SMART GRID INNOVATION PROCESSES AND THE SOCIAL CONSTRUCTION OF TECHNOLOGY IN JAPAN AND THE USA

A Thesis

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BROR MARTIN KARLSSON 126841

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Advisor: Project Associate Professor Yarime Masaru

Co-Advisor: Professor Masafumi Nagao

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ABSTRACT

This study examines the process of smart grid innovation in Japan and the USA. The current status of innovation efforts is investigated in terms of drivers and obstacles of innovation and stakeholder composition and involvement. The commonly held meaning of smart grid within the community that is engaged in smart grid innovation is also investigated to shed light on how social context shapes the way smart grid is interpreted.

Smart grid is an ambiguous concept with many meanings, and scholars have previously observed that there are regional variations in how smart grid is conceptualized. The potential benefits of smart grid range include less environmental impact, higher security of electricity supply, lower cost of energy and higher empowerment of consumers in the electricity system. Regardless of this ambiguity, most analysts think that smart grid will be the future for the electricity grid, and that smart grid is an important tool to achieve sustainability in the energy system. Investigating the different nuances in technology labelled as smart grid is thus an important venture from a sustainability science viewpoint, as a deeper understanding of the shaping of the technology can lead to more sophisticated promotion methods. Especially, the role of end users of electricity in the innovation processes should be investigated as smart grid has the promise of becoming a transformative technology that remakes the way in which the electricity system is governed by empowering the end users. Interviews with key stakeholders in both countries inform the bulk of the

analysis, with support from social network analysis of smart grid projects and semantic analysis of discourses around smart grid in both countries.

The study found differences and similarities in the innovation process in Japan and the USA. In both countries government support is an important driver of activity, and in both countries the existing market structures are seen to be slowing the innovation process. The more fine differences between the two countries are shaped by the way the electricity market is structured, the characteristics of the most involved private stakeholders, and the way smart grid is promoted by the governments. In both countries, there are high hopes for end user participation in the use of smart grid technology, but end users have minimal involvement in the innovation of smart grid technology. End users are largely disinterested, and there seems to be few ways for the end users to interact with the innovation systems other than by demanding products that integrate with smart grid technology or protesting against specific deployments by utility companies.

There is a difference of emphasis in the meaning of the smart grid concept between the two countries. In USA there is a focus on the transmission and distribution related functionalities, as well as a very high importance given to AMI, while in Japan there is a broader focus, and ties in more with smart home innovation and other end user interfacing technology. It seems that this difference is largely explainable due to the market and regulatory structures in both countries, rather than attention to the perspective of end users.

The findings imply that government funding and promotion of smart grid innovation is important as smart grid innovation is still in the early stages and the most important stakeholders in the electricity system, the utility companies, have little incentives to engage with the more integrative and transformative versions of smart grid. The nuances identified in the meaning of smart grid illustrates that the context in which the smart grid innovation process develops will have an influence on the type of functionalities deployed under the label of smart grid. The findings also imply that end user participation should be actively promoted in smart grid innovation efforts, as end users have little possibilities to interact with the process in the current situation, and because they seem to be disinterested in participating in the innovation process. Nonetheless participation could lead to a better chance for the more transformative versions of smart grid to become reality, which could enable a more sustainable governance of the electricity system. Such participation can be promoted by many stakeholders, but the government has a strong role to play, especially through designing electricity market regulation and through designing the mode of government promotion of smart grid innovation.

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3. LIST OF TERMINOLOGY AND ABBREVIATIONS

ARRA	American Recovery and Reinvestment Act of 2009
DOE	Department of Energy (USA)
DHS	Department of Homeland Security (USA)
EPRI	Electric Power Research Institute (USA)
EV	Electric Vehicle
FERC	Federal Energy Regulatory Commission (USA)
ICS-CERT	Industrial Control System Cyber Emergency Response (USA)
ICT	Information and Communications Technology
IOU	Investor Owned Utility (USA)
ISO	Independent System Operator
JSCA	Japan Smart Community Alliance (Japan)
METI	Ministry of Economy, Trade and Industry (Japan)
NEDO	New Energy and Industrial Technology Development Organization (Japan)
NIST	National Institute of Standards and Technology
PUC	Public Utilities Commission (USA)
PV	Photo-Voltaic (energy)
REP	Retail Electricity Provider
SCOT	Social Construction of Technology (theory)
SGCC	Smart Grid Consumer Collaborative (USA)
TIS	Technological Innovation System
TSO	Transmission System Operator

4. INTRODUCTION

RESEARCH QUESTIONS AND SCOPE

This thesis investigates and compares the process of smart grid innovation in Japan and the USA. The investigation is guided by the questions:

- What are the main drivers and obstacles of smart grid innovation in Japan and the USA?
- What is the role of end-users of electricity in these processes?
- Is there a difference in emphasis within smart grid technology in Japan and the USA?

i. The Not-So-Smart Grid

Modern industrial economies produce enormous amounts of goods and services for the enjoyment of citizens in most inhabited areas of the world. Most of this production is made possible by utilizing energy originating from another source than human or animal labour. Today we extract most of that energy from fossil fuels. Some energy is extracted from renewable sources such as the heat of the sun or the insides of the earth, the movement of water along the earth's surface such as in hydropower plants and wave power plants, or non-fossil biological fuels, and some energy is extracted from controlled nuclear fission processes.

Energy is normally distributed from the source of extraction. Most of the energy embedded in crude oil refined into petroleum products is used outside of the refinery, for example in cars and airplanes. Similarly, the energy produced at a hydropower plant is mostly used far away from that plant. Today, energy is mostly transported in two different shapes; as fuels and as electric current. There have been many other energy distribution systems, and many are in use still today. Compressed air and flows of water have both been used to transport energy in different settings. However, the electricity distribution system has evolved from modest beginnings as a system for providing street lighting into becoming a vast system of millions of components, which plays in most of the activities of the modern citizen. The modern electricity grids can truly be called the largest machines on the earth.

The electricity system is of vast importance for modern societies. But it is not a perfect system, and a lot of energy is put into research, economic and political action for improving it. One can identify three main discourses concerning the electricity system in industrialized societies. The first, often dominating one is that of security. The second is that of cost reduction and marketization. The third and newest one is that of environmental impact.

The electricity system is now understood as a “critical infrastructure”[1], an infrastructural component of our societies that must function in order for society to continue to function. Ever since the First World War, when the importance of stable electricity supply for armaments production made states take a deep interest in electricity generation and transmission, security of electricity supply has been seen as a core national security value[2]. The complete industrialization of the developed economies through the 20th century made virtually every aspect of economic life dependent on a stable electricity supply, and the ICT revolution of the late 20th century exasperated this development. In the words of Ole Wæver and Barry Buzan, the electricity grid has become securitized[3]. Events that could potentially disrupt electricity supply, such as electrical outages caused by mistakes, natural disasters or malicious tampering with the electrical grid infrastructure, have come to be seen as grave security threats to nations, communities, economic entities and the well-being of human beings.

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[1] *(Zio & Aven, 2011)*
[2] *(Hughes, 1993)*
[33] *(Buzan, Wæver, & de Wilde, 1998)*

A second important theme of discourses on electricity supply is cost. The electricity system has evolved as one of the main partners of the industrial capitalist system. Electricity is now a crucial factor of production in most industrial products. As internationalization and globalization has increased, the competitive pressure on all factors of production has increased. As a key factor of production, cheap and reliable electricity is often seen as a prerequisite for economic competitiveness. However, the electricity grid is a machine, not a market[4]. It requires coordination between the different components in order to function properly. At all times, supply of electricity must be similar to the consumption of electricity, lest the characteristics of the electricity on the grid, in terms of voltage and frequency, change to values that are harmful to the grid itself, or the appliances that consume electricity. Governments all over the world have therefore sought to enhance the reliability and decrease the price of electricity within their borders, so as to lure investors and protect established production plants, while keeping the electricity market regulated so as to preserve its proper functioning. The ways in which these goals have been pursued has been different in different contexts, much depending on the ruling ideologies, which prescribes different ways of achieving good macro-economic performance. Public control over the electricity system has historically been a favoured method of securing a stable and affordable electricity supply. However, the first power grids were under private control, and market systems have come to be the most common mode of governance of electricity systems, also those under public ownership. As the electricity system is a natural monopoly, government use regulation to protect consumers from the monopoly power of utility companies. Under the influence of neo-liberalism, there has been a broad trend towards liberalization and marketization of the electricity systems during the period 1980 onwards in the developed world, and the electricity systems of industrial countries started to become

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[4] *(Joskow, Deregulation and Regulatory Reform in the U.S. Electric Power Sector, 2000)*

systems governed more by market forces rather than engineers[5]. This process started in the UK, much due to the ideological belief in privatization and liberalization of the Thatcher administration. During the period 1990-2008, when the neo-liberal consensus reigned strong among the advanced economies, most countries pursued liberalization and privatization, to different degrees, inspired by the example of the UK. Marketization of the electricity system is mostly based on the assumption that this will bring prices down through competition. Another argument for deregulation in the electricity sector is that it will bring in incentives for innovation of energy efficient equipment, and possibly electricity generation technology[6]. In the UK, an unbundled market with state-controlled transmission grid, and a regulatory regime that focuses on using competition to protect consumers interests, has given too much focus to price alone, and has been found to cater primarily to large invested interests[7]. In the UK, now it is recognized by scholars[8] and parts of the establishment[9] that free competition is not conducive to sustainable energy transition without a careful alignment of incentives, in spite of a general belief in markets without government intervention as the best way of governing society. More generally it has been argued that the pace of innovation in market based regimes might be too slow and the type of innovation might be less than optimal for the societal good[10].

The third important theme of electricity supply discourses is the environmental one. The environmental impact of the electricity grid has been recognized since the beginnings of centralized energy supply. When coal was the predominant source of electricity in the early industrializing England and Belgium, the problems of air pollution and its effects on human health and the natural environment was widely discussed. In the

[5] *(Verbong, Beemsterboer, & Sengers, 2013)*
[6] *(Joskow, Deregulation and Regulatory Reform in the U.S. Electric Power Sector, 2000)*
[7] *(Mitchell & Woodman, 2009)*
[8] *(Mitchell & Woodman, 2009)*
[9] *(HM Government, 2009)*
[10] *(Mitchell & Woodman, 2009)*

1990s, climate change became widely recognized as a global environmental problem. Greenhouse gasses, including CO_2, became identified as culprits contributing to the warming of our planet. Because of the scale of the electricity system and the automotive transport system, these two were early on identified as key areas that would need to change in order for climate change to be mitigated.

In contrast to the case of the automotive transport system, virtually all emissions in the electricity system are made far from the end user. This means that the end user does not usually experience any pollution as part of the act of electricity consumption. The supply of electricity is instead identified with pollution. Coal-powered plants and other fossil fuel consuming thermal power plants were the easily identifiable devils in the electricity system so early efforts concentrated on decreasing the impact of electricity generation. Thus, technology areas such as CCS, nuclear power generation and renewable energy generation received most attention, with particular hopes being placed on renewable energy generation because of its few negative externalities. Continued attention to pollution control at the supply end has failed to produce much tangible results. The CO_2 emissions per economic output have even increased globally in the decades since global warming started to be discussed[11]. One of the problems have been that renewable energy sources did not prove to become enough economically viable for them to supplant fossil fuels. Experts noticed that the traditional electricity system was biased in favour of centralized production, whereas the newly developing renewable generation technologies were more fit to distributed production. Moreover, the new energy sources required more adaptability of the level of consumption to the availability of energy, something which the existing system was incapable of achieving.

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[11] *(Peters, et al., 2012)*

While these discourses on how the electricity system could be made better have been going on, the grid in developed countries have had to tackle technical problems that are growing more pressing. One is that of increased complexity and interconnectivity, while the infrastructure is aging and decreasing in performance. Transmission and distribution losses have risen dramatically, according to some authors it has doubled over the last 40 years[12].

