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Evaluating the Possible Involvement of the Danish Consumer Council in Smart Grid Development

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Abstract

The smart grid is an emerging electric networking technology that will improve the capabilities of the electric grid. Consumer's needs should not be overlooked as this new technology develops. Our project's goal was to determine the extent the Danish Consumer Council (DCC) should become involved in the standardization process. Our research identified several critical aspects of the emerging smart grid technology, resulting in a number of recommendations for the DCC on how to monitor its development and protect consumer interests.

Executive Summary

In 2012, the Danish Parliament passed the Energy Agreement, which mandated the creation of a smart grid. The smart grid is a rapidly evolving electric networking technology that has the potential to vastly improve the capabilities of the existing grid. This technology integrates an electric grid and communications network, as well as software and hardware to manage energy generation and consumption. This technology will impact every electrical device and has the potential to radically change the way consumers use electricity. Consumer advocacy groups, such as the Danish Consumer Council (DCC), are concerned that consumer needs will be overlooked as this technology evolves and is standardized. Our group was tasked to answer the question of, "when, where, and to what extent should the DCC become involved in the smart grid implementation and standardization process?"

The goal of our project was to determine the aspects of standardization the DCC could focus on to ensure evolving smart grid standards are designed to meet consumers' needs. To accomplish this goal, we identified several critical components of the emerging smart grid that will affect consumers through background research. These categories include:

- current appliance interaction with smart grid technology
- interoperability between different smart grid products
- data privacy and grid security
- future smart grid development

These categories defined the scope of our project, and enabled us to focus our research.

We interviewed thirteen representatives from twelve different organizations that are working to accelerate the standardization and implementation processes of the smart grid. We focused on smart grid experts, smart technology providers, and pilot project researchers. We created a general structure for our interviews that included questions about the aforementioned categories and asked further probing questions during the course of the discussions. In order to organize our results, we categorized our them into a thematic library of responses.

The conversations brought up several key concerns that need to be addressed in order to ensure that the smart grid will develop to meet the needs of both consumers and the electric sector. The common themes that the discussed up include:

- insufficient incentive for consumers to modify electric consumption behavior
- frustration over current heat pump standards
- concerns on the accessibility of energy consumption information
- the need for development of smart appliances
- lack of consumer education on the smart grid and smart grid technologies

Using these themes, we were able to conclude which aspects of the smart grid need to be adjusted in order to resolve these issues.

Consumers need to change their electric use habits in order for the smart grid to effectively distribute peak loads, but currently lack an incentive to do so. A solution to this problem is to create a flexible market where electricity prices vary throughout the day. A Danish electric bill is 75% taxes; therefore, this system will need to come from both variable electric rates and variable taxes. One of the suggestions that we developed through our interviews was that the taxes could be lower on renewable or green energy and/or when the demand for energy was low (i.e., off-peak hours).

We found that heating makes up 80% of the Danes' electricity consumption and many use heat pumps. The representatives we interviewed informed us that heat pumps on the market today require additional equipment to connect to the smart grid, and that power cycling them negatively impacts their life-cycle. Moreover, current appliances may not be compatible with the smart grid, and require additional testing.

The smart grid requires a significant amount of consumer data in order to function. Detailed information about a home's electricity consumption will be recorded and stored by smart meters, and, after implementation, by aggregators and home automation systems. Current smart grid products use the Advanced Encryption Standard (AES), a 128-bit encryption protocol that is commonly used for online banking. Through our interviews, we found that this protection is fairly uniform throughout the industry, and will most likely become a standard. The main place a problem could arise in terms of protecting consumer data stems from who has access to it. DataHub is a centralized collection of both generation and consumption data operated by Energinet.DK, and was brought up as an area for concern by one of our interviewees. The privacy concern arises from the fact that energy suppliers have access to all of the data within DataHub. Although the penalty for accessing data without permission results in a ban from DataHub, we feel that this is an area that needs to be addressed.

The interviewees believed that consumers need to be educated about the smart grid, but the majority of them thought that it is too early in the process for education to have a significant impact. Furthermore, they suggested waiting until the products are closer to mass deployment before beginning education campaigns. Educational materials and teaching strategies for consumers participating in smart grid pilot projects should be developed and could be used once smart grid is ready for wide-scale implementation.

We conclude that the smart grid is an emerging technology, and that it will impact consumers' lives once it is ready to be fully implemented. Furthermore, the current method for taxing electricity is inhibiting the development of a smart grid-compatible market. The flat rate, high taxes combined with the lack of smart grid compatible heat pumps need to be addressed in order to implement the smart grid in Denmark. These conclusions led us to recommend that the DCC should become involved in the smart grid standardization process. It should focus its efforts primarily on the creation of a variable taxation scheme that minimizes lost revenue while still providing consumers an incentive to change their energy use. Additionally, we recommend that the DCC:

- Push for two changes to heat pump standards:
    - Add components to heat pumps that enable remote control capability, including a standby mode option
    - Increase heat pump capacity to 130% of current standards and require the inclusion of a buffer tank
- Encourage appliance companies to invest in consumer-friendly smart appliances
    - Request tests be performed on the effects smart plugs have on current appliances and publish results for consumers
- Advocate for the European Union to create a “Smart Grid Ready” label to assist consumers with their appliance purchases
- Provide educational material for consumers on smart grid on:
    - How to choose an electric supplier
    - Current and emerging aspects of smart grid
- Work with Energinet.DK to increase privacy of the information stored in DataHub

By following our recommendations, we feel that the DCC will be able protect consumer interests during the implementation and standardization of the smart grid.

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Authorship

This Interactive Qualifying Project (IQP) was edit and reviewed by all member of the IQP team. The paper was written in section by the three authors, which remained the same through out the entirety of the paper. These sections were; smart grid technology by Andrew Childs, smart grid projects by Hannah McCallum, and consumer concerns by Zachary Gendreau.

Disclaimer

This Interactive Qualifying Project was written as a portion of the completion of a Bachelors of Science degree for Worcester Polytechnic Institute. The authors are not professional or experts on smart grid or smart grid technologies. This document was written for the Danish Consumer Council (Forbrugerrådet), and does not represent the opinion of the Danish Consumer Council. The report does not represent the opinion of Worcester Polytechnic Institute, but rather is the analysis of interview with parties interested in smart grid and smart grid technology.

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1 Introduction

Demand on the Danish electricity grid is increasing, and is expected to overreach its capacity in the near future (“Smart Grid in Denmark” 2011). This trend, combined with the Danish government’s desire to increase the amount of renewable resources connected to the country’s electric grid led the government to invest in its electric system. There are two possible solutions the government has considered; the first is to expand the current grid using traditional methods and the second is to convert to a smart grid (“Smart Grid in Denmark” 2011 p. 5). The smart grid “generally refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation” (“Smart Grid” 2012 p. 1). Of the two possibilities, smart grid has the potential to increase the efficiency of the electric grid thus reducing the need to expand the current infrastructure. Furthermore, implementation of the smart grid will result in the creation of new job opportunities as well as make it easier to integrate renewable technology into the power system (“Smart Grid in Denmark” 2011).

March 2011, Denmark’s Parliament passed the “Energy Agreement,” which calls for the development of smart grid (Liddegaard 2012). The Danish Government decided to pursue the smart grid approach due to its capability to integrate renewable technology into the electric grid. Smart grid technology can also be used to unite electricity generation with district heating systems, improving the overall efficiency of the power network (Strategic Research Centre for 4th Generation Heating Technologies and Systems [4DH] 2012). It is a rapidly evolving technology that may radically change the way consumers interact with electrical appliances (Flick 2012). Therefore, it is important to ensure that consumer needs are not overlooked as this new technology develops. This has inspired consumer advocacy groups, such as our sponsor the Danish Consumer Council (DCC), to follow the emerging the policies and standards governing the smart grid.

Many places around the world are beginning to test smart grid concepts and standards are being developed as a result. Industry generally is the driving force behind standardization; however, consumer advocacy groups participate in the development of standards as well. These groups ensure that consumers are not overlooked in the standardization process by lobbying to make sure that products are safe, interoperable, accessible, and environmentally friendly (ANEC 2012). Consumer advocacy groups are examining the evolving smart grid standards in order to ensure the technology positively affects consumer’s lives. Standards that benefit consumers will help ensure that the smart grid is an effective solution to the increasing energy demand.

The purpose of our project is to determine possible approaches the DCC could use to ensure evolving smart grid standards are designed to meet consumers’ needs. In order to accomplish our objective, we identified areas within the development of smart grid that have a large potential to negatively affect consumers. We researched:

- current industry standards relating to smart grid technology
- how appliances interact with current smart grid technology
- interoperability between the different smart grid products
- data privacy and grid security
- future smart grid development

We investigated these topics by interviewing representatives from organizations invested in the creation and standardization of smart grid. The information that we gathered from these interviews enabled us to determine how the DCC can become involved in the development of smart grid standards.

2 Background

This chapter identifies both the potential benefits and concerns relating to smart grid and smart grid technology. The chapter introduces the current status of energy use worldwide and in Denmark, and proceeds to discuss Denmark's current electric grid. It continues by defining smart grid technology, and discusses how it has the ability to progressively change the electric system. Next, consumer concerns springing from these changes are identified. The last section of this chapter examines current projects involving smart grid technology, and concludes with an in depth examination of different, ongoing pilot projects located in Denmark.

2.1 Changing Energy Consumption

Energy demand throughout the world has increased over the past decades. World energy consumption was 354 quadrillion Btu (373 exaJoules) in 1990 and is predicted to increase to 770 quadrillion Btu (791 exaJoules) in 2035, roughly doubling consumption ("Smart Grid" 2012). Figure 1 displays this information graphically, showing recent world trends. Demand for all types of energy sources is increasing, whether they are renewable or not ("Smart Grid Legislative and Regulatory Policies and Case Studies" 2011). This rise is forcing countries around the world to look for ways to use technology to improve the efficiency of energy delivery. Denmark has been working to reduce its carbon footprint and energy consumption by using more renewable energy sources and using technology to improve its electric system. In spite of these efforts, the demand for energy is still rising (Dal, Rusbjerg, Zarnaghi 2012). Between the years of 1990 and 2010, "final energy consumption [in Denmark] increased by 4.9%," which equates to about 0.2% per year" (Dal et. al. 2012 p. 6). Increasing energy demand is predicted to be a long-term trend and results in a higher load on the electric grid. There are two different options to solve this problem; smart grid or traditional grid expansions ("Smart Grid in Denmark" 2011). The Danish government decided to invest in the smart grid solution because its net cost is estimated to be less than expanding the current grid's infrastructure ("Smart Grid in Denmark" 2011).

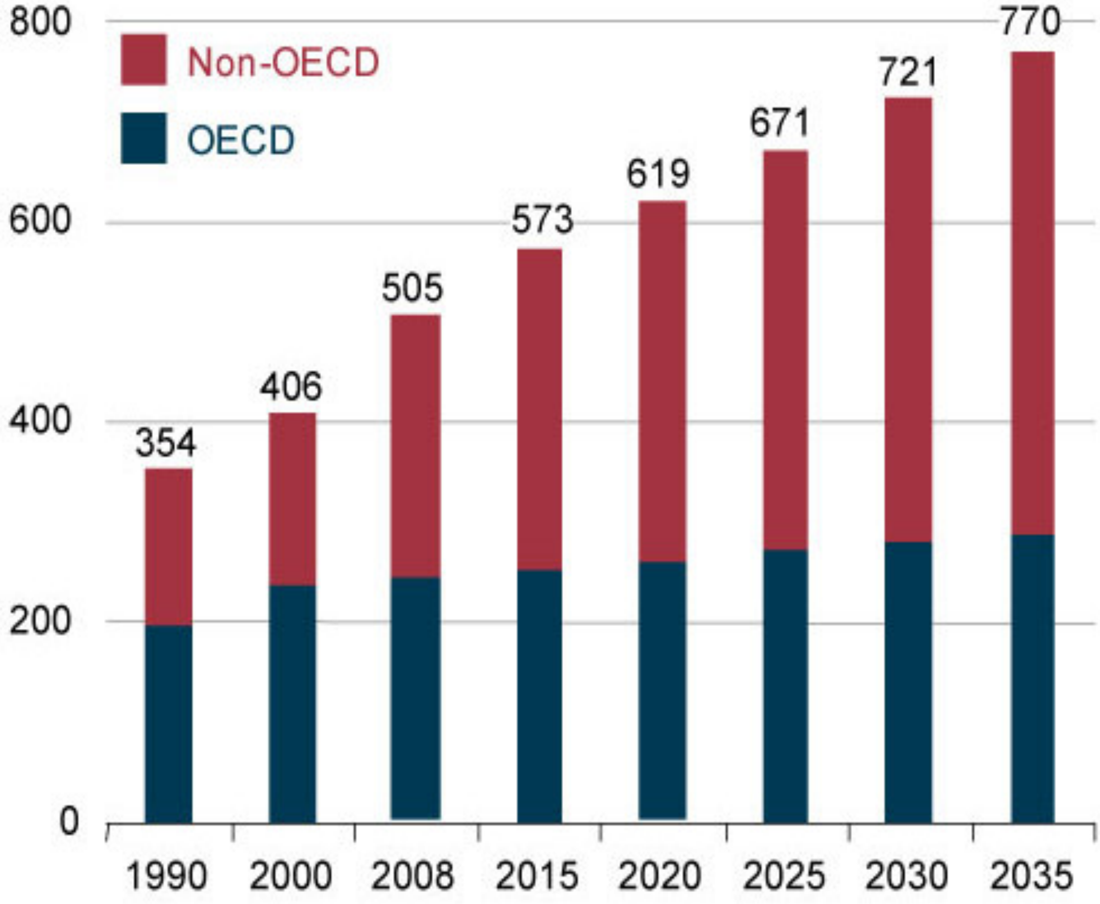

Figure 1: World energy consumption from Organization for Economic Co-operation and Development (OECD). Note form "International Energy Outlook 2011," United States Energy Information Agency.

2.2 Energy Generation and Consumption in Denmark

Denmark first invested in renewable energy sources after the Arab Oil Embargo of 1973 temporarily shut down the accessibility of oil to the country. Before that time, 90% of the country's energy needs were met with foreign oil imports (Koch 2009). The Danish government imposed taxes on oil, coal and natural gas to encourage conservation and the growth of renewable energy sources ("Energy Policy in Denmark," 2012). These taxes spurred investment in renewable energy sources, established a nationwide natural gas based grid, and improved the efficiency of buildings ("Energy Policy in Denmark," 2012). Another development in the Danish energy sector was the discovery of oil in the North Sea ("Denmark: Energy mix Fact Sheet" 2007). The taxes on non-renewable resources combined with the Danes' fear of being caught in another oil shortage and their proximity to the oil-rich North Sea enabled Denmark to completely reverse its role in the energy market. By 1999, Denmark had established its energy potential to the extent that it became a net exporter of energy ("Denmark: Energy Mix Fact Sheet" 2007; "Energy Policy in Denmark" 2012).

Denmark's transformation to a net energy exporter was assisted by the addition of oil from the North Sea, the development of wind and biogas technology for energy and heat production, and the implementation of district heating ("Denmark: Energy Mix Fact Sheet" 2007; "Smart Grid Denmark"

2012). District heating involves using one heat supply for an entire neighborhood or district instead of individual houses using separate furnaces (Togeby 2012).

About 30% of Denmark's energy production comes from renewable resources ("Energy Policy in Denmark" 2012; "Denmark- Energy Mix Fact Sheet" 2007). The primary sources are wind and biomass, and are used both to directly produce electricity as well as provide thermal energy for district heating ("Energy Policy in Denmark" 2012; Storywise 2013). Currently, Denmark's primary energy source is coal; however, a large portion of the country's energy production is being converted to renewable sources ("Denmark-Energy Mix Fact Sheet" 2007, Liddegaard 2012).

2.2.1 Current Energy Policy in Denmark

The Danish Parliament has ambitious energy plans for its country. In March 2012, it passed the Energy Agreement, which contains comprehensive goals for Denmark's energy future (Liddegaard 2012). The overarching goal of the Agreement involves stopping the use of all forms of fossil fuels by the year 2050 ("Energy Policy in Denmark" 2012; Liddegaard 2012). The agreement plans to have 50% of the electricity Denmark produces come from wind power by the year 2020. The government set a goal to reduce the overall consumption of electricity by 7.6% as compared to levels from 2010 (Liddegaard 2012). Another short-term goal set forth by this act is for Denmark to reduce its net greenhouse gas emissions by 34%, compared to the levels of emissions from 1990 by 2020 ("Energy Policy in Denmark" 2012; Liddegaard 2012). In order to accomplish these goals, Parliament created a new "Security of Supply" tax that taxes all fuel sources so that the country will not lose too much revenue as fossil fuels are phased out of consumption. The new tax will help subsidize renewable sources of energy ("Energy Policy in Denmark" 2012). This tax reflects the fact "the role of the government has fundamentally changed with electricity market liberalization," which according to Claude Mandil, the Executive Director of the International Energy Agency, is necessary in order for renewable energy to become a primary resource for electricity production ("Power Market" 2012).

The Energy Agreement identified smart grid technology as a necessary development in order to achieve energy independence on fossil fuels (Liddegaard 2012). Smart grid technology has the potential to integrate more renewable sources into the electric grid and to unite the heating and electric systems (Flick & Morehouse 2011; Storywise 2013). The smart grid accomplishes this by using a communications network –similar to the Internet– to relay information from many small sources to utilities and consumers (Carvallo 2011). Further details of how a smart grid functions are included in Section 2.3. The Energy Agreement calls for negotiations to take place between the government and utility companies to start installing smart meters (described in Section 2.3.1), as well as ceasing installation of any gas or oil powered heat plants. Both smart meters and enabling technologies need to be deployed in order to successfully combine the electric and district heating systems and to integrate more wind energy into the grid (Liddegaard 2012; Krishnamurti, Schwartz, Davis, Fischhoff, de Bruin, et al. 2012).

2.2.2 Danish Electric and District Heating Systems

Currently, energy in Denmark is distributed through different media. The electric grid and thermal power production plants are currently separate systems (4DH 2012). However, both compose the overall power system, and are also largely inefficient due to the division (4DH 2012).

Denmark's current energy delivery system, or grid, is based on three assumptions. The first is that the utilities generate electricity and heat in response to the demand from the consumer

(Energinet.DK 2012). This means that the utilities predict how much electricity is needed at any given moment during the day, and turn generators on or off accordingly. When they overestimate the amount of energy needed, it goes to waste; however, when they underestimate the energy requirements, blackouts occur (Flick & Morehouse 2011, Energinet.DK 2012). The second assumption is that power distribution and generation is "one way," that is, a large energy power plant (either a windmill farm or a generator that is fuelled by fossil fuels) generates electricity, which is then distributed to the consumer (Energinet.DK 2012). The third and final assumption is that the grid always has to keep some central power stations operating in order to maintain system stability, even though this can lead to wasted energy (Energinet.DK 2012). The current electric grid in Denmark is interconnected with the transmission systems of the neighboring countries Germany, Sweden, and Norway through high voltage, direct current (DC) lines (Jensen 2012). Voltage is stepped down through large substations owned and maintained by Energinet.dk. These substations are controlled remotely via fiber-optic lines. After being stepped down, the electricity is distributed at the local level to individual consumers; it is overseen by the local utilities called distribution system operators (DSO).

Denmark's district heating system is one of the most developed in the European Union (4DH 2012). Unlike the electric grid, district heating is entirely localized which makes it more efficient than individualized heating. All major cities in Denmark are equipped with district heating systems such that around 50% of the population is connected (4DH 2012). The current generation of district heating systems utilizes water at high pressure and at moderate temperatures. The next generation "should embrace lower distribution temperatures, assembly-oriented components, and more flexible materials" (4DH 2012 p. 3). This next generation is called the 4th Generation District Heating System (4GDH). Its major components include a smart technological and institutional system. Namely, this new generation will incorporate the smart grid.

2.3 Defining Smart Technology

In order for the discussion of the smart grid in Denmark to be meaningful, a more concrete definition of smart grid technology needs to be developed. According to A. Carvallo and J. Cooper (2011) smart grid is defined as:

> *The integration of an electric grid, a communications network, software and hardware to monitor, control and manage the creation, distribution, storage and consumption of energy (p. 1).*

Smart grid technology encompasses all of the aspects of the current electric grid, but adds to it a communication network that more closely monitors the distribution and use of energy. The key difference between a smart grid and the current electric grid is the addition of an advanced communications network that reports more accurate energy consumption data (Flick & Morehouse 2011; Janaka 2012).

Table 1 lists the primary differences between the current electric grid and the smart grid. Smart grid uses more advanced communications between utilities and consumers, giving consumers access to up to minute-to-minute energy use information (Flick & Morehouse 2011). This enables consumers to moderate their electricity use, and provides better information to utilities about the load on the grid at any given point in time (Janaka 2012).

Table 1: Key differences between the current grid and the smart grid.

