



Roadmap of Future Smart Grid, Smart Home, and Smart Appliances

Wang Xiang, Marc St-Hilaire, and Thomas Kunz
Systems and Computer Engineering
Carleton University, Ottawa, Ont., Canada

Contents

- CHAPTER I: INTRODUCTION1
- CHAPTER II: CONSUMER SURVEY2
 - 2.1 Smart Grid Is Not Well Known.....2
 - 2.2 Public Willing To Learn More2
 - 2.3 Roadmap to Long-term Adoption.....3
 - 2.4 Study of Consumer Segmentation4
 - 2.5 Social Norms and Activities to Stimulate Participation5
 - 2.6 Automation Acceptance5
 - 2.7 Chapter Remarks6
- CHAPTER III: CURRENT DEVELOPMENTS7
 - 3.1 Government Moves7
 - 3.2 Utility Developments.....8
 - 3.3 Electric Vehicle Advancement9
 - 3.4 Technology Giants..... 10
 - 3.5 Innovative Solutions Developments..... 11
 - 3.6 Smart Home & Smart Appliances Developments 12
 - 3.7 Standards Developments 14
 - 3.8 Chapter Remarks 15
- CHAPTER IV: CONCLUSIONS..... 16
- REFERENCES 17

LIST OF FIGURES

Figure 1: Consumer End of the Smart Grid [33]1

Figure 2: Consumer Questions about Smart Grid [4]3

Figure 3: Utility Industry Evolution Model over the Next Decade [5]4

Figure 4: Consumer Segmentation [4].....5

Figure 5: U.S.A Smart Grid Project Stimulate Coverage [12]7

Figure 6: Smart Meter Coverage in Canada [14]9

Figure 7: GM – Volt..... 10

Figure 8: CISCO Home Energy Controller [45] 12

Figure 9: Communication Testing Model with Multiple End Devices [46] 14

CHAPTER I: INTRODUCTION

This report summarizes the research findings on current developments on smart grid [1], smart home, and smart appliances, focusing on the best interests of consumers, consumer service providers, product developers, and academic researchers. Residences and small businesses are the target consumers of this report.

The central theme of the report is energy consumption reduction and carbon footprint reduction using different demand response [2] technologies. Smart home and smart appliances here refer to those optimized power usages based on electricity pricing information, weather condition, tenant occupancy, and other conditions. They automate the processes of scheduling devices operation time and the selection of energy source (power transmission line/local renewable energy/battery). As shown in Figure 1, a conceptual smart home has knowledge of electricity pricing information via the Advanced Metering Infrastructure (AMI), or internet/FM radio. Based on this information, a smart home intelligently schedules the smart appliances' operating time. Under suitable conditions for local renewable energy sources, such as solar panels and wind mill, a smart home efficiently utilizes those energies. Upon power outages, a smart home switches the energy source to renewable sources or the batteries, such as an electric vehicle. In addition, if there is surplus energy generated locally, a smart home pushes energy back to the power grid to serve those who are in need [3]. Other issues such as bulk generation, power transmission, distribution, and security will not be covered in this report.

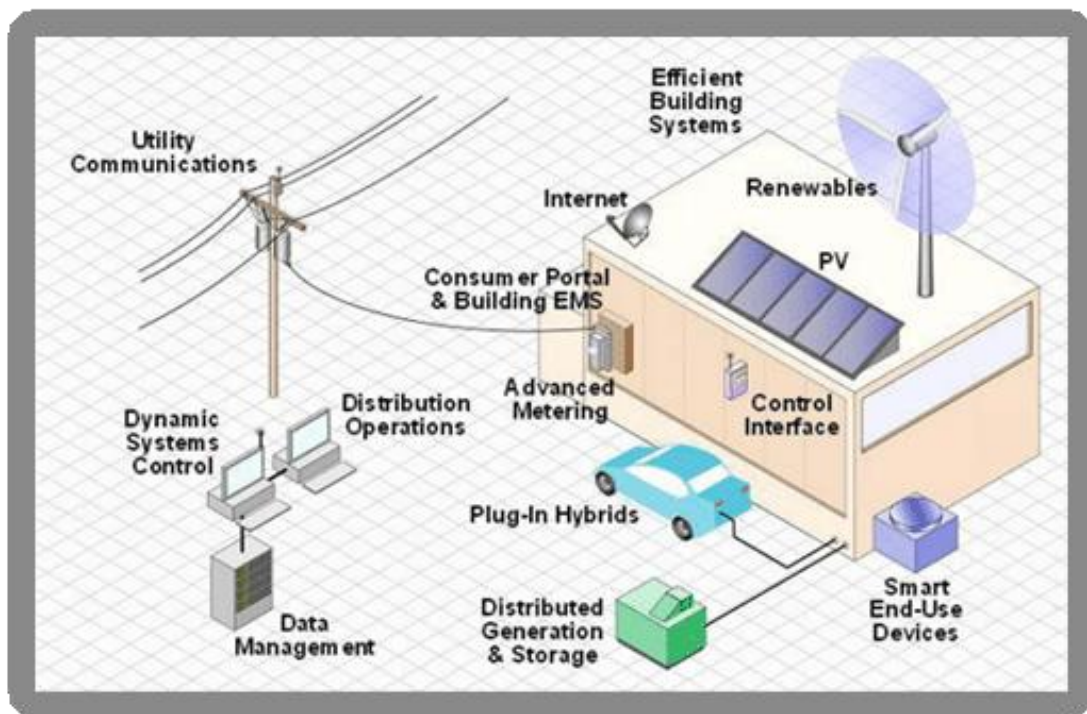


Figure 1: Consumer End of the Smart Grid [33]

CHAPTER II: CONSUMER SURVEY

As a starting point, it is important to understand the consumer or general public's opinion about smart grid technology and smart home technologies. The needs and requirements from the consumers are among the driving factors for both business and academic research.

Several different groups of people and organizations conducted a few thorough and meaningful surveys [4] [5] [6] [7] [8]. The U.S. based Smart Grid Consumer Collaborative looked over 80 research studies and white papers, and generated the "2011 State of the Consumer Report" [4]. Although this report, similar to many other surveys, is heavily focused on smart meter programs and on the best interest of utility companies, it does reflect the current state of consumer attitudes and awareness about the smart grid. Therefore, [4] will be used as the guideline and framework to present the survey findings.

2.1 Smart Grid Is Not Well Known

Multiple surveys reveal that only a small percentage of people have knowledge of how energy is generated and distributed. According to [4], only 28% of sampled individuals have a general understanding of what the smart grid really is, and what benefits it brings to both the environment and the economy. Of these 28%, only 9% of them have enrolled in an electricity management program. Less than half of the consumers are aware of smart meters, even when those are deployed in their area. In the U.S. more than a quarter of the population does not know that they have the choice of purchasing energy from someone other than their local electric utility.

Although these facts are not encouraging, they otherwise indicate a huge potential market for growing business opportunities. All people who do not know about the technologies, or have not yet participated in a demand response program, are potentially open to new products and services.

2.2 Public Willing To Learn More

A promising result from almost all surveys is that a large percentage of population is willing to learn how to save energy and money, and how to reduce their carbon footprint. When they are introduced to the smart grid and smart meters, consumers have questions that they wish to know as shown in Figure 2. Not surprisingly, the top two questions they have are on the cost of the technologies and the savings achievable from the technologies. Some other less prominent questions also motivate researches and business, such as pricing options and consumption presentations. In another survey [5], it further discusses that consumers would spread to different programs and services that together meet their full preferences. Also, consumers are willing to seek services and products from third party companies and retailers. This grants an open market and competition for innovative solutions.

