the CAMX figure shows average summer load or electricity demand during summer without EVs being implemented. The peak during around 3-4pm of this graph usually cost more to maintain because most grids need backup to supply excess energy to the grid if the peak capacity is passed.

Figure 3.1 is the example of peak load issues when EV charging is unmanaged and the worst case scenario results. Surpassing the electrical threshold (71GW) in which the utility companies can provide will result in undesired consequences the smart grid will have to face. Results of peak issues can be felt immediately through blackouts or brownouts as the smart grid cannot provide enough electricity (DeForest, 2009). Blackouts and brownouts are results of overworking the power plant to the point where its maximum output of electricity does not meet the load demands. These issues usually require utilities to quickly shutoff their power plant for safety measures rather than letting it overheat.

Another note toward CAMX (Figure 3.1) is the fact that this figure is only displaying 25% of Californian vehicles. This means that EVs implementation into the smart grid at 100% will make the situation worse. At 5% of Californian vehicles though, the demand of GW that EVs require plus the consumers' daily requirement will not surpass the regular max peak. This means EVs can be adopted at this level as long as it does not pass current peaks.

The 4 a.m. time period is also a possible concern to the utility companies as well if no electricity is consumed. This means that excess electricity will create stress on the grid similar to excess water in a lake putting pressure on the wall of the dam as Gadh have pointed out. To prevent this situation, current utilities actually pay large corporate buildings to consume excess electricity to relieve those stresses (R. Gadh, personal communication, 2012). This means that electricity is being spent at night wastefully for no purpose except turning on loads while there is insufficient electricity during the day.

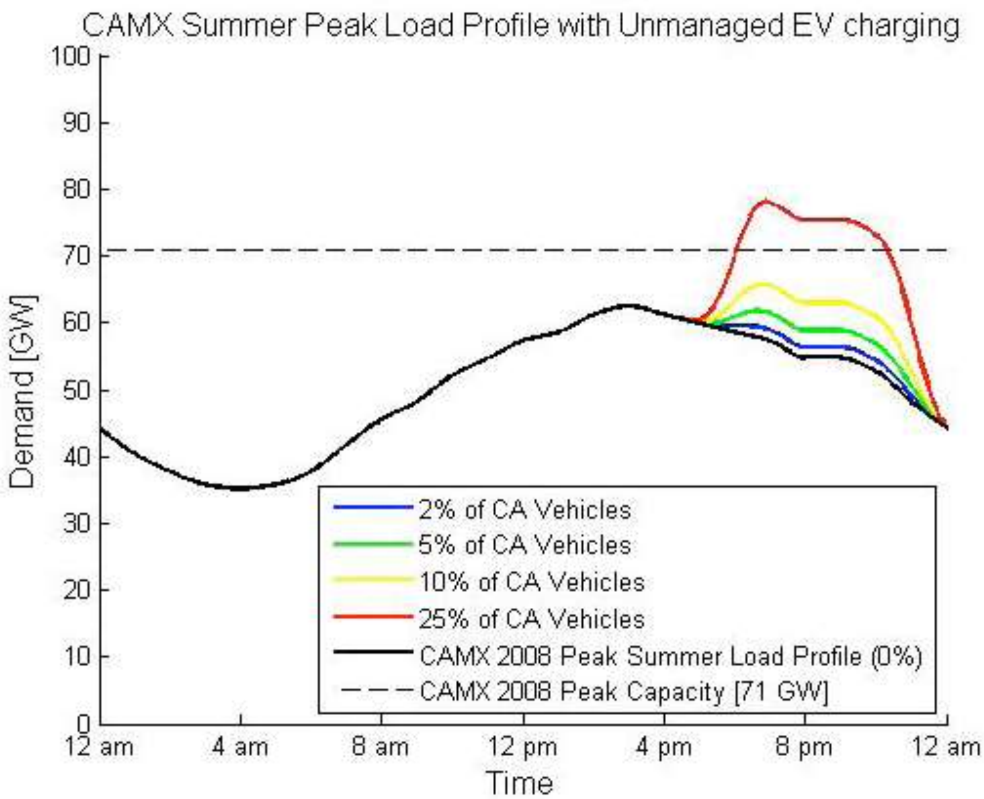


Figure 3.1. CAMX Unmanaged Demand Profile. (Deforest, 2009).

The best possible scenario is to have constant demand and, therefore, no peak (DeForest, 2009). This constant demand is also favorable to the utility companies as well because it means they can produce the exact amount the consumer desires and therefore the cost to operate the power plants. The issues with

EVs creating peak issues can, instead, be converted in to a possible solution if the management of EVs is done correctly in conjugation with the smart grid.

DeForest stated that if there is a management system in the smart grid for EVs charging time this can help prevent consumers from charging EVs during peaks hours. This technical issue of peak problem can be converted into a solution by using incentives such as cheaper night time electricity rates when demand is low and creating higher pricing for afternoon rates when demand is high. This method creates the idea of real time pricing where pricing of electricity depends on the demand by consumers similar to stocks in the stock market.

These incentives can be provided by the utility companies to benefit themselves by preventing peak issues and operating cost of power plants when peaks issues arise (DeForest, 2009). A technical solution for relieving peak issues is called peak shaving or valley filling as DeForest have stated in the article. The method is to charge EVs or PH only during the valley of the demand as a function of time curve will relieve the smart grid of peak issues. This scenario can be seen in the CAMX Figure 3.2 below.

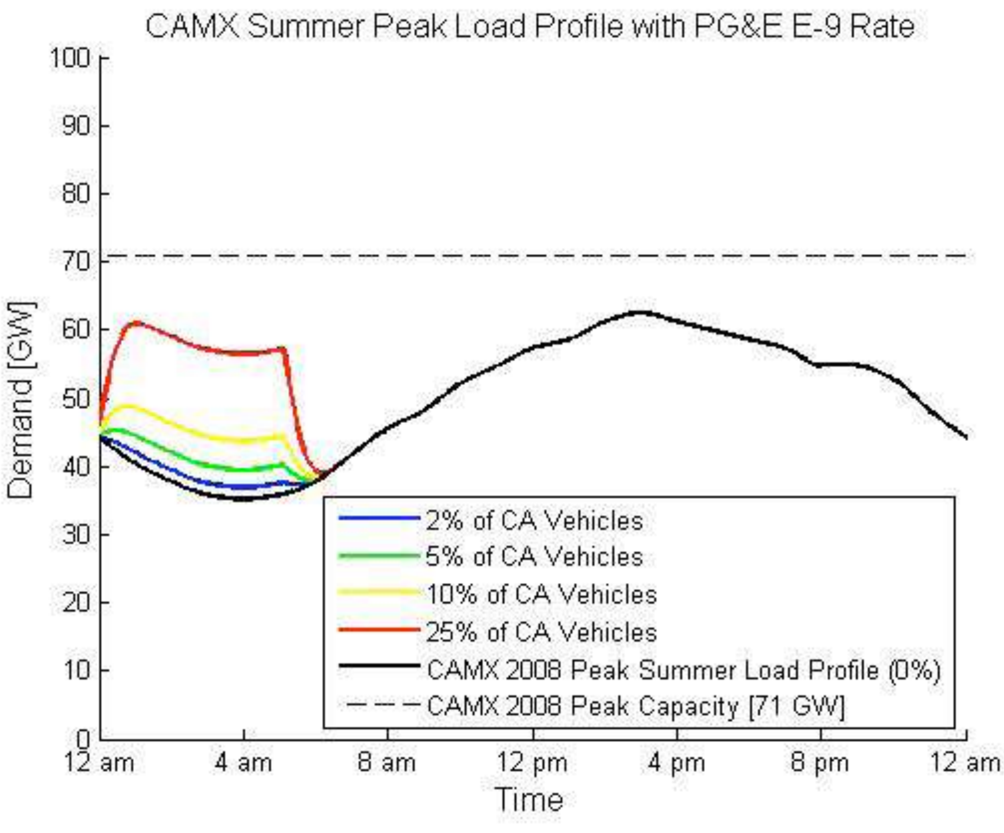


Figure 3.2. CAMX Peak Load Profile. (DeForest, 2009).

The constant demand method which utility companies greatly desire can be seen right away in this case if EVs are managed correctly by the smart grid or the consumers. With the increase during night time demand due to EVs and PHs consumption the demand at night time reach a similar level to that of the afternoon time. This technical solution will help the smart grid or utility companies manage their electricity level at a constant supply without unnecessary costs. Constant demands means constant supply so there is a much easier prediction of what supply of electricity must be made available for the consumers before it is asked for. This will relieve utility companies from excess or insufficient electricity (DeForest, 2009).

The idea behind this can be created through incentives that utility companies provide (DeForest, 2009). This could work since there will be benefits towards the utility companies after some time. Currently this does not take into account the possibility of EVs charging at night and discharging electricity during the day back to the utility grid to better manage the smart grid health. Figure 3.2 only considers the charging into the battery and not discharging from the battery to the utility grid.

The smart grid will give the possibility of two way communication and a bi-directional flow of electricity (Xi, 2011). This means that EVs implemented in the smart grid can draw excess electricity at night and release the electricity back to the utility during the day. Xi's research and DeForest's article explains that it is possible to relieve the smart grid electricity demand if night time battery are store in cars and then released during the day. If incentives are created for the smart grid to manage EVs charging during non-peak hours and discharging during peak hours are implemented correctly the stress on the utility grid can be nearly eliminated as described in the DeForest's article.

3.4 Home Energy Management Systems (HEMS) or Home Area Network (HAN)

With the development of the smart grid its general purpose is to help manage the flow of information and electricity between the utility and the consumers. Another part of this process is for the utility companies to use the smart grid management system to lower the consumption of unnecessary devices as well as save energy and money for consumers and themselves. This requires the consumers to have systems such as home energy management systems (HEMS) or home area network (HAN). HAN will enable the consumers to manage their power consumption and give the utility companies an easy way to send information through the smart grid to the consumers to turn off their devices. The creation of the smart grid will also encourage development of HAN as consumers see higher incentives to save more energy. The basic idea here is for HAN to be either automatic once information is inputted by the consumers or controlled by the utility grid. The technical issues that arise with this technology come from lack of smarter appliances and cost of implementation.

The information of electricity consumption by home appliances gathered to a smart meter's gateway does not necessarily need to be sent out to the utility companies. The HANs technology gathers various electricity (and water consumption, only currently been installed by GWP) and other consumption together at a gateway which is then processed for transfer. The information about consumer consumptions is later displayed in the consumer installed screen or utility install screen. This information is normally for consumers' awareness of their energy consumption and is not sent out to the utilities (Steiger, 2012).

Figure 3.3 (left) & Figure 3.4 (right).

Picture frame alternate between pictures and consumption data. (Steiger, 2012).