	Current Grid	**Smart Grid**
Meter type	Generally electromechanical	Smart meters
Consumer interaction	Limited, usually just monthly bill	Extensive, up to minute by minute energy prices and use available
Operation/maintenance	Manual equipment checks, meter reading	Remote monitoring, condition-based maintenance
Power generation	Mainly centralized	Centralized and distributed
Grid structure	Radial	Network
Power flow control	Limited, primarily controlled by the utility	Comprehensive, both consumers and utility play an active role
Reliability	Prone to failures due to lack of information in the system	Self-regulating, information passes through system, sending alerts when there's a failure
Problem-response capability	Limited due to reliance on reports of outages	Self-healing; identifies problem area, isolates it, and proceeds to do an internal assessment

Note*: Adapted from tables published by T. Brendlinger (2012) in "Smart Grid," and Dikinson (2010) in "Are your transformers ready for the smart grid?"*

2.3.1 Smart Meter

Many countries use a simple version of the smart grid in the form of smart meters. Smart metering is the first step towards creating a smart grid; due to lack of standards, many of the smart meters that have been deployed are only able to communicate to the utility (Flick & Morehouse 2011). A smart meter performs the same basic function as an analog meter, but has more advanced functions as well. The key differences are that smart meters report more detailed data about energy use to utilities and do not require manual readings (Krishnamurti et al. 2012). Smart meters are directly integrated with the grid and are capable of monitoring all home energy consumption. Many consumers mistake smart meters for enabling technology, and while both are necessary for a successful operation of the smart grid, enabling technology is what creates consumer interaction component (Krishnamurti et al. 2012). Enabling technologies, include home displays and smart appliances. Figure 2 shows the difference between the full smart grid system and smart metering; as can be seen from the figure, smart grid encompasses and relies on the smart meter.

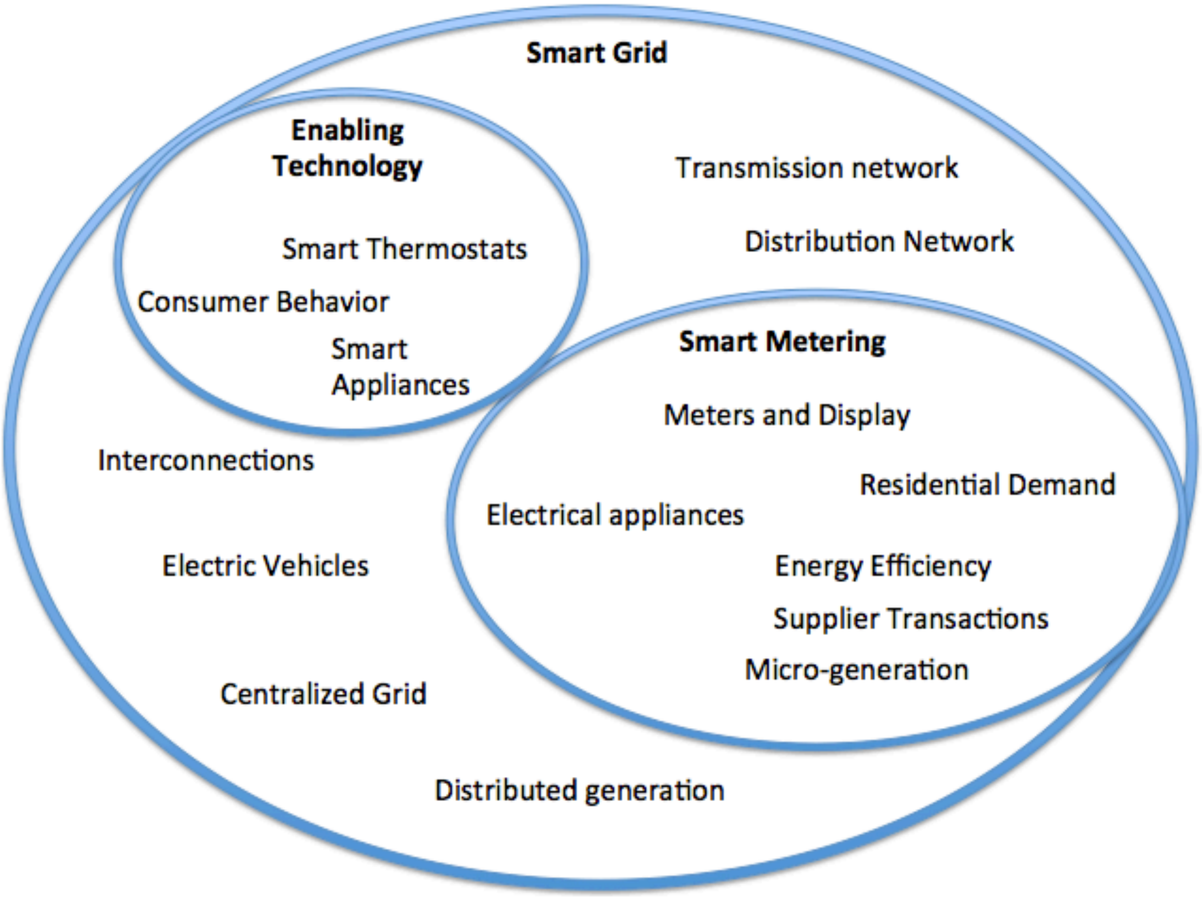

Figure 2: Pictorial representation of difference between a full smart grid, smart metering, and enabling technology. Note*: Picture is adapted from a figure produced by BPL Africa (2010), "What is smart grid."*

The smart grid encompasses the networks and the main electric grid within its influence. According to a study performed by Krishnamurti et. al. on consumers in the Mid-Atlantic region of the United States, consumers are unaware of the difference between smart meters and the technologies that enable consumer interaction with the grid. These enabling technologies are essential to helping consumers modify their energy use (Queen 2011).

2.3.2 Enabling Technologies

Enabling technologies will help consumers actively participate in the energy market. Enabling technology begins with the interface that permits consumer interaction with the grid, and includes connecting individual appliances and devices to monitoring devices, which then record the individual appliance's electric consumption (Krishnamurti et al. et al 2012). This type of monitoring can then inform consumers about the electric consumption of different appliances in their homes and enable them to be controlled remotely. The enabling technologies include in home displays, web and phone applications, and devices that enable energy consumption to be monitored.

Figure 3 depicts how smart meters, a communications network, and enabling technologies connect the different players involved in smart grid.

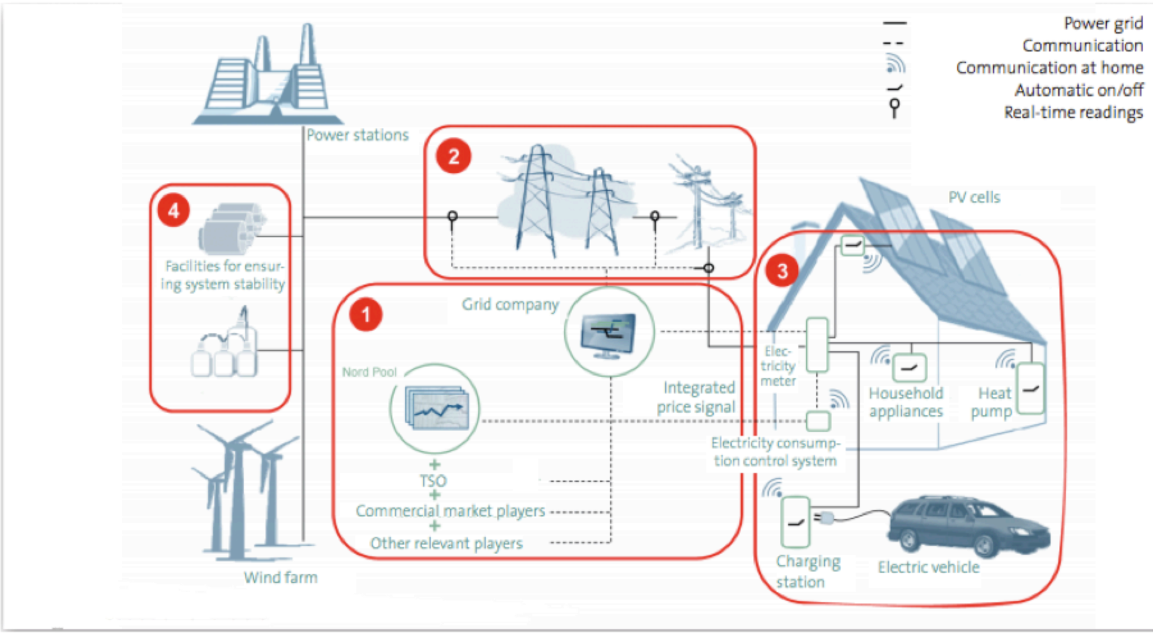

Figure 3: Smart grid functionality diagram. Note: From "Smart Grid in Denmark," 2012. Energinet.DK: Denmark.

It shows how renewable sources -both large scale and micro- production can be integrated into the smart grid network. Furthermore shows how electric vehicles and other consumer appliances can connect to this network. In addition it shows how generation, transmission, and consumption are connected through a centralized communication network, highlighting the key concepts behind smart grid. This depicts an idealized smart grid system that Denmark is pursuing (Liddegaard 2012).

2.3.3 Variable Pricing and Market Liberalization

Enabling technologies can be used in the future to promote the creation of flexibility in the grid. The word "flexibility" when applied to the smart grid means the ability of a consumer to change their immediate electric consumption thus dispersing the load on the grid ("Smart Grid in Denmark 2.0" 2012). Consumers need an incentive to change their electricity consumption habits, which creates flexibility in the grid. Many sources agree that varying the price of electricity throughout the day provides such an incentive ("Market Deregulation is Required to Promote the Installation of Smart Grid Technologies to Gain a Competitive Edge" 2012; "Smart Grid in Denmark 2.0" 2012; Liddegaard 2012). This technique provides incentive by allowing consumers to save money by adjusting their usage habits; for example a consumer could save money by using electricity at off peak hours, paying less for their consumption ("Smart Grid in Denmark" 2011). Varying energy prices is a process known as dynamic pricing and can be implemented in different ways. For example, prices can vary from hour to hour; peak time rates can be set such that they do not vary from day to day, or day-ahead announcements of the rates can be posted ("Power Market" 2012). The dynamic pricing method needs to be simple for the consumer to understand and to be integrated with enabling technology (Faruqui 2009).

2.3.4 Benefits of Smart Grid

Smart grid technology has the potential to positively affect many aspects of Denmark's energy network as well as Danish consumers' lives. It will accomplish this through enabling the integration of renewable resources into the grid and improving energy efficiency throughout the entire energy network.

Benefits for Denmark

Smart grid technology has the potential to help Denmark meet its future energy goals by enabling the country to integrate more wind energy into the grid, to combine the heating and electricity systems, and to improve the overall efficiency of the grid (Andreasen & Aagaard 2012). Smart grid technology addresses the current problems of increasing wind energy in the power generation system. The issue is that renewable sources, such as wind, produce electricity at an unsteady and unpredictable rate (Flick & Morehouse 2011). Another problem is that the windmills could produce more electricity than the immediate demand on the grid because they cannot be turned on like a traditional power plant. The current method to deal with this is to simply shut off the power generation capability of the windmill (Flick & Morehouse 2011). Smart grid technology helps solve these problems by providing more information to the distribution system operators and helping create flexibility in the system. For the first case, smart grid technology could monitor the energy output of the windmill, and reduce the load on the grid accordingly (Togeby 2012). For the second case, smart grid technology would inform utilities of the energy surplus, which can then be transformed into heat for district heating systems or to charge electric vehicles (Andreasen & Aagaard 2012). This is an example of how smart grid technology can unite the electric and district heating systems, thereby improving the overall efficiency of the power grid (Togeby 2012). Another way that the smart grid can help Denmark improve efficiency is through the creation of virtual power plants. A virtual power plant ties together disparate energy resources as if they were a single power supply, however, they do not require any physical generator (Kumagai 2012). Instead, this process identifies areas with small excesses of energy or areas where certain appliances can be turned off, "collects" this power, and then diverts it to places with increased demand. This process is only possible by using smart grid communication network (Kumagai 2012). Virtual power plants enable small energy producers to be connected to the electric system, opening the market for consumers ("Energy Policy in Denmark" 2012).

Business Development

Smart grid has the potential to increase development in two sections of the business world. With the increased control over the grid, electricity aggregation and load distribution companies can improve the services they offer to better control energy use. According to "Smart Grid in Denmark 2.0" (2012), an aggregator provides flexibility to the grid by offering electricity management services to consumers, guaranteeing them a lower electric rate, which creates small, distributed electricity savings in large enough volumes to be sold to the electricity markets. Consumers do not always have time to adjust their energy usage and so they may choose to utilize an aggregator. Figure 4 depicts a simplified version of the role an aggregating company may have in the electric system.

Figure 4: Role of an aggregator in energy market

As depicted in Figure 4 the role of an aggregator is to take over energy management and adjust usage on behalf of the consumer (Gulich 2010). Aggregators would use variable pricing information as well as home automation systems and controls to effectively reduce home energy usage saving money for the consumer (Gulich 2010). An aggregator's profit come from the consumer in exchange for energy management and savings, or from DSOs in exchange for voltage and frequency control. A load distribution company would ensure that the electric load on the grid is always balanced; a task currently performed by transmission and distribution systems operators (Gulich 2010).

Home Automation System

Home automation, or "smart homes," originated in 1984, and refers to interactive technologies within the house (Harper 2003). A home automation system "can be defined as a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants" (Harper 2003). Essentially, every appliance in the home is connected to a home network, which contains a portal for the end user. The inhabitant of the house is able to program appliances connected to the system to suit his/her needs (Harper 2003). Home automation systems will be one of the methods that consumers could use to connect to the smart grid (Janaka 2012).

Benefits for Consumers

Smart grids will enable consumers to feed energy from their own renewable sources back into the grid (Siemens 2011). This means that consumers would be able to transition to so-called "prosumers" (people who both produce and consume energy) by integrating micro-power plants (i.e. micro wind and solar generation units) into their homes. This process already exists on a small scale, but has a number of inefficiencies due to grid limitations. Smart grid technology can improve the system's efficiency using virtual power plants, as described previously (Kumagai 2012). Smart grid technology provides consumers with more accurate information on their energy consumption, both overall and on the individual appliances in their homes. Smart grid can help consumers identify energy systems within their homes that use the most energy, enabling them to replace inefficient machines (Janaka 2012). It has the potential to help consumers lower their electric bills by using a demand response system– that is, utilities would change the prices of electricity throughout the day to reflect the amount of energy available, and consumers would be able to modify their electricity use according to the price ("Power Market" 2012).

2.4 Consumer Concerns

Four categories of concerns have arisen from the development of smart grid technology; the interaction between appliances and the smart grid, interoperability between smart devices, privacy and data security, as well as potential health issues.

2.4.1 Appliance Issues

The standards to which current appliances are designed and manufactured may need to be changed due to the new structure of the electric grid. Currently, there are some appliances that may be unable to interact with the electric grid by using “smart plugs.” These plugs interact with the smart meter to turn power off at the wall, effectively disconnecting the appliance. This kind of interaction may cause problems for older appliances; for example, you should “Never disconnect the power to the washer while it is in the service mode” (GE Front Load Washer Service Mode). This would mean that some older appliances would need to be replaced before the installation of a smart grid could be fully completed.

The replacement is an added expense for consumers because many appliances last for more than ten years, as shown in Table 2. Note that the consumer may replace appliances more often. These two critical factors, the number of older appliances that cannot connect to the grid and the potential damage they could receive from using smart plugs, could present a large problem when it comes to the installation of a smart grid system.

Table 2: Industry average for life expectancy of appliances Note: *Lifetime Expectancy of Major Appliances.*

Appliance	Years
Freezers	19
Ranges	16
Clothes dryers	18
Refrigerators	18
Clothes washers	14
Dishwashers	13

2.4.2 Interoperability

Interoperability is the ability of large, diverse systems to work together. When applied to the smart grid, it encompasses the communications network, the hardware required to use it, and any appliances connected to the system. According to Dick DeBlasio, from Public Utilities Fortnightly (2011), in order for smart grid technology to be successful, there has to be a “seamless interconnection of computing, communications, and power systems” (DeBlasio 2011). This means that standards governing smart grid technology need to be more thoroughly developed. A general set of interoperability requirements needs to be created enabling utilities, engineers, and businesses to further the development of this technology. In 2009, the Institute of Electrical and Electronics Engineers (IEEE) started an interoperability standards project for smart grid technology (“IEEE Launches Smart Grid Interoperability Standards Project P2030” 2009). The project, called P2030, should provide a, “knowledge base for understanding and defining smart grid interoperability of the electric power system with end use applications and loads" ("IEEE Launches" 2009). IEEE P2030 established a consensus on a proposed interoperability framework based on three primary components that create the smart grid. P2030 created a basic outline of interoperability standards for smart grid, but it has barely breached the surface of the standards that need to be created (DeBlasio 2011).

2.4.3 Security and Privacy

The information exchange between consumers and producers/suppliers will change dramatically with the addition of smart grid technology. Presently, the majority of interaction that consumers have with their utility exists only through their monthly bill. With smart grid technology the amount of information would increase to include, potentially, as much as minute-by-minute energy consumption and price information, affecting the way consumers use energy (Faruqui 2009). "Enabling technologies such as programmable communicating thermostats and [air conditioning] switches automate demand response and increase the effectiveness of dynamic prices in promoting demand reduction" (Faruqui 2009 p. 58). In order for the technologies to be programmable, or to effectively use a dynamic pricing scheme, there needs to be an increase in data exchange. This increase generates concerns about the consumer privacy and data security.

Privacy

Consumer concerns about data privacy will need to be addressed as smart grid and its associated technology reaches the deployment stage. Organizations such as the IEEE, various municipal utilities, and businesses are designing regulations to govern who is permitted access to the information smart meters collect (DeBlasio 2011). Privacy issues centered on the possibility of learning about an individual's behavior by their appliance usage may arise. Consumers are concerned that this information will be used for "the benefit of third party data miners, promoters, intrusive law enforcement, and tangential commercial interests" (Schoechle 2012 p. 12). They are concerned their privacy is being impinged upon with no benefit for themselves. According to Deblasio (2011), the government and other regulating agencies should be involved in determining requirements for smart grid security.

The Danish parliament passed the Act on Processing of Personal Data in 2000 with the purpose of protecting data gathered on consumers. The act outlines all of the conditions in which it is acceptable to process data as well as situations in which the opposite is true. Section 6.1 of the Act lists the prerequisites for processing data (Danish Data Protection Agency 2012). Section 6.2 ensures that data cannot be used for advertising purposes except in situations outlined in section 6.3, where it is stated that general consumer information may be distributed (name, address, email, etc.) (Danish Data Protection Agency 2012). It is always illegal, however, to obtain information on an individual's race, religion, political views, trade union membership, health, or sex life without the consent of the data subject as dictated in section 7.1. Section 35 of the Act states that a data subject may, at any time, object to data collection or processing, and if the objection is justified, all data collected and must be deleted (Danish Data Protection Agency 2012). The Danish Privacy Act places limits on the manner of use of consumer data collected by the smart grid, and promises a degree of privacy for consumers. Additionally it gives individuals the option to opt out of all data processing provided they have legitimate cause and are willing to bring the issue forth.

Grid Security

Data security is an important issue with smart grid technology because energy use data is transmitted wirelessly. A hacker could reprogram a smart meter, potentially triggering a series of events that could result in power outages (Office of Electricity 2009; Xu Li et. al 2012). The sources and types of threats are very broad, for example, threats can come from thieves, terrorists, or cyber warfare (Sioshansi 2011). If a thief obtains the detailed information on power usage from a smart meter, they could determine when a consumer is at work or otherwise away from home. This gives thieves opportunities to rob houses with little threat of getting caught (Sioshansi 2011). Hacking is another security threat that needs to be considered. A hacker may break into the smart grid for a large variety of reasons. According to Sioshansi's book, *Smart Grid*, these reasons include, "intellectual challenge, self-expression and peer recognition, testing computer security..." among others (Sioshansi 2011 p. 7). If thieves or terrorists gain access to the system they can cause damage to the grid or a consumer's home.

Title IV of the Danish Privacy Act details the security requirements associated with data. Per section 41.3, processing agencies and their superiors are charged with "[implementing] technical and organizational security to protect data against destruction, alteration, unauthorized disclosure, abuse, or other processing in violation of [the act]" (Danish Data Protection Agency 2012). If data is of interest to foreign powers, measures must be taken to ensure that it can be destroyed in times of war or other similar situations. These provisions only outline the security requirements placed on consumer data after it has been obtained, but does not address the transmission process or wireless communications present in smart grids.

2.4.4 Health Concerns

Consumers are concerned with possible health related side effects of smart grid technology. Some of this technology emits high-frequency radio waves, which is a form of low-level radiation. This technology was allowed to enter the marketplace without having to undergo health testing (Schoechle 2012). Health organizations, specifically the International Agency for Research on Cancer, raised concerns about potential health issues related to this technology (Schoechle 2012).