What type of information about the Smart Grid would be the most valuable to you?

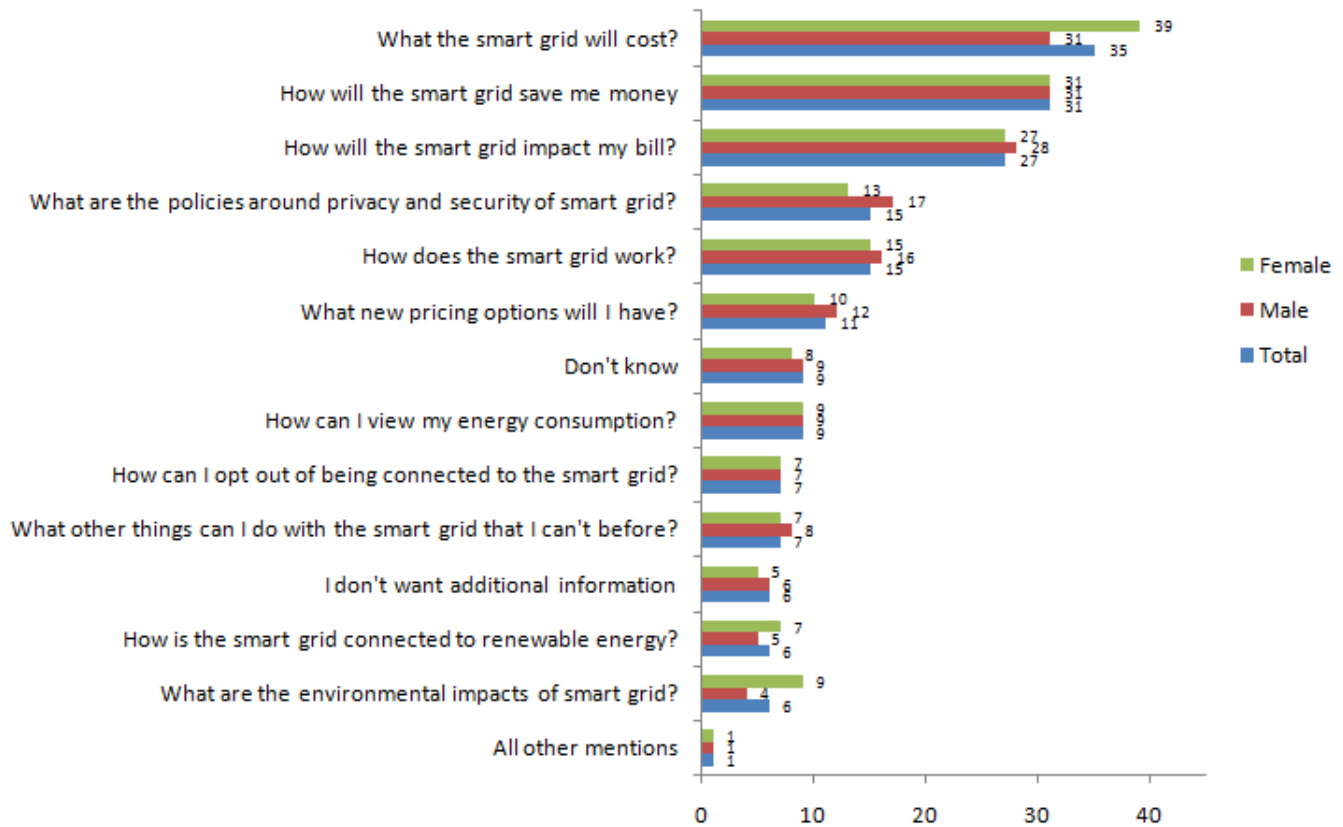


Figure 2: Consumer Questions about Smart Grid [4]

2.3 Roadmap to Long-term Adoption

Some studies identified the populations who are early adopters and those who would wait. The authors in [4] indicated that people with higher income are more likely to consider getting a smart home, and people who live in areas where widespread of outages caused by storm and such are most likely to be the first group of people to adopt smart grid technologies. These groups of people share some common characteristics; they all have a high sense of the needs and commitment. Any current deployment plan should be targeting them and also use them as examples to educate and motivate the later adopters to join. Figure 3 shows a model for the utility industry evolution. It is a gradual process where the final goal is to allow consumers to have high control over their energy usage with the aid of various technologies.

In our opinion, there should be two major phases to smart grid adoption. The first phase should focus on developing energy consumption presentation/visualization technologies, in order to get more consumers to participate in smart grid integration and to learn about the technology and their individual consumption patterns. This is the stage for consumers to realize their potentials to cut down on

unnecessary consumption and to proactively think about and change their lifestyle towards power efficient. The second phase of adoption is then to promote using smart appliances and/or energy management programs that best suit individual preferences and lifestyles. Consumers at this stage have already understood their usage, and learnt what they could/are willing to save, potentially without interfering greatly with their lifestyle. After they have a clear idea about this, they then actively seek a personalized service or program to help them automate the energy management. In this way, we can achieve the “Participatory Network” stage as shown in Figure 3.

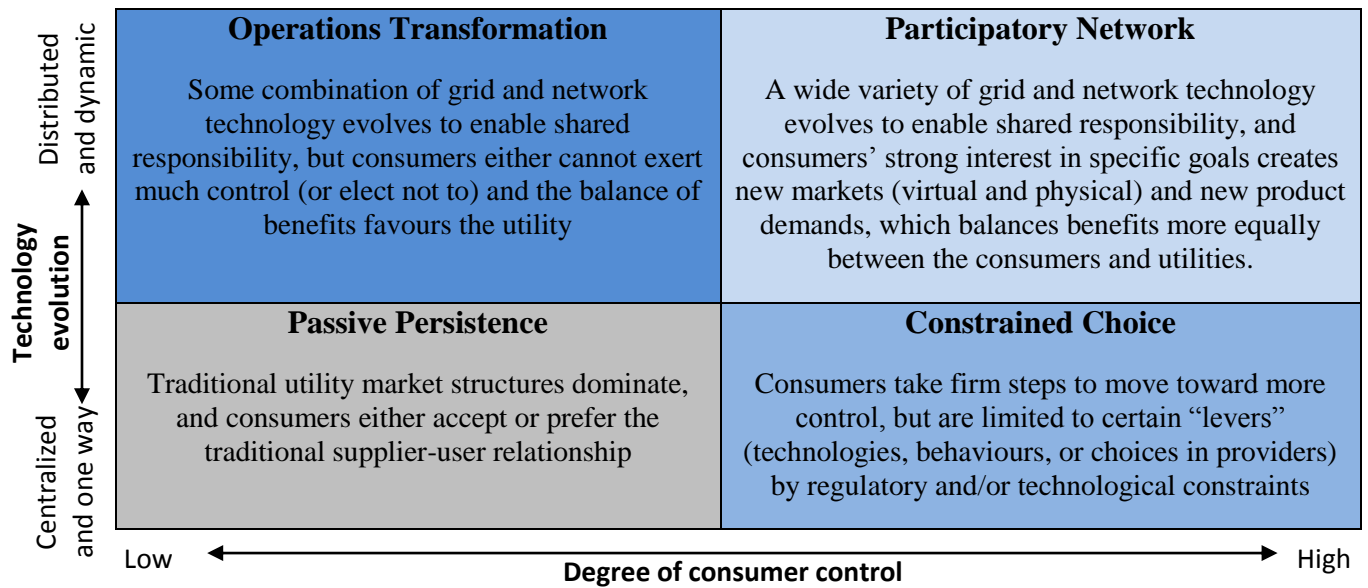


Figure 3: Utility Industry Evolution Model over the Next Decade [5]