With this HAN installed the utility companies can easily give notice on the display screen for certain programs offers. GWP has already planned these screens to be installed in homes as a moving picture frame as display in Figure 3.3. HAN is an extremely difficult task as Gadh (personal communication, 2012) has mentioned because of the equipments and technologies that have to go in to the homes. Currently many researches are currently being done on smart technologies that will make appliances controllable by the HAN through Zigbee or other form of wireless network Gadh (personal communication, 2012).

HAN technologies basically manage the power consumption of home appliances. The energy consumption data that HAN receive is from the utility managers. Managers of the utility grids will be able to suggest controls of home appliance through the HAN (Steiger, 2012). Through incentive programs, Gadh (personal communication, 2012) explained that consumers can lower electricity consumption and save money for utility and consumers by raising temperature of AC, switching off lights, and moving drying and wishing times of clothes (incentives still need to be researched to maximize benefits for both consumers and utility grid companies).

HAN is technologically possible but the home appliances that can be controlled by the HAN are still under development by researchers. These technological issues can lead consumers to question the point of HAN technology if there is a wireless controller like HAN but no products that can be controlled by HAN. Making home appliances compliable with the HAN is an unresolved technical issue that the smart grid researchers are trying to explored. The stage of HAN technology as of right now can only be viewed as a battle of cost vs. benefit. Since the cost of the technology outweighs the benefits to implement HAN no direct technical solutions are possible unless smart appliances cost are greatly reduce through other means.

3.5 Power Consumption with the Development of Smart Technology

Even with the development of the smart grid, the question is how EVs can be entirely dependent on the smart grid for energy and if EV will even be able to benefit the smart grid at all. These issues are the same for other smart appliances and other network systems like AMI and HAN. These issues are due to EVs, smart appliances, HAN, and AMI consuming large amounts of energy from the smart grid. The smart grid’s main purpose is to manage all of these devices and help lower energy consumption. It is important to understand that the smart grid implementation is to help solve the technical issue of distribution of power to location where needed and make managing demand and response for electricity easier.

Steiger explains that governments were initially fearful of the risks. But now the growth of Glendale’s smart gird is a leading example for its surrounding cities. The CEO of GWP explains that with the implementation of smart grid successfully done, GWP will be able to get profit and return from the smart grid in a few years. Steiger explains that Glendale was able to actually reduce the power consumption of the smart technology to a great degree and actually gain benefits through smart grid implementation.

On the other hand, since EVs have not been employed to a large enough scale only research data is available. DeForest stated in his research that Figure 3.1 and Figure 3.2 of the CAMX graph suggest that it is possible to adopt EVs if there are effective policy to shift charging time to non-peak hours. DeForest explains that EVs can reach an adoption rate of 43% without the need of additional power generation and transmission if the smart grid is able to manage charging time of EVs successfully.

From the research data it can be concluded that the smart grid can be very successful if all technical issues are handle correctly. However the ethical aspects of the smart grid must also be analyzed before the smart grid can be truly successful.

3.6 Cost vs. Return

Amongst the issues in the design and construction of the Smart Grid Infrastructure comes the cost at which its completion is feasible. Although it may appear that this may not be a technological issue, it is important for one to note that the amount of money invested in such a large project like the smart grid will dictate how advanced the technology will be. It also may appear as an ideality to have the "latest and greatest" technologies implemented by the top companies of the world to ensure the accuracy and functionality of such a complex system. This, however, is at the expense of the government which can cost the nation several billions of dollars. It is therefore apparent that a standardization of the technology implemented will occur that may or may not serve the smart grid justice in functionality, efficiency, and lifetime. Questions have arisen of whether the designed infrastructure can last long enough to provide sufficient output of data readings and performance. For the federal government, it has become an issue of whether the return of investment will outweigh the investment itself.

According to the United States Department of Energy, President Barack Obama has announced the nation's largest power grid modernization investment in United States history with a total of $3.4 billion dollars in grant awards to various organizations across the nation that are working on smart grid research (2011). It has been reported, however, that as of 2012, the federal government has already invested $3.7 billion in distribution, transmission, and customer system assets (U.S Department of Energy, 2012). Although the nation is still in a financial crisis, the ideal is that this power grid modernization will eventually be saving the nation several billions of dollars after the smart grid is instated. The grants that are awarded by the United States are going to Local Distribution Companies that are integrating advanced metering and two-way communication technologies as well as various research and development projects. Such initiatives are working towards defining the requirements needed in establishing the advanced metering infrastructure (AMI). The AMI is a two-way communications network that is the compilation of all the technologies needed to have a functional smart grid from monitoring, collection, and distribution of information to the consumer and provider. Despite the existence of a wide variety of technologies that are already available in the market or those that are still in development, "it is very critical for electric utilities to define the communications requirements and find the best communications infrastructure to handle the output data and deliver a reliable, secure, and cost-effective service throughout the total system" (IEEE, 2011). This is extremely crucial if a federal government wishes to distribute this network across the entire nation. The cost of installation would be enormous and thus must be thought out if it is worth the investment for a nation already in debt.

According to the U.S. Department of Energy's official smart grid initiative reports, the federal government along with the Smart Grid Investment Grant (SGIG) program, a total of $8 billion will need to be invested to fully implement the system across the nation (2012). Investments would include $4.5 billion to AMI and Customer System Assets that include hardware, software, and programs to enable smart grid functionality, $2.5 billion in distribution assets, and $1 billion in transmission assets as described in Figure 3.5. The United States is already working towards achieving their goals but speculation exists if the smart grid system can save the nation large amounts of money and energy consumption. More importantly, the United States must seek out the technology needed in constructing an AMI that will meet the smart grid requirements for functionality.

Figure 3.5. Total Smart Grid Investments. (U.S Department of Energy, 2012).

3.7 Consumer Technological Concerns

The smart grid project has a lot of benefits in regards to regional energy consumption and efficiency on a great scale. It is, however, the customer and utility provider that must adapt to a technological upgrade in their private residence or business. Speculation arose from the public and businesses if the smart grid would actually be benefitting both the consumer and the service provider. Consumer concerns have included the overall ease of use of the smart grid and its universal compatibilities with new appliances purchased. A well-designed smart grid system will have an established set of technological standards that all appliances will operate in accordance to. Such standards have yet to be established by the United States and it raises concern if it can be implemented successfully for ease of use.

Other technologies that must be implemented with the smart grid must reduce current carbon emissions. The current power grid is currently contributing to the consumption of fossil fuels to produce energy. According to Ali Keyhani in his book "Design of Smart Power Grid Renewable Energy Systems", the author reports that "fossil fuel sources of energy are the primary cause of environmental pollution and degradation" (2011). High emissions of carbon dioxide have led to global warming in which the earth experiences drastic climate changes and changes in ecosystems and ocean levels (National Geographic, 2007). The smart grid is not only a brand new design in energy consumption, but the project should enhance the way it generates its energy to improve the environment as a whole. Extensive research and development is going into renewable energy in which electricity is generated from natural resources such as solar and wind energy. This is, however, a challenge for developers as renewable energy can contribute to intermittency within the smart grid, pose more cyber-security risks, and is difficult to predict and stabilize (Johnston, 2012). Concern consists of whether the smart grid can actually contribute a positive stride towards a greener future while maintaining an ease of use for the consumer and utility provider. The overall functionality of the smart grid cannot be compromised as a result of it attempting to use "greener methods" of energy consumption and having less harmful impacts on the environment.

4 Ethical and Societal Issues

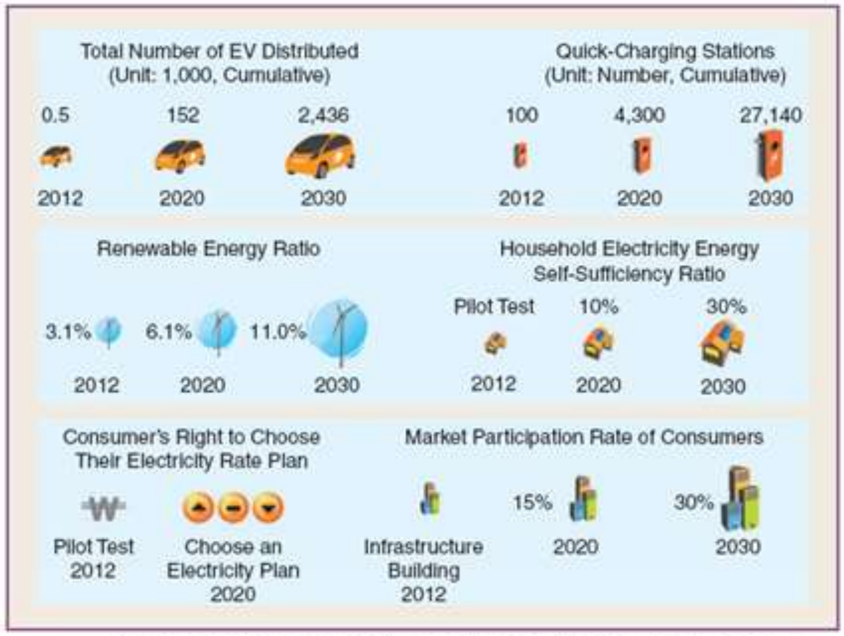
4.1 Building Fast vs. Right

The rapid development of modern technology incites the growth of an ethical issue: the concept of implementation either through rapid or timely measures. Quickly implementing the smart grid grants the United States standardizations of appliances and elements that are to be compatible with their smart grid across the globe. However, rapid startups of the new grid would leave domestic consumers and firms unattended to their needs, such as enabling transparency between firms to communicate efficiently through the new grid. This issue recalls duty ethics set forth by politicians in the 1700s: serving the people. Serving the people may be twofold in this regard as there is the natural need to evaluate and oversee the smart grid industry for the people's benefit, where there is also the expectation to lead the industry towards improvement, a viewpoint that falls in line with creating initial standardizations. This dilemma may be further explored through two case studies: China's current research in smart grid improvement and Korea's plan in addressing their populace's concerns and expectations.

China's smart grid presents many similarities and challenges if we place the American smart grid in contention and comparison with China's grid. The Chinese grid idealizes the type of competition contending with the American grid in seeking successful implementation and standardizations of the grid's technology throughout the world. The two grids are similar in several ways, however, such as "reading data real-time, two-way and efficient, which will greatly enhance the interactive operation of the power". (Wu et al., 2011) These characteristics require similar technologies that have already been established between both the Chinese and American smart grids. This baseline for the smart grid may also be observable in other smart grid startups, such as that in Korea.

China is also continuing to push the forefront of the smart grid through new technology; the method by which the smart grid performs affects the overall efficiency and reliability of the smart grid. The Chinese smart grid aims to utilize the full potential of "fiber optic backbone communications network", apply compatibility in the "centralized access of big power [which also includes], distributed clean energy", and strengthen the smart grid by using Ultra-High-Voltage (UHV) power grids. (Wu et. al., 2011) This poses a challenge for America due to concept of interoperability standards, which ensures that technology amongst the smart grid works in synchronization. (Adam, 2011) If China defines a successful and more efficient model of the smart grid, the American grid may continually need to achieve the growing standards that China sets with their grid. The issue behind rapid implementation impels the United States to set the standards prior to China's full attainment of leadership in smart grid technology.