In response to the three discourses and the growing problems of the grid, the importance of higher flexibility and automation was recognized. Another challenging aspect of electricity supply is that demand is not evenly spread out over time. Instead, over seasons and times of a day, demand fluctuates heavily. In Northern Europe, electricity demand peaks in wintertime, when heating demand soars. In Japan, electricity demand peaks in summertime, when air-conditioning is high in demand. In most countries, electricity demand is much higher during the day and early evening than it is during the night and morning. For the safe working of the grid, electricity must be transmitted with similar characteristics. This requires that the ratio of supply and demand of electricity stays roughly the same. Because of this, there are necessarily many points during a day, and during a year, in which the total amount of electricity demand is much lower than the potential electricity supply. This leads to a situation of allocative inefficiency, in which the capital invested in additional electricity generation capacity is wasted and could theoretically be used for some other, more economically beneficial purpose. Smart grid or the use of digitalization and ITC has importance promise in achieving higher flexibility within the electricity grid. Therefore, smart grid has become recognized as a central aspect of the clean energy debate[13], of the security of electricity supply discourse, and a key

[12] *(Zio & Aven, 2011)*
[13] *(Berst, Kick in the pants time: IEA says smart grid and clean energy progress too slow, 2013)*

strategy to achieve cost-efficiency. Smart grid is seen as the key to higher flexibility, resilience and efficiency[14]. Under the IEA BLUE Map Scenario, which explores the least – cost means of achieving a 50% CO_2 emissions reduction by 2050 (compared to 2005 values) smart grid technology is expected to contribute a direct reduction of up to 0.9 Gt CO_2 per year and another 0.7-1.3Gt CO_2 in indirect emissions through enabling integration of renewables and greater use of EVs[15].

ii. The Smart Grid

The most commonly cited definition of smart grid is that of the European Technology Platform for the Electricity Networks of the Future. The European Technology Platform defines a smart grid as "an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies." (ETP SmartGrids, 2013). The important key word for most understandings of smart grid is achieving new flexible functionalities using 'integration', which generally means higher communication between different components within the electricity system. There is a wide range of ways to achieve benefits through better communication between different components of the grid, from the simple concept of doing meter readings remotely rather than visiting each household physically, to complex software solutions integrating information from weather stations, meter readings, sensors measuring the performance of the grid infrastructure, and market information to allow grid regulators to do more informed choices. The functionalities achieved through smart grid can be roughly divided into basic and advanced ones. Basic smart grid functionalities allows for higher integration of information at central points. This includes the creation of automatic responses to communication that is distributed over the grid, but it managed by and oriented towards the

[14] *(Zio & Aven, 2011)*
[15] *(International Energy Agency, 2010)*

needs of the central regulators. Advanced smart grid functionalities create distributed intelligence by giving distributed components more information about the electricity grid, giving the actors that control those components more possibilities to participate in the grid.

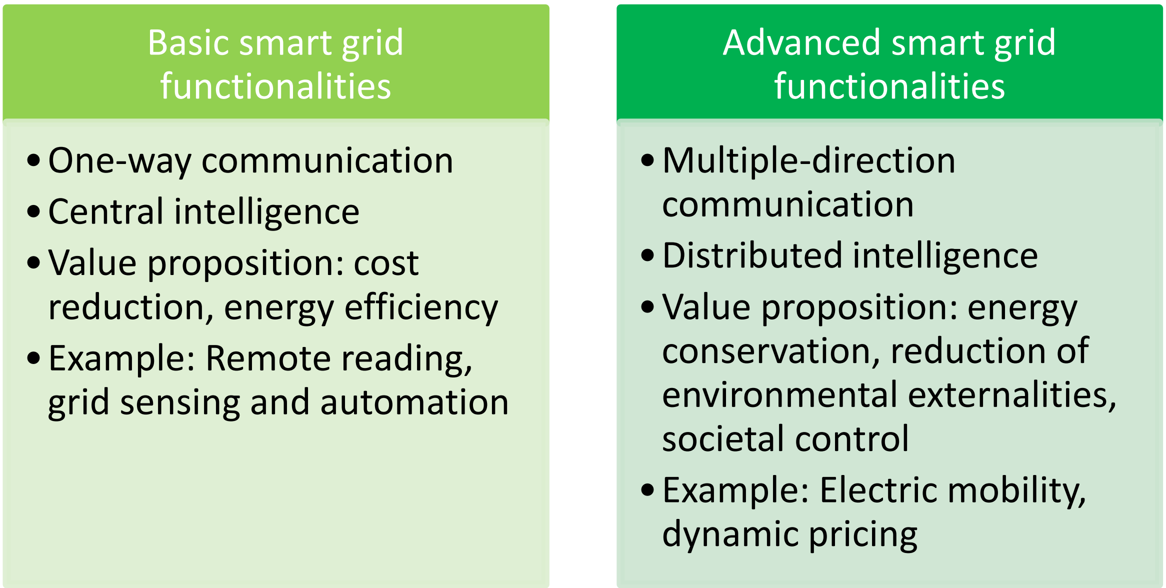

Figure 1 – Schematic division of smart grid functionalities

Smart grid is, like most modern technological artefacts, a bundle of different equipment and practises. Smart grid can be seen as an aggregate word for a host of different equipment and practises that can improve the electricity grid by introducing new functionalities. The smart grid concept is a notoriously vague one, which has been used by a variety of actors and scholars to describe different kind of technological assemblages. As such, it is not surprising that there are differences in the nuance of the concept in different contexts. (Clastres, 2011) identifies two different definitions of smart grid, one European and one American. The European one focuses on creating an infrastructure that can use information collected and distributed among all connected users, to ensure that the various objectives of the electricity grid are achieved in a more intelligent way. The American one has a specific focus on security, with concept such as self-healing and resilience against physical and cyber threats as key features, Clastres argues. The IEA[16], whose work is global in scale, divides smart grid technology into the following functional technology areas, which gives a good understanding about the full breadth of the smart grid concept globally:

[16] *(International Energy Agency, 2010)*

Table 1 Smart Grid Functional Technology Areas

Functional Technology Areas	**Description**
Electricity generation control, automation and power electronics	Communication with, and the intelligent control of, generation sources are part of a smart grid, but not the generation itself. For example, power electronics technologies that allow wind generation to supply reactive power are essential to the smart grid. The wind turbine is not
Advanced computing and grid control software	The data created from embedded sensor and metering technology will require significant computing and system control software to enable the use and management of the grid and to meet stakeholder needs.
Embedded grid sensing, automation, measurement and control technology	This technology provides the information and control capability to optimise grid operation and manage power flows within the constraints of the grid technology. Flexible alternating current transmission systems, phasor measurement units and automated switch gear are examples.
Communication infrastructure	The infrastructure required for two-way communication including wireless, internet and satellite communications may use existing or specialised methods.
Conductor technology and approaches	Advanced conductor technology such as high temperature superconductors (HTSs) can enable electricity systems to respond to operating changes more quickly, benefiting automated control, which will be especially important with the increase in remote variable renewable generation. High voltage direct current configurations can also offer management and control benefits to the grid.
Electrical load control and advanced meters	Advanced metering at residential, commercial and industrial levels can give customers and electricity providers the information they need to be able to respond to operational signals either by choice or automatically. Smart meters can enable demand response initiatives.
Energy storage	Energy storage can be used as a load or as a generation source to help peak load management. Storage could also be used to provide ancillary services such as reactive power for frequency and voltage support.
EV charging infrastructure	The EV charging infrastructure will have an impact on grid operation. It must be capable of being managed intelligently.

From (International Energy Agency, 2010)

Because the functionalities discussed as part of the smart grid are many, there is also a breadth of benefits envisioned for society when smart grid is finalized. Which benefits will be materialized will depend on the mix of functionalities deployed. (Pérez-Arriaga, 2009) made the following summary of different potential benefits:

Table 2 Potential Smart Grid Benefits

Potential Smart Grid Benefits
• Significant reductions in residential peak demand energy consumption achieved by providing real-time price and environmental signals in conjunction with advanced in-home technologies. • Potential carbon footprint reduction as a result of lowered residential peak demand and energy consumption, improved distribution losses and increased conservation options. • Possible reductions in the number of customer minutes out as a result of improved abilities to predict and/or prevent potential outages, and more effective responses to outages and restoration. • Expected deferral of capital spent for distribution and transmission projects based on improved load estimates and reduction in peak load from enhanced demand management. • Potential utility cost savings from remote and automated disconnects/reconnects, elimination of unneeded field trips and reduced customer outage and high-bill calls through home automation.

Adapted from (Pérez-Arriaga, 2009)

To understand the distribution of these functional technology areas and the benefits, it is important to look at the electricity grid in more detail. The technology of the electricity system can be divided into upstream, or generator technology, or downstream, consumer technology. Many of the functional technology areas that are being discussed fall mostly within the downstream technology sphere. The most important functional area in this regard is that of metering. Smart meters are electricity metering devices with ICT functionality, allowing for remote metering. For the consumer, the direct benefits of smart meters are lesser exposure to blackouts and a potential to save money. Indirect benefits include possible linkages to other enabling technology such as smart heating systems, societal benefits through reduced CO_2 emissions and higher allocative efficiency[17]. Traditional electromechanical meters have a decreasing accuracy and gradually underestimate actual consumer usage. If a consumer switches to a smart reader, a higher electricity bill is therefore likely[18]. Billing data collected through a smart meter can reveal sensitive information such as when householders are away from their houses, information

[17] *(Krishnamurti, et al., 2012)*
[18] *(Krishnamurti, et al., 2012)*

which can be used for theft or fraud. Thus privacy is an important issue from many consumers regarding smart meters[19]. Smart meters are often misunderstood by consumers and ascribed with functionalities originating in associated smart technology[20]. This said the associated smart technology is enabled through the smart meter. When a smart meter is linked to consumption monitoring devices connected to specific appliances in a building, and this information is displayed on for example a specifically designed screen or on an internet website, then an electricity consumer can gain access to information about his/her own consumption of electricity, how it is distributed, and how it relates to the overall grid status. More availability of information on the side of end users of electricity will also make it easier end users to become producers of electricity. In the smart grid, the traditional relationship between supplier and consumer will go from being unidirectional into something complex. This new role for consumers has been dubbed 'prosumer'[21].

Upstream technology is also an important part of the smart grid concept. Some functionalities enabled by smart grid rest solely in this sphere. One example is dynamic line rating. Traditionally transmission lines are evaluated by system operators using static models that constantly take into account the possibility of weather conditions impairing the performance of the lines. This means that transmission lines most of the time work much below their capacity, and in cases when they are needed to transmit more power, the system operator has little information about its actual performance. Dynamic line rating integrates sensing equipment spread throughout the transmission grid and also weather readings that can come from external sources, to dynamically model the performance of lines to give system operators close to real-time information about the condition of transmission lines.

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[19] *(Krishnamurti, et al., 2012)*
[20] *(Krishnamurti, et al., 2012)*
[21] *(Mah, van der Vleuten, Hills, & Tao, 2012)*

This allows the system operators to operate the grid in a more efficient way, and allows much greater room of manoeuvre in case of transmission line failures.

While some functionalities of the smart grid are centred in the upstream or downstream spheres, the most promising benefits are from those functionalities that cross the sphere. The load shedding functionalities of smart meters, if combined with dynamic line ratings can, for example, enable consumer loads to be adjusted automatically in the case of transmission line failures, which can prevent blackouts and benefits society as a whole. It is these integrative functionalities that are often called advanced smart grid. The realization of these functionalities will require the most adjustments both from utilities and consumers. Many of the functionalities will require and enable consumers to take a much more active role in the electricity system, and would require and enable utilities to cede agency to the consumers. In this regard, smart grid has the potential to be an integrative and transformative technology bundle that will change the governance structure of the electricity system.