2.4 Study of Consumer Segmentation

Different analyses group consumers into different segments such as cost consciousness, comfort/convenient, green altruism, tech enthusiasm, indifference, and resistance. Different consumer segments have different attitudes towards smart grid technologies. As shown in Figure 4, 31% of the surveyed population are passive ratepayers. These people are not involved in energy usage decisions and thus are indifferent to services and technologies. 22% are frugal goal-seekers. They represent the cost conscious consumers. Their actions highly depend on the cost and benefit tradeoffs. Another 26% are energy epicures. This group of people is only interested in maximizing their quality of live with little concern about the energy consumption. The only driving factors to get them involved in smart grid technologies are the comfort and convenience benefits that come with the technologies. The last categorization comprises the energy stalwarts. These people are true environment and energy savers. They have a clear view of the issues and are willingly taking actions. However, they represent the smallest percentage of all consumers.

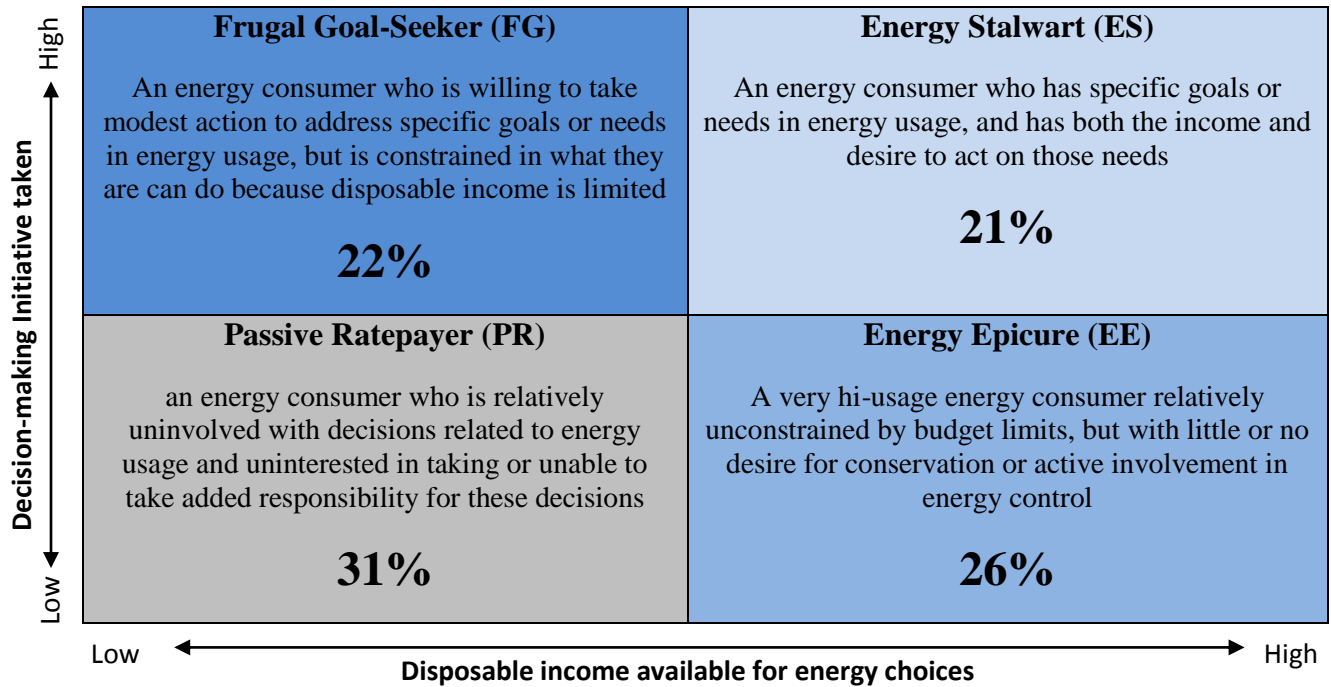


Figure 4: Consumer Segmentation [4]

There exist challenges to design new smart grid technologies and products to meet the requirements of different consumers. Unlike disruptive products, smart grid services and products will be used for all consumers who use electricity. It is important to find the right balance to meet most of the requirements and preferences.

2.5 Social Norms and Activities to Stimulate Participation

To promote smart grid technologies, one effective way is to trigger consumers’ sensibilities. One of the triggers is that consumers want a way of comparing energy consumption with their neighbours. For example, EnergyOne experimented with the idea to print the usage chart of the household along with the neighbourhood average consumption. They claim to observe a 1-2% of reduction. Also mentioned in [8], some consumers suggest turning the energy consumption reduction into a game or reward program. The biggest saver of the neighbourhood can be rewarded. This will stimulate more households to participate in proactive energy conservation activities. Overall, other than technical advancement, social activities and education are another important and effective method to motivate participation. If technologies can be embedded into the social activities to make the social activities more interesting and/or rewarding, it will be easier and quicker to get more consumers involved.

2.6 Automation Acceptance

Consumption feedback, price feedback, and appliance automation are part of the core development of the smart grid. However, studies show that most current consumers do not want to hand over controls on

appliances to utilities due to convenience reasons and privacy reasons. There is not yet a mutual trust built between consumers and utilities. This problem can be eased by offering price discounts to encourage consumers, in particular the early adaptors, to participate, but most people will wait until their old appliances wear off.

In general, we believe automation options are still a little too early for current state consumers. Even for the most environment conscious individuals, they can shift their energy consumption towards more efficiency without automated devices. In this case, privacy concerns would stop them from obtaining automated appliances. On the other hand, this actually leaves time to learn people's consumption patterns and also allows some time for the development of suitable automations. For example, a simplistic home heating and ventilation system control solely depending on the price of electricity is not the best automated solution. At the very least, consumer preferences and home occupancy patterns and/or home occupancy sensors would have to be included as well. More intelligent appliances are needed to be developed to meet different requirements and preferences.

2.7 Chapter Remarks

To conclude this chapter, smart grid technologies' development and adoption is a gradual process that will span the next 10-20 years [16]. The ultimate goal is to automate energy consumption of individuals to meet their requirements and preferences, with the aid from heterogeneous energy sources, services, programs, and appliances. While technology developments are progressing towards that goal, consumers are still at the initiation phase of the process. Some of them do not yet feel the pressure to conserve energy, some of them do not know about the technologies, and some others do not trust the technologies. This leaves only a very small portion of the population as potential first adopters: those who are energy conscious and willing and capable to take actions. For long-term adoption, there should be two major phases. The first phase targets at deploying and promoting smart grid technologies. The goal of this period is to get more people to join green developments, and encourage them to learn about their own energy consumption and proactively change their lifestyle towards energy efficient within the acceptable rate of individual comfort loss or without a loss. The markets in this phase are open to effective infrastructure developments and energy consumption presentation methods. The next phase is to automate these observed patterns to facilitate savings. Consumers in this stage know what they want and perhaps learnt what is available in the market. They are capable of choosing the products and services that meet their preferences. The markets in this phase are open to a variety of automation products that target either all general usage or specific purposes such as high rise apartment specific, business travellers, or tenants. Once the smart grid concept is adopted by the majority, the later developments will utilize different energy sources and achieve automated smart grid integration as previously illustrated in Figure 1.