Current policies and standards can be applied to smart grid technology, however, extensive modifications are needed before smart grid can be fully deployed (DeBlasio 2011). As smart grid technology develops, these potential problems will become a foundation for the standards upon which the smart grid is regulated. The majority of these problems arise from the lack of education on the topic of smart grid technology (Janaka 2012). Any future projects will need to take these concerns into account if smart grid is going to be implemented successfully.

2.5 Smart Grid Projects

In the past ten years, there have been a number of small-scale smart grid projects in both the United States and in Europe. The majority of these projects focused on the technical aspects of smart grid, neglecting consumers' input. Most recently, projects have moved away from testing the technological aspects of the smart grid. Instead, they are focusing on advancing consumer knowledge and changing their energy consumption habits.

2.5.1 United States

California began testing smart grid technology because of a massive blackout that occurred during an energy crisis in 2001 (Faruqui p. 56 2009). The California Public Utilities Commission chose the smart grid to see if they could influence consumer demand by changing the price of electricity. One of the key findings of this study showed that the biggest monetary savings for the consumer and the utility occurred when the rate changed for large blocks of time instead of hourly. Furthermore, they found that the system worked better when advance notice of the rate change was given. The system was most effective when the consumer was provided with added technology, such as a smart meter interface which solely provided rate information (Faruqui, p. 61-62).

The District of Columbia is an innovator in the area of consumer education of smart grid. Members of the Public Service Commission, the Office of the People's Counsel, the Consumer Utility Board, and the local utility Pepco developed a pilot project called PowerCentsDC. The project illustrated that improved communication between the members correlated with improved communication with consumers. It led to the formation of the Advanced Metering Infrastructure Task force. This group "will develop educational materials for use during smart meter deployment..." (Chopra, Kundra, & Weiser 2011 p. 39).

In order to address consumer interaction with technology, the Environmental Protection Agency began developing new specifications for climate control systems under the Energy Star program. These devices include programmable thermostats as well as advanced user interfaces to control heating/air-conditioning systems (Chopra et al. 2011). The specifications that Energy Star is developing are targeted at reducing the impact on consumers. These specifications include requirements for internet-enabled devices, such as smart phones, to be connected with the smart grid (Chopra et al. 2012). This would enable users to control their home climate system remotely.

The United States Government outlined the components of smart grid technology that require standards in "A Policy Framework for the 21st Century Grid." In the United States, the Extended Industry Standard Architecture called for the National Institute of Science and Technology and the Federal Energy Regulatory Commission to oversee the design, adoption, and operation of interoperability standards for smart appliances and smart grid technology. These efforts promise, "to lead to flexible, uniform, and technology-neutral standards that can enable innovation, improve consumer choice, and yield economies of scale" (Chopra et al. 2011). Interoperability standards are the most applicable to consumers. They require that devices from different manufacturers operate in harmony under the smart grid. One example of this type of standard is the Universal Serial Bus (USB) port found on nearly every computer manufactured today. Standards of this nature ensure that any investments made presently will still be valuable in the future even as the technology continues to develop. This will reduce the risk a consumer takes when purchasing new technology because the future technology will be compatible with the older versions. If a consumer is considering converting to or purchasing smart appliances, he or she will be more willing to invest in this technology because there would be a guarantee that it will not become useless in the near future (Chopra et al 2011). This ensures that consumers will not be restricted to purchasing similarly branded devices. In essence, these standards ensure that the technology of today will be compatible with that of the future.

2.5.2 Europe

In 2011, the European Commission called for the establishment of smart grid standards in Mandate 490 ("Smart Grid Mandate" 2011). This mandate both identified smart grid as a major part of the future electric grid in Europe and stated that standards need to be created that govern the technology. The mandate identifies grid operation, grid automation, distributed energy resources management, industry automation, building and home automation, and smart metering as aspects of smart grid that require standards. These standard requirements concentrate on interoperation while ensuring "consistency, security, data protection, privacy, and cost efficiency" of the grid remain intact ("Smart Grid Mandate" 2011).

A study conducted in Switzerland examined the consumer-perceived value of smart meters. A total of 87 consumers were supplied with smart meters and then presented with different scenarios (Kaufmann, Künzel, Loock 2013). These scenarios examined preferences based on pricing as well as the attached devices. The pricing schemes used included charge per kWh consumed as well as base monthly fees. In addition, the study examined preferences based on more accurate monthly reading, real-time consumption feedback, and programming, steering, home security surveillance and alert devices. With the exception of the base fee per month, the study showed that the majority of consumers preferred the new scenarios. The overall conclusion of the study was that consumers perceive smart metering positively and are willing to pay for it (Kaufmann et al 2013).

A European wide study was conducted in 2012 by the International Journal of Marketing and examined the opinions of consumers on the following three advantages and three concerns of the smart grid: Improved transparency, pollution reduction, cost reduction, additional costs, individual benefit, and data privacy, respectively. Individual responses were divided into three categories: supporters, those who were ambiguous, and skeptics of smart grid. The results of this study are shown in Figure 5.

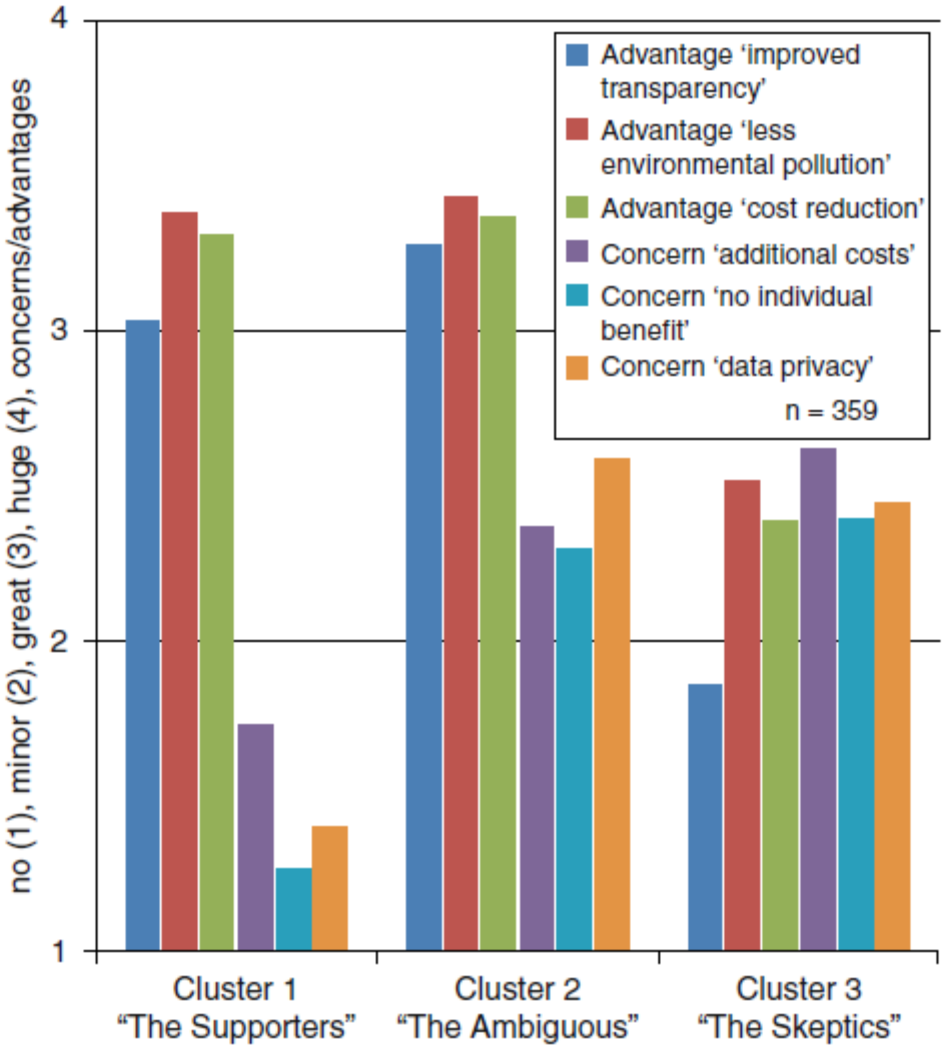

Figure 5: Consumer responses to some sort of smart grid study. Note: From "Generic customer segments and business models for smart grids," by Curtius et al. International Journal of Marketing: Switzerland.

This data shows that supporters see high benefits and have few concerns, the ambiguous see high benefits and have deep concerns, and the skeptics see low benefits and have deep concerns. This project provided links between consumer attitudes towards smart grid technology and the level of concern they have over the technology.

2.5.3 Smart Grid Technology in Denmark

Currently, Denmark has 22% of all of the European Union's smart grid projects, and would like to have a fully integrated smart grid system in the next 15 to 20 years (Stouge 2011; Behnke 2012; Liddegaard p. 5 2012). The country is major a test site for smart grid technology because of the large integration of wind and other renewable resources in their power system. Several of these pilot projects are sponsored by Denmark and other countries within the European Union, and are located on the Danish island Bornholm. An example is EcoGrid EU, a project implementing one of the largest deployments of smart grid technology in the world (Togeby 2012). Bornholm hosts several other, smaller projects including EDISON and PowerLab.DK. The EDISON project is attempting to integrate smart grid technology with hybrid electric and electric vehicles. PowerLab.DK is a research center for the technical aspects of the smart grid, which is run by Jacob Østergaard, Professor and Head of the Centre for Electric Technology at the Danish Technical University's (DTU) Department of Electrical Engineering (Togeby 2012). The goal of PowerLab.DK is to assist stakeholders in the energy industry to develop intelligent energy systems. Of all the smart grid projects, the smart grid pilot project EcoGrid EU, is the most extensive and advanced (Togeby 2012).

Dong Energy Test Program

Dong Energy began a small-scale smart grid pilot project called eFlex, which was set to run from 2010 to 2012. The utility sent out general information to its customers as well as posted information about the program on their website. The project consisted of 155 families ("Become eFlex Test Pilot" 2010). The participants in the study needed a Danfoss heat pump, a PC and an internet connection for the test period, but were given all of the other smart equipment, including a remote-read meter and an iPod Touch in order to take full advantage of the program ("Become eFlex" 2010). Dong Energy invested in the project because they want to integrate more wind and solar power into the electric grid and to observe the smart grid's ability to reduce energy demand on a small scale ("eFlex-A demonstration project" ["eFlex"] 2012). The eFlex project has several purposes, one of which is to determine consumers' abilities to be flexible in their electricity consumption given different incentives ("eFlex" 2012). Telvent GIT (now Schneider Electric) provided the equipment used in the study, adding more capability to its advanced distribution management system. By directing this study, Dong Energy will be able to continue its work to develop "a sustainable concept for flexible electricity consumption in Danish households" ("eFlex" 2012).

Bornholm and EcoGrid EU

Sixteen different countries throughout Europe fund the EcoGrid EU project. This organization rose €21 million to developing smart grid technology for 2000 residents on the island of Bornholm (Bornholm 2011; Benkhe 2012; IBM Joins EcoGrid 2011). One of the objectives of the project is to show that intermittent, renewable resources can form the basis for a reliable and sustainable power supply by using smart grid technology (Siemens 2011; Bornholm 2011). Bornholm was chosen for this study because over 50% of its electric consumption is supplied by wind power (Kumagai 2012; Bornholm 2011; Siemens 2011). Figure 6 shows the distribution of power generators on the island of Bornholm as of April 2011, as well as the main electric connections. It shows Bornholm is a good location for studies on smart grid technology because of its relative isolation to other grids (Østergaard & Nielsen pg. 1 2011). The study started in 2012 and will be used to test a new smart grid market design to encourage consumer participation.

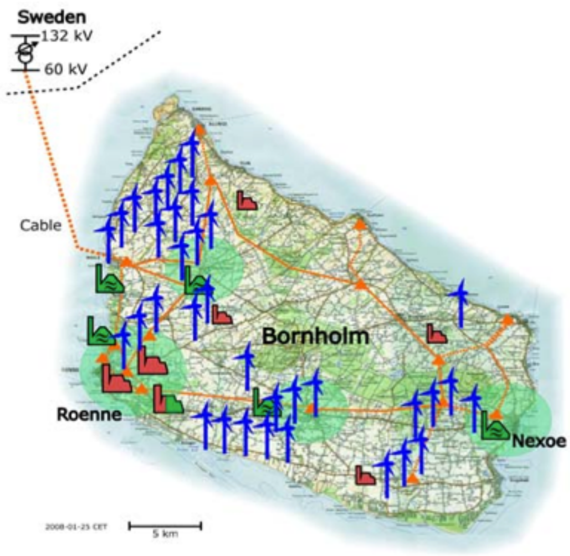

Figure 6: Island of Bornholm with its major generation units labeled. Note: From "Bornholm Power Systems," by Østergaard & Nielsen 2011. DK-2800Kgs: Denmark.

The study on Bornholm involves 2000 consumers that reside on Bornholm. This group was divided into five sub groups that will provide different forms of data to the researchers orchestrating the study. The first is a reference group used to provide statistical data on current consumer behavior. This group involves 200 households that were merely supplied with smart meters, but do not have access to the short-time-frame consumption information or smart technologies ("The EcoGrid EU project," 2012). The second group, composed of 400-500 households, was given access to their energy use information and to changing electric prices throughout the day; however, they have to turn on/off appliances manually. The third and fourth control groups are very similar in that both groups were given access to smart heating systems that respond to signals from the utility to adjust energy use autonomously. The difference between these two groups is the provider of the smart technology; the third group (700 consumers) has automation equipment provided by IBM Green Wave Reality whereas Siemens provides it for the fourth group (500 consumers) ("The EcoGrid EU project," 2012). The fifth group contains 100 business consumers. The businesses have fully automated buildings with integrated smart appliances and heating, all of which are connected to the smart grid communications network.

The overall goal of the pilot project on Bornholm is to demonstrate the smart grid is able to efficiently operate a power distribution system that relies on renewable energy while meeting consumers' energy requirements ("Bornholm will be Europe's first Smart island," 2011; "The EcoGrid EU project," 2012). According to Kumagai (2012), a key outcome of the study is to change consumers' habits with regards to their energy consumption. Denmark plans to use the results of the Bornholm study to provide a blueprint to convert the rest of the country to a smart grid. Energinet.DK and the Danish Energy Association suggest that three changes be made so this transition can take place:

- develop a concept for power system operation
- create an information model for data communications
- design a roadmap for actual use of smart grid technology (Vinther 2012).

This chapter explained the differences between the smart grid and existing grid as well as identified several key players in this emerging industry. Furthermore, the chapter introduces current consumer concerns, requiring consideration in order for the successful implementation of smart grid technology. The section concludes with identifying the location of the largest, full-scale deployment of smart grid technology in Denmark. This information provided a basis for our field research.

3 Objective

Our group was tasked with determining when, how, and to what extent should the DCC become involved in the smart grid standardization process. In order to answer these questions, we identified the following four aspects of smart grid that will impact a consumer as smart grid becomes available:

- the ability of existing technology to interact with the grid
- communications standards within smart grid systems
- data security and privacy
- future smart grid development

Investigating these aspects helped us answer the questions posed to us and achieve the primary goal of our project: to map out possible progressions of smart grid development and standardization, identify areas where consumers need to be represented. Our sub objectives are:

- to identify current forces driving the industry
- to determine possible approaches the DCC could use to ensure evolving smart grid standards are designed to meet consumers' needs

In order to accomplish these objectives, our group developed a methodology that is described in the following chapter.

4 Methodology

The goal of our project is to provide recommendations to the DCC as to how, when and to what extent they should become involved in the standardization and implementation processes of the smart grid. We contacted key organizations involved in smart grid development to meet this goal and accomplish the objectives outlined in Chapter 3. We interviewed representatives from these organizations with the intent to gain knowledge of the state of smart grid standardization and to predict how it will likely evolve in Denmark.

4.1 Data Collection Preparation

In the first week of our project, we met with our project liaison, Martin Salamon and our academic advisor Reinhold Ludwig in order to review the objectives and goals of the project. During this meeting, we discussed the four aspects of smart grid technology used to define our objectives in Chapter 3.

After defining the scope of the project, we decided that the best method for data collection was to conduct interviews with representatives for orginizations who are currently developing smart grid technology. Mr. Salamon ruled out surveys as methods for that data collection due to the lack of consumer knowledge of the smart grid. The following sections describe the structure of our interviews as well as outline the reasons we contaced the different organizations.

4.2 Interviews

We used the “Smart Grid Report,” edited by C. Hestbœk (2011) as a starting point to research different Danish organizations working with smart grid development. This process enabled us to define the following three categories of individuals and organizations to interview:

- smart grid experts
- smart technology providers
- project researchers

We used these categories to organize our respondents into groups of similar bodies to compare the results.

In order to initiate contact with key organizations working with the smart grid, we developed a generic email that introduced our project’s purpose and asked if the correspondent was willing to answer our questions. This email can be found in Appendix A. We corresponded with a total of 13 individuals and conducted interviews with them in person, by phone, or by email. We created a general schedule for our interviews that included questions about the aforementioned categories. The interview schedules can be found in Appendix B and a full list of contacted individuals can be found in Appendix A. We developed a Thematic Library (Appendix C) that we used to keep track of and organize the responses by category. We generated detailed copies of our notes after each interview, which we sent to the interviewee to review before analyzing them.

4.2.1 Smart Grid Experts

We interviewed, Søren P. Nielsen, an IT architect and project manager at House of Dreams/Villa Watt, and Regnar Schultz, a Senior Standards Consultant at Dansk Standard. Furthermore, we spoke with Katrin Behnke, a Project Team Coordinator for ANEC. These standardization consultants are working to develop, standardize and implement the smart grid. We contacted them upon the recommendation of our project liaison and with the intent to gain insight into the standardization process and how it could work for the smart grid.

The first interview we conducted was with Nielsen at the House of Dreams/Villa Watt. House of Dreams is an office/showroom that displays sustainable technologies. Nielsen contributed to a report, titled "The Smart Grid Network's Recommendations," that outlined steps needed to be taken by the Danish Government, utility companies, and other "authorities" to promote implementation of the smart grid.

We interviewed Schulz after obtaining a better grasp of the standardization process. Dansk Standard creates standards, promotes eco-labeling, and is responsible for national and international standardization. The goals of our discussion with Schultz were to become familiar with current governing standards of the smart grid and smart grid technology as well as to identify consumer-industry interactions leading to the creation of standards.

Behnke provided our group with a paper that outlined ANEC's position on smart meter standards. ANEC describes itself as "the European consumers' voice in standardization," and actively participates in the creation of European wide standards.

4.2.2 Smart Technology Provider Interviews

We interviewed members from four smart technology providers: GreenWave Reality and Siemens AG, providers of home automation systems; Landis+Gyr, a smart meter manufacturer; and Electrolux, a large appliance producer. GreenWave Reality, Siemens AG, and Landis+Gyr provide technology for the EcoGrid pilot project on Bornholm. We sought their perspective on smart grid technology's current interactions with consumers and appliances and the developments their companies are looking for in the future. Furthermore, we hoped to learn what standards these companies used to create their products.

The first smart technology provider we interviewed was Oliver Dufour Senior Sales Engineer Europe, from GreenWave Reality. GreenWave was subcontracted through IBM to provide home automation systems for participants in the EcoGrid EU study. The second smart technology provider interview we conducted was with Martin Sjoeberg, a Project Manager at Siemens. Siemens supplies home automation technology to the second major EcoGrid group. Siemens' system is different from that of GreenWave, meaning it was possible that different standards were used in their construct. We asked both Dufour and Sjoeberg questions about:

- current communication standards between smart technology systems
- interoperability between systems and appliances
- privacy and security standards that were used in the deployment of both solutions for the Bornholm study
- where consumer advocacy organizations like the DCC could become involved in the smart grid standardization process

We hoped to gather information regarding smart grid systems, standards, and their future development as well as obtain recommendations and suggestions relating areas of potential involvement for the DCC.

The third smart technology manufacturer we talked to was Bo Hansen, a Sales Manager from Landis+Gyr. The company supplied smart meters for the EcoGrid project. We discussed the capability of the smart meter to communicate with different types of interfaces as well as the method through which data from the meter was secured. We hoped Hansen would be able to provide us with specific information on existing industry standards for interoperability as well as security within smart meters.

We spoke with a representative from Electrolux, an international appliance manufacturer. Electrolux focuses on producing high quality products for consumers. Our interview concentrated on discovering the extent of research being done to create smart appliances and the company's concerns for future development.

5 Project Researchers

We attempted to get a better perspective on the effects of smart grid after implementation by conversing with four people involved with different aspects of smart grid technology. We conducted interviews with three people connected to smart grid pilot projects and a person who works with DataHub, Energinet's smart meter data collection service.

We conducted a phone interview with Henrik Bindner, a Senior Scientist at the Danish Technical University who works on the iPower project. During the interview, we asked Bindner to explain some of the different standards that were used or considered for the iPower project and to identify areas where standards need further development. Furthermore, we asked about privacy and security standards and any consumer concerns the project encountered.