As we have seen, the potentials of smart grid are varied, a smart grid can contain many different kinds of components, and the meaning of smart grid can differ in different contexts. Despite this ambiguity, smart grid is likely to be developed and implemented across the world in one form or another, because of its utility in ameliorating the main problems of the electricity system in terms of cost, security of supply and environmental impact. How smart grid innovation can be promoted and what kind of smart grid will be the outcome of innovation efforts are therefore important research areas of great societal value.

iii. Previous Research and Contribution of This Thesis

Many of the benefits of smart grid depend on end users of electricity, and many of the functionalities will benefit the end users. Because of this the importance of engaging the end users in the technology has been recognised as a key question for smart grid innovation[22]. This is made difficult by a traditional disinterest of the end users towards the electricity grid, much due to the fact that opportunities for agency have been very limited due to the centralized characteristic of the electricity grid. The desires, aspirations and attitudes of end users appear elusive to an industry and an academic discipline that has not communicated much with consumers before. The importance of conducting more research to understand the attitudes of end users to smart grid technology has been affirmed by the IEA[23]. This is also compounded with an understanding in environmental management studies that the focus on electricity suppliers is not conducive to developing optimal solutions to the GHG emissions problem of the electricity sector. As (Parag & Darby, 2009) argue, there is a principal-agent problem when suppliers are only focused on, as consumers have a very big influence on the performance of the whole system.

In light of this, several studies have tried to capture how electricity consumers could become engaged with smart grid technology. These studies build on work about adoption of energy efficiency technologies on the consumption side, and studies of willingness to adopt energy saving behaviour[24]. (Blumstein, Krieg, Schipper, & York, 1980) early on showed that information deficiencies about cost-effectiveness of energy efficiency actions was making adoption less probable. Many analysts expect that smart grid technology will lead to increased prices, because of better monitoring, investment costs, higher regulatory cost and the potential for market abuse as the information asymmetry

[22] *(Gangale, Mengolini, & Onyeji, 2013)*
[23] *(International Energy Agency, 2010)*
[24] *(Dowd & Hobman, 2013)*

between suppliers and consumers increase. It is however expected that the smart grid will enable enough consumption reduction to ensure that consumer total cost will be lower or stay the same[25]. (Mah, van der Vleuten, Hills, & Tao, 2012) studied consumer perceptions of smart grid technologies in Hong Kong through an extensive survey. Their results indicated that consumers are generally enthusiastic about smart grid technology and want to participate more actively on the electricity grid. Cost was considered the most important factor for most consumers. They also found that consumers in Hong Kong are much less concerned about privacy issues than results have shown in Western countries. (Leenheer, de Nooij, & Sheikh, 2011) investigated motivations to generate own power in the Netherlands. Surveying more than 2000 households, they found that the most important driver for consumers to start producing their own energy was environmental concerns. In this survey, financial motives were found to not play a role in decisions to start producing own electricity. They argue that economic considerations should probably be thought of as enabling conditions, in which motivations are able to play out or not. (Da-li, 2009) studied the market constraints and awareness constraints for electricity end users to adopt technology enabling energy efficiency in China.

Many trials and demonstration projects have been implemented over the world to test how consumers can behave with smart grid technology. (Gangale, Mengolini, & Onyeji, 2013) studied finished or on-going smart grid projects in Europe and noted that there was a strong trend towards generating knowledge content focusing on the consumer. Their study identifies two main objectives of such studies, first; to understand consumer behaviour, second; to develop tools to create prosumers. (Verbong, Beemsterboer, & Sengers, 2013) also found a strong trend towards involving consumers in smart grid projects in the Netherlands. In all these projects, there has been a focus on the residential

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[25] *(Clastres, 2011)*

sector, as the current electricity market paradigm only bills end users of electricity directly when the use is within the residence of the user[26]. Demand response, as a key mode of end user participation in the grid, has been the focus of many studies. Many quantitative studies of the effectiveness of different demand-response schemes have been carried out, often designed to convince utilities about the viability and cost-effectiveness of such functionalities. Most of these have been carried out in the US, but studies have also been carried out in Korea, the UK, Denmark, Japan, France, Norway and Australia[27]. One of the most extensive demand response programs being carried out so far is California's State-wide Pricing Pilot, carried out in 2004 and 2004 by PG&E and SCE. 2,500 households and small businesses participated in the pilot, and the major utilities in California used the data from the analysis in their decision to roll out smart meters across California[28]. (Hargreaves, Nye, & Burgess, 2010) has carried out a qualitative study in the UK, explaining the dynamics through which demand-response is successful.

Much research has been done, but more comprehensive analyses of the socio-political and economical milieu of smart grid innovation have yet to be done. This thesis aims to contribute to the understanding of smart grid and innovation for sustainability through a comparison of smart grid innovation in two countries, using the integrative technological innovation systems approach and the social construction of technology framework, to add knowledge about the social, political and economic pressures that affects the pace and character of smart grid innovation.

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[26] *(Gangale, Mengolini, & Onyeji, 2013)*
[27] *(Krishnamurti, et al., 2012)*
[28] *(Haney, Jamasb, & Pollitt, 2009)*

5. METHODS

Theoretical Frameworks

i. Sustainability and innovation for sustainability

This thesis is written within the academic discipline of sustainability science. With this discipline comes a set of normative considerations that the researcher attempts to address. One important theme of sustainability is that of interdisciplinarity and systems-thinking. Sustainability problems are complex creatures with cannot be understood from the lens of one academic discipline alone. Therefore sustainability science strives to achieve a holistic understanding by operating within more than one discipline. Sustainability science studies frequently refer to the 3 pillar framework of sustainability, which urges the researcher to cover the three different domains of environmental sustainability, economic sustainability and cultural sustainability. However, many scholars of sustainability science argue that the student of sustainability problems must go further. They would argue that 'opening the box' of scientific enquiry to incorporate other disciplines is insufficient. This is because, as one discipline is only able to provide one perspective of a problem, one social perspective is similarly limited. Thus, transdisciplinarity and reflexivity is necessary. In solving sustainability problems, it is often argued, searching for panaceas is futile, as problems are context based and our understanding of them is only limited (Ostrom, Janssen, & Anderies, 2007). This research seeks to both be problem-solving, and critical, as it aims to improve the current situation of smart grid innovation by adding critical reflection over the mode and goals of innovation processes[29]. For such a complex system as the electricity system, a holistic mode of research is needed. The need for transdisciplinary research on smart grids has been recognized, as not only the technical aspects but also the regulatory and economic incentive aspects need to be dealt with[30]. In view of this, this thesis aims to

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[29] *(Jerneck, et al., 2011)*
[30] *(Clastres, 2011)*

create a broad, big picture, incorporating perspectives of different stakeholders in the social process observed, rather than a precise description of a strictly defined area.

In the perspective of sustainability, the stakes for smart grid innovation is huge. Infrastructure is expensive, inert and long-lasting. Innovation in the infrastructure sector is particularly susceptible to path-dependency[31]. Moreover, the stakes of end user involvement is equally great. The efforts of the smart grid innovators to engage end users could, if they failed, result in an even greater apathy towards the electricity system[32].

ii. Technological transitions and innovation studies

This study primarily relies on technological transitions and innovation studies as a way of understanding the process of smart grid innovation. The study of technological change and innovation for sustainability is a highly relevant one for sustainability science. Technological change and innovation is often touted as the solutions to the sustainability problems the world is facing today. Sustainability science takes no stand on the truth of this statement in itself. However, sustainability science would argue, that this innovation cannot be considered as occurring in an economic and social vacuum. This point has not been missed by recent studies of innovation. (Green, 2005) points out that the study of environmental innovation should, if it wants to broaden its concern to that of sustainability rather than only the environment, incorporate the holistic perspective of innovation systems research, which takes into account political, economic and social factors affecting innovation processes.

Technological transition and innovation studies focus on changes in how human societies use technology. Technology here is not to be understood as only machinery. (Geels, 2002) sees technology as a vast network of heterogeneous elements,

[31] *(Verbong, Beemsterboer, & Sengers, 2013)*
[32] *(Krishnamurti, et al., 2012)*

centred upon a physical artefact. This network usually attains a form of stability and self-reinforcing dynamics. Geels sees technology as a vast network of heterogeneous elements, centred upon a physical artefact. This network usually attains a form of stability and self-reinforcing dynamics[33]. Change can therefore take many shapes, including the replacement of equipment used for achieving a specific task, or a change in behaviour or use of equipment. Technological change can be divided into regime optimization or regime transformation. Regime optimization is the change of current practices into more efficient ways. Regime transformation is the change of current practises that requires a reorientation of other areas of human society. As (Hoogma, Weber, & Elzen, 2005) point out, most technological change is occurring within the sphere of regime optimization, because technology is so embedded within society. However, even regime changing technologies usually start off within the sphere of the established regime. For smart grid, as we shall see, the dynamics of optimizing and transformative change is present, and both play an important role in current innovation efforts.

Innovation systems theory argues that innovation is an activity embedded within a complex web of social and economic relations, cultural norms and values and political institutions. Thus, even though the firm is central to the study of innovation, a more holistic view is necessary to understand the dynamics that lead to innovation[34]. (Geels, 2002) situates innovation within a socio-technical landscape, which is the relatively inert. Geels even mentions the electricity infrastructure as an important component of this landscape, as this infrastructure is relatively solid (does not change over time) and its setup affects most other technologies. The socio-technical landscape includes cultural values, political structures and processes and economic arrangements. For technology to be

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[33] *(Geels, 2002)*
[34] *(Green, 2005)*

evolutionary viable, it needs to adapt to or be able to shape the landscape in which it emerges. For the electricity system this is obvious, and the sheer size and complexity of its landscape makes swift radical change impossible.

When new technologies or practices take hold in society, it is because they fulfil some criteria of usefulness that relevant actors have put up. The criteria for selection of technology were first seriously problematized by the alternative technology movement in the 1970s[35]. Heightened awareness about the social processes that underlies innovation processes for sustainability will also help avoid that the innovation process becomes path-dependent, guided only by the perspectives of the most privileged who gets to frame the problem[36]. As (Smith, Stirling, & Berkhout, 2005) argue, more attention must be paid to the process of consensus building around new technological futures, and the power dimensions featuring in that process. In the interest of sustainability, it might be more suitable to create a “portfolio of options” rather than to “engineer a consensus”[37]. In this context, having persistent critical voices within the innovation system would be an asset[38]. The value of bringing in different perspectives from all sections of society is also evident. These different perspectives must be given agency to participate in the selection of technology, or the governance of regime transformation. (Smith, Stirling, & Berkhout, 2005) define agency within regime transformation as “the ability to intervene and alter the balance of selection pressures or adaptive capacity.”[39] Because such agency always takes place within the networks that constitute a regime, political, economic or institutional power is necessary for wielding of agency. Here the role of consumers stands out as an important missing piece

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[35] *(Smith, 2006)*
[36] *(Stirling, 2006)*
[37] *(Stirling, 2006)*
[38] *(Stirling, 2006)*
[39] *(Smith, Stirling, & Berkhout, 2005)*

of the puzzle in much of the existing research efforts[40]. Many techniques for consumer involvement such as Constructive Technology Assessment and Participatory Technology Assessment have been put forward, but these have only gained marginal influence[41]. Scholars such as Eric Von Hippel have explored the democratization of the innovation process. Increasingly, consumers find that their needs are not met by the innovations produced by manufacturers. This is especially true of those consumers who are at the forefront of consumption trends, called the 'lead users'. These lead users have increasingly started to innovate on their own, and their innovations are often later commercialized by manufacturers. Von Hippel defines these as lead users, who fulfil the two following characteristics:

1. "They are at the leading edge of an important market trend(s), and so are currently experiencing needs that will later be experienced by many users in that market."
2. "They anticipate relatively high benefits from obtaining a solution to their needs, and so may innovate"[42]

Von Hippel's work is both descriptive and proscriptive, as he finds that democratization of innovation can bring many benefits both in terms of quality and pace of innovation.