South Korea is also another country aiming to implement the smart grid. They seek to "enter the global market and [create] a major export industry by capitalizing on smart grid technology." (Kim et al., 2011) The Korean method of implementation, however, differs from the rapid implementation adopted by the Chinese government. According to Kim and Park, their nationwide investment in the smart grid focuses on five areas: the smart power grid, the smart place (or metering system), smart transportation, smart renewable energy, and smart electricity service. Figure 4. to the right shows the steady returns resulting from adherence to the implementation plan; they have chosen to implement the smart grid at regular 10 year intervals before fully cementing the smart grid's functionalities. The Korean smart grid began at the Jeju Smart Grid Test Bed in 2009, whose goal is to conduct experiments and prototypical runs of the smart grid before fully implementing the smart grid into Korea. (Kim et al., 2011)



Key implementation targets for smart transportation, renewable energy, and electricity service.

Figure 4.1 Projected Returns of Smart Grid. (Kim et. al., 2011).

This measure of cautiousness, observed from the involvement of prototypes, is also applied by government policies. As stated before, the government intends to incrementally improve the smart grid, rather than expecting a steep adjustment by its populace and firms to the new smart grid. For example, the "Smart Consumer" is expected to choose rates during the first stage (2010-2012), encourage consumer involvement and increase smart grid build rates in the second stage (2012-2020), and ultimately provide zero energy homes/buildings by 2021 to 2030 in the third stage. The private sector and government's investment of about 27.5 trillion KRW also projects 50,000 newly created jobs per annum and creates domestic demand creation at 74 trillion KRW. These measures reflect the concept of building the smart grid in the right way, as phrased by Adam. The right way shows Korea's intention to provide for the people's benefit by addressing the concerns of the people by slowly incrementing their way towards the full implementation of the smart grid, as shown in the Jeju smart grid. This may require the addressing of unexpected, developing issues relative to the grid. This response falls in line with the need to attend to the concerns of society who are expected to benefit from the implementation of the smart grid. They also address the smart grid market and industry by ensuring the fulfillment of the plan to create jobs and domestic demand creation, all qualities of building the smart grid “correctly”.

4.2 Consumer Privacy

The potential of any smart grids relies heavily on the two-way communication between the grid and the consumer’s home. However, with this open access there will be an easy way to attack the home or steal personal information from the consumer. Companies or other entities with malicious intent could take advantage of consumers by using this information inappropriately and without consent. This open communication could leave consumers and their homes vulnerable to a rapid and nearly invisible attack on their accounts and well being.

Some personal information that would be available through the smart grid include: name, address, account number, billing history, and service provider (Liu, 2012). With access to such information on the grid consumers are susceptible to fraud. This becomes an even bigger issue when one’s personal energy consumption is not in one specific location. For example, if a consumer intends to use a PHEV they the ability to plug their vehicle into the grid from places outside of their own home is required. This in turn will require the ability of the grid to track the user and charge their account accordingly. And with much of the system turning to automation, it will be hard to notice fraud quickly and could be even harder to track and bring the criminal to justice.

The introduction of HAN provides a convenient means of tracking which appliances are utilized, when they are used, and how often they are used. Although the intent is to increase user awareness of how they consume power, such information could be used against the consumer. Companies could use this information to void product warranties or use the data to create target market plans the same way many internet sites work nowadays (Liu, 2012). This is an infringement on the consumer’s privacy and allows companies to harass and abuse consumers. Being able to monitor consumer use of a product would be like tapping a person’s phone without their knowledge. Target market not only uses your information to create specific products, but also allows companies to advertise directly to you. All of this could be done without any consent from the consumer.

Most concerning of all is the way the grid could be utilized to track and affect a person’s personal lifestyle. A person’s actions and location inside a building can be pin pointed in real time (Fadulullah, 2011). This would provide two easy ways for hackers to abuse the consumer. First, they could simply use this information to know when you are or are not at home, thus allowing them to time a robbery of your house. Second, the hacker could choose to infect all of your devices. The malicious software could do anything from tampering with your consumption readings to cutting your power off altogether. If such a thing happened to a facility such as a hospital, many lives could be endangered.

4.3 Pricing/Availability

With a more centralized control that the smart grid pursues, there is the risk of allowing companies to generate a monopoly on electricity. Everyone depends on electricity and this centralized control leaves fewer companies for them to choose from. Dynamic pricing will also be sought after. Dynamic pricing is intended to increase the efficiency and savings that the smart grid could offer. However, there is concern on whether or not lower income families will be able to cope with a fluctuating price. The main issue is whether or not these proposed changes will fit a utilitarian ethical framework since providing the most good for the greatest number is essential to the success of the smart grid.

Electricity is a vital source for consumers of all levels of income. The availability of this power source for an attainable price is essential in keeping America's workforce productive. The main fear is that switching to a smart grid will produce a monopoly on electricity. Controlling companies could set specific prices to specific customers which can be tragic for lower income families. If not properly regulated the smart grid could force everyone to change their income allocations. Not only is this against a utilitarian framework, but this could also cause even more people to cut back and possibly lead to another downturn in the nation's economy. The greatest good for the greatest number is of the upmost importance.

Dynamic pricing provides a means to fully realize the benefit of the smart grid however the fairness of the model is in question. Dynamic pricing requires placing users into different categories and giving each category different pricing depending on the amount of energy they consume. The main idea is that users who consume a lot of power will be charged more than those who do not. It also would make power more expensive during the peak hours of the day. The question is whether this model is fair to low income consumers, seniors, disabled people, small businesses, and other consumers who have limited means of creating income (Faruqui, 2010). Another concern is whether the real time prices will be reasonable and if companies in control of these prices can be kept in check. For dynamic pricing to be successful consumers must be convinced that these questions can be adequately answered to prove that the greatest good is being done for the greatest number.

4.4 Health Concerns

Nearly all wireless devices rely on and produce Radio Frequencies (RF), commonly defined as frequencies between 3 kHz and 300 GHz. Concerns over exposure to RF radiation were first brought forth with the success of cell phones. If the smart grid is implemented there will be thousands of new sources relative to this unseen danger. Although we have seen little to no effects due to cell phone usage, the smart grid would greatly multiply the concentration of RF radiation present in a consumer's home. With every appliance equipped with a smart meter such as microwaves, dishwashers, stoves, washing machines, dryers, refrigerators, and more, everyone could potentially be exposed to unhealthy amounts. These concerns are, however, often buried beneath the positive aspects of the smart grid. From a duty ethics standpoint, people must know about the potential health effects in order to make an informed decision regarding whether or not smart grids are really "smart".

Despite the lack of public acknowledgement, RF radiation has been found to contribute to serious health problems. These problems include, but are not limited to: cancer, immune system defects, and fertility problems (Perlingieri, 2011). Other minor issues take the form of sleeplessness, dizziness, memory loss, headaches, and fatigue. All of these findings were found through studies of the effect of living near cell phone towers. What is more alarming is that "many of these symptoms mirror what some people are reporting within days of Smart Meters installed at their homes" (Levitt, 2011). Any benefits of the smart grid would be negated if the system would eventually cause serious harm to its users. According to Dr. Ilya Sandra Perlingieri from Global Research, "there has been no testing of these meters for any kind of safety." This is an issue that requires more research before a smart grid can be ethically installed. The safety and health of the consumer must always come first.

4.5 National Security

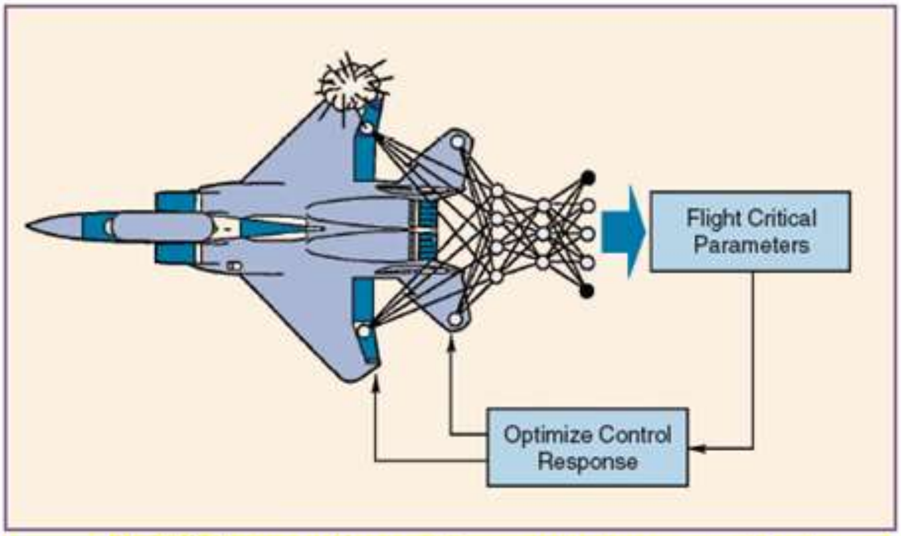
4.5.1 Government Involvement

Concern about the national security of the smart grid draws a salient organization into the picture: the government. The implication that the smart grid connects a region of the country creates scrutiny about the "security" of the grid's interface. The question is: how involved should the government be with the smart grid? One of the immediate discomforts of allowing the government to interact with the smart grid is the possibility of the institution to overstep their bounds; this renders firms upholding the smart grid immobile should the government increase regulations. Government involvement may have positive effects at times as observed in the case of the development of self healing systems. With respect to these two perspectives, a utilitarian pursuit may be desired: the attempt for the people to benefit by encouraging the free market to prosper while allowing the government to engage and redefine the forefront of scientific discovery. The benefits may be seen in the analyses of foreign countries struggling to establish the free market in the electric industry and the case study of the self healing F-15.

If a country is a proponent of free market and capitalistic values, certain characteristics must be met such as the extent of government intervention. The reason why government becomes involved is the level of regulation that needs to be administered in the grid for generators and suppliers. According to Haas and Auer, generators and grid operators or suppliers should be separated, or "unbundled", because it "ensures fair transmission access by potential new entrants." Regulation becomes the role of government in this aspect of market competition. This idea of separation ensures the presence of competition should new firms seek to join the market, a healthy aspect of capitalistic market.

The problem with government intervention, as indicated, is the extent of oversight that is granted to the government. Privatization of the market, solely, does not encourage market development; instead, free market competition provides the true source of positive feedback. (Haas & Auer, 2006) Haas and Auer also believe that post-reform electricity industry, which implied a successful implementation of the smart grid, should not include excessive intervention in response to "spot price volatility" which may be caused by "demand surges or supply failures". This refers to sudden bursts or activity that may incite government regulation to alter or increase. Haas and Auer may support these implications because these outbursts are seen to be regular occurrences of the free market; they may be a result of sudden preference changes of a large group of consumers. These bursts may be indicative of the healthy or unhealthy condition of the market. Nonetheless, government intervention should be restricted to a minimum due to the expected oscillations that occur in the market.