CHAPTER III: CURRENT DEVELOPMENTS

After the preceding discussion on consumers' attitudes and expectations about the smart grid technologies, this chapter presents current developments in all aspects of smart grid related technologies and regulatory developments.

3.1 Government Moves

Many countries and governments have committed to green developments and more specifically smart grid developments. The United States announced \$3.4 billion stimulus funding for smart grid development on October 27, 2009 [12]. The funding is awarded to cover 6 areas of developments as illustrated in Figure 5. For the detailed description of grant area and the full list of awarded projects, please visit [42].

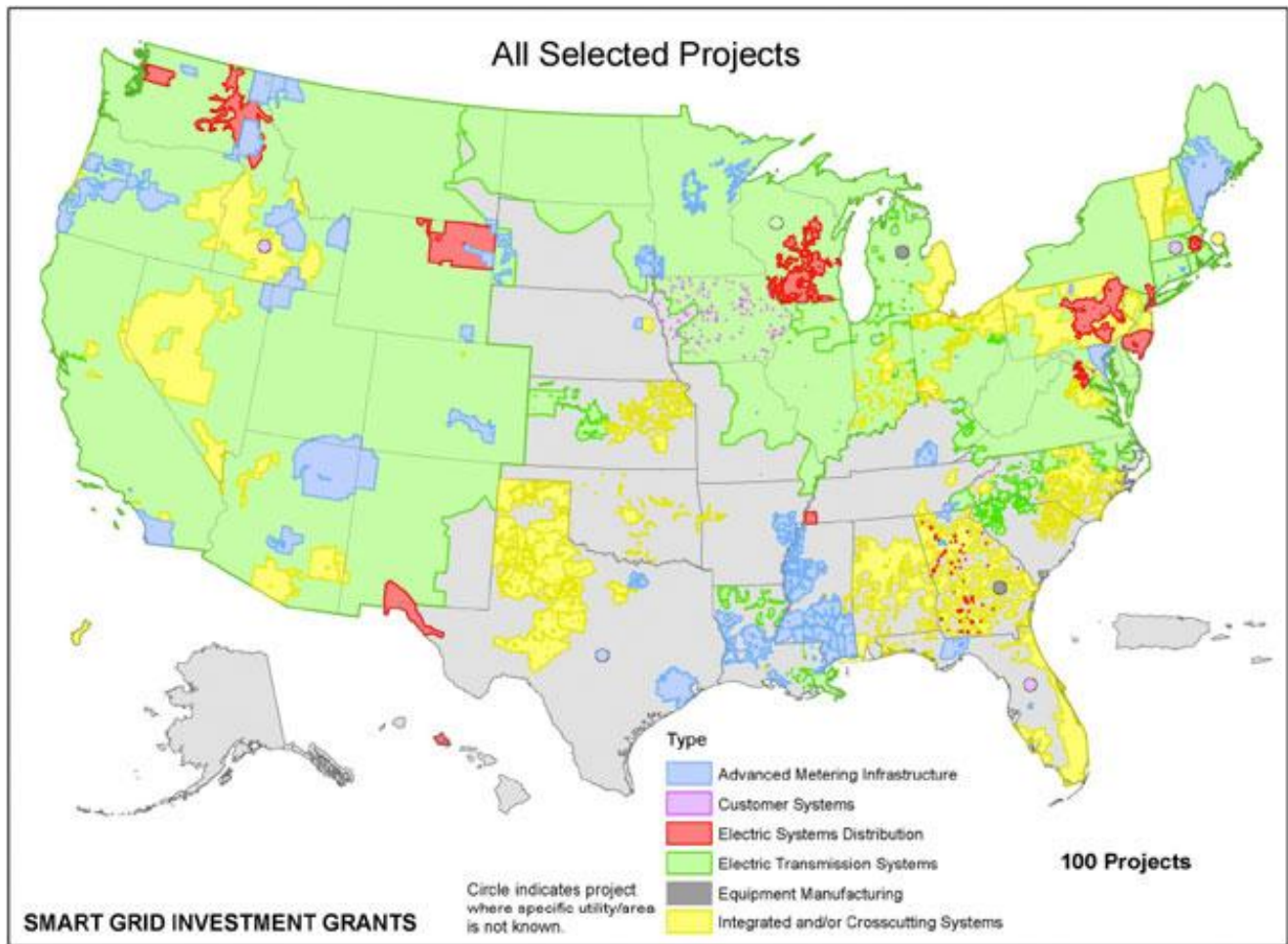


Figure 5: U.S.A Smart Grid Project Stimulate Coverage [12]

The Canadian government has also played a very positive and active role in the development of the smart grid. A significant contribution was the introduction of the *Green Energy and Green Economy Act*

(GEGEA) in 2009 [16]. GEGEA mandates the need for modernization of the electricity system. It sets specific goals to give consumers more control over their energy usage; and recommends to make the grid flexible to adapt to an increasing use of renewable energies; and makes the grid easy to integrate with emerging energy saving technologies. On February 12, 2011, the Canadian government also announced \$22.5 million in funding for smart grid network research and developments [13].

Table 1: Major Regulatory Contribution

Region	Document	Website
U.S.	[3]	http://www.oe.energy.gov/smartgrid.htm
Canada	[9] [16]	http://www.nist.gov/smartgrid/ http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/renewables/integration_der.html
Europe	[10]	http://www.smartgrids.eu/
Asia	[11]	http://www.asiasmartgrid.com.sg/en/Home/

Table 1 lists a few major government documents and websites. For example, [3] explicitly defines the smart grid functionalities to be achieved, recommended research areas, available funds, and other specifications. For Asia, different countries and governments are currently investing a significant amount of capital on smart grid developments. However, there is little to no cooperation among them. The website provided is just a portal to looking into the smart grid developments in Asia.

3.2 Utility Developments

Utility companies are probably the most impacted by the smart grid technologies. In the end, the relationship between utilities and households will not be simply one of service provider and consumers [5]. Households will have abilities to sell energy back to utilities, and consumers will have the choice to buy energy from various energy providers, which might have their surplus energy entirely generated by communities instead of power generation plants. Also suggested in [15], it's important for utilities to remain as "Trusted Energy Advisor" to consumers. Under such a relationship, consumers would continually follow the utilities decisions and would seek services and solutions for their energy needs only from their utility.

For North American utilities, similar to any other utilities in the world, their current primary developments are deploying smart meters and introducing Time Of Use (TOU) pricing. Ontario is one of the provinces around the world to first realize the need for modernization of the electricity grid. The Independent Electricity System Operator (IESO) works as the heart of Ontario's power system, cooperating with governments to define the provincial vision of the smart grid and to establish

government policies. The second report on “Modernizing Ontario’s Electricity System: Next Steps” [16] was issued in May 2011. This report details the current developments in the area of the smart grid in the province and the next steps to take. The report includes a very clear and detailed provincial roadmap to follow. IESO members include the majority of the utility companies in Ontario. By the end of 2010, more than 4.5 million smart meters were deployed to cover almost all residences and small businesses. Other provinces are following too, as shown in Figure 6. Still, the report mentioned that utilities are moving cautiously, waiting for specific rules governing smart grid activities and investments.