The electricity system exists as a regime at a fairly high level of aggregation, and there are numerous sub-regimes like for example those for coal power plants, transmission lines, transformation systems. Moreover, the electricity systems of the world are all technologically inter-linked with a global regime of extracting, trading and utilizing

[40] *(Green, 2005)*
[41] *(Smits, 2002)*
[42] *(Von Hippel, 2005)*

fossil fuels[43]. All these regimes relate to each other, creating a great force of inertia. When we consider that also the various regimes for electricity consumption are also closely connected to that of the electricity system, it becomes very understandable why transformative innovation is less likely to occur without the help of strong agency. As (Smith, Stirling, & Berkhout, 2005) point out, regime membership is not concurrent with agency, and this is very visible in the electricity system. In the electrical system regime, electric utilities are obviously heavily involved in the generation, distribution and sale of electricity, so they are core actors in the electricity regime, and have strong agency. Households all use electricity on a daily basis and can therefore be expected to have strong agency as well. However, this is not the case, because involvement itself does not confer agency. Rather, the type of regime membership is crucial for understanding the potential to wield agency. When actors steer the direction or pace of innovation or technological change, we can say that there is transition governance. (Smith, Stirling, & Berkhout, 2005) argues that there are two different realms of transition governance. The first one is that of altering the selection pressures within a technological regime, so as to accelerate or change the form of transition. The second one is that of changing the quality and distribution of adaptive capability. From the perspective of sustainability science and innovation studies, there seems to be an argument for transition governance of both reams when it comes to smart grid innovation. The first realm of transition governance would serve to create the incentives for smart grid innovation that maximises different sustainability vales such as low environmental impact, higher level of participation from non/skilled stakeholders and lower costs. The second realm of transition governance would serve to create the capabilities among disempowered actors in the electricity system to influence the direction of innovation. This would allow for a more transdisciplinary creation of knowledge and a

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[43] *(Smith, Stirling, & Berkhout, 2005)*

more democratic innovation process, which in turn would lead more sustainability oriented innovation. Some research on how the smart grid innovation process is governed in different context has already been done. For example (Ling, Sugihara, & Mukaidono, 2012) make a useful description of main differences between Japanese and American perspectives on smart grid. (Lin, Yang, & Shyua, 2013) compare smart grid promotion policy in China and the USA, but stops at the role of governments. (Schiavo, Delfanti, Fumagalli, & Olivieri, 2013) uses the case study of Italy to investigate how electricity regulators try to manage innovation. This research aims to contribute to this field by making a broad analysis of the currents status of smart grid innovation and how it is governed in order to shed light on how the transition governance of the power grid could be made better.

iii. Social shaping

One main theoretical assumption of this thesis is that technology is socially shaped. The social shaping of technology has emerged as a counter-vision to the more tradition understanding of technological change as deterministic, following a predetermined path towards progress. Technological deterministic view of innovation argues that the direction of innovation follows a predictable and traceable path that is governed by a natural tendency towards the most effective technology possible. Better technology thus always prevails, and we can see the historical development of technology as a linear succession from primitive technology towards better technology. Social Construction of Technology (SCOT) theory arose in opposition to the technological deterministic view of technological development. SCOT researchers have argued that economic, social, cultural and political factors strongly influence the way in which societies innovate. The core of SCOT's opposition to technological determinism is that SCOT questions the concept of "better" technology. SCOT researchers argue that the criteria for "better" technology depends upon a range of factors, such as what actors are empowered to make the decision, what kind of cultural values they hold, in what economic context this choice is made and so on. The most classical SCOT account is that of the modern bicycle by Trevor Pinch and Wiebeke Bijker, which illustrates how evolving social norms and gender roles shaped the development of the bicycle from a machine for masculine enjoyment to a mode of transport that even women could drive by themselves[44].

For the student of electricity grid, the SCOT argument has obvious utility. Vast amounts of money and time has been put on developing and perfecting the operations of electricity grids, and electricity grid technology is present in every nation across the earth. However, the architecture of grids has notable variations across the world. These variations seem to have persisted over time, and thus social factors seem to influence the choice of technology at least in the medium term. It is possible to interpret social shaping of technology in a 'strong' and a 'weak' way. A strong constructivist understanding would argue that technology is completely socially mediated, and its shape depends on social processes. (Winner, 1986) argues that a strong constructivist understanding of technology is not sufficient, because of the material character of technology. Winner argues there are two ways that artifacts can embody politics. One is through their design, when they are intentionally or unintentionally made to accommodate a certain interest. The second way is in the institutional patterns of power and authority that technologies are better suited to, regardless of superficial design. The second way thus depends more on the physical nature of the technology than the social processes that creates it. In Winner's view, we should see technology and the social world as co-evolutionary entities, where each exerts influence on the other.

A second important point of the SCOT framework is that events and processes have a strong influence on the evolution of technology. Looking back at the history of

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[44] *(Pinch & Bijker, 1984)*

electricity grids, the importance of single individuals, such as Thomas Edison and Nicolai Tesla, and of events such as the world wars can be clearly identified[45]. This is and will hold true for smart grid technology as well. (Zio & Aven, 2011) predicts that specific contexts and severe events (such as major power outages) will shape the way in which smart grids become designed.

Analytical Frameworks

This thesis adopts two main frameworks for the collection and analysis of information. These are the system of innovation framework, and the technological innovation systems approach.

iv. System of innovation and technological innovation systems

The system of innovation approach aims to look at the interactions between different stakeholders to identify any obstacles to innovation within the institutions that govern those interactions[46]. Innovation occurs, system of innovation scholars would argue, in the interactions between different kinds of actors, who through interaction, be it competition or cooperation, reshapes some aspects of human society. In the absence of, or malfunctioning of, interactions, the most important obstacles to innovation can be found. In this framework, the most important stakeholders in the networks that engage in innovation must be identified, and wider patterns of stakeholder configurations should be investigated. System of innovation thinking was developed by (Lundvall, 1985) and further developed by (Freeman, 1988) and others to look at national systems of innovation, and how governments could actively promote innovation through linking different stakeholders. Traditionally, the system of innovation scholars focused on the role of firms, government and knowledge institutes within the innovation system. However, experience of the last

[45] *(Hughes, 1993)*
[46] *(Klein Woolthuis, Lankhuizen, & Gilsing, 2005)*

decades has shown that other influences such as activities by end users, economic structures or societal discussions can have an important role in driving innovation.

The main theoretical framework this thesis uses to understand the process of innovation is that of technological innovation systems (TIS). TIS builds on system of innovation studies, and aims for a more holistic understanding of innovation, and is an appropriate tool for an interdisciplinary investigation of innovation. (Carlsson & Stankiewicz, 1991) defines a TIS as "A network or networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilise technology."[47] The TIS is primarily an analytical construct. It is not so that all actors at all times are acting as parts of a system. Very seldom do actors share the same view and aim, and they may or may not be aware of each other's' existence efforts[48]. The TIS model aims to capture the activity directed toward development, diffusion and use of a particular technology[49]. TIS is often regarded as a problem-solving discipline, and is many students of TIS are preoccupied with finding ways to accelerate and enhance innovation processes. Therefore, TIS has mostly been applied to the study of green technology, which is taken to have a clear positive social value. Examples include (Kamp, Smits, & Andriesse, 2004) on wind turbines in the Netherlands and Denmark, (Jacobsson & Bergek, 2004) on renewable energy systems in Germany, Sweden and the Netherlands, and (Suurs, 2009) on renewable vehicle fuels. This study shares the normative goal that technology addressing sustainability problems should be adopted as quickly as possible. However, this study is more interested in the characteristics of the resulting technology rather than the innovation pace. Thus some adjustments have been necessary.

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[47] *(Carlsson & Stankiewicz, 1991)*
[48] *(Bergek, Carlsson, Jacobsson, Lindmark, & Rickne, 2008)*
[49] *(Bergek, Carlsson, Jacobsson, Lindmark, & Rickne, 2008)*

This thesis uses the research framework developed by (Bergek, Carlsson, Jacobsson, Lindmark, & Rickne, 2008). They identify 6 steps that a researcher should pass through to analyse the performance of a TIS. These are:

1. Defining the TIS in focus;
2. Identify the structural components of the TIS (actors, networks and institutions);
3. Analysis of functions and functional pattern;
4. Normative analysis;
5. Identification of drivers and blockages to desirable functional pattern;
6. Specify key policy issues related to these drivers and blockages[50]

This thesis makes use of this structure. For the two case studies, steps 1 through 3 are done in the Findings section, while step 4 is done in the Discussion section, step 5 in the Implications section and step 6 is done in the Policy Recommendations section. Structural analysis, as described above, is a standard method in TIS studies. The main thrust of the framework of (Bergek, Carlsson, Jacobsson, Lindmark, & Rickne, 2008) is the functional analysis. These authors argue that while structural analysis is helpful, the aim of a TIS is not to achieve structure, but rather to have a successful process. They have drawn upon a wealth of empirical studies of innovation systems and have isolated 7 key processes that are key influencers of the development, diffusion and use of new technology. These are: knowledge development and diffusion, societal guidance, entrepreneurial experimentation, market formation, legitimation, resource mobilization, and development of positive externalities.

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[50] *(Bergek, Carlsson, Jacobsson, Lindmark, & Rickne, 2008)*

1) *Knowledge development and diffusion*

This is the core function of a TIS. It encompasses the creation of different kinds of knowledge, including scientific, technological, market or logistic knowledge.

2) *Societal guidance*

The function 'Societal Guidance' refers to the way in which society creates incentives for a certain type of technology to emerge from a TIS. If this function is performing well, there is a clear common understanding of the expectation and probabilities of technology development and diffusion, shared by industry actors, the government and consumers. As (Smith, Stirling, & Berkhout, 2005) point out, this particular function is important as a battleground for different interest, and an important arena for power within innovation processes. A more vague vision can be helpful to mobilize a broad coalition. But if the interpretative flexibility is too great, the innovation system will not be pulling in the same direction, and will therefore not be very meaningful as a system[51].

3) *Entrepreneurial experimentation*

This function refers to experiments carried out by actors expecting to be able to use the technology to achieve their aims. These activities are on the forefront of the innovation process. From a societal perspective, the experimentation of entrepreneurs makes uncertainty about the use of technology lower, as they create hard evidence for the likelihood of success or failure of certain types of technology.

4) *Market formation*

For the benefits of innovation to become widespread, a market for the technology needs to be created. Emerging TIS often have very small and weak markets, but a strong market with ample possibilities for profit, innovation is normally accelerated.

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[51] *(Smith, Stirling, & Berkhout, The governance of sustainable socio-technical transitions, 2005)*

5) *Creation of legitimacy*

This function refers to the process in which the technology becomes socially accepted and becomes integrated into the legal system. When this function is not fulfilled, societal guidance and market creation is unlikely to occur as well, and regulatory barriers can create obstacles to innovation.

6) *Resource mobilization*

Normally, innovation requires different kinds of capital and assets in order to proceed. Financial capital and human capital are the most important among these, and the availability of those will enable innovation.

7) *Development of positive externalities*

Empirical studies have shown that the existence of complementary innovation systems is important for a TIS to be successful[52]. For example, the success of nuclear power technology benefited greatly from advances within nuclear weapon technology, even though these are two distinct technology areas.

Model and Data Collection

v. Defining the TIS

The TIS being analysed in this thesis are those of smart grid innovation in Japan and the USA. I use the definition of the European Technology Platform, which basically defines smart grids as electricity production and/or consumption integrated with ITC for various purposes. My two case studies are of geographically defined innovation systems. This might seem to the reader to be a gross oversimplification. Of course the innovation systems of the USA, Japan and other countries do not progress in isolation. Cross-border influences are extremely important in the development, diffusion and use of smart grid technology. (Green, 2005) points out that a multi-level understanding of

[52] *(Bergek, Carlsson, Jacobsson, Lindmark, & Rickne, 2008)*

innovation must include the supranational level, as regime change is very unlikely to occur on a domestic level. While I am supportive of this consideration, my study keeps the national level as the main area of analysis. Different jurisdictions have different regulations when it comes to electricity grids. Moreover, the electricity system has come to be seen as a foundation stone of the economic life of industrial countries. Because of this, virtually all countries have strong governmental influence on the electricity system, and still today in our age of globalization, most electricity grids are remarkably national in character. Japan and the USA are no exceptions to this, even though both have strongly fragmented grids. Thus a focus on the national level is a justified one.