There are benefits to the involvement of government in the smart grid's progression. In the 1980s, an F-15 had a midair collision with a wingman's F-15, resulting in a loss of over 90% of the 1st F-15's right wing; amazingly, the pilot was able to guide the fighter jet to the landing strip through expert utility of control surfaces. Adding to this fortunate news, this also incited the development of the damage-adaptive intelligent flight control systems (IFCS). Ultimately, this instigated the study of a self healing power system through new institutions such as the Department of Defense's (DoD) Complex Interactive Networks/Systems Initiative (CIN/SI). (Amin & Wollenberg, 2005) As shown in Figure 4.1**Error! Reference source not found.**, a small block diagram shows the system's capability to assess the duress of the situation, concluding in producing a solution to safely continue the maneuvers of the F-15. The self healing power system is also a fundamental inclusion to the smart grid in its ability to assess its own faults and determine various reparations for its damage. This development may be seen as a derivative of the research conducted in a field relative to the smart grid, in this case the F-15 self healing station.



The IFCS design goal is to optimize controls to compensate for damage or failure conditions of the aircraft. (Picture courtesy of Boeing and NASA.)

Figure 4.1. F-15 Self-Healing Schematic. (Amin and Wollenberg, 2005).

4.5.2 Cyber Security

The centralized control over the smart grid brings in to question how much the government should be involved. While government control over our infrastructure would be invaluable in times of need, it also leaves a convenient cyber attack point that could cripple the nation. From a utilitarian standpoint it is essential that security be ensured before we even think of implementing the smart grid. As Bennie G. Thompson, Chair of US House Committee on Homeland Security, stated, “Any failure of our electric grid, whether intentional or unintentional, would have a significant and potentially devastating impact on our nation.”

Attacks from terrorists groups and unfriendly countries have been using the internet to gain intelligence. Terrorism experts believe that least 80% of the information required to plot an attack on the smart grid can be gained from public sources, such as the internet (Clemente, 2009). Furthermore, with each new connection made to the grid, another access point is made for intruders. It is estimated that an attacker with only $500 of equipment and basic electrical knowledge could gain control of the smart grid and manipulate the system to their liking (Clemente, 2009). Control of the smart grid would allow the intruder to tamper with price settings as well as supply and demand trends. More shockingly, it may be feasible to shut off the grid entirely given the correct circumstances. The possibility of such a catastrophic situation is not in the nation's best interest and steps must be taken to make sure that a technological breach never happens. The security needs to be able to adapt and avoid becoming obsolete in just a few years like so many other technologies being pushed today. Although the benefits of the smart grid are definitely needed, we cannot fully implement it until its security can be assured.

5 Recommended Solutions

5.1 Cost vs. Return Solutions

After conducting an analysis of the potential and functionality of the smart grid project, it can be shown that the total energy consumption of each region in the grid will drop dramatically assuming all of the technological logistics are worked out on the smart grid's end. Though the investment of the government will be great, over a length of time the savings made by the smart grid will outweigh the large amount of dollars the government invested. The project, therefore, should be implemented and carried out to ensure that the nation consumes less energy and has a greener future.

According to a San Diego Smart Grid Study, a capital investment of $450 million produced over $1.4 billion in reduction of costs (2006). The study was one of the first in the nation to apply smart grid concepts to a specific region and conduct an analysis of the technical feasibility and cost effectiveness of the program. This was accomplished by the project team developing "a series of future probable scenarios based on spectrum of extreme states of economic, environmental, and technology development" (2006). These scenarios were then applied on the operation of the regional electric grid and its impacts were documented. The study indicated that after 3.5 years of the smart grid's installation, the service provider would begin to see profit. Most importantly, after 5.5 years the internal rate of return is optimized with reduced costs, energy consumption and energy pricing. Finally, the study concluded that the region of San Diego would benefit economically, environmentally, and technologically from the implementation of the smart grid. On a national scale, it can be realistic to assume that the number of years for the program to optimize its return of investment and a profitable outcome would increase but so will the savings. If the nation is investing approximately $8 billion for the smart grid, (by using the same proportionality to that of the San Diego Study) the nation could be saving about $24.9 billion dollars in the long run. This is a savings that could be very valuable to the nation in its future financial endeavors and could potentially assist the nation in getting out of its debt.

Another important aspect is having the appropriate equipment to fully implement the smart grid system and ensure the lifetime of the equipment is maximized. The fortunate truth is that there are a lot of organizations and companies that have developed the necessary devices to handle output data and delivering reliable and cost-effective services to the customers. A published study from the Institute of Electrical and Electronics Engineers (IEEE) named "Smart Grid Technologies: Communication Technologies and Standards," presented essential requirements that the smart grid infrastructure must be able to meet for large-scale functionality. The infrastructure "requires two-way communications, interoperability between advanced applications and end-to-end reliable and secure communications with low-latencies and sufficient bandwidth" (November 2011). It was also report by the study that wireless communications have some advantages over wired technologies as a result of the low cost of infrastructure and ease of connection to difficult or unreachable areas (November 2011). This is very beneficial for deployment across the nation. Fortunately, such technologies exist and it is in the best interest for the federal government to invest in a technology that is cost effective while meeting operability requirements.

The most important factor to consider when choosing a technology is to understand that two types of information infrastructure are needed for information flow in a smart grid system. One flow includes the data transfer between sensors and appliances to smart meters. The second flow is from the meters to the utility's data centers. There are technologies that are available to accommodate such data transfer that include the ZigBee, Wireless Mesh, Cellular Network Communications, Powerline Communications, and Digital Subscriber Lines (November 2011). All of these technologies have their advantages and disadvantages in efficiency, cost, and functionality. In Table 5.1, several technologies are listed with specifications and limitations.

The options are available for the federal government to decide what systems they wish to use for the smart grid. Smart grid technologies are constantly under development and improving in performance and system reliability. The implementation of the smart grid is feasible and should be pursued.

Table 5.1. Advantages and Disadvantages of Wireless Smart Grid Technologies. (Güngör, 2011).

Technology	Spectrum	Data Rate	Coverage Range	Applications	Limitations
GSM	900-1800 MHz	Up to 14.4 Kpbs	1-10 km	AMI, Demand Response, HAN	Low date rates
GPRS	900-1800 MHz	Up to 170 kbps	1-10 km	AMI, Demand Response, HAN	Low data rates
3G	1.92-1.98 GHz 2.11-2.17 GHz (licensed)	384 Kbps-2Mbps	1-10 km	AMI, Demand Response, HAN	Costly spectrum fees
WiMAX	2.5 GHz, 3.5 GHz, 5.8 GHz	Up to 75 Mbps	10-50 km (LOS) 1-5 km (NLOS)	AMI, Demand Response	Not widespread
PLC	1-30 MHz	2-3 Mbps	1-3 km	AMI, Fraud Detection	Harsh, noisy channel environment
ZigBee	2.4 GHz-868-915 MHz	250 Kbps	30-50 m	AMI, HAN	Low data rate, short range

5.2 Solutions to Consumer Technological Concerns

To ensure the satisfaction of the customer, the smart grid must be designed with ease of use within the household. The establishment of a technological interoperability standard must be implemented that can communicate to any consumer appliance. Although a standard has yet to be established, smart grid compatible appliances are already in development and gaining the attention of large companies such as Whirlpool, a leading home appliance manufacturer. The company reportedly announced that it “is positioning itself to take advantage of the growing interest in Smart Grid technology [and] all of its electronically controlled appliances will be Smart Grid compatible by 2015” (Greenbiz Staff, 2009). This will assist in the transitional phases of the smart grid deployment that will allow consumers to use appliance brands that they are already familiar with and will already have interoperability with the smart grid network in their residences.

The need for an established interoperability standard is the key for companies like Whirlpool to deploy enhanced technologies that are energy and cost efficient. Although the United States has yet to produce a standard, there are organizations that have already been addressing the issue and are offering their technological solutions. The International Special Committee on Radio Interference (CISPR), for example, has proposed technological standards that smart grid technologies may utilize for system measurements and control (IEC, 2012). CISPR’s solutions allow for the smart grid to withstand an electromagnetic environment without causing any form of interference to electronic devices. This is crucial to the overall functionality of a smart grid system due to the wireless communications of electronic devices within a residence. As a result, the United States will have enough support through organizations like CISPR to ensure that the functionality of the smart grid is successful and efficient.

One of the most important key factors of the smart grid is its ability to have implemented alternative methods of energy generation that is eco-friendly and beneficial to the environment. National concern regarding the overall well-being of the environment has escalated over the past few decades as carbon emissions have skyrocketed. According to an article by Justin Gillis for the New York Times, the overall global carbon dioxide emissions were approximated to have increased by a record jump of 5.9% from 2009 to 2010 (2011). The United States alone is the second largest emitter of greenhouse gases and as a result, has contributed a devastating 2.2 billion tons of carbon into the atmosphere (2011). Although Gillis reports that this increase may not occur again, it is still estimated that the global carbon emissions will continue to grow annually by approximately 3% which includes growth from the Unites States. This is certainly a growth that is alarming for the preservation of the environment and its continuous threats from greenhouse gases. It is therefore the opportunity for the smart grid to contribute in carbon reductions.

One of the greatest contributions to carbon emission reduction will be the method in which the smart grid can generate energy for distribution. Extensive research is dedicated towards renewable energy sources that include utilizing solar and wind resources. Although concern has risen from the idea of implementing renewable energy sources as it poses more potential cyber-security threats, there are technological solutions that may respond to this issue. The issue is not necessarily the integration of renewable energy sources into the smart grid system but who owns it. It was reported by Ken Geisler of

Siemens Smart Grid Division that if the renewable energy sources are owned by the utility then security should be fine. It is renewable energy sources that are not owned by the utility provider that can potentially pose cyber-security threats (Johnston, 2012). The most efficient method of addressing this issue is to allow the utility to have control of renewable energy sources for the best security from cyber-attacks. This does pose another concern, however, if renewable energy sources alone can sustain utility's energy requirements especially during peak energy demands. Fortunately, techniques have been devised to address the issue. The technique is called load-shedding and it is a method to conduct real-time, dynamic load management for renewable resources (Johnston, 2012).

The method of load shedding for smart grid appliances has been test to produce very intriguing results. Mason County Public Utility District 3 (PUD3) tested GridMobility technology on approximately 100 residential water heaters in a smart grid project. The goal was to manage the fluctuations of wind energy generation (Johnston, 2012). PUD3was able to successfully monitor water heater usage with GridMobility technology and during heavy periods the water heaters would be shut down. This allowed the utility to successfully control the need for hydropower to balance the load thus providing more flexibility when using wind power. The test was reported to have produced a 30% increase in efficiency, a 90% reduction in peak energy use for water heating, and a 78% increase in renewable energy used for the water heaters (Johnston, 2012). Dynamic usage of smart grid appliances is the key to stabilizing the smart grid and thus placing more reliance on renewable energy. This, in return, will contribute to less carbon emissions from the consumption of fossil fuels.