We interviewed two people connected to the EcoGrid project on Bornholm, We corresponded with Maj Dang Trong, an independant consultant from Energinet.DK, and Mark Moseholt, a Project Officer for Østkraft. We corresponded with Trong through email, sending her a questionnaire so she could respond at her convenience, and interviewed Moseholt in person. We asked both Trong and Moseholt about the standards used to create the smart grid network on Bornholm, the challenges the EcoGrid project faced and the main aspects of the smart grid that our project focused on. In addition to our interview, Moseholt gave us a tour of the smart home "VillaSmart" located on Bornholm.

Our final interview was with Louise Rønne Christensen, a marketing manager from Energinet.DK. Energinet.DK manages a centralized smart meter data point called DataHub. We focused our questions on the privacy of the users whose data is collected in DataHub as well as the security that protects this data.

5.1 Danish Consumer Council Discussions

We contacted several people who work within the DCC to discuss various aspects of our project that may affect their work, then conducted two brainstorming sessions about our preliminary findings. We spoke with Helen Amundsen, a Senior Advisor involved in standards development, and Annette Høyrup, a Senior Jurist, and Andreas Melchior, Project Assistant, who both work on protecting consumer privacy.

We spoke with Amundsen to gain insight on general standards development, and which aspects of smart grid technology should be standardized. Moreover, we wanted to discover the amount of influence the DCC has to advocate for the creation of standards. We discussed Danish privacy standards and regulations with Høyrup and Molchior. We desired to learn if there were any aspects of consumer privacy we had not previously considered that could be connected with the smart grid.

Once the majority of our data collection had been completed, we organized two brainstorming sessions with Salamon and other interested members of the DCC in order to go over our preliminary results and discuss possible recommendations that we would make. We organized these sessions to ensure that the recommendations we created would be feasible and realistic for the DCC to pursue.

After completing the interviews and the brainstorming sessions, we used the information to put together different scenarios as to how smart grid technology could develop, identified areas where standards could be implemented, and made recommendations to the DCC that will have the highest impact on consumers.

6 Results and Discussion

6.1 Smart Grid Experts

We interviewed three people who work with the creation of standards, and are currently focused standardizing smart grid technology and smart meters.

6.1.1 Nielsen Interview

We conducted our first interview with Søren Peter Nielsen. Before working at House of Dreams, he worked as a chairman of the Smart Grid Network, a committee organized by the Minister of Climate, Energy, and Building, Martin Liddegaard. Nielsen was able to provide us with information about interoperability, privacy and security, and future development of smart grid technology.

Interoperability

Nielsen (personal communication, April 3, 2013) stated that the development of smart grid would be hindered by the creation of specific standards. He believes that the creation of IT standards should be primarily market driven, but the technology should accessible through open source toolkits to promote innovation. An open source toolkit would ensure that individuals developing smart grid technology start in the same place. This would promote smart grid's development without technical standards prohibiting innovation (Nielsen, personal communication, April 3, 2013).

Privacy and Security

Smart grid requires more information than the current grid to run efficiently. Denmark is collecting energy consumption/production data from smart meters that have been installed in about 3.4 million homes. This information is stored in a centralized hub owned by Energinet.DK. During our interview with Nielsen (personal contact, April 3,2013), he stated that Danes appreciate centralized solutions despite having an increased security risk. He recognizes that there are problems with this structure, but said that people typically ignore the issue until a problem arises. In spite of his worries that the data may be mishandled, Nielsen suggested that people could benefit by allowing a third party analyze their energy consumption data. Energy data can show interesting consumption trends and inefficiencies in the system. During our interview, Nielsen showed us an energy profile of a house collected by a smart meter over a 24-hour period. Figure 7 shows that a person can ascertain the exact appliances being used at various times throughout the day with a meter reading only once every 15 minutes. If a person had access to readings from multiple days, they could identify energy consumption trends.

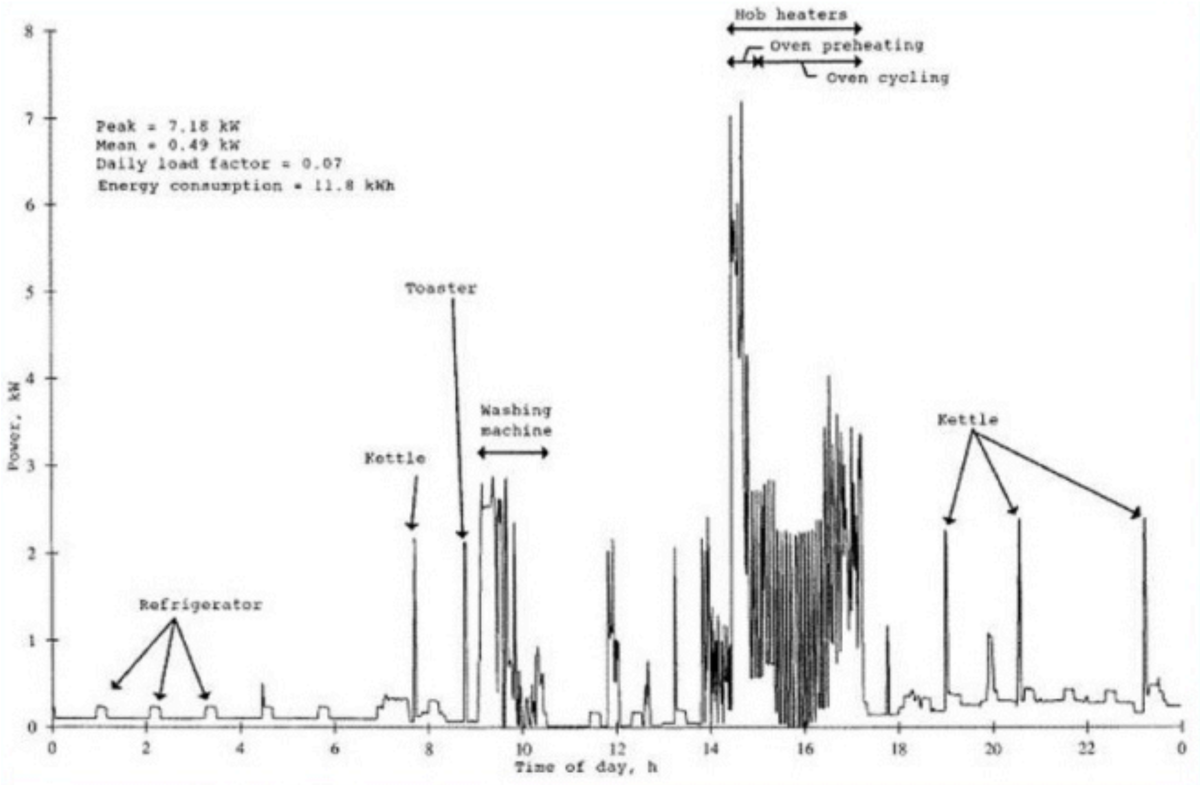

Figure 7: Consumer profiling Note: From "Detailed Data Derived from Smart Meter," posted by Naperville SM Awareness (2012).

There seems to be a need for a minimum level of security for handling data containing this level of detail. In discussions of security, Nielsen indicated that a governing body should ensure that security standards governing smart grid data exist, but to allow the specific standards to be market driven. The standards should come from the market due to the fact that European countries have inextricably intertwined electric networks, meaning the data will have to meet the minimum requirements of multiple countries (Nielsen, personal contact, April 3, 2013). The European Union already requires a minimum level of security for personal data, which can be found in the European Union Directive 95/46/EC, or the “Personal Data Directive.”

Future Development

Nielsen told us his opinions about possible future development of smart grid technology. Part of the time he worked with the Smart Grid Network was spent writing a report, which summarized the Network’s findings. This report outlines nine key tasks that need to be completed to ensure that the smart grid can develop successfully. Of these tasks, we discussed variable pricing, new businesses, and smart appliances in detail.

6.1.1.1.1 Variable Pricing/Flexible Markets

Both Nielsen (personal communication, April 3, 2013) and the “Main Report: Smart Grid Network,” (2012) identified the need to develop monetary incentives to persuade consumers to change their electricity consumption habits. Variable pricing will most likely be used to motivate this change, but currently is not possible due to the rigid market structure. Electricity suppliers provide flat rates to their customers, which are subject to change only on a quarterly basis. The electric market needs to become dynamic, allowing the price of electricity to fluctuate significantly throughout the day. This is predicted to provide consumers with incentive to change their energy consumption habits because they could save money. A flexible market is the direct result of variable pricing, and is required to use the smart grid (Nielsen personal communication, April 3, 2013).

6.1.1.1.2 New Business

Nielsen (personal communication, April 3, 2013) looked into the potential growth of new businesses resulting from the implementation of smart grid. One important service is that of an aggregator; it would provide flexibility to the grid and save both large and small consumers money by adjusting their energy consumption. At this point in time, it is not clear if aggregating companies will evolve from existing companies or if they will emerge as new entities in the energy market.

6.1.1.1.3 Smart Appliances

Nielsen (personal communication, April 3, 2013) said that the transition to smart appliances will be market driven. He believes that appliance companies will invest in smart appliances as the electricity market becomes more flexible. Consequently, standards do not need to be developed requiring appliances to be able to interact with the smart grid. Nielsen (personal communication, April 3, 2013) also believed that connecting home appliances to the smart grid would not create a large electrical savings. He informed us that only 20% of the energy consumed by a home is used by appliances; the remaining 80% of energy goes toward heating (Nielsen, personal communication, April 3, 2013). These statistics imply that connecting heating systems to the smart grid would create the largest savings for consumers.

6.1.1.1.4 Denmark's Goals

We asked Nielsen if he believed that the smart grid could be implemented in Denmark within the next 10 to 15 years in accordance with Denmark's Energy Agreement. He said that it was possible, but that there is still a lot to be done to make this goal a reality. Furthermore, we asked him if Parliament's goal for Denmark to be powered entirely by renewable sources by 2050 was realistic. His response was mixed. He believes that electricity and heat production could come from renewable sources. However, it is unreasonable to assume that automobiles and other forms of transportation will operate on electricity and connect to the smart grid because of their heavy reliance on fossil fuels (Nielsen, personal communication, April 3, 2013).

Part of Nielsen's work for the Smart Grid Network involved examining the state of Denmark's electric system, and resulted in recommendations for updates to create a functioning smart grid. The committee presented nine key recommendations and thirty-five sub recommendations to Parliament describing how to implement smart grid. The complete details of this taskforce are compiled in "Main Report: The Smart Grid Network's Recommendations." The sub-recommendations were further divided into 3 sections as seen in Figure 8. Energy suppliers, DSO's, TSO's and generators comprise the energy sector, and the government and standardization organizations are the main components of the authorities sector. These tasks are prioritized by time, suggesting when the various groups should address their designated recommendations. The numbering system in the figure corresponds to the number of the recommendation in the report.

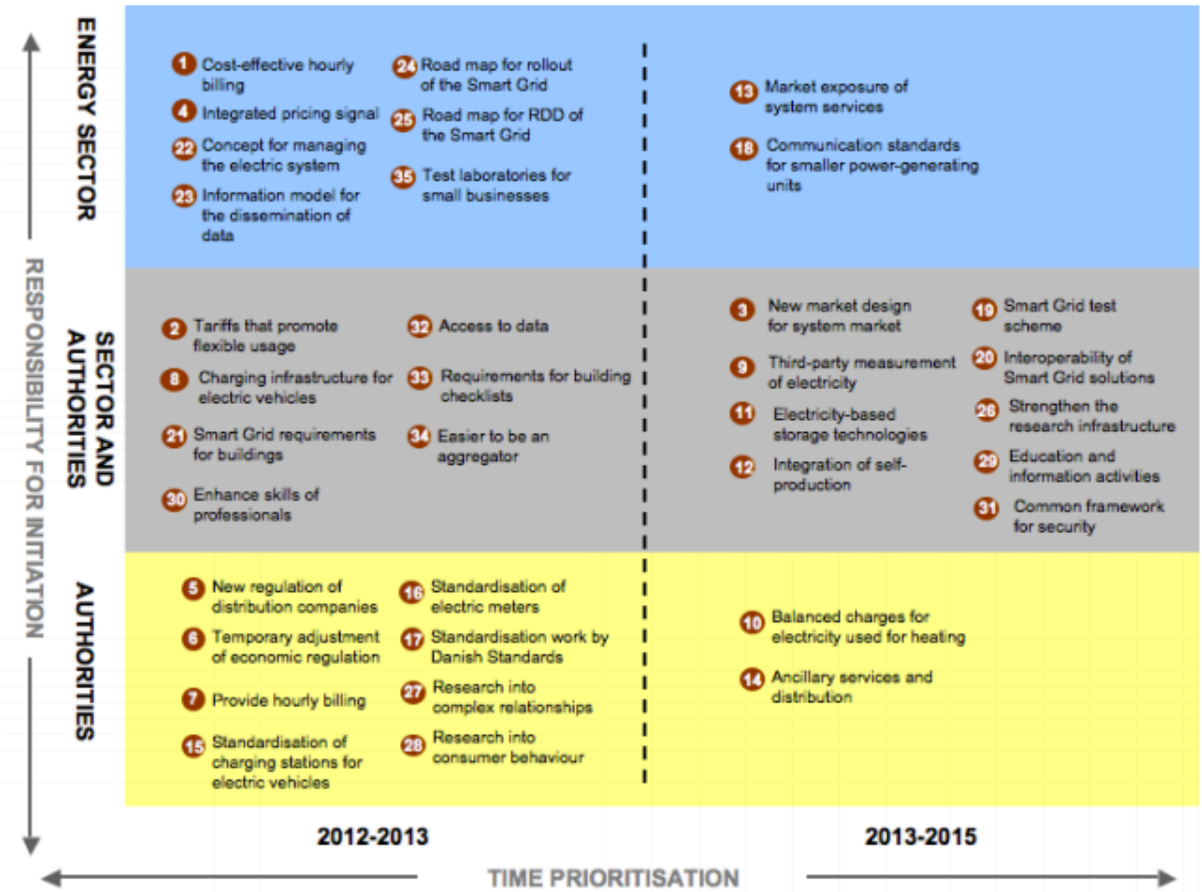

Figure 8: Time prioritization of 35 sub-recommendations. Note: From "Main Report: The Smart Grid Network's Recommendations"

According to Nielsen (personal communication, April 3, 2013) the biggest problem that will be encountered during the development and implementation of smart grid is creating a flexible market. In his opinion, standards should define what needs to be accomplished, not how to accomplish it. Therefore, the government must not over regulate businesses because it may inhibit the development of the smart grid and enabling technologies. He also felt that the standards should be created in response to a problem. Finally, he said that it is crucial for everything to merge together seamlessly when the smart grid is fully implemented.

6.1.2 Standardization Organizations

Regnar Schultz (Dansk Standard) and Katrin Behnke (ANEC) gave us a general idea of their organizations' positions of smart grid standardization. Dansk Standard is assisting international organizations such as the National Institute of Standards and Technology (NIST) with the creation of smart grid standards while ANEC is a standards development organization representing consumers. Schultz described smart grid as a giant IT project that was chosen to bring balance to the grid.

Appliances

Schultz (personal communication, April 11, 2013) stated that standards regarding heat pumps need to be changed to accommodate the smart grid. Heat pumps can be controlled remotely, but with current technology the controls have to be added to the system. The ability to remotely turn them on/off will be necessary to ensure effective energy savings. Schultz said that only a small number of companies are investing in “smart” heat pumps, and that the DCC could help push for new heat pump standards. In his opinion, these standards need to require that heat pumps are capable of connecting to the smart grid and home automation systems. He also said that the DCC should recommend that consumers purchase heat pumps that are larger than the minimum required to heat their homes.

Interoperability

Schultz provided us with insights into the types of interoperability standards that will be important for the smart grid. We discussed smart meters, home interfaces, and electric vehicles. We discussed a possible standard that would mandate all smart meters to have a data port on them (Schultz, personal communication, April 11, 2013). He recommended that the design of the port itself be left to the manufacturer, and that the only requirement be that one should be present on the device. During a discussion of smart meter/home automation system interfaces, Schultz (personal communication, April 11, 2013) informed us that he believes home interfaces should not be standardized. Without a standard, consumers would have the option to choose the interface most suitable to their lifestyle. Schultz (personal communication, April 11, 2013) felt that interoperability standards should be developed by European Union standards organizations because most appliances and devices that will be connected to the smart grid are used throughout Europe.

Privacy and Security

During our discussion, Schultz (personal communication, April 11, 2013) identified security and privacy of electric consumption data as extremely important features of the smart grid. He suggested that the method to secure data will most follow online banking models. Similar to online banking, however, phishing schemes could be applied to the smart grid (Schultz, personal communication, April 11, 2013). Schulz believed that this is an issue the DCC should be made aware of.

The main concern that Schultz brought to our attention is to ensure that data remains private. He gave the example of DataHub, which stores Danes’ smart meter and electricity use information. He said that there is some worry over who has/should have access to this database, and suggested that the DCC look into the matter.

Future Development

We discussed future developments of smart metering and smart grid with Schultz and Behnke. Our interviews focus on electric vehicles, smart meter development, and where the DCC could become involved.

6.1.2.1.1 <u>Electric Vehicles</u>

Electric vehicles are a new transportation product that is just starting to be widely available, and consumers need education on them. European-wide plug standards for electric vehicle charging stations will come into effect in 2017, which will affect the type of vehicle consumers purchase (Schultz personal communication, April 11, 2013). According to Schultz (personal communication, April 11, 2013) electric vehicles will need to have two-way communications with charging stations. The standards for this communication should be established by the European Union (Schultz, personal contact, April 11, 2013).

6.1.2.1.2 <u>Smart Meter Development</u>

The consumer should have a secure user interface that gives access to consumption and historical information, contains the current and predicted price of electricity, and informs the consumer of their CO_2 emissions. Furthermore, the interface should display billing information; either the amount of money added since the last billing period or the amount of credit left when in prepaid mode ("Position Paper" 2013). It should contain an alert function that informs a consumer if their information is out of date or if the meter loses its connection to the network ("Position Paper" 2013). The consumer should have access to this information to make informed decisions on how they use electricity.

6.1.2.1.3 Danish Consumer Council Involvement

According to Schultz (personal communication, April 11, 2013) the DCC should concentrate on the issues of heat pumps, variable pricing, and consumer privacy. The DCC should recommend that consumers purchase heat pumps that are larger than the minimum needed to heat their home and push for standards that ensure they contain a communication system. Additionally, the DCC should work with the government to adjust energy taxes so that they reflect the new market and vary with production (R. Schultz, personal communication, April 11, 2013). The tax rates could be lower when the demand is low and/or when renewable energy is being generated. Schultz also suggested that the DCC could prepare educational materials on electric supply companies. These comparisons could be similar to how consumers compare telephone services currently.

6.2 Danish Consumer Council Discussions

Part of our project involved discussing the impact of smart grid with different members of the DCC. We discussed interoperability and the general standardization process with Amundsen as well as consumer privacy and security concerns with Høyrup and Melchior.

Interoperability

In general, Amundsen, said that the DCC promotes interoperability standards, and believes that consumers should be not be restricted to a single company or manufacturer when choosing home appliances. Essentially, the DCC wants the consumer to be able to purchase any appliance without worrying about its compatibility with other devices (Amundsen, personal communication, April 5, 2013).

We discussed the consumer's interface with the smart grid and home automation systems. Amundsen suggests that multiple user interfaces be available for the consumers. This way, "tech savvy" individuals can be more involved in the smart grid while the average consumer can easily install the system and perform minimal maintenance on it.

Privacy and Security

The issue of consumer privacy seems to be important to the DCC but not to the average Dane (Høyrup, personal communication, April 9, 2013). Høyrup and Melchior (personal communication, April 9, 2013) believe anonymity should be guaranteed. They suggested a consumer could be issued a unique numeric identification that is solely used for the electric system. This solution will increase a consumer's anonymity, giving them an added layer of protection.

6.3 Smart Technology Providers

The majority of the interaction consumers will have with the smart grid will come through the enabling technologies. For this reason, we contacted and interviewed representatives from home automation, smart meter, and home appliance suppliers; specifically, we spoke with representatives from GreenWave Reality, Siemens AG, Landis+Gyr, and Electrolux. Our questions focused on interoperability, security, and future development of the smart grid. Through our discussions, we were able to get a sense of what standards exist, and where additional development or research is required.

6.3.1 Home Automation Suppliers

GreenWave Reality (sub-contractor by IBM for the EcoGrid project), and Siemens AG both produce home automation systems and are suppliers of technology being used in the EcoGrid EU project on Bornholm. We spoke with Oliver Dufour and Martin Sjoeberg, representatives of GreenWave Reality and Siemens, respectively.

Appliances

Both Dufour and Sjoeberg agreed that development is required in the area of home appliances. Currently, there are very few appliances that are capable of connecting to home automation networks and the smart grid. The most important area that needs development is in heating systems (O. Dufour, personal communication, April 4, 2013; M. Sjoeberg, personal communication, April 12, 2013).