The technology providers are arguably the least geographically bounded of the important actors. All serious electricity and electronics manufacturers today target more than their domestic markets. Thus they gather intelligence and respond to market incentives from a wider area than one nation. However, the technology which they sell on the domestic market must be adjusted to the existing market and grid conditions in the domestic market. Moreover, foreign firms who want to sell smart grid technology must sell it within the context of the domestic market and grid conditions. Thus it is natural to count IBM in Japan and Siemens in the USA as important players within those smart grid TIS, even though both firms probably receive much more feedback in terms of smart grid technology from other markets.

vi. Finding the actors

The preliminary survey of the Japanese case identified 5 kinds of stakeholders in smart grid innovation. These are: government agencies, academia, vendors, utilities and end users of electricity. Government agencies include the strategic authorities that directs public and private R&D efforts (such as NEDO in Japan or DOE in the USA), and regulatory authorities that have authority over the electricity system and associated activities.

Many important actors in the smart grid TIS were found to be organizations with membership from several different kinds of actors. These include industry organizations such as the JSCA in Japan which involves government agencies, academia, and technology suppliers, and the SGCC in the USA, which involves utilities, technology suppliers and consumer organizations. This study treats such actors as platforms of collaborations, which sometimes can take on agency on their own.

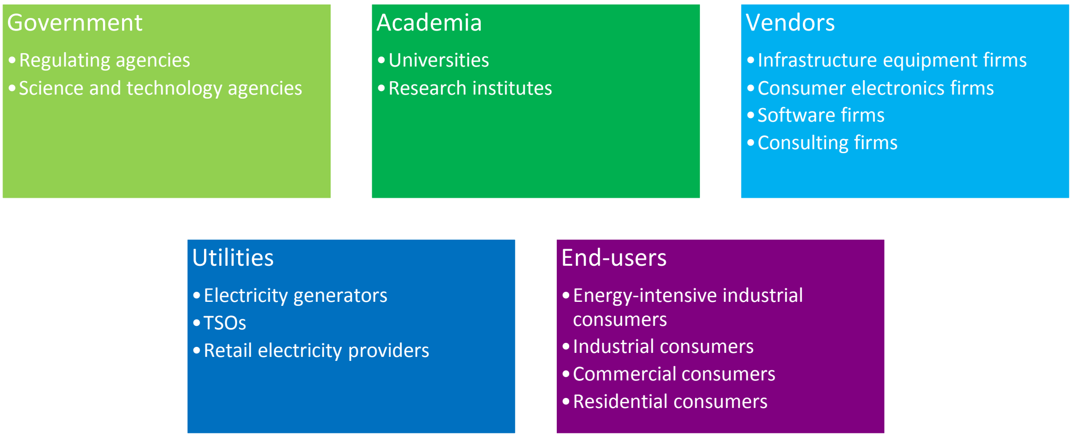

Table 3 Typology of actors in smart grid innovation systems

To analyse the network of actors engaged in smart grid innovation, social network analyses were made. Databases for the social networks of both countries were constructed by the author, using information from existing databases online (such as the Smart Grid Clearinghouse Initiative) or from extracting information from materials of different smart grid projects and organisations. A social network was constructed from each database, analysed using UCINET[53], and visualized using the software Pajek[54].

vii. Semi-structured interview

Interviews with experts is a well-established method for TIS analysis. Through gathering perspectives of practitioners within a TIS and filtering their voices through the TIS model, a good understanding of TIS processes can be achieved. This study aimed at conducting 10-15 interviews in each of the two case studies. Experts were sought from academia, technology suppliers, government agencies and other stakeholders such as think-tanks and consumer groups. In the USA, 12 interviews were held. In Japan, 13 interviews were held. An interview instrument designed according to the TIS structure was used to discuss different aspects of smart grid innovation with each expert. The interview instrument can be found in appendix 2. Experts were also initially asked to provide ratings of the performance of specific sub-processes of the smart grid TIS in the respective countries. The quantitative data provided was however hard to use, as respondents gave different ratings with similar qualitative justifications. However, the practice of asking for a rating was retained to stimulate discussion and reflection.

The interviewed experts were also asked to rate the importance of different functional technology areas of smart grid on a scale from 1-5. The list of functional technology areas was adapted from (International Energy Agency, 2010). It is represented in full in the Introduction section.

Table 4 Smart Grid Functional Technology Areas

	Functional Technology Areas
1	Electricity generation control, automation and power electronics

[53] *(Borgatti, Everett, & Freeman, 2002) UCINET is available at https://sites.google.com/site/ucinetsoftware/*
[54] *Pajek is available at http://vlado.fmf.uni-lj.si/pub/networks/pajek/*

	Functional Technology Areas
2	Advanced computing and grid control software
3	Embedded grid sensing, automation, measurement and control technology
4	Communication infrastructure
5	Conductor technology and approaches
6	Electrical load control and advanced meters
7	Energy storage
8	EV charging infrastructure

viii. Visions

Finally, the experts were also asked to rate the importance of different visions within the community engaged with smart grid innovation. The list of visions was compiled by the author after extensive reading about global visions for smart grid technology. A list of 13 visions was compiled. All respondents were asked if they found the list exhaustive, and most agreed, while some wanted to add consumer empowerment and awareness-related visions. The list can be seen in table 5.

Table 5 Smart Grid Visions

	Vision	**Description**
1	Attack resilient	A grid that can withstand hostile physical and cyber attacks
2	Disaster resilient	A grid that can withstand natural disasters and other unexpected events
3	Quality	A grid that provides reliable high-quality power
4	Conserving	A grid which utilizes less energy in total
5	Intelligent	A grid that achieves better allocative efficiency, including by achieving peak-shaving
6	Renewable	A grid that can integrate more fluctuating energy sources such as wind power or solar power
7	Distributed	A grid that can integrate more distributed energy sources, including renewables
8	Vehicle	A grid that can integrate more electric vehicles
9	Monitored	A grid in which electricity theft and reporting fraud is less
10	Efficient	A grid with less transmission and distribution losses
11	Utility cost-efficient	A grid with less cost for the utilities
12	End user cost-efficient	A grid with less cost for the end users
13	Market-driven	A grid more fit for free market competition

ix. Semantic analysis

To substantiate the analysis of dominant themes, technological function areas and goals of smart grid innovation in the two countries, a bibliometric analysis was made. The method of bibliometric analysis was adopted from (Vlieger & Leydesdorff, 2010). A search was made using the on-line database ‘Web of Knowledge’ provided by Thomson Reuter. Searches were made for academic journals including the keywords “smart grid” or “smart meter” in their title, abstract or keywords listing. A separate search was made for articles authored or co-authored by researchers based in Japan and one search for articles authored or co-authored by researchers based in the USA. The hits were then manually checked to control if their subject matter was related to smart grid innovation. The titles and abstracts were then extracted from the database, and arranged as two databases.

Using the software TextSTAT-2[55] four lists of the 30 and 60 most commonly occurring words were retrieved from the two databases. Only words with a conceptual semantic meaning were retained, and words such 'the', 'is' and 'to' were ignored. Using the software FullText[56], the co-occurrence of the lists in their each database was analysed. The resulting network was visualized using the software Pajek[57], showing semantic maps of the scientific discourse surrounding smart grid innovation in the two countries. KH Coder[58] was used for semantic analysis of the academic journal abstract corpora. Project documentation from both countries was also used as material for semantic analysis using KH Coder.

Research Questions Revisited

As stated before, the research questions that guide this thesis are:

- What are the main drivers and obstacles of smart grid innovation in Japan and the USA?
- What is the role of end-users of electricity in these processes?
- Is there a difference in emphasis within smart grid technology in Japan and the USA?

The first question is motivated by the identification of smart grid as a good tool to work towards energy sustainability as a goal. Smart grid can enable energy efficiency, higher economic efficiency, and more emancipation of end users, and is therefore something normatively good within the sustainability science perspective. The second question is motivated by the desirability of involving marginalized perspectives in governance, to achieve sustainability as a process. It also links the concern of innovation studies to the importance of diversity for innovation to succeed, and the positive role end users can play within innovation processes, effectively democratizing them. The third

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[55] *TextSTAT-2 is available at http://www.niederlandistik.fu-berlin.de/textstat/software-en.html*
[56] *FullText is available at http://www.leydesdorff.net/software/fulltext/*
[57] *Pajek is available at http://vlado.fmf.uni-lj.si/pub/networks/pajek/*
[58] *(Higuchi, 2001), KH Coder is available at http://khc.sourceforge.net/en/*

question aims to identify if the way the innovation process is governed and how it plays out affects the actual technology that gets implemented.

6. FINDINGS

Japan

i. Policy Environment

1) Market regulation

Japan started liberalization of the electricity system in 1995, as part of a broader liberalization drive called the Deregulation Action Program, informed by the neoliberal privatization ideology of the ruling party. This meant that in the year 2000, the monopoly of the regional power companies was partly broken, with distribution still in the oligopoly's hands. Liberalization proceeded only slowly – by 2010 new companies accounted only for 3.5% of the market[59]. These companies own power plants, and sold wholesale to large industrial end-users. Because these companies can offer competitive rates, industrial end-users increasingly rely on new companies, especially as these have been largely economically untouched by the energy crisis following the Fukushima disaster[60]. The oligopolies still control the most lucrative accounts with small residential end-users[61]. As the Fukushima disaster unveiled large deficiencies within the oligopoly, the government of Shinzo Abe decided in April 2013 to further liberalize the electricity grid, again as part of a broader ideologically informed deregulation effort However, the liberalization is again expected to be completed only in 2018-2020[62][63]. The Japanese electricity prices are moderately high compared to in other OECD countries. Before regulations, the utility companies have been free to pass costs, as well as a margin calculated as a rate of return on invested capital, on to electricity consumers, after approval by METI. This created an incentive for the oligopoly to invest as much as possible in

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[59] *(The Japan Research Intistute, Limited, 2012)*
[60] *(Japan Times, 2013)*
[61] *(The Japan Research Intistute, Limited, 2012)*
[62] *(Power Engineering, 2013)*
[63] *(METI, 2013)*

capital[64]. After deregulation, only the residential contracts are covered by this pricing system.

2) Government promotion

The Japanese government interest in smart grid grew out of the government's promotion of renewable energy sources, an area in which Japan was an early champion In. the first decade of the millennium NEDO promoted domestic projects aiming at developing grid-connecting technologies for renewable energy projects. Projects supported included clustered PV generation, mega solar generation, wind power stabilizing and power quality management, and micro grids. These projects were not carried out under the label of smart grid, but touched upon some of the functionalities now associated with smart grid.

As global interest in modern infrastructure has grown, the Japanese business community and METI have seen opportunities for Japanese exports of smart grid and other infrastructure equipment and know-how. To assist this goal, NEDO is conducting several smart community demonstration projects abroad, to display Japanese goods and services, and to help Japanese companies get a foothold overseas. Also, it is difficult to gain permission for experiments with the electricity grid in Japan, and thus Japanese companies can do more sophisticated demonstration projects overseas. NEDO has in some cases successfully used the promise of future investments to gain permission to alter the grid in overseas project sites.

In 2012, a joint project between NEDO and Los Alamos County Department of Public Utilities, and 19 Japanese companies, was opened[65]. The project demonstrates smart

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[64] *(Swedish Agency For Growth Policy Analysis, 2012)*

[65] *(New Energy and Industrial Technology Development Organization, 2012)*

grid and smart house functionalities, including renewable micro grid management and energy storage[66] as well as automatic demand-response for commercial end-users[67][68].

The Japan-Spain Innovation Program was founded in 2008 by NEDO and the Centre for Industrial Technological Development of the Spanish Government. The program is implementing a smart grid project involving a consortium of Japanese and Spanish companies, including Mitsubishi Heavy Industries Ltd, Mitsubishi Corporation and Hitachi Ltd., and focuses on EV charging infrastructure and grid management[69].