The smart grid system as a whole can have large environmental benefits beyond the integration of renewable energy sources. Even though a quantitative measure of the exact environmental benefits is not entirely feasible, there have been studies that have shown impressive results. According to an article by Alex Zheng, Bruce Renz, and Joe Miller entitled "Your Smart Grid Environmental Benefits Toolkit", a study was conducted by an Electric Power Research Institute (EPRI) in 2003 of potential benefits accrued from a nationwide smart grid deployment. It was reported that the smart grid system could reduce national greenhouse gas emissions between 13%-25% (Zheng, 2008). Alex Zheng and his colleagues also reported that The Climate Group conducted a study and reported that the smart grid could reduce carbon emissions by 4% by the year 2020 (Zheng, 2008).

Overall, the smart grid system will have no negative effect on the environment and can only benefit the United States. The only limiting factors are the technologies that are being implemented into the smart grid all of which are being developed and improved. The ease of use, efficiency, and the dynamic functionalities of the smart grid have been proven by several studies that the system can benefit large regions in energy consumption, generation, and have great environmental benefits.

5.3 Building Fast vs. Right Solutions

The smart grid is symbolic of the continual progression and development of technology. Perhaps the most rewarding quality of implementing the new grid may develop out of patiently constructing the new grid. One of the intentions of the smart grid is to efficiently distribute electricity as a result of a population and industrial growth. As it follows, proponents of the smart grid should recognize the smart grid's need to serve the populace and the firms seeking to take advantage of the new grid's benefits. Recalling the application of duty ethics to building fast as opposed to building the smart grid correctly, there is the duty of building quickly to establish the nation as the world's leading smart grid technologist. There is also the duty of attending to the needs of the people by equilibrating, or monitoring, the implementation of the smart grid. China's method of implementing the smart grid quickly expects a "trickling effect" since the effect of having a leading stance in the smart grid's worldwide technology allows dividends to return out of demand for the leading technology. Korea, however, intends to involve its citizens in the process by incorporating their needs into their implementation plan. In reflection of these two approaches, the United States should implement the smart grid similarly to Korea's implementation method. The United States' duty to serve the people requires a direct measure of effect; the "trickle down" effect does not necessarily ensure that the people benefit from having leading technology. Korea's invested plan involves incremental builds of the smart grid. A plan similar to Korea's incremental build allows the United States to attend to its people through the incremental builds of its own smart grid. Duty ethics, aside from the duty adherence, expects adherence to the norms. Directly addressing the duty, without implications or indirect measures, is a true and positive measurement of ethical value. There is, therefore, a first and foremost obligation to ensure that the nation's firms and citizens are benefited.

5.4 Consumer Privacy Solutions

The key to the successful protection of an individual's consumer data is to make sure that the access points to the smart grid interface are well secured. Proper regulations and standards must be established to divide data between what is private and what is public. In addition a good protection system will implement early detection of attacks and anomalies as well as providing secure and reliable consumer interface access. A well established and protected authentication process is needed for all access points in a user's home. However, this process must not inhibit the ease of use for the consumer. This means that there must be two points of protection to properly monitor access to a users smart grid account. The user must actively try to protect their passwords and account numbers as well. The same technology that makes the smart grid convenient for consumers will also make it convenient for attackers to take personal data. A consumer should treat their smart grid account much like they would a bank account.

To aid the consumer in protecting their data, a control center which can monitor activity in certain areas should be established to alert users of abnormal activity (Fadlullah, 2011). These control centers would not be used for individual tracking, but rather monitor the overall activity and trends in a given area. The control center will be able to alert the area of the questionable activity should an anomaly. This early detection is essential to catching attackers as well as deterring future attacks. s

In addition to the control centers, the National Institute of Standards and Technology (NIST), the American National Standards Institute (ANSI), the International Electrotechnical Commission (IEC), and many other standard development organizations are working on developing protective standards and regulations (Liu, 2011). Their standards and regulations will aim to define personal information as well as give a baseline of requirements for smart meters. However, even with these planned safety regulations consumers must not forget to read and understand these regulations. These regulations can only prevent so many issues before they encroach on the benefits of smart grid products. It is up to the consumer to understand the data necessities of the HAN, back by new appliances. It is also up to consumers to be aware of the contractual agreements that will outline data ownership (Liu, 2011). The agreements will be very similar to those found in smart phone applications. So consumers must carefully understand what information they will be actively providing. And in most cases, the information is only meant to improve service rather than malicious intents.

Further strategies and principles for smart grid cyber security will be discussed with national security solutions in section 5.7.2 Cyber Security Solutions

5.5 Dynamic Pricing

Dynamic pricing is a model that could further improve the benefits of smart grid technology. It can even help improve the efficiency of current grid. The main opposition to this model is the perception that it will be unfair. However, the analysis from Ahmad Faruqui, a principal member of The Brattle Group, shows that the majority of users will save money using a dynamic model. Granted protective measures will still be needed to prevent users from being overcharged, the model's benefits outweigh its dangers.

Faruqui splits electricity customers into three groups: Average Users, Peaky Users, and Flat Users. By defining peak hours from noon until 6 pm Average Users consumer twenty-five percent of their power during this period, Peaky Users use forty percent, and Flat Users only ten percent. With these three groups he compares three different dynamic pricing models: Critical Peak Pricing (CPP), Time of Use (TOU), and Real Time Pricing (RTP).

CPP relies on drastically raising the price of power during peak hours and decreasing it during off hours (see Figure 5.1). TOU is a very similar model, however the difference between peak hour prices and off hour prices are not as drastic (see Figure 5.2). RTP will utilize the smart grid's real time tracking ability and will adjust prices based on demand (see Figure 5.3). All of these models are intended to discourage over-use during peak hours. If any of these models were adapted on today's current grid, we would see a decrease in wasted electricity, risk of black outs, and monthly bills by most customers. As Faruqui finds, Flat users are paying $3.92 billion above what they would have paid under a TOU rate while Peaky Users are benefiting from this subsidy. This is extremely unfair. Essentially, Flat Users are paying for a good portion of the power used by Peaky Users. Any of these models can remedy this injustice and make sure that everyone pays fairly for what they use.

Furthermore, dynamic pricing will benefit the majority of users without any change in their electrical usage. Figure 5.4 shows the percentage change in monthly bill customers will see before and after customer response. Nearly eighty percent of customers will benefit from a dynamic pricing model. Figure 5.5 shows that even low income customers will benefit. This is largely caused by low income customers who do not have a very large electrical demand since they do not usually have luxury appliances such as air conditioning which gobbles up power. In a pilot program in Washington, D.C, Stanford University researcher, Frank Wolak found that the demand response shown by low income customers to a critical peak pricing rebate program was almost twice as large as that exhibited by non-low income customers (Faruqui, 2010). If these are the results that we see on the current grid, then the savings with smart grid technology could be even more.

The success of dynamic pricing will hinge upon a proper implementation of the model. First, Faruqui suggests that customers must be provided with some form of bill protection. This would allow the customer to pay either the current flat rate or the dynamic price rate, whichever is lower. The customer must also be allowed to design their own payment plan. Some customers may not want to risk following a dynamic model right away. Thus the option to combine different pricing schemes needs to be offered that allows the customer to define how they will be charged for certain periods of time. For example, an Average User may want to use RTP pricing during 2-6 pm while using TOU for the rest of the day. This flexibility in payment programs will help customers adjust into the dynamic pricing model.

Dynamic pricing models have found success in many other industries. Cell phone plans rely on this model to accommodate all types of users. Airlines, car rentals, and hotels change their pricings to reflect demand as well. Many sporting events have also adopted dynamic pricing models by charging more for more popular games and charging less for less popular ones. All of these industries have met great success with dynamic pricing and the smart grid has the potential to do just as well. Failure to provide this option to customers would greatly diminish the benefits of the smart grid technology.

With each of these dynamic pricing models, fair availability of power should not be an issue. All consumers will only be paying for the electricity they actually use under a price plan they have chosen. And utility companies will only benefit if they create pricing that consumers find fair (Faruqui, 2011). If the utility cannot provide pricings on terms that the consumer is comfortable with then both the consumer and the utility will lose. The utility should not see any loss in profits and the consumer should not be overcharged. The idea of having high priced peak hours is meant to discourage overloading of the grid and waste of energy. It will require a change of habits on both the utilities and the consumers, but the result should offer fair availability and cost of power while providing improved energy efficiency and environmentally conscious practices.

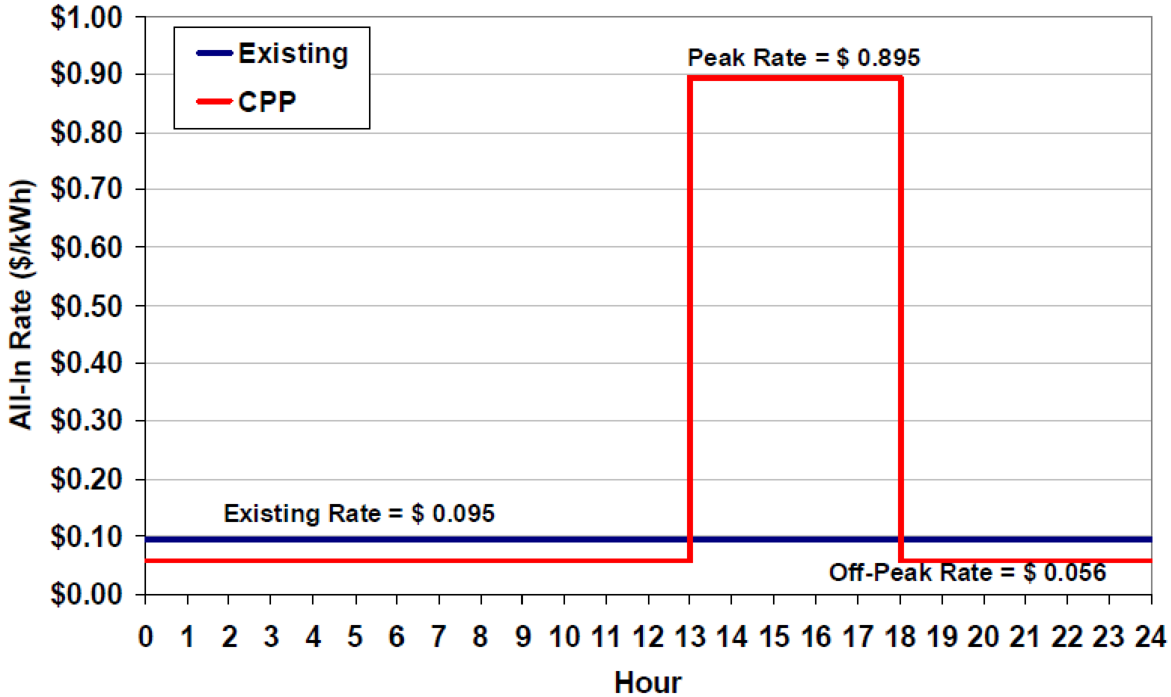


Figure 5.1. Illustration of CPP Rate. (Faruqui, 2010).