Figure 6: Smart Meter Coverage in Canada [14]

3.3 Electric Vehicle Advancement

The support for Electric Vehicles (EV) is one of the major driving factors for smart grid development. The Ontario government predicted that by 2020, one in twenty cars will be an EV. Imagine that, with traditional power grid, everybody with an EV arrives home around 5:00pm to 7:00pm, after work. If everyone plugs in their EV to recharge at that time, there is a good chance of power grid overload and consequently power outages. Therefore, charging stations that know the TOU pricing and the ability to shift charge schedules to off peak hours will become essential.

EV developments are well on the way by both car manufactures and utility companies. As an example, the Chevrolet Volt made my General Motors (GM) is now receiving a large amount of attention [43]. It is the first Extended-range Electric Vehicle (E-REV) that also includes a gasoline engine on board

which does nothing else but recharges the battery. Other than this core technology, the Chevrolet Volt also re-engineered the on board entertainment system and other electricity consuming system to become more energy efficient, this makes the Volt a fun and ecological friendly EV as shown in Figure 7.



Figure 7: GM – Volt

To support the potential widespread of EV deployment and adoption, charging station development and deployment are among the essential tasks. General Electric has designed a stylish charging station named WattStation, which reduces the charging duration and allows utility to manage the impacts of EV to the power grid [44]. This will help to ease the potential problem where the off peak hours at night might become the new peak because of the introduction of EV.

As an example of utility works with car manufacture to introduce EV is that Toronto Hydro Electric System is cooperating with Mercedes-Benz Canada to launch the Toronto Hydro Smart Experience project [16]. The project provides 15 EVs to customers with each one equipped with a charging station. The aim of the project is to learn about the usage and charging habits of customers in order to better design future products. Broader than this specific case, most of the big car manufactures are putting great effort into developing eco-friendly vehicles. Hybrid cars are the current direction of development. Once the smart grid and charging stations are deployed widely, EV will be the next step.

3.4 Technology Giants

Many world famous technology giants are moving forward to join the development of Smart grid related products and services. Companies such as Cisco Systems [20], General Electric [23], Google [25], IBM [26], Intel [27], Microsoft [28] and Siemens [29] are developing products ranging from communication networks, digital sensors, to home energy monitoring and managing devices and software.

General Electric is one of the major players in this business. It has announced to build a \$40 million Smart grid innovation center in Markham, Canada [17]. It also announced its newest solution for electric

distribution named Proficiency® Grid Manager [24]. It is designed to help utilities to reduce the chances of outage, enhance equipment life cycles, and manage customer loads. What is more promising about this manager is that it is an open architecture that allows for further enhancement and innovations. GE's vision of smart home/smart appliance development is to achieve "Self-powered devices for building automation" [18] and "net-zero energy consumption" [19].

While many technology giants are investing in developing their own products to participate in the smart grid evolution, some of them are dropping their developed technologies. By the end of June 2011, both Microsoft and Google have dropped their online power consumption monitoring programs [52]. The reason for this failure is that both companies did not truly understand the needs of consumers. Consumers do not want to keep track of the hourly total household power consumption. Instead, they want to know the power consumptions from each home appliance, and they want possibility to remotely control the appliances. This lesson should be learnt by all other developers.

3.5 Innovative Solutions Developments

Many enterprise solutions and new innovative solutions are being developed or have already been marketed over the past few years. Cisco developed the first smart grid operating system, and marketed the Cisco Home Energy Controller [21] [22], as shown in Figure 8. Google has obtained a licence to create a web application to allow users to access their power consumption data through the Internet [25]. TalkingPlug has developed a power outlet that identifies the connected appliances, measures the power consumption, and sends the data to a server. A customer then can access this data through the Internet or their smart phones [30].

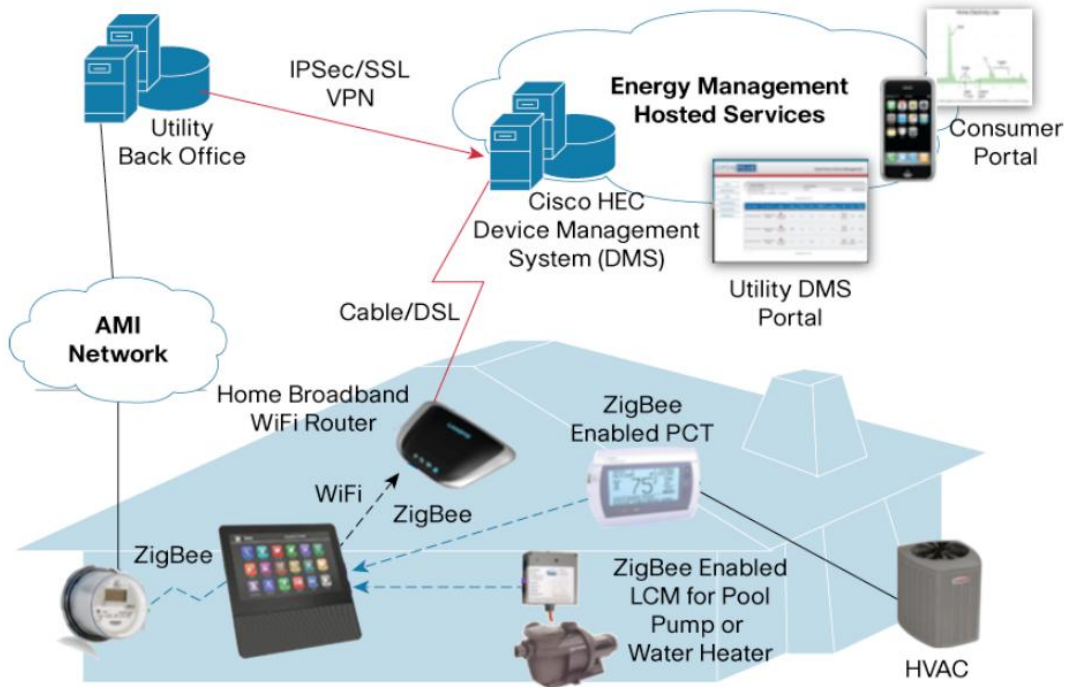


Figure 8: CISCO Home Energy Controller [45]

Another trend of innovation is through the method of distributing the TOU pricing signal. E-Radio inc. and CBC were chosen and funded by the Canadian government to develop solutions through broadcast [31]. They take the advantage of thorough radio station coverage in Ontario. The change of TOU signal can reach end devices impressively fast. This technology opens a new research and development area to distribute the TOU signal without going through the smart meters, which further opens much more possibilities for free and innovative solutions. They have laid the foundation to one-way demand response solutions through FM [32].

Some start-up companies are interested in helping customers to use their energy efficiently and thus save money. Efficiency2.0 created a Personal Energy Efficiency Rewards Program to help customers realizing suitable ways to lower energy consumption, keeping track of their commitment, and rewarding customers for their efficiency [34]. Serious Energy utilizes the cloud computing technology to cut the upfront costs for their energy management system [35]. There is no server needed to be purchased and installed, and neither for software. Serious Energy mainly targets at enterprise customers who own a building for their employees. This manager automates the controls of the thermostats of the entire building to achieve energy efficient and cut down the energy bill for the company.