NEDO is also involved in a project Hawaii that focuses on creating an island grid model, together with amongst others the Japanese EV charging infrastructure standard organisation CHAdeMO association, a project in Gongqingcheng, China on advanced smart community applications in small and medium sized cities, and a project in Lyon, France with a focus on EMS and EV charging infrastructure. NEDO is also involved in other smart grid projects in Germany, United Kingdom, Singapore, Malaysia, Vietnam and India. In addition to the overseas demonstration projects METI launched a program in 2012 of supporting private companies in conducting feasibility studies on deploying the Japanese “smart community” concept abroad, with a focus on emerging economies. 18 projects were selected, mostly situated in East and South-East Asia. METI hopes that these feasibility studies will boost Japanese infrastructure solutions exports, especially to emerging economies[70]. A few of these studies have proceeded into becoming NEDO-funded demonstration projects, such as the Smart Community Demonstration Project in Java, Indonesia, in which Sumitomo Corporation, Fuji Electric Co., Ltd., Mitsubishi Electric

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[66] *(Los Alamos County)*
[67] *(Tokyo Gas, 2012)*
[68] *(New Energy and Industrial Technology Development Organization, 2012)*
[69] *(New Energy and Industrial Technology Development Organization, 2012)*
[70] *(Ministry of Economy, Trade and industry, 2012)*

Corporation and NTT Communications Corporation will demonstrate Japanese smart grid technology and FEMS in an industrial park in the suburbs of Jakarta[71].

In 2010 METI started four large-scale smart grid demonstration projects in different areas of Japan. These were called “Next-Generation Energy and Social Systems Demonstration Areas”, later known as “Smart Cities. These demonstration projects are all based on a strong role of local authorities and one coordinating corporation per project, which receives support from METI and coordinates with other partners[72]. These projects focus on creating practical examples of different smart grid technologies.

The Yokohama Smart City Project is the most active of these projects. Headed by the city of Yokohama and Toshiba, it aims at introducing energy management systems for homes, apartment blocks, commercial buildings as well as factories, and to introduce an overarching energy management system for the city. PV cells, storage batteries and EVs are also being introduced to test the system’s adaptability to energy fluctuations. In the project, equipment installation is focused on generation and consumption points, as well as communication infrastructure, with no equipment changing the transmission and distribution grids. The other smart city projects in Toyota city, Keihanna and Kitakyushu all follow the same pattern[73][74][75].

A similar project but less in scale, the Future City[76] initiative was one of the 21 National strategic projects of the “New Growth Strategy” that the Cabinet approved in June 2010. The aim of this initiative was to tackle various issues focusing on urban sustainability,

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[71] *(Sumitomo Corporation, 2012)*
[72] *(Uetake, 2013)*
[73] *(Japan Smart City, 2012)*
[74] *(Japan Smart City, 2013)*
[75] *(Japan Smart City, 2012)*
[76] *In Japanese* 環境未来都市*, literally “Environment Future City”*

green innovation and Japan's aging society problem[77]. It is being run by the Regional Revitalization Office, and collaborates with a wide range of governmental departments, academic organizations, private corporations and local governments. The Future City initiative, though not originally intended as such, has come to be part of Japan's crisis recovery efforts for the Tohoku region, as a majority of the participating cities are located there. 11 cities are given assistance to, in cooperation with private companies and universities, draw up plans for regional development. Of these 11 cities, 7 incorporate smart grid developments as a core goal[78]. These are mostly the cities which suffered damage from the March 11.

In 2011, METI started giving subsidies to residential electricity end-users to install HEMS using the ECHONET-lite standards[79]. Additional subsidies have been provided in for example Yokohama by the city government[80].

TEPCO became required by law to deploy smart meters in 2011. Before the Fukushima disaster, TEPCO had already conducted a study about the architecture of future smart meter systems. In this context, data security was deemed to be of highest importance, and new functionality was not seen as very important. Therefore, TEPCO advocated a proprietary communication protocol. After the Fukushima disaster in 2011, the government decided to mandate smart meter roll-out in TEPCO's service areas, and TEPCO relied on its previous study to suggest the specification of the smart meters. TEPCO's own suggestion was criticized, because the TEPCO suggestion would create a separate communication network owned by the electric company, rather than using the internet, as

[77] *(Public Relations Office, Government of Japan, 2011)*
[78] *These are, Yokohama, Kashiwanoha, Kesen Region, Higashimatsushima, Minamisoma, Shinchi and Iwanuma*
[79] *(Ministry of Economy, Trade and Industry, 2012)*
[80] *(横浜グリーンパワー, 2012)*

most smart meters globally do[81]. The criticism forced TEPCO to adopt international standards for the smart meter roll-out[82]. There have indications that the government intends to use the TEPCO roll-out of smart meters to develop a national smart meter requirement for all electric power companies[83]. The smart meter roll-out in TEPCO's service area will commence during 2014.

3) Standardisation

METI founded a smart grid standardisation strategy working group in 2009 and in January 2010 it released a road map where 26 focus areas were chosen, including distribution system control equipment and EV charging infrastructure[84]. The focus areas include different sensing and automation functionalities on the transmission and distribution levels, demand response networks, AMI, energy storage functionalities and EV. In the area of energy storage, Japanese government in cooperation with Toshiba and Hitachi managed to secure the right to chair the International Electrotechnical Commission technical committee on electrical energy storage, which is set to develop the international standards for smart grid energy storage units[85].

On the smart home side, there has been collaboration since 1997 within the ECHONET Consortium, and in the HEMS Alliance since 2011. The communication protocol ECHONET-Lite for smart house appliances is ECHONET's main accomplishment so far, and it has been adopted by major Japanese electronics producers. There are already many ECHONET-ready appliances in Japan, for example 10 million air-conditioning units, which could potentially be linked to an ECHONET network[86]. Currently standardisation of the interface between grid level demand response signals and ECHONET-Lite is being

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[81] *(Global Energy Policy Research, 2012)*
[82] *(Office of Energy and Environmental Industries of the USA Department of Commerce, 2012)*
[83] *(The Global Smart Grid Federation, 2012)*
[84] *(CEN/CENELEC/ETSI , 2011)*
[85] *(Denki Shimbun, 2012)*
[86] *(International Electrotechnical Commission, 2011)*

developed, and ECHONET is working with the Wi-SUN Alliance to develop interoperability between ECHONET and global standards.

METI has sanctioned ECHONET-Lite as a national standard for smart home systems, and opened in 2012 an ECHONET test centre at the Kanagawa Institute of Technology, available for Japanese SMEs wanting to test ECHONET-Lite appliances. METI, JSCA and ECHONET are all promoting ECHONET-Lite as a global standard for smart house networks. However, the Japanese standard has been attacked for being overly insular, and risks pushing Japanese manufacturers into a separated technological ecosystem in a similar way to what happened with mobile phones earlier[87].

ii. Structural analysis

1) Actors

Government actors

Many government actors are involved in smart grid innovation in Japan. The highest instance for this involvement is The Ministry of Economy, Trade and Industry (METI). METI has a very broad policy portfolio, and is characterised by strong relationships with the private sector. Due to its strong relationships with business organizations, it has been called the most effective industrial policy agency in the developed world[88]. METI is a crucial partner for Japanese firms, and its bureaucrats can exert much influence on business decision. Also, the bureaucracy has much contact surface with big industry, and its positions are mostly coloured by the preferences of the big keiretsu firms.

The New Energy and Industrial Technology Development Organization, (NEDO,) is a governmental agency subordinate to METI. NEDO is Japan's largest public R&D funding and management organization. As one of the responses from the government

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[87] *(Global Energy Policy Research, 2012)*
[88] *(Lincoln & Gerlach, 2004)*

to the oil crisis of the 1970s, NEDO was formed in 1980 to promote development and diffusion of new energy technologies in Japan. Before 2000, NEDO-supported research on electricity grids focused on extending grid connection to single producers of renewable energy. In the first decade of the new millennium, NEDO shifted focus to inclusion of large-scale or multiple renewable energy producers. After 2010, a broader focus on the "Smart Community" concept is made, with more attention to consumer domain technology[89].

METI and NEDO conduct their smart grid innovation efforts in close collaboration with the private sector.

Some local governments, especially on the city level, are active in the smart grid activities in Japan. Especially, the cities allocated money through the Japan Smart Cities project and the Future Environment City project, as well as some cities that have partnered with vendors such as Fujisawa City which is partnering with Panasonic, or Toshima ward in Tokyo which has collaborated with the Tokyo Institute of Technology[90].

Vendors

The most important actors in Japanese smart grid efforts are large firms with strong keiretsu networks, such as Hitachi, Toshiba and Mitsubishi. The size of these companies and their networks with other firms give them access to expertise in various different aspects of smart grid technology[91]. Their large portfolios give them an interest in the broadest definition of smart grid as possible. These companies refer to the smart grid business area as part of the "smart community" area, with many products and services facing residential end-users of electricity. ITC companies and consultancies are also active, mostly in the production of software components. Residential developers and department

[89] *(Morozumi, 2010)*
[90] *(Hirai, 2013)*
[91] *(Office of Energy and Environmental Industries of the USA Department of Commerce, 2012)*

store holding companies are also active stakeholders, as they aim to provide customers with additional services and potential for cost-reduction through installing smart grid technology.

Academic actors

Japanese academic and research institutes are much involved in Japanese smart grid initiatives, especially the more large-scale projects. Mostly, these are engineering departments, and often the smart grid and smart community efforts are cast as efforts by engineering departments to realize the promise of new technology to the citizenry.

Utilities

The regional monopolies still control most of Japan's electricity system, but these companies are operating in a very uncertain and economically difficult situation since the Fukushima crisis. TEPCO, the largest of the utilities and one of the largest utilities in the world, has not been showing much enthusiasm about smart grid. Prior to the Fukushima disaster, TEPCO could argue that the Japanese grid is world-class and smart grid is thus not very necessary[92]. Post-Fukushima, the financial standing of the electric companies would hinder them from much engagement.

2) Networks

In April 2010 the Japan Smart Community Alliance (JSCA) was formed by METI with NEDO as the secretariat, as a response to the recommendation of a roadmap produced internally that suggested that international standardisation efforts were needed. In February 2013, 408 companies were part of the organization, with Toshiba serving as the president [93].

The Energy Conservation and Homecare Network (ECHONET) Consortium is a network of private companies in the smart home area. Active since 1997, the consortium develops communication standards for smart appliances, which are open and universal, to

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[92] *(Dasher, 2012)*
[93] *(Japan Smart Community Alliance, 2013)*

promote the emergence of home networks connected to smart appliances[94]. As of January 2013, the Consortium has 8 core members representing some of the largest electronics producers in Japan such as Panasonic, Sharp and Toshiba, as well as Japan's largest utility company, TEPCO[95]. After its founding, ECHONET experienced a steady decline of interest during the early 2000s as consumer interest for smart appliances was quite low, and a proliferation of communication protocols meant high cost and uncertainty for vendors. In 2011, ECHONET-Lite, an enhanced and Wi-Fi-based standard was released, and in the same year the government endorsed the ECHONET-Lite standard for HEMS in Japan, and started giving subsidies to HEMS using the standard. This led to a sharp spike in interest and membership in the ECHONET consortium[96].

In some areas, local associations for business and research institutes involved in smart grid or smart house developments have been arranged. One example is the Yokohama Smart Community association, which started following the beginning of the Yokohama Smart City project. It is an association of local SMESs who work in collaboration with the smart grid initiatives, and act as suppliers for some of the corporations involved[97].