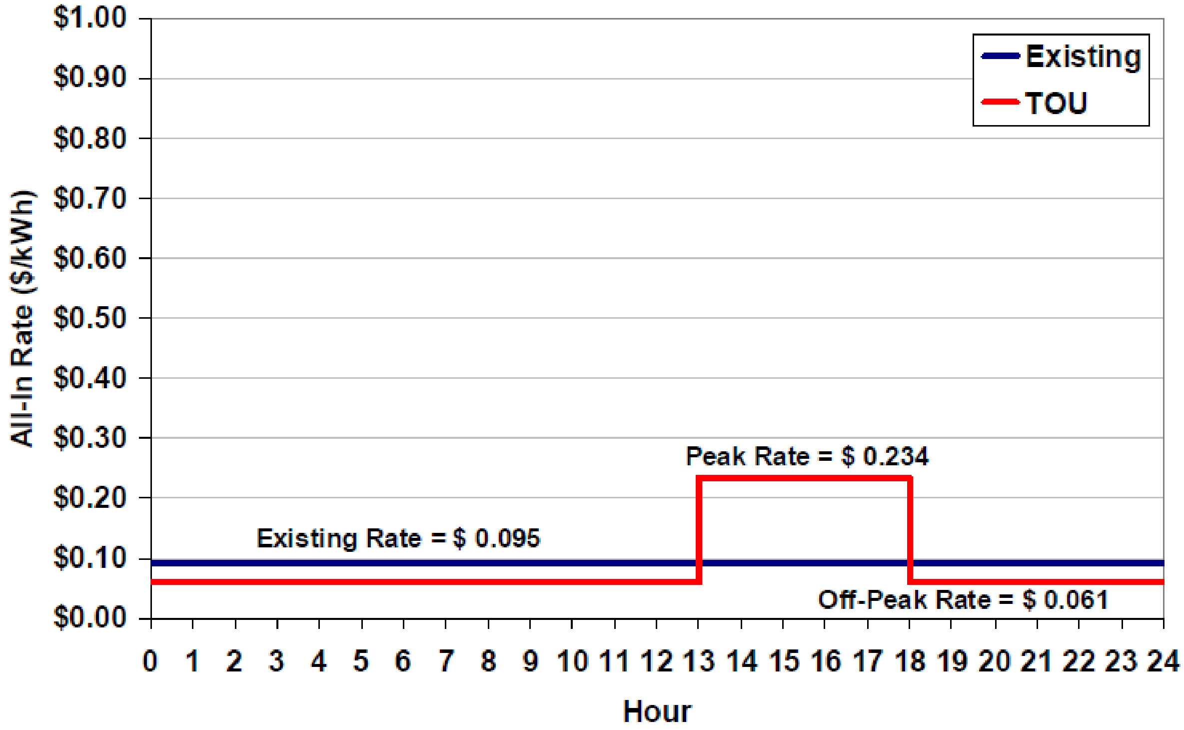


Figure 5.2. Illustration of TOU Rate. (Faruqui, 2010).

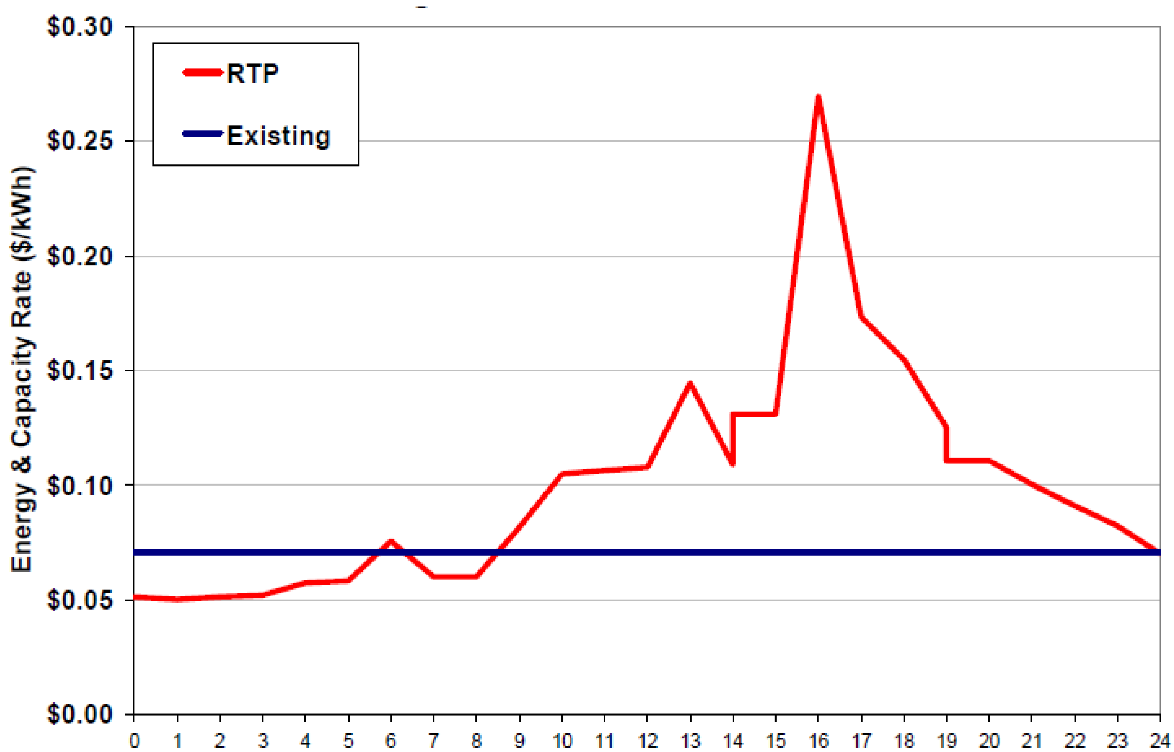


Figure 5.3. Illustration of RTP Rate. (Faruqui, 2010).

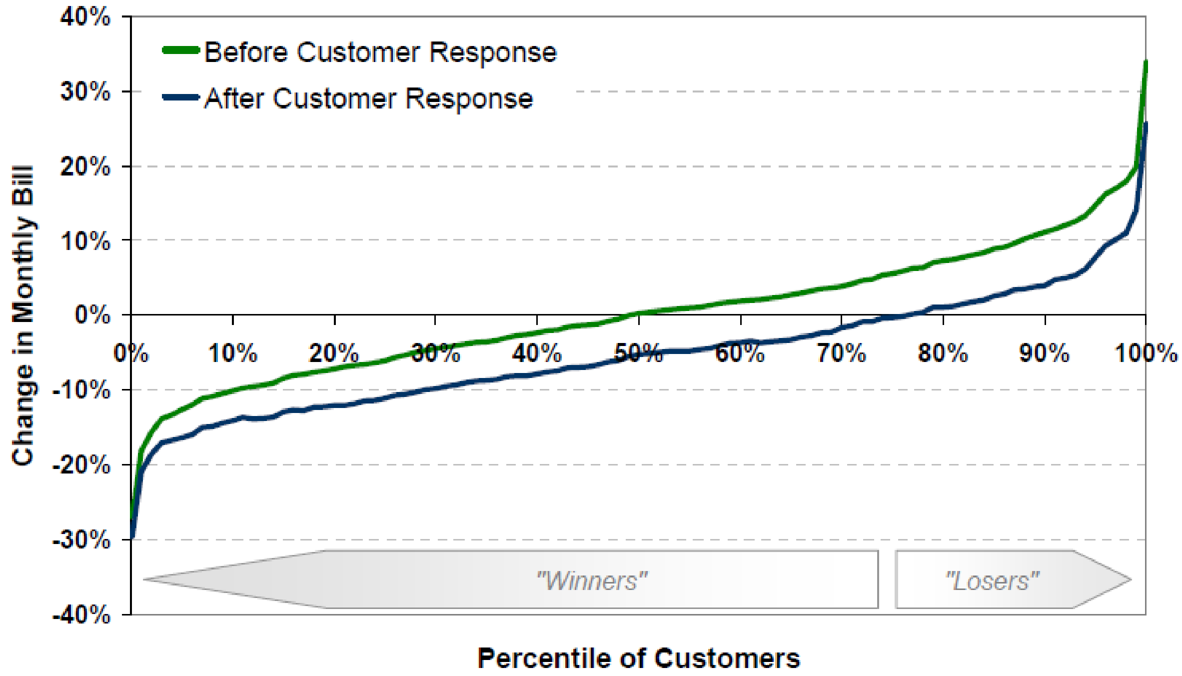


Figure 5.4. Distribution of Dynamic Pricing Bill Impacts. (Faruqui, 2010).

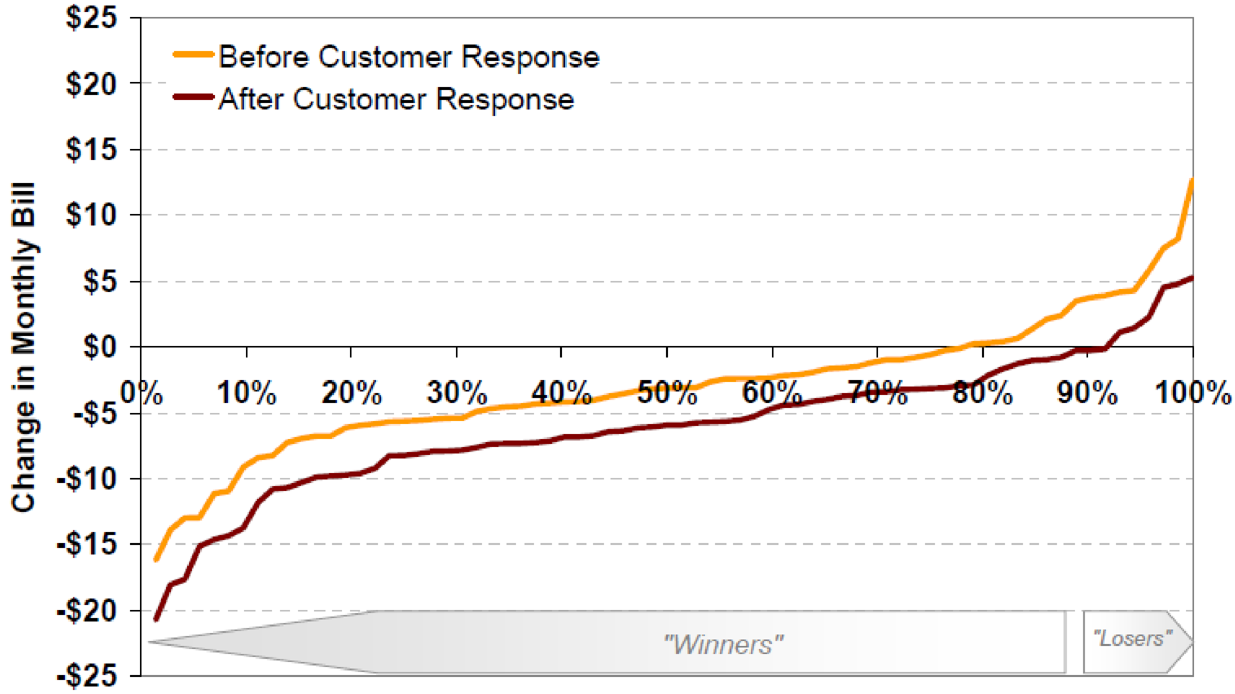


Figure 5.5. Bill Impacts for Low Income Consumers. (Faruqui, 2010).