6.3.1.1.1 Heating

Heating makes up a large portion of home energy consumption, and presents the biggest potential for energy savings (O. Dufour, personal communication, April 4, 2013). A significant portion of heating in Denmark comes from electric heating systems or heat pumps. Electric heating systems are easily integrated into home automation networks. Heat pumps, on the other hand, have several problems connecting. They are not designed to work with home automation systems as they lack the ability to be controlled over a network (O. Dufour, personal communication, April 4, 2013). Instead, heat pumps are controlled using a Danfoss relay, which must be installed on the in-wall electricity connection to the heat pump as shown in

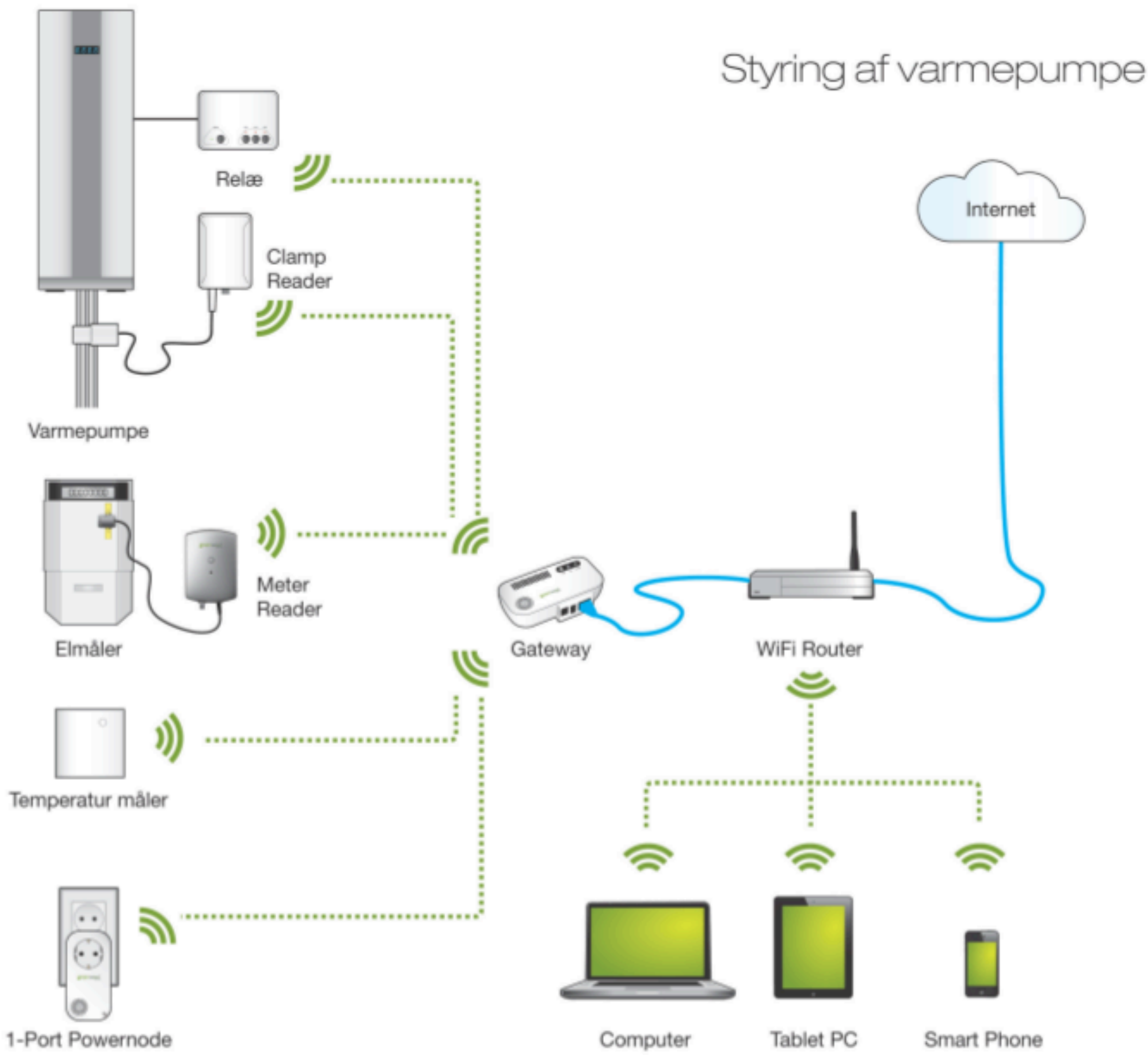
Styring af varmepumpe
Relæ
Clamp Reader
Varmepumpe
Internet
Elmåler
Meter Reader
Gateway
WiFi Router
Temperatur måler
1-Port Powernode
Computer
Tablet PC
Smart Phone

Figure 9.

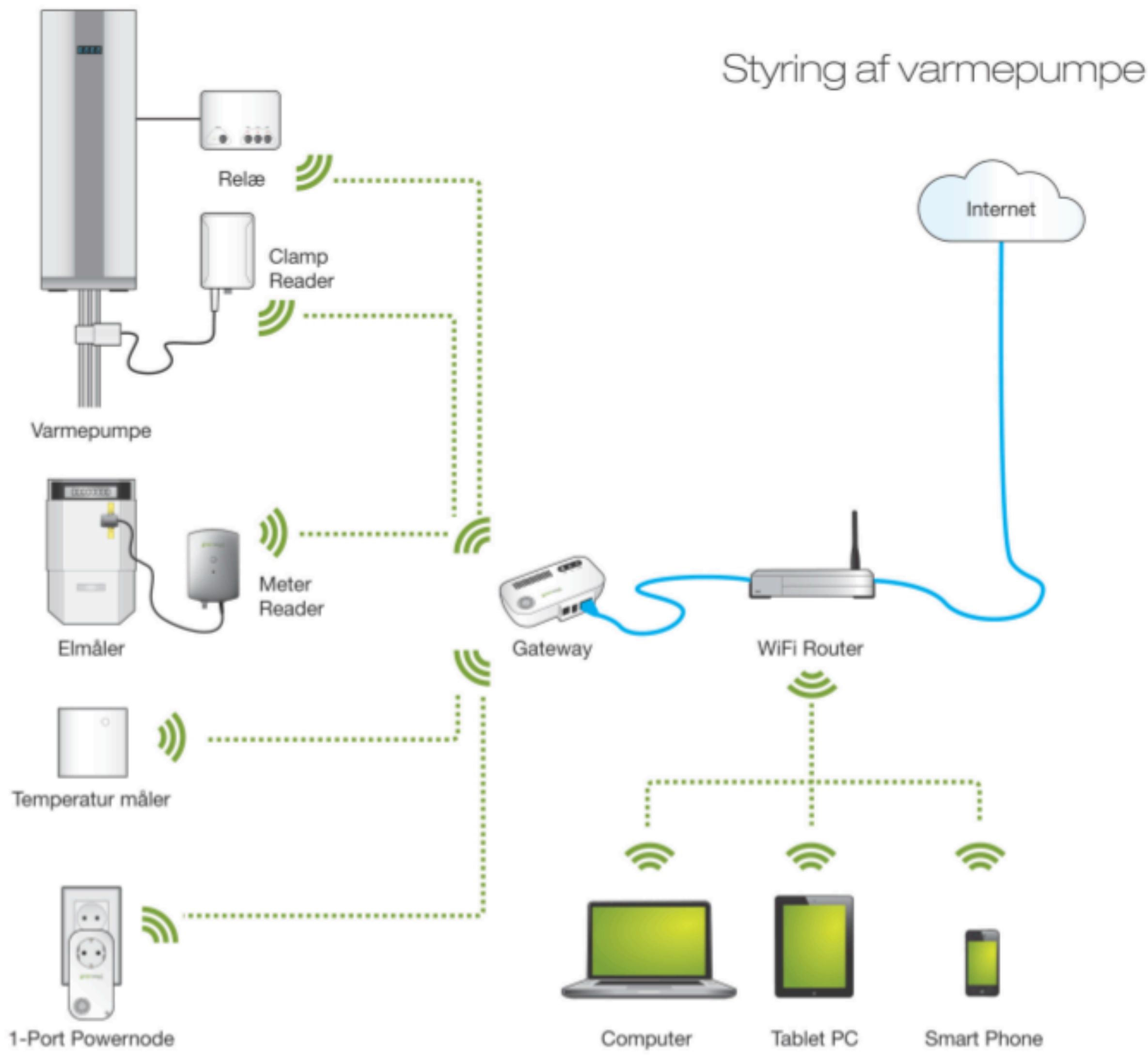

Figure 9: Heat pump diagram with home automation connector inserted. Note: From "Factsheet on EcoHome," produced by GreenWave Reality.

Heat pumps are difficult to control due to the sensitivity of the compressors; they have to fully decompress before the power is shut off (O. Dufour, personal communication, April 4, 2013). Although the current methods used to turn off heat pumps successfully distribute peak loads, the energy used by power cycling the heat pump uses more energy than if it were left on (O. Dufour, personal communication, April 4, 2013). Both Dufour (personal communication, April 4, 2013) and Sjoeberg (personal communication, April 12, 2013) concluded that heat pump manufacturers need to produce heat pumps with the ability to connect to home automation systems/smart grid network as well as increase their capacity to reduce the energy lost from cutting power.

Interoperability

6.3.1.1.2 Communication

We asked both the GreenWave and Siemens representatives about the communications standards they used to create their systems. Our questions led to discussing the merits of interoperability in smart grid and home automation products. Dufour and Sjoeberg explained their companies' communication systems. Diagrams of the GreenWave and Siemens systems can be seen in Figure 10 and Figure 11, respectively.

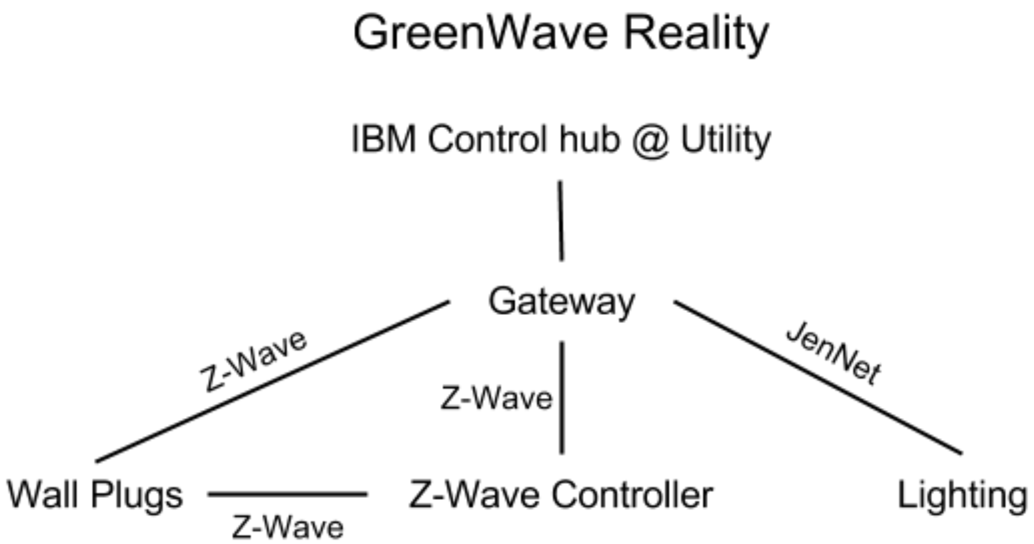

Figure 10: Diagram of GreenWave home automation communication network

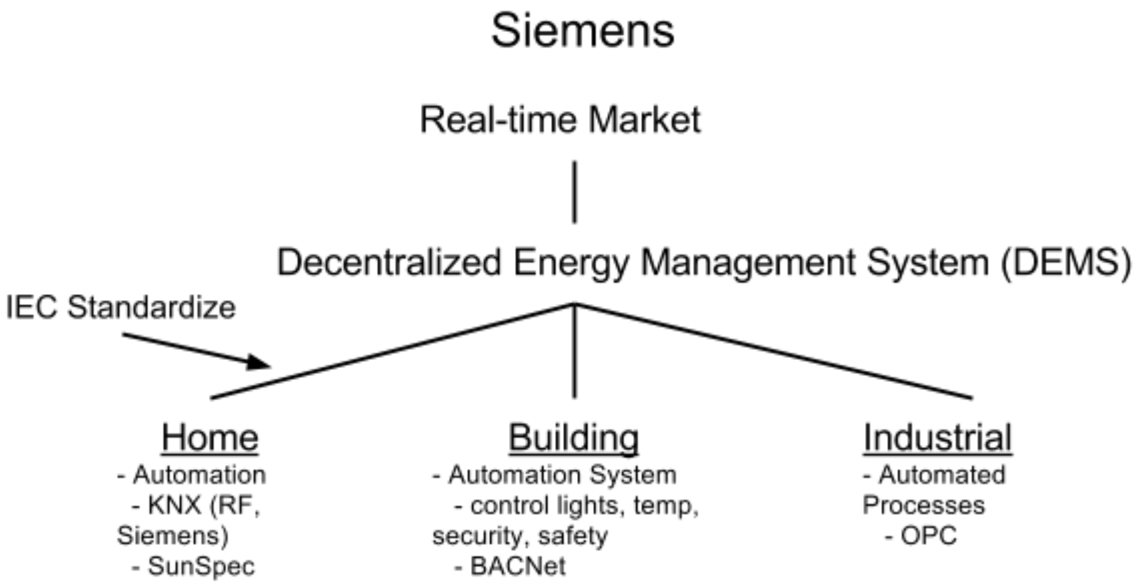

Figure 11: Diagram of Siemens automation network

GreenWave Reality's system connects a consumer's home to a centralized aggregator provided by IBM, or, in the case of the EcoGrid project, located in Østkraft, the local utility. This hub controls heat pumps and monitors electricity consumption. Within the home itself, the GreenWave system utilizes "smart plugs," called nodes, which are network enabled adapters that operate between devices and the outlet in the wall. They can be used to connect any device to the home automation network. GreenWave Reality's system was designed to communicate with devices in addition to those connected through the nodes. This is accomplished through the Gateway, which communicates using the Z-Wave, ZigBee (based on IEEE 802.15.4), and JenNet (based on IEEE 802.15.4) communication protocols. Z-Wave and ZigBee are commonly used to connect devices to a network while the JenNet protocol is used in network-enabled lighting systems (O. Dufour, personal communication, April 4, 2013).

Siemens created a localized system instead of taking the centralized approach that GreenWave developed. Consumers that have the Siemens solution are provided with a PC which operates as a Decentralized Energy Management System (DEMS), controlling the home automation system (Sjoeberg, personal communication, April 12, 2013). The DEMS interfaces to inter-connected controls using the KNX (IEC 14543-3) communication standard (M. Sjoeberg, personal communication, April 12, 2013). Unlike GreenWave Reality, the Siemens system does not control devices but instead monitors parts of the house. Contact pads are connected to windows and doors, which are then identified in the home automation network's online portal. This feature adds several security benefits as well because it enables a consumer to monitor their home while away. In addition to contact pads, the Siemens system integrates electric heating into their system, granting both consumers and aggregators the ability to remotely control the temperature of the home.

Unfortunately, the communication standards used by GreenWave Reality (Z-Wave, ZigBee, and JenNet) are not compatible with those used by Siemens (KNX) (O. Dufour, personal communication, April 4, 2013; M. Sjoeberg, personal communication, April 12, 2013). Both Dufour and Sjoeberg acknowledged the need for a common communications standard but feel that this standard will emerge naturally from the market.

6.3.1.1.3 Interface

The GreenWave and Siemens solutions incorporate and in-home interfaces. They are designed to give users control over all aspects of the home automation system (O. Dufour, personal communication, April 4, 2013; M. Sjoeberg, personal communication, April 12, 2013). A consumer can program the home automation system by selecting various parameters regarding the cost and source of electricity (O. Dufour, personal communication, April 4, 2013; M. Sjoeberg, personal communication, April 12, 2013). In addition, the interfaces display the current electric rate to consumers, permitting them to adjust aspects of their energy use that was not programmed into the system. Both parties agreed that systems should not be standardized in order to promote product variability for consumers (O. Dufour, personal communication, April 4, 2013; M. Sjoeberg, personal communication, April 12, 2013).

Privacy and Security

Privacy and security are key aspects of home automation systems. Whenever there is wireless communication, security becomes a concern. We determined that all the data transfer protocols used by both GreenWave Reality and Siemens is the AES (128 bit) encryption standard (O. Dufour, personal communication, April 4, 2013; M. Sjoeberg, personal communication, April 12, 2013). A major difference between the two systems arises when the level of privacy is examined. The GreenWave system sends the electricity consumption information to IBM's centralized processing server (O. Dufour, personal communication, April 4, 2013). This means that whoever has access to the control hub can determine details as specific as which lights are on in various rooms in the consumer's house. Currently, consumers cannot choose which data is transferred because it is part of the system (O. Dufour, personal communication, April 4, 2013). The Siemens system, in contrast, is more private as no automation data is sent out of the house (M. Sjoeberg, personal communication, April 12, 2013).

Future Development

6.3.1.1.4 Updating

Dufour and Sjoeberg both indicated that they are continuously updating their systems. This process is made simple by the fact that both systems can be remotely updated with upgraded firmware when it is made available (O. Dufour, personal communication, April 5, 2013; M. Sjoeberg, personal communication, April 12, 2013). There is no specific standard surrounding this process, but it is common practice in the industry.

6.3.1.1.5 Variable Pricing

Both groups stressed that variable pricing schemes need to be developed in order to stimulate investments in smart grid products. According to Sjoeberg, the DCC should lobby the government to promote variable pricing within the electricity market. This will provide the monetary incentive for consumers to modify their electricity use habits to (Sjoeberg, personal communication, April 12, 2013). Dufour (personal communication, April 4, 2013) told us that the majority of the costs associated with electricity come from taxes. This means that the government could lose a significant amount of revenue if electric rates drop significantly through variable pricing. According to Sjoeberg (personal communication, April 12, 2013) a variable pricing scheme is one of the most important aspects of smart grid that needs to be developed.

6.3.2 Smart Meter Suppliers

We spoke with Bo Hansen from Landis+Gyr to learn about the standards used in the design of smart meters. Landis+Gyr is the supplier of smart meters for the EcoGrid project on Bornholm. We focused our questions on privacy and security standards and future development because smart meters are not directly connected to appliances.

Landis+Gyr smart meters use both DMS and Meter-BUS (M-BUS) communication protocols. The DMS protocol operates over phone lines while the M-BUS protocol enables wireless meter reading and is a European standard for modern smart meters (Hansen, personal communication, April 4, 2013). Similar to the home automation communication protocols, M-BUS utilizes the AES (128 bit) encryption standard (Hansen, personal communication, April 4, 2013).

Landis+Gyr smart meters can work with different operating systems (Hansen, personal communication, April 4, 2013). This means that, in the future, consumers will not have to replace their smart meters when they switch suppliers. On a more general level, Hansen indicated that standards should be developed for all aspects of smart grid in order for it to be successful. The most important aspect of standardization is for devices to be "plug-and-play" for consumers (Hansen, personal communication, April 4, 2013).

6.3.3 Appliance Suppliers

Many future benefits of smart grid depend on the availability of smart appliances. We spoke with a representative from Electrolux hoping to learn about smart appliance development. We learned that Electrolux is supplying smart appliances for a project in Stockholm, Sweden. The smart appliances that Electrolux is developing work with the ZigBee (based on IEEE 802.15.4) communications standard and WiFi (IEEE 802.11) (Electrolux, personal communication, April 23, 2013). In order to take full advantage of the connectivity, these appliances will be programmable and be able to switch on/off based on the price or availability of energy, or time schedules. Variable pricing exists in Sweden, but the current rates do not have the range necessary to make it effective. The representative from Electrolux (personal communication, April 23, 2013) indicated that consumers require some sort of incentive if smart grid is to be successful, and this could come from variable pricing/tariffs.

6.4 Project Researchers

We interviewed four people who are currently working on projects relating to smart grid and smart metering. We had the opportunity to discuss EcoGrid EU and the development of smart grid for 2000 customers on Bornholm with M. Trong and M. Moseholt. We also discussed the challenges developing controls for a system based off of dynamic pricing signals with H. Bindner, a researcher for the iPower Plaform. Finally, we discussed the security and privacy of the electric data stored in DataHub with L. Rønne Christensen.

6.4.1 Ecogrid EU Project

6.4.1.1.1 Recruiting Challenges

The project managers and researchers working on the EcoGrid project on Bornholm identified several common concerns that consumers have about smart grid technology. These concerns involve:

- the cost of adding smart grid technology to a home or building
- the direct cost of electricity if they join the project and use the variable pricing
- access to practical information about how smart grid will affect their day to day lives (M. Trong, personal communication, April 8, 2013)

The first two concerns will not have significant impact on consumers due to the nature of EcoGrid; the participants are being provided with the smart grid products necessary for the study. Moreover, the study is set up so consumers will only save money if they modify their electricity consumption habits (M. Trong, personal communication, April 8, 2013). The final concern is much more important, and was addressed by the sponsoring DSO/Supplier Østkraft. The company created a “Smart Grid Hotline” and email address where participants can ask questions about the setup of the project and learn more about the smart grid. Østkraft also hosted several open houses at VillaSmart, their demonstration house, and hosted Energy Fairs in order to stimulate interest and provide information about smart grid (M. Trong, personal communication, April 8, 2013).