3) Social network analysis

A social network analysis of a database with 22 projects and 2 organisations was made to identify key stakeholders in Japanese smart grid innovation. A social network was modelled in which each joint project was treated as a connection, and organisation membership was treated as one connection to the organisation vertex. The two organisation vertices were removed after calculation. The table below shows the most connected vertices according to the betweeness measure, or how important linking points the vertexes are for

[94] *(ECHONET Consortium)*
[95] *(ECHONET Consortium)*
[96] *(Mochizuki, 2013)*
[97] *(Uetake, 2013)*

other vertices. The other indicators include degree (number of connections of vertex), average reciprocal distance (a measure of average distance between the vertex and any other vertex) and Eigenvector centrality (the influence of the vertex on the centrality measures of all other vertices).

Table 6 –Top 20 Betweeness Vertices in Japan Smart Grid TIS Social Network

	Type	**Degree**	**ARD**	**Eigenvector**	**Between**
Hitachi	Electronics giant	74	303	0.173066	5212.703
TOSHIBA	Electronics giant	64	298	0.165316	3735.588
Mitsubishi Corporation	Trading company	67	299.1667	0.171806	2908.344
NEDO	Governmental promotion agency	28	265.3333	0.044392	2735.742
Sharp	Consumer electronics company	91	262.4989	0.243331	1603.521
DENSO	Automotive component vendor	55	293	0.174657	1567.229
Fuji Electric	Infrastructure vendor	53	277.6672	0.141623	1516.667
JX Nippon Oil & Energy	Petroleum company	55	293.5	0.166895	1481.08
Panasonic	Electronics giant	35	283.5	0.098062	1276.681
Furukawa Electric	Infrastructure vendor	47	272.5004	0.132096	1187.081
University of Tokyo	University	13	269.5	0.025997	1154.299
Sumitomo Electric Industries	Infrastructure vendor	55	293.5	0.160089	1123.101
Urban Renaissance Agency	Real estate agency	47	275.5005	0.123371	960.8317
TOTO	White ware vendor	30	278	0.101322	917.3737
IBM	Software vendor	30	278	0.101322	917.3737
OMRON	Automotive component vendor	24	275	0.061349	770.785
Kansai Electric Power Co	Electric utility	24	275	0.061349	770.785
Iwatani	Gas equipment vendor	29	263.3333	0.098677	658.7583
NITTETSU ELEX	Infrastructure vendor	29	263.3333	0.098677	658.7583
Tokyo Gas	Gas utility	31	281.5	0.089186	609.8406

As can be seen from the table and the illustrations below, the key actors identified from the social network analysis are mainly large conglomerates with broad portfolios, covering both electronics and infrastructure areas, and they are members of both JSCA and ECHONET, and they are participating in several demonstration projects. The top two, Hitachi and Toshiba, are especially important, and the importance of NEDO is also clearly seen. The large utilities, as we can see, are not centrally connected in the smart grid social network.

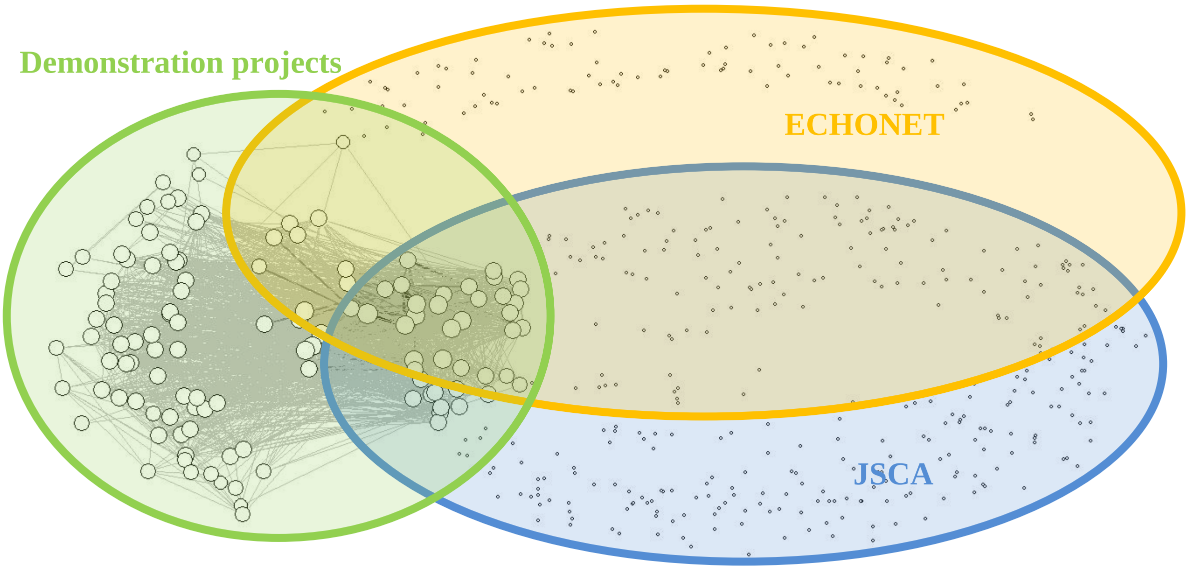

Figure 2 – Illustration of the Japanese smart grid social network

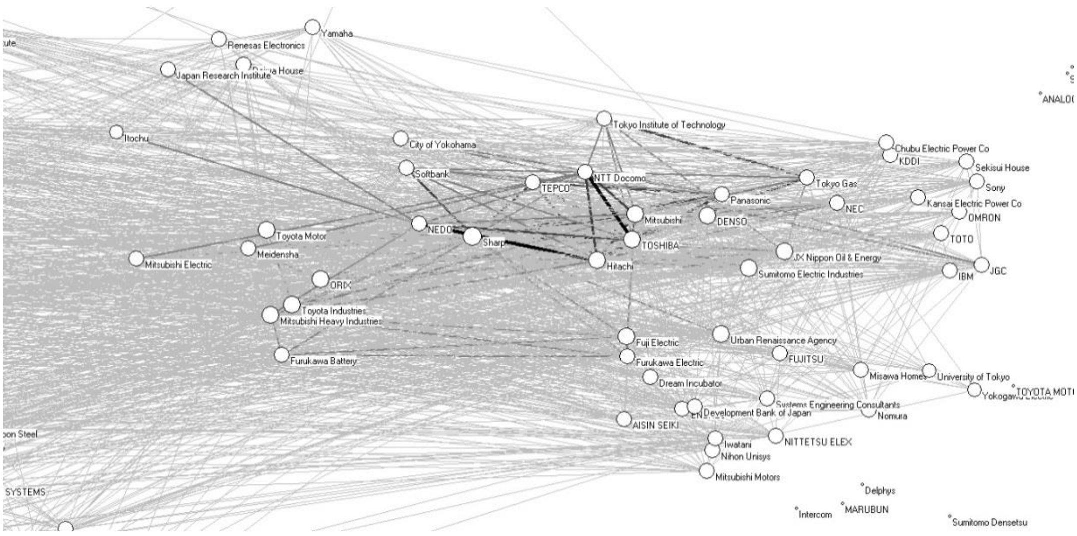

Figure 3 – Enlargement of central area of illustration of Japanese social network

iii. Functional Technology Areas

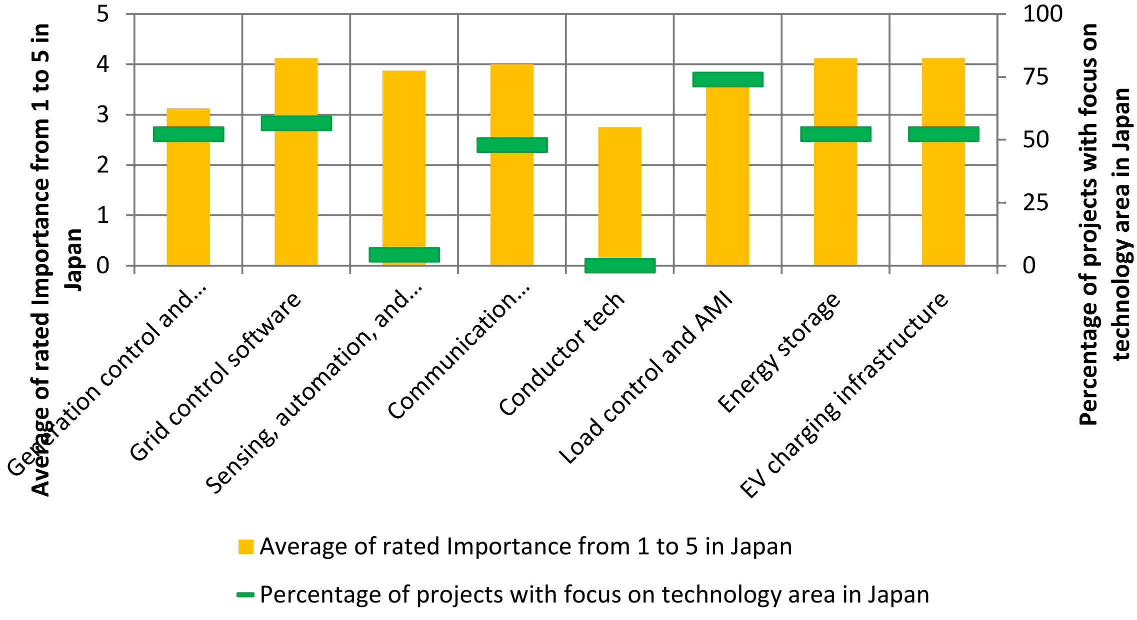

Figure 4 – Graph of respondent evaluation of importance of different functional technology areas and percentage of projects focusing on those areas in Japan.

Compared to the responses from the USA, there was some disagreement about the functional technology emphasis of smart grid in Japan. One interviewee argued that the focus on HEMS and the smart house concept in Japan is different from how smart grid is generally envisioned in Europe and the USA. In Japan, the close link to the smart home area which a HEMS creates will create a more end-user oriented smart grid with a more diverse spectrum of services given to electricity end users. Embedded grid sensing and infrastructure automation was seen as already existing.

iv. Visions

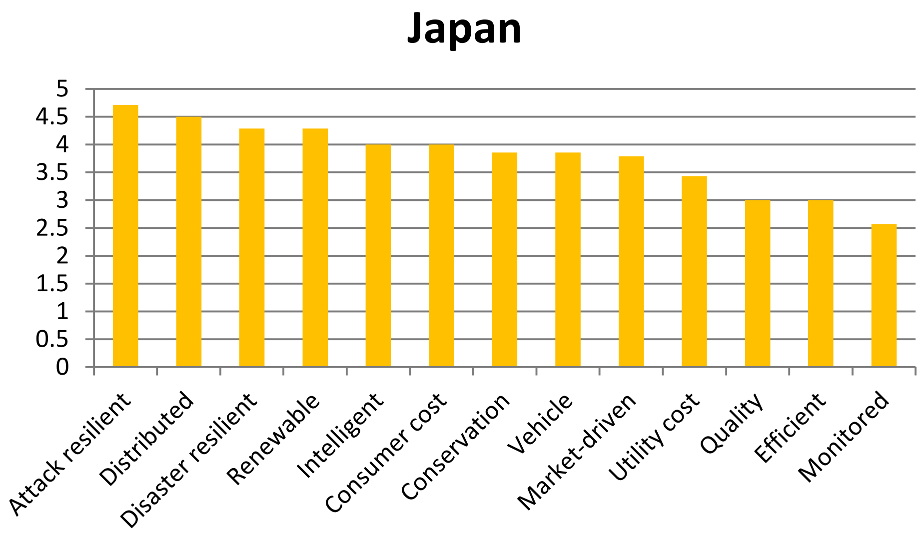

Figure 5 – Graph of respondent evaluation of importance of different visions for smart grid innovation in Japan.

Many respondents argued themselves that while there is a shared understanding about the basic concept and desirability of smart grid, the emphasis varies much between different stakeholders.

Many respondents argued that disaster resilience was not a primary goal of smart grid in Japan, at least not a selling value proposition, because disaster resilience is already a deeply entrenched goal within the electricity grid. This view has some resonance with the utility perspective prior to Fukushima, that smart grid is not really necessary in the Japanese context, because resilience is already achieved.