5.6 Health Precautions

Without concrete evidence to support the effects of RF radiation, it is hard to prevent the advancement of smart grids. However, this does not mean we should not prepare by taking precautions to what can develop into very serious side effects. Consumers need to be aware of the implications of having smart meters in their homes. Developments of devices that could act as an RF radiation protection system provide a way to protect consumer health while utilizing the benefits of the smart grid.

It has been shown that RF radiation can indeed contribute to health issues, all the way from headaches to cancer and immune system damage. Although most of these cancers are due to people being hyper sensitive to RF radiation, the smart grid cannot be used if the smart grid causes these detriments. Most medical professionals are unfamiliar with RF radiation and it is often times mis-diagnosed (Perlingieri, 2011). Until smart meters can be definitively shown to have no adverse health effects, the smart grid cannot become the universal power distribution model.

However, the smart grid must be tested somehow. The option should be given to consumers if they want to have a smart meter installed in their home. This will require the involvement of city governments and protective regulations from organizations like NIST, ANSI, and IEC, to make sure a system is established in which those who would like to have a smart meter are given that opportunity while ensuring the safety of those who do not want one. It will be a very tedious process and perhaps be the biggest obstacle the smart grid faces. But it must be done to avoid later repercussions similar to lead paint and asbestos towards consumer health.

Another alternative is to remove the wireless portions of smart meters. By using fiber optics or another form of wired connection, consumers could still benefit from the capabilities of the smart meters without the adverse affects caused by the wireless receivers. The system may not be as convenient, but it would be just as effective and have even better security. Fiber optic cables are more rugged and harder to attack both physically and cybernetically (Kennedy, 2011). The reliability and longevity of the system would also be much more stable than a wireless system: a fact which should not go overlooked. However the cost and maintenance of a wired ground would be very expensive. Thus a true solution will likely involve use of both types, wired and wireless, to meet demands (Güngör, 2011).

5.7 National Security Solutions

5.7.1 Government involvement

Government involvement is a controversial issue; this ultimately requires regulators and legislative bodies to be cautious in outlining the extent to which government may be involved. In order to reinforce the state of a free market, the government should maintain a stance of laissez faire when handling industry issues. Despite these restrictive bounds, the case study of the F-15 has shown the benefits of inclusive government interaction with the firms as the government's institutions helped push the forefront of science.

The dire case of industrial collapse requires definite involvement of the government. The natural oscillations in the capitalistic market should not cause distress amongst government officials, however, as Haas and Auer implied that the free market has its peaks and valleys when firms enter or exit the market. Unlike the free market policy, China's governance structure renders the market to accord to the leaders' expectations and desires. (Adam, 2011) In contrast, the American government has also helped mobilize certain parts of the industry, both public and private sectors, as indicated through the F-15 case study. Overall, this type of government involvement aids the economy as the officials try to lead the scientists at the forefront of smart grid technology. The role of government to help push the boundaries of the smart grid, while monitoring the firms' and citizens' vitality through the grid's correct implementation, creates a more unified and coherent cause to pursue between the government and its people. Without this stance, the government and people may develop diverging opinions on the smart grid implementation issue, resulting in an imperfect and disjointed construction of the smart grid.

5.7.2 Cyber Security Solutions

Many of the solutions to consumer privacy concerns can be applied to cyber security on a national level. But a more elaborate support system is desirable to protect the grid on the national scale. This protection system needs to have extremely rapid and accurate anomaly detection. A division of the grid into sub-grids may also desirable. Doing this enables other parts of the grid to be protected if one portion should be attacked or fail.

First, a plan that prevents total grid failure is required. At the IEEE Canada Electrical Power Conference Alexander Hamlyn, *Helen Cheung*, Todd Mander, Lin Wang, Cungang Yang, and Richard Cheung presented a smart grid role-based access control (SRAC) strategy (Liu, 2012). In this strategy, the entire grid is divided into micro grids and those micro grids are divided even further into several sub-domains which are differentiated by functionalities and energy resources. The local SCADA system is then used to authorize access to all users by following predefined "roles". A user can be assigned several roles with different authorities and functions. These roles can share responsibilities and follow a tree structure where "parent" roles inherit all aspects of the connected "children" roles. This strategy provides a means of checking the reliability and trustworthiness of any user request before given them a certificate. If managed correctly this multilevel framework can provide the distributive control needed to make a grid that stifles widespread failures should one portion of the grid be compromised. The ability to isolate a failure of the grid will ensure that the nation's defenses are never completely powerless and allow for speedy recovery of the failed area.

As addressed with consumer privacy, an anomaly detection system is vital to the security of the grid. Qingle Pang, Houlei Gao, and Xiang Minjiang from Shandong University presented a multi-agent based fault location algorithm at the 10th IET International Conference on Development in Power System Protection (Liu, 2012). The model defines three different types of agents: node agents, control agents, and database agents. Every smart grid element will have an agent attached to it in order to measure transient voltage. The way the three agents interact is very similar to the control center concept discussed in consumer privacy. The node agents monitor access points to the smart grid. They utilize voltage and current measurements to determine whether the node is faulty or not. This information is then received by the control agent (which would be located at a central control center). Here the control agent decides whether or not to trigger the alarm. At the same time this is happening, the database agent is recording all of this information to provide a history of incidents. These three agents are free to communicate allowing them to provide the best response to pin point and react to fault incidents. This algorithm will be able to "learn" as a supplementary by the database agent. Also the free communication between three separate entities will make attacks on the security much more difficult.

Finally, for legal as well as trouble shooting purposes, security technologies that are implemented must be recordable and traceable. This is to ensure accountability whenever future problems and vulnerabilities arise. This accountability is desirable since homeowners could end up receiving two separate electric bills, one from the utility company and one from the smart meter (Liu, 2012). Having a means of placing accountability will keep both users and providers honest and organized. Combined with suitable punishments in the real world this plan could help prevent attacks. However, such a traceable framework will inevitably encroach upon consumer privacy. This issue will again require NIST, ANSI, IEC and other organizations working together to establish protective regulations which clearly state the definition of private data (Güngör, 2011).

6 Conclusion

The smart grid system is a necessary technological advancement for the United States that should be taken with great priority in its development. The current power grid, though functional, is outdated, inefficient and harmful to the environment. The technological advancements of the smart grid system will be benefitting the nation economically, environmentally, and technologically. After an analysis of the different controversial aspects of the smart grid features and the feasibility to which the project can be completed, it is certain that the project should be carried forth.

The overall construction of the smart grid consists of large financial investments from the federal government, stakeholders, and other organizations in research and development. The key components of a smart grid system will be the implementation of an Advanced Metering Infrastructure for bi-directional flow of data. The installation of AMI technologies into homes and new infrastructures will create the possibility of communication between homes and the utility grid companies. With the current technological developments of wireless technologies and communication protocols, an infrastructure can be developed. It is, however, in the best interest of the federal government to improve on these technologies to ensure a cost effective and efficient form of data transfer and metering.

Another concern of the current and smart grid is the rising peak energy demands from the nation. It has been proven that the current power grid is not sufficient in meeting these demands. The smart grid will have technologies such as the ability to plug in electric vehicles to plug in directly to the utility grid and recharge their batteries from the grid as well as submitting electricity back into the grid. The developments of these technologies are underway in many car industries and are already commercialized. The overall benefit is to lower pollution generated from cars as well as a method in reusing unused energy for power grid stability. The technologies continue to enhance and should therefore be implemented into the smart grid for optimal performance.

Unlike the current power grid, the smart grid will have technologies implemented that will encourage its consumers to consume less energy. Consumers will have systems such as home energy management systems (HEMS) or home area networks (HAN). HAN will enable the consumers to manage their power consumption and give the utility companies an easy way to send information through the smart grid to the consumers to turn off their devices.

In addition to the reduction of energy consumption, the smart grid will implement alternative methods of energy generation that is eco-friendly and beneficial to the environment. National concern regarding the overall well-being of the environment has escalated over the past few decades as carbon emissions have skyrocketed. One of the greatest contributions to carbon emission reduction will be the method in which the smart grid can generate energy for distribution. Extensive research is dedicated towards renewable energy sources that include utilizing solar and wind resources.

From a technological perspective, the smart grid will continue to thrive in its development as new technologies are created and improved. Strong financial investment in technological research will be the main contributing factor in deploying a fully functional smart grid. After conducting an analysis of the potential and functionality of the smart grid project, it can be shown that the total energy consumption of each region in the grid will drop dramatically assuming all of the technological logistics are worked out on the smart grid's end. Quickly implementing the smart grid grants the United States standardizations of appliances and elements that are to be compatible with their smart grid across the globe. Rapid startups of the new grid, however, would leave domestic consumers and firms unattended to their needs, such as enabling transparency between firms to communicate efficiently through the new grid.

From an ethical standpoint, the smart grid must be implemented with intelligent and protective regulations. Consumer safety, health and privacy should be of the highest concern. Regulations and standards that clearly outline the boundaries of privacy and also establish the minimum requirements for health safety will be responsible for a successful transition from the old grid to a smart grid. In addition, an understanding of the advantages of dynamic pricing must be provided to consumers so that the true potential of the smart grid can be realized. A dynamic pricing model is fair and will allow people to only pay for the power they actually use, rather than the current system which is based on a flat rate.

Most importantly, the smart grid must have an adaptive and responsive security system. Without a reliable security system, the smart grid would provide a convenient point for the nation's enemies to attack. Early anomaly detection and rapid recovery are key components to a successful smart grid security system. Proposed models such as SRAC and multi-agent based fault location algorithms are promising solutions. These models combined with intelligent, specific, and adaptive standards and regulations will make the smart grid much safer and more efficient than the current power grid.