EcoGrid’s experience with attracting consumers and keeping their interest highlights one of the key problems with smart grid technology; people do not know enough about the smart grid to to accept it. Both Trong (personal communication, April 8, 2013) and Moseholt (personal communication, April 16, 2013) from the EcoGrid project said that lack of consumer knowledge of smart grid is one of the largest barriers to its deployment. Both of them agreed that some form of educational campaign about smart grid needed to be developed before it could be widely deployed. Despite this problem, Trong (personal communication, April 8, 2013) informed us that many of the “participants have been disappointed with the lack of perceived ‘smartness’ in the project,” and said that “it is important to ‘temper the expectations’ and explicitly inform participants that they are pioneers and do not have the product of the future yet.”

6.4.1.1.2 Technical Challenges

The EcoGrid project has encountered several unforeseen challenges during the setup on Bornholm. These problems range from people dropping out of the study due to problems with, "the many little light bulbs that are on the different devices" of the home automation equipment to incompatibility between the smart grid technology used by EcoGrid and the appliances used in the houses (M. Trong, personal communication, April 8, 2013). Many of the houses just were not "smart grid ready" (M. Trong, personal communication, April 8, 2013). Trong (personal communication, April 8, 2013) provided a list of reasons why a house could not be integrated into the project:

- "Electrically heated houses which are registered to have electrical heating, but actually use their wood stove oven most of the time are not ideal for participation.
- A house with an air/air-heat pump is not compatible with the EcoGrid-equipment.
- The heat pump in the house is of a brand and/or type that is not compatible with the EcoGrid equipment
- The participant does not have an internet connection, which is necessary as the equipment needs an internet connection at all times. Internet is also needed for the variable prices, which are fed into the system in the house.
- The participant does have an Internet connection, but only through a mobile device (wireless broadband). The Internet connection has to be through e.g. a cable for the equipment to be connected to it." (M. Trong, personal communication, April 8, 2013)

Both the problems with internet connections and with the heating systems within houses are issues that need to be resolved before smart grid can be widely deployed.

The interviews with both Moseholt (personal communication, April 16, 2013) and Trong (personal communication, April 8, 2013) identified heat pumps as one of the main problems that they have seen while installing the smart grid equipment. The heat pump/heating system in a consumer's home is the only device that Østkraft will remotely control for this project. Many homes interested in participating in EcoGrid were unable to join or were relegated to either to the reference group or the "manual control" group due to incompatibility of different heat pumps with the EcoGrid equipment (M. Trong, personal communication, April 8, 2013).

Moseholt (personal communication, April 16th, 2013) elaborated on the difficulties encountered by Østkraft while installing heat pumps in the study participants' homes during our interview. He identified two main problems:

- The current method for controlling heat pumps involves inserting more equipment into the actual pump, which can be difficult and expensive.
- Heat pumps are designed to work at capacity, that is, at full power, in order to heat a home. This means that it uses more power once it is turned back on, negating the potential energy savings.

Moseholt (personal communication, April 16, 2013) also recommended several technical solutions to these problems. In order to make controlling heat pumps easier, he suggested that they be built with remote control capability. He also suggested that a "smart grid compatible" labeling system be created so consumers know which heat pumps are compatible with the smart grid. As a solution to the second problem, Moseholt (personal communication, April 16, 2013) determined that houses using heat pumps should purchase a pump that has about 30% greater capacity than needed (i.e. the heat pump should have 130% of the capacity needed to heat the building) and that they should be required to contain a buffer tank. Both of these changes would enable heat pumps to save power if they were turned off (M. Moseholt, personal communication, April 16, 2013).

6.4.1.1.3 Variable Market

EcoGrid is testing a market concept to see if consumers are willing to change their consumption habits in order to save money. The participants will have access to the ordinary market price of energy and will be provided with information as to "how many bonus points they have collected by using electricity when the prices are low" (M. Trong, personal communication, April 8, 2013). Through this method, participants in the project can see the amount of money they saved by modifying their consumption (M. Trong, personal communication, April 8, 2013). However, consumers will not be able to save a significant amount of money due to the large tax applied to electricity. The EcoGrid project can only vary the direct price of electricity, amounting to no more than 25% of a consumer's bill. The other 75% charged to a Danish electric bill comes from taxes (M. Moseholt, personal communication, April 16, 2013). Unless the tax structure promotes flexibility, there will not be enough of a monetary savings to motivate consumers to change their electricity consumption habits (M. Moseholt, personal communication, April 16, 2013). Moseholt (personal communication, April 16, 2013) suggested that the DCC could help create a flexible taxation structure that would minimize overall revenue loss while providing consumers with an adequate incentive to change electric use habits.

6.4.1.1.4 Privacy & Security

The security of the electric data collected on Bornholm is taken very seriously by Østkraft. Moseholt (personal communication, April 16, 2013) informed us that the wireless communications are encrypted and all of the other communications require a direct connection to a cable. During our tour of the smart grid demonstration house, we had the opportunity to look at the room where the primary smart grid connectors and routers were kept, and to see the safe-box that held all of the transmitters. Access to this equipment is limited and strictly monitored (M. Moseholt, personal communication, April 16, 2013). EcoGrid is collecting a significant amount of personal information, including data on electric consumption, consumption habits, the EcoGrid price of electricity, and the standard regional prices. The *Customer Agreement for Participating in the EcoGrid Project* provides information as to how the data collected by Østkraft can be used. The electricity consumption information is available for the individual consumers through the EcoGrid feedback system/user interface. Østkraft also collects and stores the information and is free to forward it to the project partners to fulfill EcoGrid's objectives (M. Trong, personal communication, April 8th, 2013). Østkraft follows the rules laid out in Danish privacy laws for all other uses of the information (M. Trong, personal communication, April 8th, 2013).

6.4.2 iPower Project

We spoke with H. Bindner (April 10, 2013) about the iPower project, which is examining how to make flexible consumption a reasonable possibility for the grid.

6.4.2.1.1 Problems with Smart Grid

One of the first concerns Bindner (personal communication, April 10, 2013) mentioned was the probable complications involved in integrating more renewable technology into the grid. He stated that there could be negative effects if large quantities of dispersed, renewable technology are integrated into the electric grid while removing the large, centralized generation plants. He suggested that there could be larger variations of frequency and voltage than there is currently, which could negatively impact appliances. He suggested that this issue could be approached by augmenting the controls structure of the grid and adding “frequency transformers” to buffer the frequency fluctuations.

6.4.2.1.2 Variable Markets

One of the key questions that iPower is looking at is “How do you design a system capable of working with flexible markets, production, and consumption?” (H. Bindner, personal communication, April 10, 2013). The answer to this question lies in how appliances will be controlled and united with the grid, which is one of Bindner’s areas of research. He told us that it is difficult to examine due to the lack of standards/consensus for how the controls architecture should be created. In order to connect appliances to the grid, they need to have a uniform method of communication, and they need to be able to be controlled by the price –and through the price, the availability– of electricity at any given point in time (H. Bindner, personal communication, April 10, 2013). Another question that iPower is examining is the relative benefits of connecting every appliance to the smart grid. Bindner (personal communication, April 10, 2013) suspects that the only appliances that will generate large savings in electric power are those that relate to heating, and, in the future, electric vehicles. This means that the communications standards for controlling heating systems and electric vehicle chargers should be developed.

6.4.2.1.3 Aggregators

When smart grid is deployed, consumers will most likely not be directly involved in controlling their consumption; the process of moving around electricity will be fully automated, and most likely will be controlled by aggregators (H. Bindner, personal communication, April 10, 2013). Theoretically, the aggregators would work with a real time market, and help out both the people in charge of ensuring the security of the electric supply and the consumers (H. Bindner, personal communication, April 10, 2013). In this system, the consumer would set his/her comfort requirements through an interface either online or through a contract with an aggregator, and the aggregator would proceed to control the system turning on/off heating pumps and possibly large appliances to provide flexibility while maintaining the person’s comfort (H. Bindner, personal communication, April 10, 2013).

6.4.2.1.4 Consumer Council Involvement

Bindner recommended that the DCC monitor the development of standards, and ensure that they address the consumers and not just the technological aspects of smart grid. He recommended that the DCC investigate different types of consumer interfaces due to the high level of automation that will be in the system. Bindner recommended that the consumer interfaces include the ability to specify the types of control on each unit, so they have the final control over any appliance, and have override capability if needed.

6.4.3 Data Hub

Energinet.DK owns and operates a centralized meter data collection and storage system known as DataHub. This hub contains information about all electric consumption and production in Denmark (L. Rønne Christensen, personal communication, April 21, 2013). DataHub stores information about a consumer's identity, the meter point address (which can be different than the actual address of the consumer), the type of meter, the settlement method (hourly or profiled settled), and historical consumption information. The data is accessible to consumers, who can request it by accessing the information online using "NemID" as identification as well as a password. The only other entities that permitted to access a specific consumer's data are required to have explicit permission or signed contract with the consumer (i.e. grid operators or electricity suppliers). Rønne Christensen said that a consumer has to give a supplier a "power of attorney" in order for them to legally access his/her data before entering into a contract with the consumer. DataHub is accessible by all energy suppliers who have agreed to Energinet.DK's conditions of use and sign a contract (L. Rønne Christensen, personal communication, April 21, 2013). If a supplier violates this contract (e.g. by violating the market rules), their access to DataHub is revoked (L. Rønne Christensen, personal communication, April 21, 2013).

Rønne Christensen (personal communication, April 21, 2013) informed us that Energinet.DK is working on making it easier for consumers to give third parties access to the information contained in DataHub by implementing a "privacy by design" feature, so that consumers have even more control over the companies who have access to their energy data and indicated that is an area where the Danish Consumer Council could get involved (L. Rønne Christensen, personal communication, April 21, 2013).

6.5 Summary of Results

Our interviews gave us a grasp of the variety of smart grid standards that currently exist, as well as areas that still require development. We compiled a list of standards resulting from our interviews as well as areas where standards were suggested:

- Communication
    - Home automation - appliance
        - ZigBee (based on IEEE 802.15.4) - GreenWave Reality
        - Z-Wave - GreenWave Reality
        - JenNet (based on IEEE 802.15.4) - GreenWave Reality
        - KNX (IEC 14543-3) - Siemens
    - Smart meter - supplier
        - M-BUS (EN 13757-x) - Europe-wide
    - Aggregator - automation/appliance
        - Heat pump network connectivity [DEVELOP]
- Security
    - AES - 128 bit encryption standard - Industry Standard
- Variable pricing/taxation schemes for consumers [DEVELOP]

Using this list as reference, we can begin to understand the different smart grid standards that exist and those that need further development.

6.5.1 Current Appliances

Our discussions identified two issues with current appliances interaction with smart grid technology. The first issue is that heat pumps on the market today are not "smart grid ready" and require the installation of additional equipment to be connected to an automation network. Concerns arise when they are power cycled, as compressors must first decompress before they can be reactivated. The second issue was that integrating more renewable sources into the grid could cause the frequency of the AC output to vary. We investigated this further, and this issue will be resolved by adding "frequency transformers" to the grid to buffer these spikes, and will not affect the end user.

We learned appliances are often used in the home for around 10 years. Because of this, the consumer needs information as to whether or not an appliance is smart grid ready, similar to the way televisions were similarly advertised as "digital TV-ready" in the United States. A problem with this solution is that appliance companies do not want to make products available when the market does not exist.

6.5.2 Interoperability

We obtained information about current communications standards used in the home that relate to interoperability. There are very few smart appliances available on the market at this point, so interoperability concerns stem from home automation systems. GreenWave Reality and Siemens, two producers of home equipment able to connect to the smart grid, currently use different, incompatible communication standards in their solutions. It was suggested that the industry would naturally develop communications standards. Moreover, many of the interviewees insisted that a strict standard regulating communication would prevent innovation in the industry.

6.5.3 Privacy and Security

All of the people we spoke with believed that the market will develop security standards that will adequately protect the data. Companies that are developing smart grid capable technologies appear to use a common a method, even if it is not yet a standard; they use AES-128 bit encryption protocol, which is also used for online banking. The main place a problem could arise in terms of protecting consumer data stems from who has access to it.

DataHub was a topic of interest in our discussions with Schultz which eventually led to our interview with Rønne Christensen. DataHub is a centralized collection of both generation and consumption data. There are potential privacy concerns with DataHub as data is accessible by any of the suppliers who are part of it. Access permission must be granted by the consumer through power of attorney, but checks for this permission are random. The penalty for accessing data without permission, however, is severe in that it results in a ban from DataHub.

6.5.4 Future Development

6.5.4.1.1 <u>Variable Pricing</u>

Variable pricing was the most prominently discussed topic for the future of smart grid. When the transition is made to smart grid, energy consumption will change to a supply and demand base, forming part of the variable market. The issue in Denmark is that 75% of electric bills are taxes. A potential solution would be a variable taxation system where taxes would be lower on renewable or green energy and/or when the demand for energy was low (i.e., off-peak hours).

6.5.4.1.2 Education

Consumers need to be educated about the smart grid but the majority of the interviewees believe that it is simply too early in the process for it to have significant impact. Furthermore, they suggested to wait before issuing education campaigns until the products are closer to mass deployment. Educational materials and strategies for consumers who have the option to partake in a smart grid project should be developed. They could be used as part of an education campaign once smart grid ready for wide-scale implementation.

6.5.4.1.3 Transitioning to the Smart Grid

Throughout our research we developed a thorough understanding of the current grid structure in Denmark, and future possibilities for the smart grid. Our interpretation of the current and future grids is depicted in Figure 12 and Figure 13. Figure 12 portrays the most common type of grid structure and it is what most of Denmark uses, outlining the various connections between different components. Figure 13, however, shows one possible way that the smart grid could be implemented. These pictures were developed as a result of the technical aspect of our interviews.

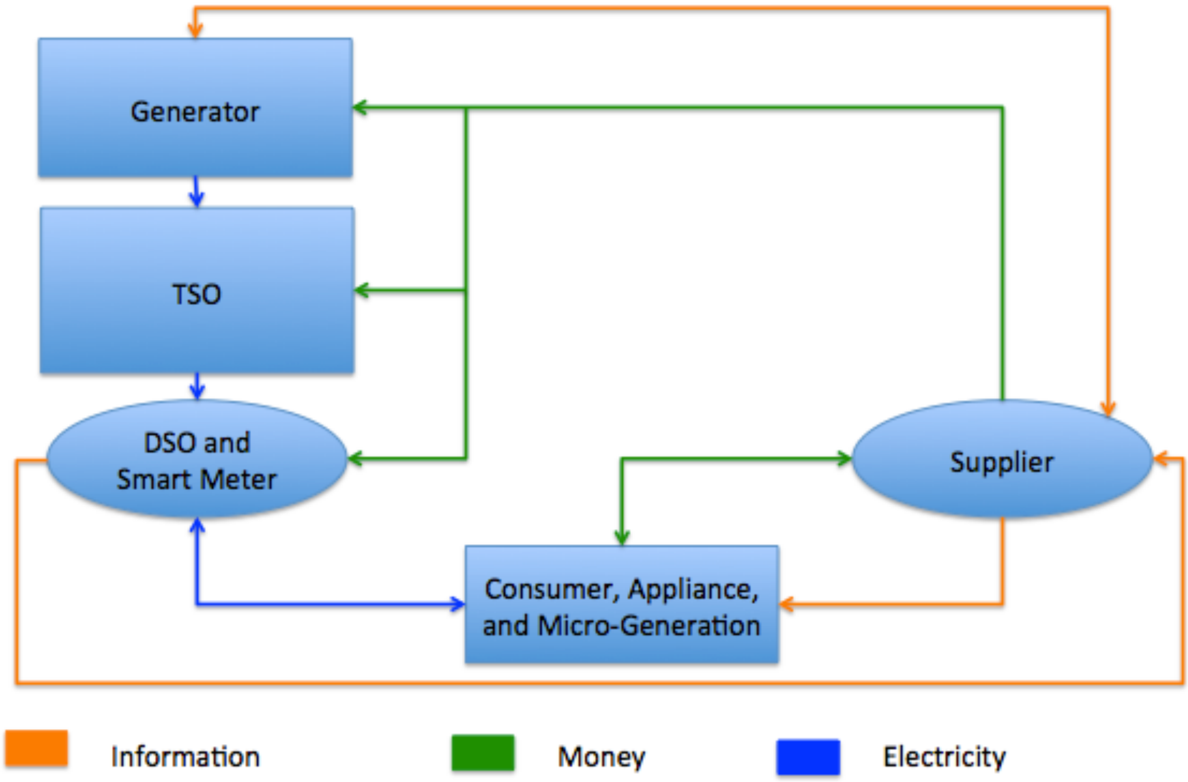

Figure 12:The changing structure of the grid DSO and supplier separation completed by October 2014

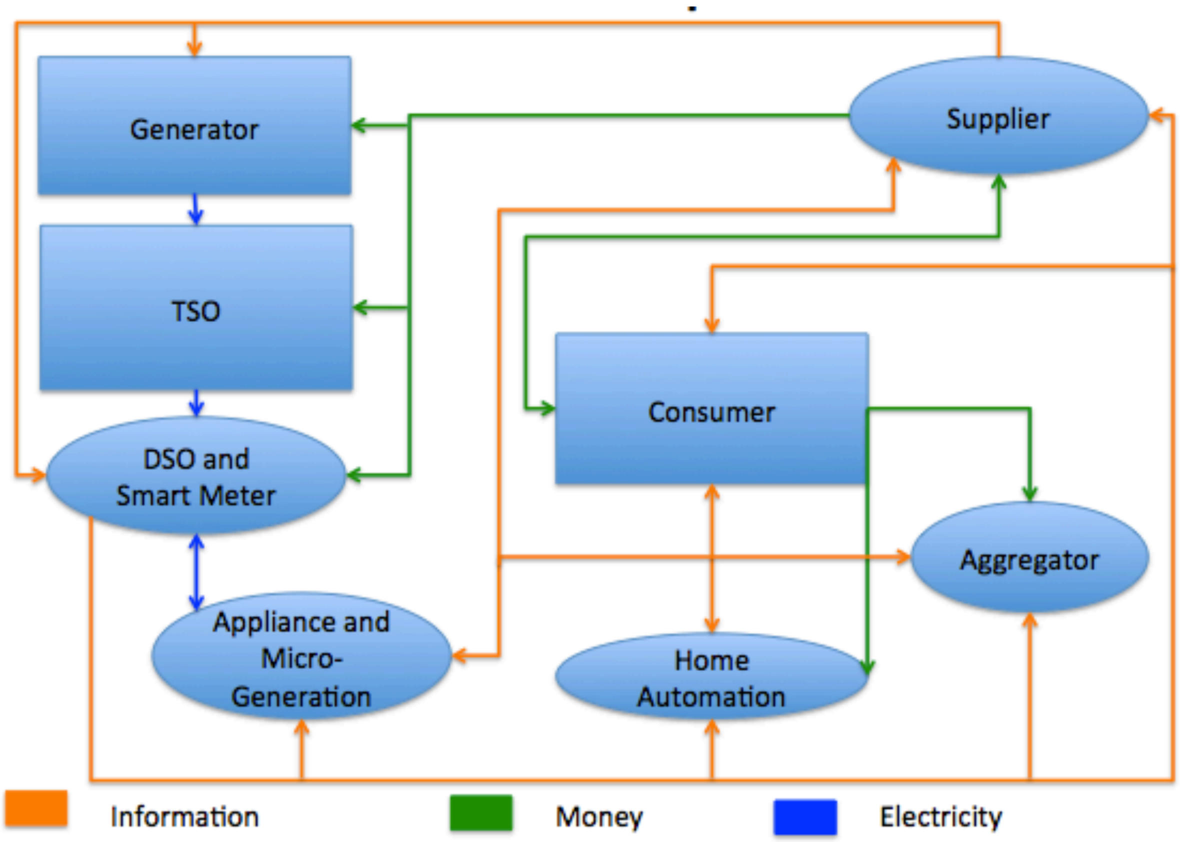

Figure 13: A possible structure of the key players in the smart grid and the interactions between them

Other possibilities and figures containing the old and current structure can be found in Appendix C. Of all the potential solutions, that portrayed in Figure 13 includes the most players. The solution above has the home automation system, aggregator, and supplier as separate entities. The other solutions have different combinations of this set. These figures depict the complexities smart grid is going to bring into the electric system, especially as compared to the current system.

7 Conclusions

This project determined that consumer advocacy groups should play a large role in the development and standardization processes of the smart grid. All of the individuals we spoke with suggested that the DCC should represent Danish consumers as this technology evolves. Common themes were brought our attention as to where this involvement would have the most impact. We conclude that five key issues are inhibiting further innovation of the smart grid: the excessive tax on electricity; absence of smart grid compatible heat pumps; non-uniform communication standards; insufficient data privacy and security standards; and the absence of consumer knowledge.