3.6 Smart Home & Smart Appliances Developments

Another major component to smart grid integration is the smart home developments. The anticipated smart home is capable of automatically making smart decisions on energy consumption activities, and managing smart appliances to efficiently reduce energy consumption. Zpryme's report estimates that the

market for smart appliances will grow from \$3.06 billion to \$15 billion by the year of 2015 [48]. Several groups of people, alliances of companies, and individual companies are developing related technologies.

ClimateTalk Alliance is an organization of companies developing a common communication infrastructure for interoperability among diverse systems [41] [46]. It works with Electric Power Research Institute (EPRI) to develop a modular communication interface that enables any end device to work with any communication system to talk to establish communication among each other with the module plugged in. Their products have been tested and demonstrated to be functioning well with various products from different companies as shown in Figure 9. This opens possibility for appliance manufacture to not worry about the device communication challenges, but only need to embed the socket for the module.

Taking another approach, the chipmaker NXP designs a low-cost small-size chip that can be embedded in any appliance to measure and self report power consumption [47]. This opens the possibilities to gather power consumption for devices that are not very suitable for shifting their operation time, such as stove and TV. If equipped with a home central controller, the gathered information will help in making better decisions.

Several companies are developing home energy management systems. For example, EcoFactor automates the control of home thermostats taking into consideration the temperatures at different region of the home, the weather condition, and other information [49]. Similarly an academic research studies the relationship of tenant occupancy with the thermostat operation. The study uses a wireless sensor network to define the occupancy status, and shuts off the heater or AC when there is no one at home [36]. The smart thermostat also learns the occupancy pattern of the home owner to start slowly pre-heat or pre-cool down the home with power efficient mode, some time before the arrival of the home owner. Control4 is another home energy management system that focuses on the development of hardware control dashboard installed at home for convenient operations [50].

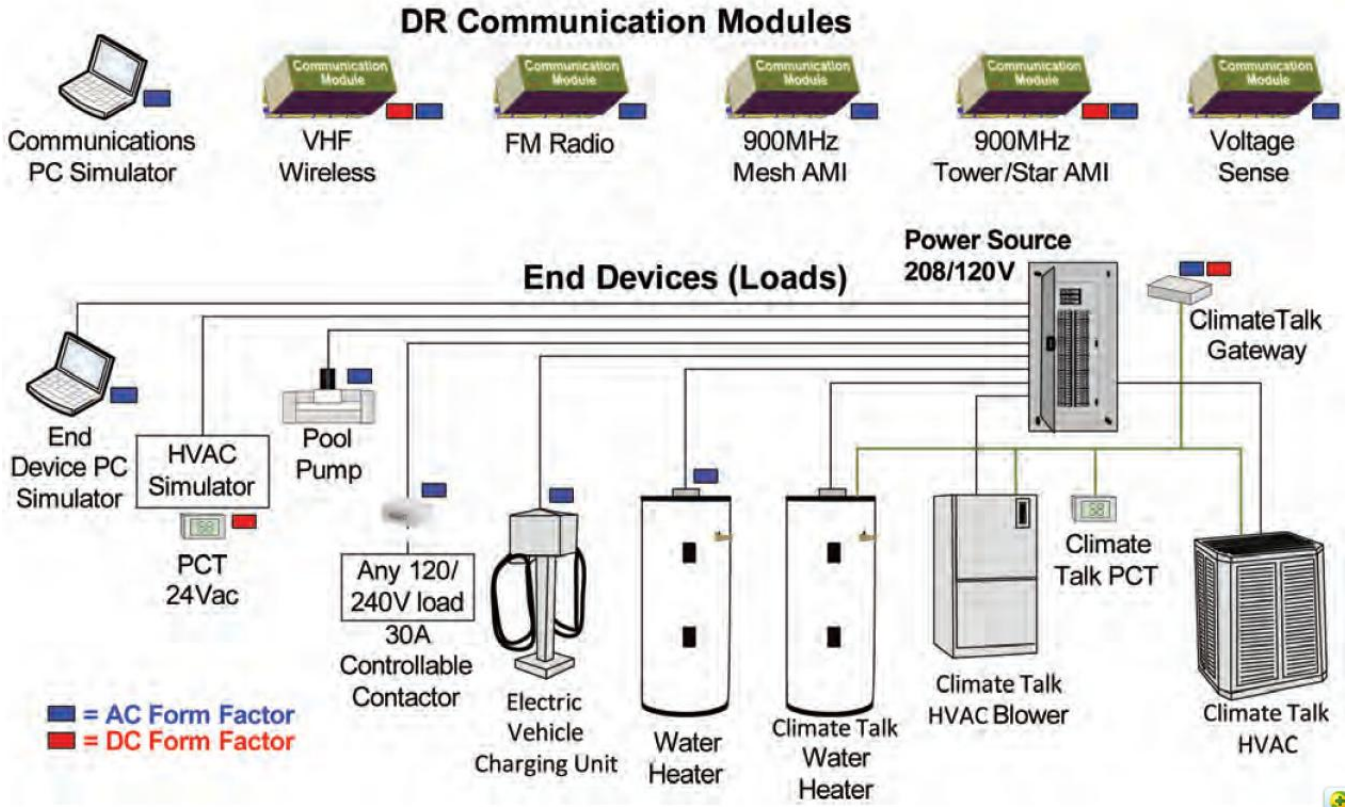


Figure 9: Communication Testing Model with Multiple End Devices [46]

LG Thinkq technology is taking a different approach. Instead of automating the scheduling of appliances operations, it features on-device display that allows user to see TOU price, power consumption information, usage history, etc. [51]. User can decide when to use the appliance based on these information. Better still, Thinkq technology integrates WiFi technology which enables access and control remotely with Smartphone applications. In this way, the user can turn on the appliance when the TOU price is low and when the user is away from home.

3.7 Standards Developments

Smart homes heavily rely on the development of home area networks. Integrating the knowledge and information from various home appliances, sensors, and TOU signals enables much more efficient and accurate control decisions. As demonstrated in [36], enabling thermostats to identify the occupancy of residents and learning the home owners' occupancy pattern can reduce the energy consumed by the home heating system by a considerable amount. However, integrating heterogeneous appliances and devices produced by different companies with different transmission technologies will be problematic for Smart home development. Therefore, this situation urges the adoption of interoperability standards for future research and developments.

The Canadian National Committee of the International Electrotechnical Commission (IEC) is working with several Forum organizations to establish some principle standards. Their activities are led and regulated by the Standards Council of Canada. A report of recommended standards is expected to be generated within the year of 2011 [16].

Well known organizations such as IEEE are standardizing wireless home area networks [37]. Forum organizations such as Zigbee Alliance and WiFi special interest groups are also working towards making their technologies become the future standard. Cloud computing is also considered as a serious contender in standardization. Several interoperability groups and organizations are tackling different levels of interoperability issues [38] [39] [40]. The works in the basic connectivity level aims at simply provide a common communication medium to allow data exchange between heterogeneous devices; whereas the goal for the network level aims at enabling data exchange between various networks. Lastly, the syntactic level development aims at establishing a set of rules and standards for data encoding to allow easy communication among heterogeneous systems.

3.8 Chapter Remarks

This chapter has demonstrated that the technical and commercial developments around the smart grid, smart home, and smart appliances are well on the way. Governments are encouraging and enforcing their development, and companies are seeing benefits in the market. To conclude, governments are funding and administrating various projects; utilities are deploying and testing smart meter related technologies and services; companies are developing a range of applications around the smart grid and energy efficient technologies; organizations and committees are standardizing smart grid information and communication activities.