Concern about the national security of the smart grid draws a salient organization into the picture: the government. Although skepticism exists as to how involved the government should be, government involvement may have positive effects at times as observed in the case of the development of self healing systems. A utilitarian pursuit may be desired in the attempt for the people to benefit by encouraging the free market to prosper while allowing the government to engage and redefine the forefront of scientific discovery.

After understanding the controversial elements and the technical necessities in constructing and deploying a functional smart grid system, it has been acknowledged that the nation will be benefitting more from the smart grid than the current power grid. With consideration to the current economic and environmental concerns of the United States, the current power grid must be updated to a more efficient and cost effective system. There have been great strides in technological advancements for the smart grid construction. The government must then seek a steady pace of development for establishing standards, regulations, and protocols that will serve the greatest benefit to the consumer and utility provider. An active and adaptive security system will be developed to ensure no cyber threat can penetrate or tamper with the established functionalities of the smart grid. The government should assist in this process and uphold a “Laissez-faire” methodology in its involvement while contributing constructive advancements in the smart grid’s deployment. The savings made by the smart grid will outweigh the large amount of dollars the government invested. The project, therefore, should be implemented and carried out to ensure that the nation consumes less energy, is supplied with energy more effectively, and has a greener future.

7 Glossary

AMI	Advance Metering Infrastructure
ANSI	American National Standards Institute
CAISO CAMX	California Independent System Operator for the California-Mexico Power Area
CIN/SI	Complex Interactive Networks/Systems Initiative
CISPR	International Special Committee on Radio Interference
CPP	Critical Peak Pricing
DoD	Department of Defense
DOE	Department of Energy
EPRI	Electric Power Research Institute
EVs	Electric Vehicles
G2V	Grid to Vehicle
HAN	Home Area Network
HEMS	Home Energy Management Systems
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFCS	Intelligent Flight Control Systems
KRW	South Korean won; South Korea's measure of currency
MDMS	Meter Data Management Systems
NIST	National Institute of Standards and Technology
PH	*See PHEV*
PHEV	Plug-In Hybrid Electric Vehicle
PUD3	Public Utility District 3
RF	Radio Frequencies (Typically 3kHz to 300GHz)
RTP	Real Time Pricing
SCADA	Supervisory Control and Data Acquisition
SGIG	Smart Grid Investment Grant program
SRAC	Smart Grid Role Based Control

TOU	Time of Use
UHV	Ultra High Voltage
V2G	Vehicle to Grid

8 References

Amin, S. M., Wollenberg, B. F., September/October 2005, Toward a Smart Grid: Institute of Electrical and Electronics Engineers (IEEE) Power and Energy Magazine, 34-41p.

Chakraborty, S., Kramer W., Kroposki B., Martin G., McNutt P., Kuss M.,Markel T., and Hoke A., 2011, U.S. Department of Energy, National Renewable Energy Laboratory, Interim Test Procedures for Evaluating Electrical Performance and Grid Integration of Vehicle-to-Grid Applications. [www.nrel.gov/docs/fy11osti/51001.pdf; Accessed February 1, 2012].

Chandler, D. L., 2011, New Battery Design Could Give Electric Vehicles a Jolt, MIT - Massachusetts Institute of Technology - MIT News. [http://web.mit.edu/newsoffice/2011/flow-batteries-0606.html; Accessed January 29, 2012].

Clemente, J., 2009, The Security Vulnerabilities of Smart Grid: Journal of Energy Security.

DeForest, N., Funk, J., Lorimer, A., Ur, B., Sidhu, I., Kaminsky, P., and Tenderich, B., 2009, Impact of Widespread Electric Vehicle Adoption on the Electrical Utility Business – Threats and Opportunities Center for Entrepreneurship & Technology, Berkeley, California,: Center for Entrepreneurship & Technology, Report 2009.5.v.1.1, 35p. [http://www.techrepublic.com/whitepapers/smart-grid-the-new-and-improved-power-grid-a-survey/3759183].

Fadlullah, Z. M., Fouda, M. M., Kato, N., Shen, X., Nozaki, Y., September/October 2011, An Early Warning System against Malicious Activities for Smart Grid Communications: Institute of Electrical and Electronics Engineers (IEEE) Network, 50-55p.

Faruqui, F. 2010, The Ethics of Dynamic Pricing: The Brattle Group, 22p. [http://www.smartgridnews.com/cgi-bin/artman/search.cgi]

Gillis, J., December 2011, Carbon Emissions Show Biggest Jump Ever Recorded, The New York Times. [http://www.nytimes.com/; Accessed March 6, 2012]

Grant, R.L., May 2010, Smart Grid Implementation Strategies for Success: Lexington Institute, 24 p. [www.lexingtoninstitute.org/library/.../Smart_Grid_Implementation.p.]

Greenbiz Staff, May 2009, Whirlpool Set to Launch Smart Grid Compatible Appliances by 2015. [http://www.greenbiz.com/; Accessed March 9, 2012]

Güngör, V. C., Sahin, D., Kocak, T., Ergüt, S., Buccella, C., Cecati, C., and Hancke, G. P., November 2011, Smart Grid Technologies: Communication Technologies and Standards, IEEE Transactions on Industrial Informatics 7.4.

Haas, R., Auer, H., 2005, The prerequisites for effective competition in restructured wholesale electricity

Markets: Vienna, Austria: Energy Economics Group, Institute of Power Systems and Energy Economics, 857-864p.

Hansen, T, March-April 2011, Personal Information Concerns Smart Grid Developers, Electric Light & Power, 70-71p. [http://web.ebscohost.com]

International Electrotechnical Commission, 2012, CISPR provides essential standards for SmartGrid EMC application. [http://www.iec.ch/emc/smartgrid/; Accessed March 9, 2012]

James, A., December 8, 2011, Hottest Issues in Smart Grid, Part 2: Interoperability Standards “Doing it Fast” Versus “Doing it Right”: ThinkProgress: Climate Progress.

Jeff, J. St., Greentech Media 2009, Smart Grid Gets $3.4B in DOE Stimulus. [http://www.greentechmedia.com/articles/read/smart-grid-gets-3.4b-doe-jolt/; Accessed February 16, 2012].

Johnston, M. W., January 25, 2012, Renewable Energy World, Smart Grid Initiatives Address Cyber Security, Renewable Energy Intermittency. [http://www.renewableenergyworld.com/; Accessed March 4, 2012]

Kennedy, M., June 2011, Leveraging Investment in Fiber Optic Communications, IEEE Smart Grid, IEEE: Smart Grid. [http://smartgrid.ieee.org/newsletter/june-2011/105-leveraging-investment-in-fiber-optic-communications]

Keyhani, A., 2011, Design of Smart Power Grid Renewable Energy Systems: New Jersey, United States, John Wiley & Sons, p. 1.

Kim, J., Park H. I., January/February 2011, A National Vision: Institute of Electrical and Electronics Engineers (IEEE) Power and Energy Magazine, 40-49p.

Lerner, E., 2003, What's wrong with the electric grid?: Industrial Physicist . [http://www.aip.org/tip/INPHFA/vol-9/iss-5/p8.html]

Levitt, B., Glendinning, C., 2011, The problems with Smart Grids: Energy Bulletin, 12p. [http://www.counterpunch.org/levitt03182011.html]

The Linc Group, 2011, EV Infrastructure 101. [http://www.thelincgroup.com/pdf/EV%20Infrastructure%20101.pdf; Accessed January 28, 2012].

Litos Strategic Communication, 2008, The Smart Grid: An Introduction: United States of America, U.S. Department of Energy, 48 p. [http://energy.gov/oe/smart-grid-primer-smart-grid-books]

Liu, J., Xiao, Y., Li, S., Liang, W., Chen, P., 2012, Cyber Security and Privacy Issues in Smart Grids, *IEEE* (2012).

Monterey County Health Department, March 2011, Review of Health Issues Related to Smart Meters, Monterey County Health Department, Public Health Bureau, Epidemiology and Evaluation.

National Geographic Society, 2007, Effects of Global Warming. [http://environment.nationalgeographic.com/; Accessed March 7, 2012]

Perlingieri, I. S., Aug. 2011, Radiofrequency Radiation: The Invisible Hazards of "Smart" Meters, Center for Research on Globalization. [http://www.globalresearch.ca/index.php?context=va]

Rates, Charts, and Tables – Electricity, 2011: United States California Public Utility Commssion. <http://www.cpuc.ca.gov/PUC/energy/Electric Rates/ENGRD/ratesNCharts_elect.htm>.

Recovery Act Smart Grid Programs, U.S. Department of Energy, March 2, 2012, Tracking Deployment. [www.smartgrid.gov]

SAIC Smart Grid Team, October 2006, San Diego Smart Grid Study Final Report.

[http://www.ilgridplan.org/]

Smart Grid: An Introduction. United States Office of Electricity Delivery & Energy Reliability. <http://energy.gov/oe/downloads/smart-grid-introduction-0>.

SMART GRID: Energy.gov. [http://energy.gov/oe/technology develohttp://energy.gov/oe/technology-development/smart-gridpment/smart-grid]

South Mississippi Electric. 2008. [http://www.smepa.coop/news/smepa_insert_august08.pdf]

Steiger, G., 2012, Glendale Water & Power's Smart Grid Project How GWP Became the First…

U.S. Department of Energy, Office of Energy and Renewable Energy, 2011. [http://www.afdc.energy.gov/afdc/laws/law/NC/9355; Accessed February 20, 2012].

Van de Poel, I., Royakkers, L., 2011, Ethics, Technology, and Engineering: An Introduction: Wiley-Blackwell, 89p.

Vidya, Editor, 2010, Smart Meter Radiation Risks, EarthCalm. 16 Feb. 2012. [http://www.earthcalm.com/5582/emf-dangers-2/smart-meter-radiation-risks/]

Vision for the Modern Grid, 2007: United States Department of Energy Office of Electricity Delivery and Energy Reliability.

Wu, Y. N., Chen, J., Liu, Li-Rong, 2011, Construction of China's smart grid information system analysis: Beijing, China: North China Electric Power University, Zhu Xin Zhuang School of Economics and Management: Renewable and Sustainable Energy Reviews, 4236-4241p.

Xi, F., Misra, S., Xue, G., and Dejun, Y., 2011, IEEE COMMUNICATIONS SURVEYS & TUTORIALS, Smart Grid – The New and Improved Power Grid: A Survey. [http://www.techrepublic.com/whitepapers/smart-grid-the-new-and-improved-power-grid-a-survey/3759183; Accessed January 25, 2012.].

Yu, Q. and Johnson, R. J., 2011, Smart grid communications equipment: EMI, safety, and environmental compliance testing considerations. Bell Labs Technical Journal, 16: 109–131p.

Zheng, A., Renz, B., Miller, J., November 2008, Your Smart Grid Environmental Benefits Toolkit. [http://www.smartgrid.gov/; Accessed March 11, 2012]