The first of the two primary obstructions to the deployment of smart grid is the high electric tax. Since 75% of the cost of electricity is from tax, and because it is a flat rate reduction would only affect a quarter of a consumer's bill. This fraction is not adequate for consumers to receive noticeable economic benefits from smart grid technology. The representatives we interviewed said that the market for smart grid products will not exist unless the taxation structure changes. Therefore, it is imperative that this taxation method is restructured in order for consumers to fully benefit from the smart grid.

The second of the primary obstructions is the lack of smart grid compatible heat pumps. Because 80% of Danes' energy use is from heating, improving heat pumps could largely reduce overall consumption. Our interview subjects indicated that heat pumps should have remote control capability and be installed with increased capacity. This will promote the development of the smart grid and enable houses to be "smart grid ready." Moreover, we found that there is little to no investment in smart appliances, and current appliances may not interact well with smart grid technology. As these technologies evolve, consumers should be able to easily identify which devices are compatible with the smart grid.

We found that communications standards will be very important in order for smart grid to work; however, there is currently a lack of common standards in the industry. Results from our interviews indicated that these standards will most likely evolve naturally through the market. Furthermore, many of our respondents believed that strict intervention in this process will inhibit innovation. Therefore, we conclude that communication standards need to be developed to ensure the system functions and devices are able to work together; however, the specific protocols should not be regulated at this point in time.

The results showed that data security standards need to be implemented uniformly throughout the European Union. This is due to the European Union Mandate 490 as well as the developing European electric network. On the Danish level, we discovered that the consumer information stored in DataHub is encrypted, but privacy remains an issue. Although suppliers are not permitted to view specific consumer information without their express consent, they are able to access it. Although strict penalties are in place for violating this contract, we feel that there is still cause for concern.

During our discussions, multiple representatives expressed frustration over the lack of consumer knowledge of the smart grid. The smart grid cannot be widely implemented without consumer education due to the rapidly evolving and dynamic nature of the network, furthermore consumers should learn the various functions of the smart grid so they can take full advantage of its capabilities.

These conclusions show that the DCC should play an active role in the smart grid standardization and implementation processes. Furthermore, the areas which the DCC should focus upon are: evaluating the electricity taxe; recommending changes within heat pump standards; examining the privacy regulations within DataHub; and educating consumers on this technology.

Table 3 summarizes our findings. The table outlines necessary events that need to occur in order for consumers to take advantage of the smart grid. It also contains a relative time scale as to when these changes are likely to occur.

Table 3: Summary of findings

	Present	Conclusion of Smart Grid Projects	Fully Implemented Smart Grid
Denmark	**- Develop a variable taxation scheme with Parliament** **- Increase capacity increased to 130% of current standards as well and require the addition of a buffer tank** - Work with Energunet.dk to develop "privacy-by-design" system for DataHub - Educate consumers about different electricity suppliers - Test current appliances to see how they interact with smart grid technology	- Develop a method to compare different home automation systems - Perform a short term study examining the participants opinions of smart grid	- Create a system to compare aggregation services - Educate consumers on how to take advantage of variable pricing schemes
European Union	**- Update heat pump standards to include the ability to be controlled remotely** - Develop a "Smart Grid Compatible" labeling system for appliances - Monitor types of communication methods between systems - Develop data security standards		
Global		- Recommend the creation of a communication standard for smart appliances	

8 Recommendations

Our research highlighted areas in which the DCC could represent consumers in the emerging smart grid market. We believe the DCC will benefit by pursuing the following recommendations (organized by priority):

- lobby Parliament for the development of a variable taxation system
- push for two changes to heat pump standards:
  - install with capacity increased to 130% of current standards as well as the addition of a buffer tank
  - add components for remote control capability, including a standby mode option
- work with Energinet.DK to increase privacy for Danes in DataHub
- change the appliance market to reduce stress on consumers
  - request tests on effects of smart plugs on current appliances and publish results for consumers
  - advocate for the European Union to create a "Smart Grid Ready" label to assist consumers with their appliance purchases
- provide educational material for consumers on smart grid on:
  - choosing an electric supplier
  - current and emerging aspects of smart grid

Going forward

As the smart grid emerges, we suggest the DCC evaluate the impact smart grid systems have on consumers' lives before it is widely implemented. To accomplish this, the DCC can monitor smart grid pilot projects for consumer feedback, and possibly distribute their own surveys to participants. Furthermore, we suggest that one or more short term studies be performed as the smart grid is being installed looks into consumer perceptions and knowledge of the technology.

Appendix A

Generic Email

To whom it may concern;

We are university students from the United States working in Denmark in conjunction with Forbrugerrådet (Danish Consumer Council) on a project examining smart grid standards in Denmark. The broad idea of our project is to examine current industry standards for smart grid technology and where standards could be created to help convert Denmark's grid to a smart grid.

Your name and contact information came up during our research, and we are hoping to discuss this project with you.

Would you be willing to schedule a time to talk with us in the next few weeks, either in person or by phone/skype to answer a few questions related to this topic?

Regards,
Andrew Childs
Hannah McCallum
Zachary Gendreau
Worcester Polytechnic Institute
Forbrugerrådet
smartd13@wpi.edu

List of Contacts

Table 4: List of contact with contact and interview date

Company	Date emailed	Contact Name	Interview Scheduled
Dream House	22-Mar-13	Søren Neilsen	3-Apr-13
Landis+Gyr	21-Mar-13	Bo Hansen	4-Apr-13
GreenWave Reality	19-Mar-13	Oliver Dufour	4-Apr-13
Danish Consumer Council		Helen Amundsen	5-Apr-13
Danish Consumer Council	21-Mar-13	Annette Høyrup & Andreas Melchior	9-Apr-13
iPower	5-Apr-13	Henrik Bindner	10-Apr-13
Danish Standards Foundation	22-Mar-13	Regnar Schultz	11-Apr-13
Siemens	25-Mar-13	Martin Sjoeberg	12-Apr-13
Ecogrid EU	25-Mar-13	Mark Moseholt	16-Apr-13
ANEC	12-Apr-13	Katrin Behnke	19-Apr-13
Energinet.DK	20-Mar-13	Louise Rønne Christensen	22-Apr-13
Electrolux	8-Apr-13	Representive	23-Apr-13
EcoGrid EU	23-Mar-13	Maj Dang Trong	Email Response to Questions

Appendix B

Interview Schedules

8.1.1.1.1 Søren Peter Nielsen

With whom: Søren Peter Nielsen
When: April 3rd, 9:00am
How: In person
Interview Questions:

1. How did you become interested in the smart grid?
2. How have you worked with smart technology?
   a. What do you find to be one of the most important aspects of smart grid technology?
3. Two different solutions to creating home automation systems involve very different methods of implementation. One uses a central network "hub" which collects and sends out information to all the users, the other is to have each home have be a hub, which then sends out information to authorized users only. Which system would you prefer and why?
   a. What do you see as the benefits/problems with either solution?
4. What sort of industry/policy standards do you believe should be required for the deployment of smart grid?
5. Do you see Denmark's goal of having a fully integrated smart grid by the year 2025 to be reasonable? Why?
6. Do you have any questions for us?

8.1.1.1.2 GreenWave Reality

With whom: Oliver Dufour
When: April 4th, 9:00am
How: in person
Interview Questions:

1. How long have you worked with energy distribution? At Green Wave Reality?
2. How did you become interested in Smart Grid?
3. Why did Green Wave Reality join the EcoGrid EU project?
4. According to our research, Green Wave Reality is one of the primary companies supplying intelligent control systems for both the domestic and business participants in the Bornholm pilot project. What motivated the company to join this demonstration?
5. As a test market, what has been one of the primary challenges for the corporation in integrating the intelligent systems?
6. What is the premise behind the communications network?
   a. Is it centralized? (ie. One control center vs. in-home)
   b. Is it compatible with all smart meters or does it require one specific model?
7. What sort of technology is included in the intelligent control systems on Bornholm?
   a. Green Wave Reality is not the only company that is involved in the smart grid project. What makes your solution different from others on the market?
   b. Is it compatible with other smart grid systems?
   c. How much does making a building/home/business smart cost?

8. Have your smart plugs been tested with appliances on the market today?
    a. What sort of security exists to protect the network?
    b. To what extent can you or a utility remotely control appliances/devices in the home of a consumer (in order to control peak load)?
    c. Do consumers have any say in the amount of control that you/utilities have over them?
9. Where does Green Wave Reality see smart grid developing?
    a. Is the schedule to have a fully automated grid in Denmark by the year 2025 reasonable?
    b. Do you think that the development of smart grid would benefit from the involvement of an organization like the Danish Consumer Council?
10. Do you have any questions for us?

8.1.1.1.3 Landis+Gyr

With whom: Bo Anker Hansen

When: April 4th, 14:30

How: By Phone

Interview Questions:

1. How long have you worked with energy distribution? At Landis + Gyr?
    a. What do you really like about your job?
2. How did you become interested in Smart Grid?
3. Why did Landis + Gyr join the EcoGrid EU project?
4. According to our research, Landis + Gyr is involved in the Bornholm pilot project sponsored by EcoGrid EU. What motivated the company to join this demonstration?
    a. What role does this company play for the EcoGrid EU Project? (Identify a key player organization in the Denmark project, and try to discover their motivation for participating in the study.)
5. What sort of intelligent control systems does Landis + Gyr make?
    a. How much does making a building/home/business smart cost? (Determine what Landis + Gyr direct products are and their current cost)
6. How does the Landis + Gyr solution work?
    a. Is it a centralized distribution network?
        i. Why was this type of network chosen?
        ii. How do appliances interact with the grid?
        iii. Utilities?
    b. Can utilities and consumers remotely control appliances? (privacy)
    c. Landis + Gyr is not the only company that is involved in the smart grid project. Is your program compatible with different components from other programs? (I.e., smart appliances, software, ect.) (Interoperability)
7. What sort of industry standards related to smart meters and smart grid technology were used in creating the Landis + Gyr products?
    a. Are there any standards specific to the company?
    b. Is there a standard frequency required for smart meters to receive information from the smart appliances?
8. How does the Landis + Gyr solution enable utilities to actively shed load when necessary?

    a. Do consumers choose which appliances have priority within their houses when the load shedding occurs?
9. Where does Landis+Gyr see smart grid developing?
    a. Is the schedule to have a fully automated grid in Denmark by the year 2025 reasonable?
10. Do you have any questions for me?

8.1.1.1.4 iPower

With whom: Henrik Bindner
When: April 10th, 10:00am
How: By phone
Interview Questions:

1. What is your experience with smart grid?
2. What was your role in the iPower project?
3. How does the iPower project plan to shift energy generation from consumption to production?
4. What sort of standards do you foresee being necessary to develop the intelligent control system (smart grid) of the decentralized power consumption/production?
    a. How do you expect consumers to respond to this system?
5. If the Danish Consumer Council were to become involved in smart grid standardization, where do you feel they would be most effective? Least effective? Should they even be involved at all?

8.1.1.1.5 Dansk Standards

With whom: Regnar Schultz
When: April 11th, 10:00am
How: In person
Interview Questions:

1. How did you become interested in the smart grid?
2. How have you worked with smart technology?
    a. What do you find to be one of the most important aspects of smart grid technology?
3. Two different solutions to creating home automation systems involve very different methods of implementation. One uses a central network "hub" which collects and sends out information to all the users, the other is to have each home have be a hub, which then sends out information to authorized users only. Which system would you prefer and why?
    a. What do you see as the benefits/problems with either solution?
4. What sort of industry/policy standards do you believe should be required for the deployment of smart grid?
5. Do you see Denmark's goal of having a fully integrated smart grid by the year 2025 to be reasonable? Why?
6. Do you have any questions for us?

8.1.1.1.6 Siemens

With whom: Martin Bo Sjoeberg
When: April 12th, 14.00 (2:00pm)
How: In person

Interview Questions:

1. How long have you worked with energy distribution? At Siemens?
   a. What do you really like about your job?
2. How did you become interested in Smart Grid?
3. Why did Siemens join the EcoGrid EU project?
   (1-3: Introductory questions to get to know Mr. Grande's position
4. According to our research, Siemens is one of the primary companies supplying intelligent control systems for both the domestic and business participants in the Bornholm pilot project. What motivated the company to join this demonstration?
   (Identify a key player organization in the Denmark project, and try to discover their motivation for participating in the study.)
5. What benefits does Siemens receive by participating in this study?
   a. As a test market, what do you foresee to be one of the primary challenges for the corporation in integrating the intelligent systems?
      (Determine the motivation for Siemens' participation.)
6. What sort of technology is included in the intelligent control systems?
   a. Siemens is not the only company that is involved in the smart grid project. Is your program compatible with (interoperability) different components from other programs? (I.e., smart appliances, software, ect.)
   b. How much does making a building/home/business "smart" cost?
      (Determine what Siemens direct products are, and if they're compatible with consumers)
7. Does Siemens provide smart appliances to consumers?
   a. How do smart appliances help with the automation process?
   b. (If no) Where could a consumer find a smart appliance?
      i. About how much do these products cost? For example, smart fridge, dryer/washer, dishwasher, oven ect.
   c. Hypothetically speaking, a consumer wants to make their home "smart" but doesn't have the money to purchase all new appliances. What would you recommend that they do?
      i. **Are there smart outlets or plugs that a consumer could purchase to make their house smart while smart appliances are being phased into the market?
      (Determine what sorts of products are currently available to a consumer and their cost.)
8. Where does Siemens see smart grid developing?
   a. Is the schedule to have a fully automated grid in Denmark by the year 2025 reasonable?
9. Are there any questions that you believe I should have asked, but didn't?
   (Determine what Siemens forecasts for SGT.)
   Do you have any questions for me?

8.1.1.1.7 Ecogrid EU

With whom: Mark Moseholt and Maj Dong Trong
When: April 16th, 13.00 (1:00pm)

How: In person and email
Interview Questions:

1. How is consumer privacy being handled for the Bornholm project?
2. What sorts of standards are being used to protect consumer's data from unrelated third parties?
3. Has any consideration gone into securing the grid against potential attacks?
4. Is there any worry about this sort of attack?
5. Can the Siemens products interact with the GreenWave reality products?
6. How much research/effort/I can't think of a better word is being put into creating interoperable systems?
    a. Appliances?
7. Is there one standard for the communications network or do the different systems handle data differently?
8. If this project were to be expanded, what sort of communications standards would need to be developed?
9. Have there been test done on how current appliances would react to a smart grid?
10. Would it be feasible to have all your appliance interact with the smart grid?
    a. If, not what should/should not be connected?
11. Based off of the experience in the Bornholm project, is the Danish government's goal for having a fully developed smart grid by the year 2020/2025 reasonable?
12. Should organizations like the DCC get into the SG standardization process?
13. How could they best fit into this process?
    a. Already involved in some education

8.1.1.1.8 Energinet.dk

Who: Louise Rønne Chirstensen
When: April 22nd, 15.00 (3:00pm)
How: By phone
Interview Questions:

1. Why is Energinet.dk looking into smart grid?
2. What sort of consumer data is collected and how detailed is the information? Daily, Hourly, more? less?
    a. What is the purpose?
    b. What sort of anonymity exists?
    c. Can consumers opt out of data collection in any way?
3. Who can access this data?
    a. Through what process?
    b. For what purpose?
4. Are there any concerns with security?

8.1.1.1.9 Electrolux

Who: Represented
When: April 23rd, 15.00 (3:00pm)
How: By phone
Interview Questions:

1. Has your company looked at smart grid technology?
    a. If so what aspect are you working on?

2. Have you looked at if current products can withstand the smart grid tech?
3. Do you have any plans to/are you develop/developing smart technology.
    a. Technology that will let appliances interact with the smart grid either through the plug or communicate with the smart meter directly.
4. Would these products cost much more than current product?
5. Would it be benefits to have a standard for communication between appliance and smart meters or technology?
6. Are there any other standards that would help develop product?
7. Are there any other concerns you have about smart grids?

Appendix C

Thematic Library

Table 5: Thematic Library

Category/Theme	Comment	Interview
Privacy	Should be handled through policy and organizations (like DCC).	Nielsen
	People gain from data sharing and analysis because it shows trends, inefficiencies, etc	
	Energinet.DK is collecting usage data at a hub	
	Consumers give informed consent before data is collected	
	Average Dane is not really concerned with privacy, they trust the government and businesses	
	EU-wide problem. Standards need to be for all countries because they lack resources	
	Consumers should give informed consent	Høyup
	Consumers should be anonymous, ID numbers are a potential solution	
	Loss of control is not a major concern (trust in govt. and business)	
	Siemens solution only sends out that there is flexibility, not who/where- -> no automation data is sent to a centralized server	Sjoeberg
	Standardize who can access data, and what data they have access to	Schultz
	Suppliers sign contract stating they will only look at information of their costumers	Rønne Christensen
Security	Standards must be uniform throughout EU (interconnectivity of systems)	Nielsen
	most people have a smart meter, but they have still have the default password	
	Should be market drive	
	Needs government mandates to ensure adequate levels of security -- need audits to ensure compliance	
	GreenWave solution uses 128 bit encryption (industry standard)	Dufour
	Smart meter on Bornholm also uses 128 bit encryption	Hansen
	Siemens uses KNX standards for communication, which has 128 bit encryption	Sjoeberg
	Should be equivalent/similar to online banking	Schultz
	Smart meters should be encrypted, but someone will need to pay for added security	Nielsen

Interoperability	Open source tool kits	Neilsen
	IT Standards should be market driven---Need to determine problems first	
	Z-Wave, ZigBee, JenNet Communication Protocols	Dufour
	Landis+Gyr meter comes with 3g capability and can be connected to via laptop/internet	Hansen
	Consumers should not have to make compatibility-based decisions	Amundsen
	The systems on Bornholm are not interoperable due to the function of an aggregator	Sjoeberg
	Could be made interoperable, but should not be mandated yet	
	Interoperability standards should be left alone for the moment to promote more R&D	
	Standard EV charging plug	Schultz
	Communications signal leaving appliances should be standardized	
	Electrically heated houses which are registered to have electrical heating, but actually use their wood stove oven most of the time are not ideal for participation.	Trong
	A house with an air/air-heat pump is not compatible with the EcoGrid-equipment.	
	The heat pump in the house is of a brand and/or type that is not compatible with the EcoGrid equipment	
	The participant does not have an Internet connection, which is necessary as the equipment needs an internet connection at all times. Internet is also needed for the variable prices, which are fed into the system in the house.	
	The participant does have an Internet connection, but only through a mobile device (wireless broadband). The Internet connection has to be through e.g. a cable for the equipment to be connected to it.	
	A communications standard should exist, but it may develop naturally. The DCC could push for its creation, though	Electrolux
	Communication standards should be developed at EU level	Schultz
	Options for interfaces should exist, no set standard	

Future Development	Need market de-regulation to promote future growth	Nieslen
	Transition to smart appliances will happen naturally	
	Need to have smarter appliances to work with the smart grid	Dufour, Sjoeberg
	There needs to be more storage capability on the grid	
	There needs to be incentives for the consumers to convert to smart grid, i.e. market liberalization	
	Technology is ready for smart grid, but the regulations/market is not ready-->Need more government support	Sjoeberg
	DataHub is working on a "privacy by design" plan.	Rønne Christensen
	Electrolux is developing "smart appliance"	Electrolux
	Market does not exist yet, so products are expensive and considered premium product	
Standards (General)	A lot of people involved in making standards, but the EU vs US will probably have different standards	Neilsen
	Denmark is too small to create its own standards	
	Siemens is using IEC standards	Sjoeberg
	Smart meters must have data port (no specific standard, just needs to exist)	Schultz
	A communication standards should exist, but it may develop naturally	Electrolux
	Ensure lower prices	Neilsen
	Help solve problems that arise during initial deployment/research	
	Restrict innovation	
Bornholm/EcoGrid Project	Landis+Gyr supplies the smart meter for the project	Hansen
	One of the goals of the project is to help create standards	
	Has a 21 million euro budget	Dufour
	IBM is supplying the algorithm for flexible pricing	
	Project breakup: 2000 homes, 1200 to Siemens solution, 700 to IBM/GreenWave, 100 control	
	Only control the utilities have is over heating	
	500 homes to Siemens, 100 businesses	Sjoeberg

<table>
<tr><td rowspan="9">DCC involvement</td><td>Deregulating energy market (Variable tax rate)</td><td>Everyone</td></tr>
<tr><td>Examine heat pumps - Network capabilities</td><td>Dufour, Schultz, Sjoeberg</td></tr>
<tr><td>In about 6 months to 1 yr. from now, re-examine standards--> one of goals of EcoGrid Project</td><td rowspan="3">Sjoeberg</td></tr>
<tr><td>Look at Aggregator Systems</td></tr>
<tr><td>Consumer education needs to occur for smart grid to succeed, but it needs to happen at the correct point of smart grid development</td></tr>
<tr><td>Make sure consumer are not forgot, look at standards address consumer not just tech aspects</td><td rowspan="3">Bindner</td></tr>
<tr><td>Consumer interface will need to be made so that they can specify types of controls</td></tr>
<tr><td>Makes more sense to have large power users (eclectic car/Heating)</td></tr>
<tr><td>Could push government for standards</td><td>Electrolux</td></tr>
</table>