With respect to the developments of smart home technologies, the current trends are among consumption visualization and remote access and device consumption control. Control automation is at its research and initiate phase, especially with the integration of TOU signals. More studies and research are needed to expose issues such as apartment buildings vs. houses, different lifestyles of consumers vs. their consumptions, relationship between household's consumption with the neighbours' consumptions, smart decisions of home appliances operations, etc.

Overall, many developments are already taking place in the world of the smart grid, yet more are needed and coming. It will be an open but regulated market for innovators, services providers, manufactures, and utilities. This open market will result in fair and intense competitions, which further pushes the entire society toward energy efficient.

CHAPTER IV: CONCLUSIONS

In this report, we first studied the consumers' understanding and expectations of the smart grid revolution. It has illustrated that most consumers are still either very unfamiliar with the smart grid technologies or distrust the technologies. They do not yet see the big picture of future needs and benefits that the smart grid brings. Most consumers are concerned with whether the deployment of smart meters can help them to reduce energy consumption without any commitments to an energy management program or proactively getting into energy conservation habits. However, more importantly, consumers are willing to learn and to know more about their choices to conserve energy, but they might not know the path to learn. Breaking down this knowledge barrier requires public education, promotion, and activities. Therefore, the first phase of developments to facilitate public adoption of the smart grid concept should aim at educating, demonstrating, and encouraging more consumers to join. With the help of technologies and education, consumers in this phase could learn more about their energy consumption and about possible ways to conserve. Companies such as Efficiency2.0 are emerging to assist this learning process and decisions on conservation methods. Following this, the next phase of development should aim at automating conservation actions with different energy sources, technologies, programs and services to meet individual preferences. After the adoption of the smart grid technologies by a majority of consumers, we will have achieved an era of true smart grid integration. Automation will further fully take control of energy generation, distribution, transportation and consumption activities.

Technology developments and regulation activities are much ahead of the consumer adaptation of the smart grid. Many governments realized the need to modernize the electric grid and thus committed to actions. Industries and companies are seeing benefits in the market and thus are investing in various innovative products and services. EPRI has estimated that the total global investments to smart grid implementation will cost \$338 billion to \$476 billion, but the resulted benefits will worth \$1.3 trillion to \$2 trillion [16]. Therefore, both world leaders of technologies and emerging start-up companies are competing for a share of the pie. A great number of essential and innovative technologies related to the smart grid is emerging or has already been marketed. These technologies cover various aspects of the smart grid, including infrastructure developments, communication developments, management developments, visualization developments, automation developments, and many more. Yet, more are needed to be studied and developed. Different consumers need the same type of technology to function differently according to different situations and circumstances. House owner would have very different experience with power consumption than apartment renters. Full time professionals would have different energy consumption patterns than retirees. Many more issues need to be discovered, and innovative solutions are required. The market for research and business will open to any innovator and the competition will be intense. As the results, the entire society will become much more energy efficient than ever before.

REFERENCES

- [1] “Smart grid Definition”. 2006. SmartGrids – European Technology Platform. Last access on June 10, 2011. <http://www.smartgrids.eu/?q=node/163>
- [2] “What is Demand Response?”. February 23, 2010. EnergyDsm.com. Last access on June 10, 2011. <http://www.energydsm.com/2010/02/what-is-demand-response/>
- [3] “Statement of Policy on Modernization of Electricity Grid”. May 14, 2009. SmartGridNews.com. Last Access on June 10, 2011. http://www.smartgridnews.com/artman/publish/Projects_Stimulus/Statement_of_Policy_on_Modernization_of_Electricity_Grid-790.html
- [4] “2011 State of the Consumer Report”. Jan. 31, 2011. SmartGrid consumer collaborative. Last access on June 10, 2011. <http://smartgridcc.org/sgcc-2011-state-of-the-consumer-report>
- [5] “Revealing the Values of the New Energy Consumer”. 2011. Accenture. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/Business_Customer_Care/Revealing-the-values-of-the-new-energy-consumer-3653.html
- [6] “EcoPinion – Resurgence for Retail Electricity Choice and Competition Survey Report”. April 2011. Ecoalign. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/Business_Markets_Pricing/Resurgence-for-retail-electricity-choice-and-competition-3654.html
- [7] “Consumer Attitudes and the Benefits of Smart grid Technologies”. Jan. 24, 2011. Parks Associates. Last access on June 10, 2011. <http://www.parksassociates.com/whitepapers/consumer-attitudes-and-the-benefits-of-smart-grid-technologies>
- [8] M. Chetty, D. Tran, R. E. Grinter. “Getting to Green: Understanding Resource Consumption in the Home”. GVU Center and School of Interactive Computing Georgia Institute of Technology. Atlanta, GA, USA. ISBN: 978-1-60558-136-1. Dec. 8, 2008. Last access on June 10, 2011. http://delivery.acm.org/10.1145/1410000/1409668/p242-chetty.pdf?ip=134.117.61.232&CFID=27906875&CFTOKEN=63587948&_acm_=1308711775_d8578a7d255a6e196e58e41cd305a30c
- [9] “Smart grid in Canada - Overview of industry in 2010”. April 4, 2011. Natural Resources Canada. Last access on June 10, 2011. http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/renewables/integration_der/publications.html?2011-027
- [10] “Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Region”. 2006. European Technology

Platform for the Electricity Network of the Future. Last access on June 10, 2011.

<http://www.smartgrids.eu/?q=node/172>

- [11] “The Dynamics of the Electricity Supply Industry”. 2011. Be Smart – Plug into the Grid. Last access on June 10, 2011. <http://www.asiasmartgrid.com.sg/en/News-Room/Download-Centre/>
- [12] “Obama Announces Winners of Smart-Grid Stimulus”. October 27, 2009. Popular Mechanics. Last access on June 10, 2011. <http://www.popularmechanics.com/science/energy/efficiency/4335113>
- [13] “Canada Announces Funds for Smart grid Research”. February 12, 2011. Smartmeters-telling it like it is. Last access on June 10, 2011. <http://www.smartmeters.com/the-news/smart-grid-news/1550-canada-announces-funds-for-smart-grid-research.html>
- [14] “Canada: tackling geographical challenges with smart”. Ernst&Yong-Quality In Everything We Do. Last access on June 10, 2011. <http://www.ey.com/GL/en/Industries/Power---Utilities/Seeing-energy-differently---Geographical-differences---Canada--tackling-geographical-challenges-with-smart>
- [15] “Smart customer communications: Simply being a ‘resource provider’ doesn’t cut it any more”. December 14, 2010. Smartgridnews.com. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/Business_Customer_Care/Smart-meter-customer-communications-Why-simply-being-a-resource-provider-doesn-t-cut-it-any-more-3338.html
- [16] “Modernizing Ontario’s Electricity System: Next Steps”. May 2011. Independent Electricity System Operator. Last access on June 10, 2011. <http://www.ieso.ca/smartgridreport>
- [17] “GE to build \$40 million smart grid tech center in Ontario”. March 2011. Smartgridnews.com. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/Delivery_Grid_Optimization/GE-to-build-40-million-smart-grid-tech-center-in-Ontario-3551.html
- [18] “GE smart grid vision: Self-powered devices for building automation”. June 6, 2011. Smartgridnews.com. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/End_Use_Building_Automation/GE-smart-grid-vision-Self-powered-devices-for-building-automation-3720.html
- [19] “Smart grid from GE to help homes achieve net-zero energy consumption”. July 15, 2009. Greenlaunches.com. <http://www.greenlaunches.com/gadgets-and-tech/smart-grid-from-ge-to-help-homes-achieve-netzero-energy-consumption.php>
- [20] “Modernizing the Energy Platform”. 2010. CISCO-Industry Solutions-Utilities/Smart grid. Last access on June 10, 2011. http://www.cisco.com/web/strategy/energy/external_utilities.html