Grid Structures

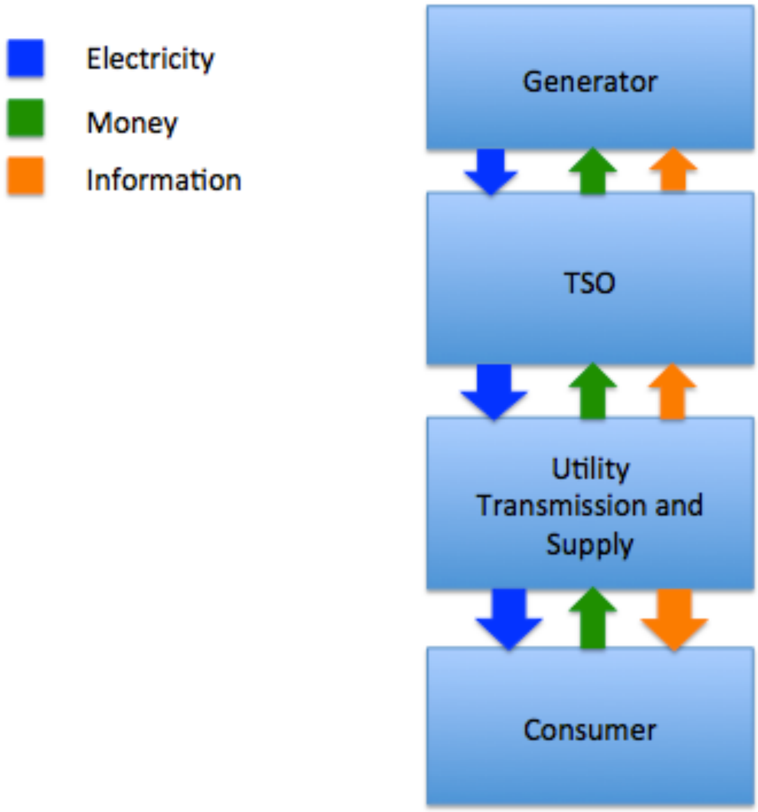

Figure 14:Old/current grid structure

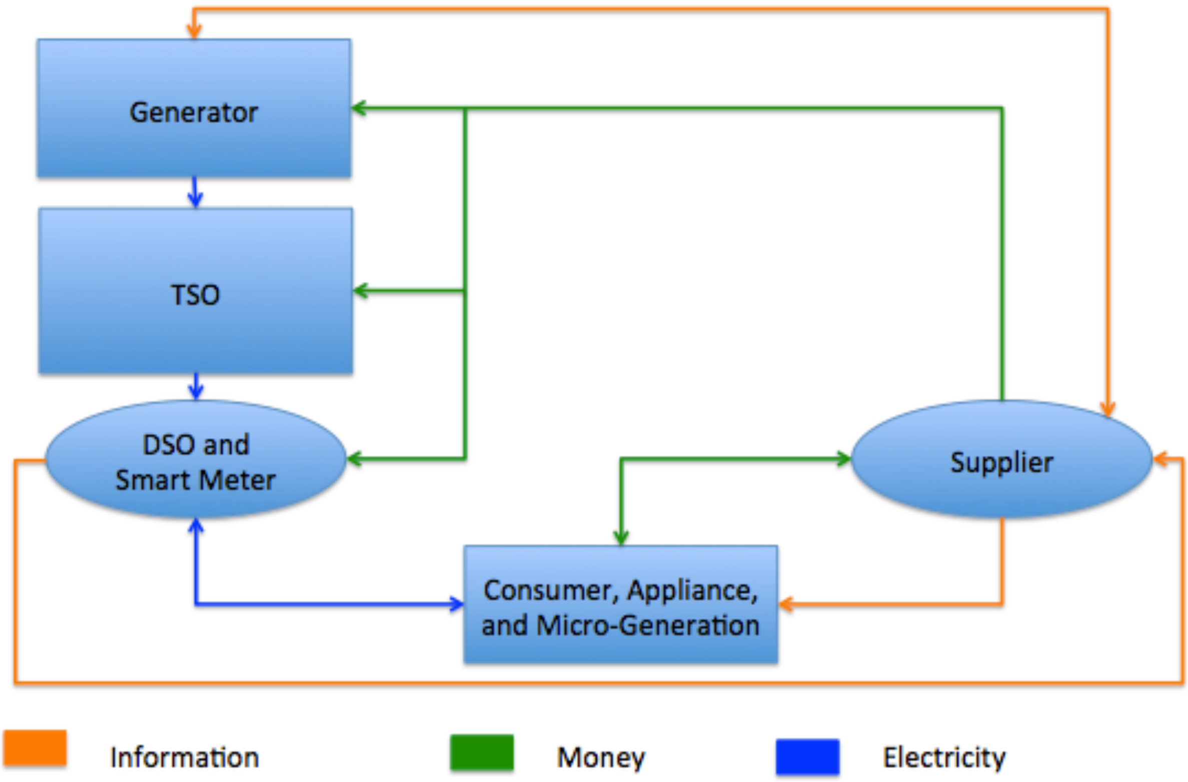

Figure 15:Changing grid structure completed in Denmark October 2014

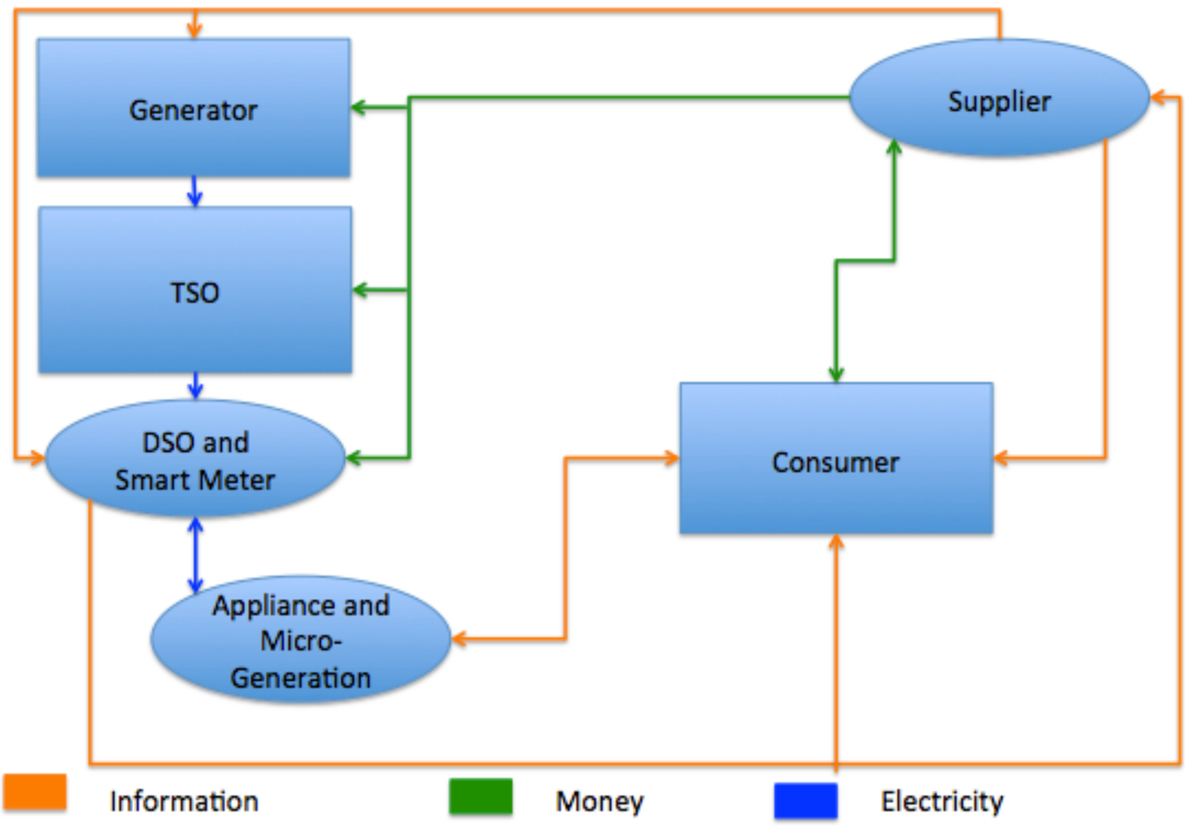

Figure 16: Manual smart grid

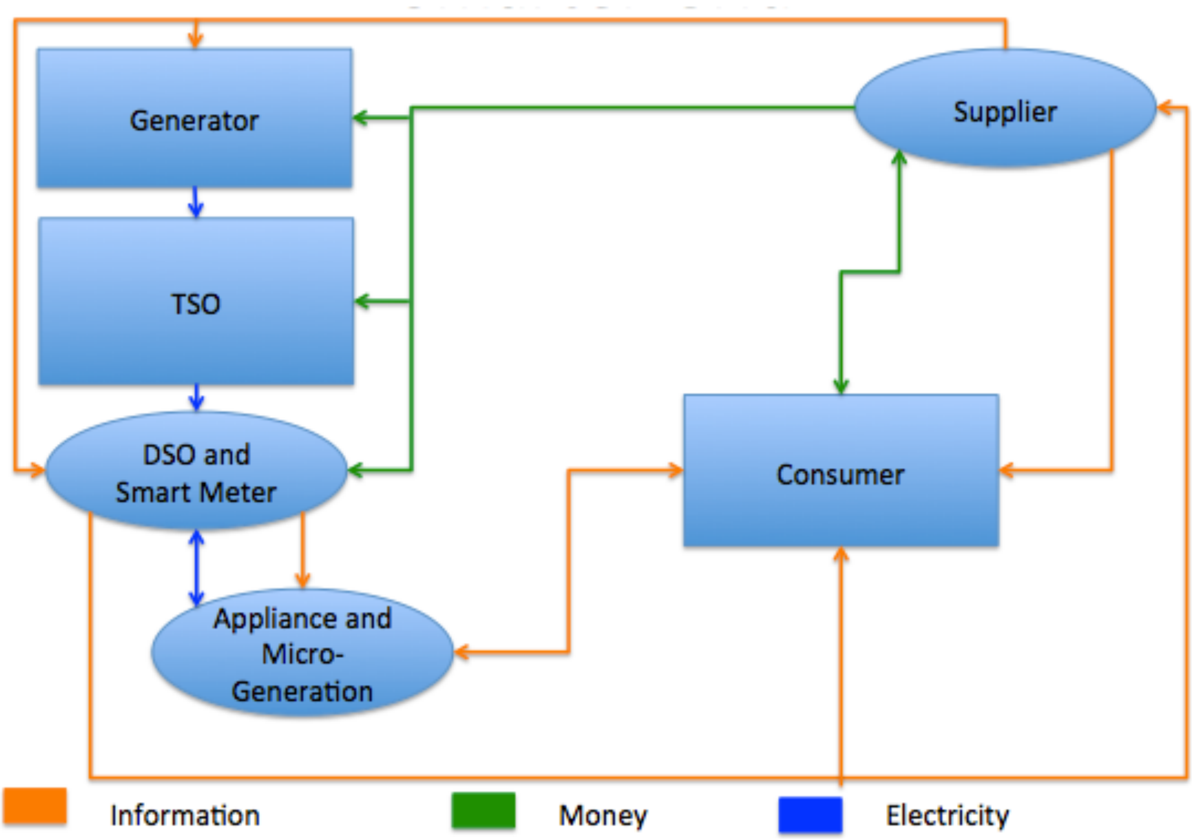

Figure 17: Basic smart grid

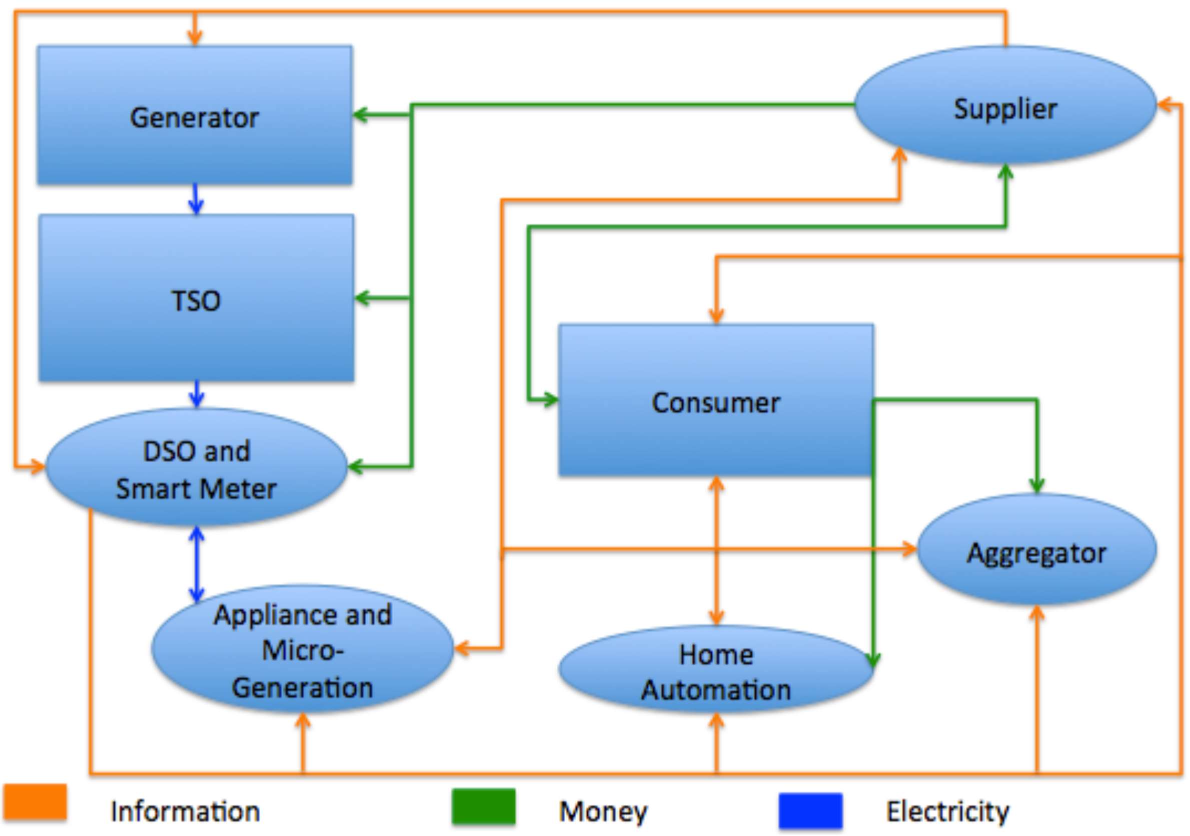

Figure 18: Smart grid all players separate

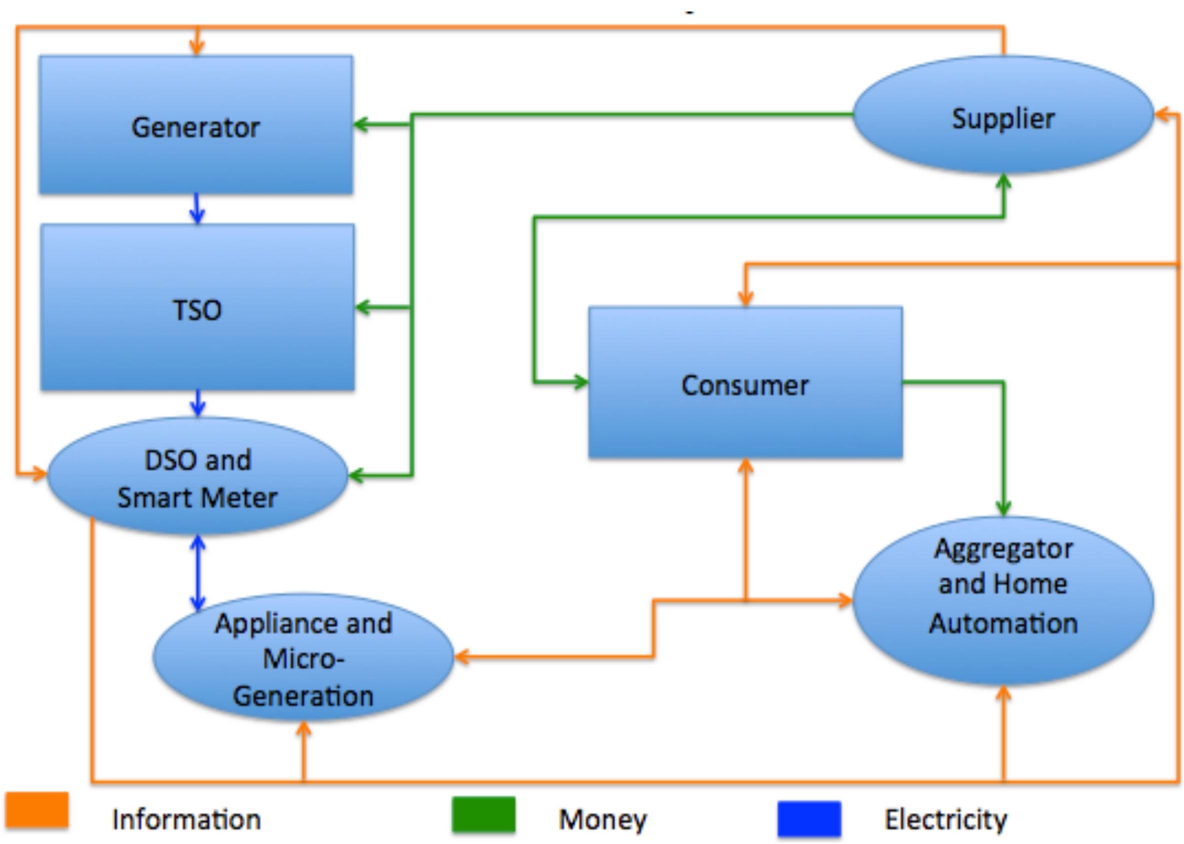

Figure 19: Smart grid home automation and aggregator together

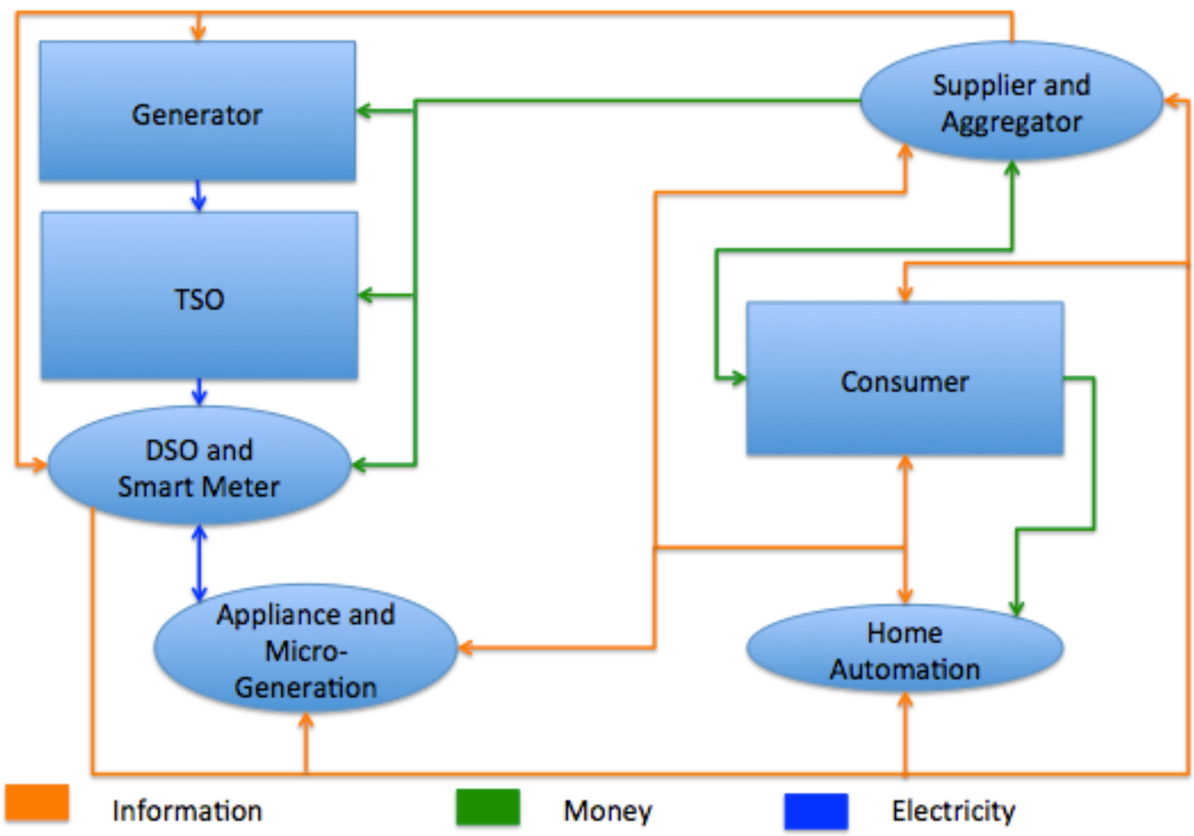

Figure 20: Smart grid supplier and aggregator together

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