- [21] “Manage Your Home Energy Use”. 2010. CISCO-Consumer-Products-Home Energy Management. Last access on June 10, 2011.
<http://www.cisco.com/web/consumer/products/hem.html>
- [22] “Cisco Smart grid Strategy: The Grid’s First Operating System”. July 15, 2010. Smartgridnews.com. Last access on June 10, 2011.
http://www.smartgridnews.com/artman/publish/Business_Strategy/Cisco-Smart-Grid-Strategy-The-Grid-s-First-Operating-System-2698.html
- [23] “Plug Into the Smart grid”. 2011. GE imagination at work. Last access on June 10, 2011.
http://ge.ecomagination.com/smartgrid/#/landing_page
- [24] “GE Smart grid Software Solution Automates the Electric Distribution Systems of Transmission & Distribution Utilities”. April 20, 2011. GE imagination at work. Last access on June 10, 2011.
<http://www.genewscenter.com/content/Detail.aspx?ReleaseID=12303&NewsAreaID=2>
- [25] “Google powermeter”. 2011. Google.org.powerMeter. Last access on June 10, 2011.
<http://www.google.com/powermeter/about/>
- [26] “Smart grid – A smarter grid is transparent, accessible, resilient. And optimized from the user on up”. IBM – Energy. Last access on June 10, 2011.
http://www.ibm.com/smarterplanet/us/en/smart_grid/ideas/
- [27] “Smart Energy and the rise of the Personal Smart grid”. February 26, 2009. CSR@Intel – Putting social responsibility on the agenda. Last access on June 10, 2011.
http://blogs.intel.com/csr/2009/02/smart_energy_and_the_rise_of_t.php
- [28] “Delivery & Smart grid”. 2011. Microsoft Enterprise. Last access on June 10, 2011.
<http://www.microsoft.com/enterprise/industry/power-utilities/solutions/delivery-smart-grid.aspx>
- [29] “It is time to bring knowledge to power”. 2010. SIEMENS – Real Smart grid solutions from Siemens get you closer to the future of energy right now. Last access on June 10, 2011.
<http://www.energy.siemens.com/hq/en/energy-topics/smart-grid/>
- [30] “Make Every Plug Talk”. 2010. Talkingplug-know your energy. Last access on June 10, 2011.
<http://talkingplug.com/>
- [31] “e-Radio-Inc and CBC/Radio-Canada team up to improve the way electricity is consumed”. January 8, 2010. CBC Radio-Canda – News releases. Last access on June 10, 2011.
<http://www.cbc.radio-canada.ca/newsreleases/20100108.shtml>
- [32] “Energate announces commercial readiness of one-way FM Demand Response solution”. October 19, 2010. E-Radio inc – technology you can use. Last access on June 10, 2011. <http://e-radioinc.com/>

- [33] “Smart grid Resource Center”. 2010. EPRI – Electric Power Research Institute. Last access on June 10, 2011. <http://smartgrid.epri.com/>
- [34] “About Efficiency 2.0”. 2011. Efficiency2.0. Last access on June 10, 2011. <http://efficiency20.com/about-us>
- [35] “About Serious Energy”. 2011. Serious Energy. Last access on June 10, 2011. <http://www.seriousenergy.com/about-us.html>
- [36] J. Lu, T.I. Sookoor, V. Srinivasan, G. Gao, B. Holben, J.A. Stankovic, E. Field, and K. Whitehouse, "The smart thermostat: using occupancy sensors to save energy in homes", in Proc. SenSys, 2010, pp.211-224.
- [37] M. Grabowski, G. Dziwoki. “The IEEE Wireless Standards as an Infrastructure of Smart home Network”. Silesian University of Technology, Institute of Electronics. CCIS 39. Springer-verlag Berlin Heidelberg 2009.
- [38] CENELEC Representatives, “Interoperability framework requirements specification for service to the home (IFRS)”, CENELEC Workshop Agreement, June 2010. Pages: 1-8
- [39] P. Thinagaran et al., “Interoperability among Heterogeneous Systems in Smart home Environment”, IEEE International Conference on Signal Image Technology and Internet Based Systems, 2008. Pages 177 – 186.
- [40] W. Kenneth, “Home Systems Standards: Achievements and Challenges”, IEEE Communications Magazine, April 2002. Pages 152-159
- [41] “ClimateTalk is a common information model developed for the exchange of information between disparate systems and devices”. 2011. ClimateTalk Alliance. Last access on June 10, 2011. <http://www.climatetalk.org/ClimateTalkTechnology/Overview/tabid/351/Default.aspx>
- [42] “Smart Grid Investment Grant Awards”. 2009. Energy.gov. Last access on June 10, 2011. <http://www.oe.energy.gov/recovery/1249.htm>
- [43] “What IS The Volt”. 2010. About GM-Volt.com. Last access on June 10, 2011. <http://gm-volt.com/about/>
- [44] “Charging ahead”. 2011. GE – imagination at work. Last access on June 10, 2011. http://www.ge.com/innovation/electric_vehicles/index.html
- [45] “Cisco Home Energy Management”. 2010. Cisco public information – data sheet. Last access on June 10, 2011. http://www.cisco.com/web/consumer/pdf/data_sheet_c78_603194_v2.pdf

- [46] “Communication Modularity – A Practical Approach to Enabling Residential Demand Response”. May 2011. EPRI-Electric Power Research Institute. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/Technologies_Communications/Communication-modularity---a-practical-approach-to-enabling-residential-demand-response-3737.html
- [47] “Smart grid trend alert: Smart appliances will soon proliferate”. October 12, 2010. Smartgridnews.com. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/Technologies_Metering/Smart-grid-trend-alert-Smart-appliances-will-soon-proliferate-3138.html
- [48] “Smart Grid Insights: Smart Appliances”. March 5, 2010. Zpryme. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/End_Use_Appliances_Resources/Smart-Grid-Insights-Smart-Appliances-1979.html
- [49] “EcoFactor ushers in the automated era of home energy management”. June 9, 2011. Smartgridnews.com. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/End_Use_Efficiency/EcoFactor-ushers-in-the-automated-era-of-home-energy-management-3740.html
- [50] “Smart homes: Coming soon – a dashboard for your home”. February 1, 2011. Smartgridnews.com. Last access on June 10, 2011. http://www.smartgridnews.com/artman/publish/Technologies_Home_Area_Networks/Coming-soon---a-dashboard-for-your-home-3475.html
- [51] “LG Thingq links your smart appliances with WIFI and smartphone apps”. January 4, 2011. Engadget.com. Last access on June 10, 2011. <http://www.engadget.com/2011/01/04/lg-thingq-links-your-smart-appliances-with-wifi-and-smartphone-ap/>
- [52] “Who is dumber about home energy, Microsoft or Google?”. July 5, 2011. Smartgridnews.com. Last access on July 19, 2011. http://www.smartgridnews.com/artman/publish/Technologies_Home_Area_Networks/Who-is-dumber-about-home-energy-Microsoft-or-Google-3792.html