Energy conservation was, many respondents noted, not very important prior to the Fukushima disaster, but has come to become very important in the wake of the energy crisis and because of the rising price of fossil fuels and electricity in Japan. One respondent argued the same had happened with peak shaving and allocative efficiency.

The importance of cost-effectiveness has been relatively decreased, some respondents argued, because of the energy crisis after Fukushima, and the large uncertainties about the future market structure of the electricity system. Other respondents argued that cost-efficiency has become the most important value of smart grid after the Fukushima disaster, because of the steep increase in electricity prices.

Efficiency sells to the private sector. Resilience sells to the public (new public actors!)

v. Process situation

1) Knowledge creation and diffusion

Overall the respondents had moderate views about the situation within the knowledge creation and diffusion sub-process. The Smart City projects were named as especially important collaborative platforms in which novel technology assemblages could be tried out. The biggest obstacles identified here related to the lack of funds from utilities, discussed later under the resource mobilization sub-process and the insecurity about future markets, discussed later under the market creation sub-process. Some respondents argued that the tightly knit groups doing the Smart City projects are producing valuable knowledge, but the sharing of that knowledge will possibly be limited. For a more rapid pace of innovation, the sharing of information must go beyond the large corporations involved in the Smart City projects.

Within the end user interfacing smart house and appliances sector, a slightly different situation was identified. The knowledge creation has proceeded further and diffusion platforms were seen as better developed, especially after the Fukushima disaster when the government started to promote standardisation and give some subsidies to consumers for purchasing HEMS.

2) Societal guidance

The respondents generally found that the performance of the social guidance sub-process is not slowing the pace of smart grid innovation in Japan. As stated before, the respondents argued themselves that while there is a shared understanding about the basic concept and desirability of smart grid, the emphasis varies much between different stakeholders. NEDO was identified as the most important consensus-seeking stakeholder, and with NEDO controlling the funds for the most important smart grid demonstration projects, the organisation has a lot of possibilities to influence the emphasis of projects. There was also identified a different perspectives about the value proposition of smart grid technology, especially between the utilities and the vendors of grid equipment.

3) Entrepreneurial experimentation

A lack of entrepreneurship was identified by almost all respondents. While the established large heavy manufacturers are making efforts to tap into new markets, the current monopolistic market structure and the uncertainty about future markets is keeping entrepreneurship down. Commenting on the Smart City projects, a few respondents argued that the concentration of activity around a few large corporations will not stimulate the full potentials of entrepreneurship. The Smart City projects also have no post-project plans, and thus there is also a shortage of entrepreneurial spirit in those projects, one respondent argued. New entrants are few, and smart grid is seen as the reserve of the established industrial giants, which is partly explainable by that small utilities do not exist in Japan, and they have relatively homogenous grids over their service areas. The potential for new entrants is seen mostly on the software side, especially with the coming of big data after smart grid roll out.

Again the smart house and appliances sector shows a different picture. The smart house and appliance sector has more involvement from smaller firms, as well as the Japanese industrial giants. The high-end real estate development industry is very involved in this innovation system, especially in creating markets for end user interfacing smart grid technology.

4) *Market creation*

The creation of a market for smart grid technology is seen as problematic by most of the respondents, mainly because of the current electricity market structure and the uncertainty about the future market regulation. While a very limited market already exists, it is still in a very early stage and many respondents commented that the uncertainties about the current set-up of the electricity market make investors wary.

In the smart home and appliances sector, the market has developed further and some demand is seen. Residential developers have been key to popularizing smart home and smart grid application. However, the residential developers who engage with the smart home concept only cater to the upper income groups, and HEMS remains expensive (Mochizuki, 2013). The high prevalence and popularity of residential PV in Japan was also seen as a driver for the smart house market. However, the FIT scheme was argued by one respondent to actually have dampened the market for some smart appliances. This is because lead users have been likely to invest in residential PVs, and the FIT guarantees a high return for electricity sold to the grid from that PV. That has meant that end-users of electricity would rather sell electricity from PVs to the grid rather than use it themselves, and then buy back electricity.

5) *Creation of legitimacy*

The creation of legitimacy was not seen by the respondents as a problematic area for smart grid innovation in Japan. There is still not much knowledge about smart grid among the population of Japan. Some of the respondents portrayed the residential end consumer of electricity as negative to smart grid technology. As of yet there is little discussion about the technology, but this might change with the TEPCO smart meter roll-out commencing in 2014.

The core stakeholders are seen to be convinced about the general desirability, but the value proposition is contested. For the government, smart grid has a strong legitimacy, and the promotion of smart grid is seen as part of Japan's response to the energy crisis. Some interviewees argued that utilities are not enthusiastic about the smart grid concept and would rather premier a more traditional vision for the Japanese grid, with emphasis on central control, but that this doesn't have much importance as utilities have very little influence over public discourse in the post-Fukushima period. One respondent stressed that cost-efficiency, a key selling point now, will not be enough to convince the end users in the short run, because cost-efficiency will only go so far. Rather, there needs to be a focus on the qualitative benefits of smart grid technology.

One respondent argued that the electricity system has come to embed important moral and political dimensions in the post-Fukushima period. As the energy crisis followed the Fukushima disaster, TEPCO and other utilities had to use planned outages to maintain grid stability. The method used for these planned outages, which mostly affected less affluent areas outside of the capital, was perceived by many as unfair. Technology and market schemes that would set up clearer rules for such events are demanded by those end-users.

In the smart house and smart appliance sector, the situation is seen as less problematic. Some respondents argued that the smart appliances are appreciated by consumers, and generally seen as being ethical purchases.

6) Resource mobilization

Generally, the respondents identified more obstacles within the sub-process of resource mobilization than drivers. The funding provided by METI and NEDO to smart grid projects was identified as an important stimulus for smart grid innovation, especially through funding the Smart City projects.

As especially the respondents who were connected to the utilities emphasized, the utilities have very low financial capabilities after the Fukushima disaster. This has directly affected their existing smart grid engagements, and this has particularly affected funding. The activities of utilities that are still on-going are mostly funded by government grants. Therefore, government funding is therefore very important for keeping the momentum.

Heavy industry in Japan is also strapped for cash, one respondent argued, and this, combined with uncertainty about future market, is putting some restraint on activities.

7) Development of positive externalities

The development of positive externalities was identified by many of the respondents, and most saw positive dynamics benefiting smart grid innovation. The most important adjacent innovation area identified was smart home and appliance technology. This sector, although by some definitions part of smart grid technology, has developed faster. The appliance manufacturers, who also have interests in the grid equipment market, are the most important stakeholders within smart grid innovation.

EV innovation was also mentioned as an important related innovation area. However, many respondents thought EV innovation is at too much of an early stage to be contributing significantly, and some expected that EV innovation will benefit more from smart grid innovation than vice versa.

Renewable energy development was a third frequently mentioned adjacent innovation area. Some respondents argued that the influence of renewable energy is still small because utilities are allowed to limit the amount that can be connected to the grid.

Hokkaido. Other mentioned innovation areas were smartphones, big data, robotics and industrial automation.

8) End user engagement

The respondents largely dismissed the influence of end users other than large scale industrial end users of electricity on the process of smart grid innovation, or lamented the lack of consideration of the perspective of the end user. Many respondents referenced to the “community oriented” nature of the Japanese electricity industry, and dismissed market based business models as being foreign to Japan. One respondent argued that virtually no stakeholder in smart grid innovation in Japan argues for the ability of end users to direct the path of innovation.

There are two prominent ways in which the end-users of electricity are cast in the Japanese smart grid community.

One way is the end-users of electricity as consumers of technology. These consumers have the economic power to provide benefits both to the vendors who sell the technology, and to society in general as their green consumption will lessen their environmental impact, and will stimulate the Japanese economy. The degree of consumer participation in projects is often thought of as how many want to buy the appliances, such as in Yokohama[98].

In this cast, cost and identity are the prime motivators of the end-user. According to a recent survey, Japanese end-users are some of the most cost-conscious in the world[99]. For example in the case of Yokohama’s smart city project, cost mattered much for both private households and companies in joining smart grid activities. The introduction of new subsidies from the central government made it much easier for Yokohama city to

[98] *(Uetake, 2013)*
[99] *(Accenture, 2010)*

find partners interested in using HEMS and BEMS[100]. METI's hope that commercial spin-offs of smart grid services will lure consumers to engage with smart grid technology also has an important cost-rationalism aspect[101].

The positive image of green consumption is also sellable in Japan for a premium price, which is evident in how real estate developers such as Mitsui Fudosan and Sekisui house have become important actors.

The other way is the end-users of electricity as local citizens. All of the smart community projects and almost all smart grid projects in Japan have a broad portfolio and a strong emphasis on the local area.

Before the Fukushima disaster, there existed demand response functionalities, contracted to large-scale electricity end users. At this time, however, the frequency of demand response events was thought to be very rare, of the order of 1 event per 10 years. After the Fukushima disaster, demand response events have been frequent. Under these circumstances, there is interest from the utilities in achieving more advanced demand response functionalities, including automated demand control and innovative market schemes for small-scale end users. This is also seen as an area where utilities will have to compete if the market deregulates[102].

vi. Semantic analysis

As described in the Methods chapter, a search for academic journal abstracts with the key word smart grid was done on the Web of Knowledge database, with a filter selecting only papers with affiliation to an institution in the USA. The results were manually screened to only allow abstracts where the topic was related to electricity smart grid technology. The resulting corpus was analysed using FullText, TextSTAT, KH Coder

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[100] *(Uetake, 2013)*
[101] *(Kasama, 2013)*
[102] *(Okamoto, 2013)*

and Pajek, to identify the most commonly occurring words in the corpus, and the most common co-occurrences of different words. Using Pajek and KH coder, the results were visualized as semantic networks, where more commonly occurring words are represented with larger nodes, and close position and a connecting edge means a high level of co-occurrence.

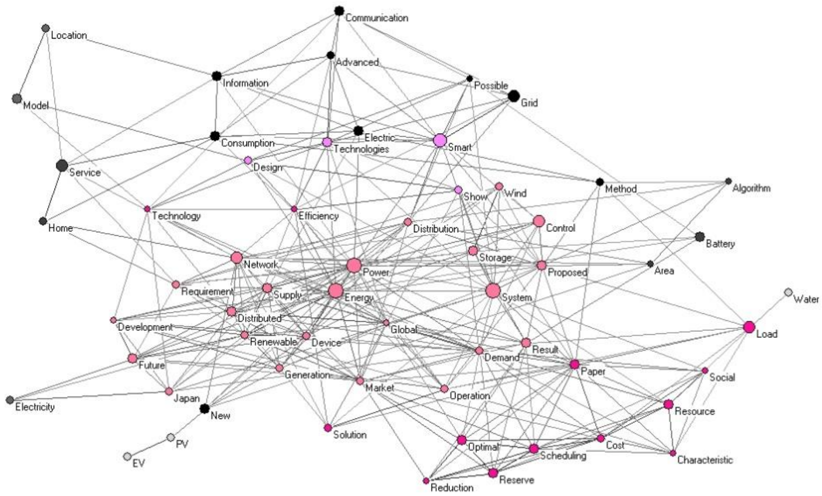

Figure 6 – Representation of the 60 most common words in academic journal abstracts with the key words smart grid and affiliations to institutions in Japan

The most important key words for smart grid-related academic research in Japan were found to be "energy system" and "power system". The "smart grid" concept itself is not at the very core of the discourse, but occupies a quite central role. Other core terms include "renewable energy", "distributed energy" and "energy storage". Other important concepts are obviously distributed generation, the creation of new service markets, EV charging infrastructure, energy storage and security. At the edges of the central discourse, there are some strong relationships. "Home" and "service" are strongly to each other and to "consumption", probably relating to smart home functionalities. Concepts such as "social", "cost", "load", "reduction", "reserve" and "optimal" form a separate cluster, probably showing a discourse on macro-level economic benefits of smart grid technology. A third semi-cluster can be seen around the concepts “smart grid”, “communication” and “technologies”.

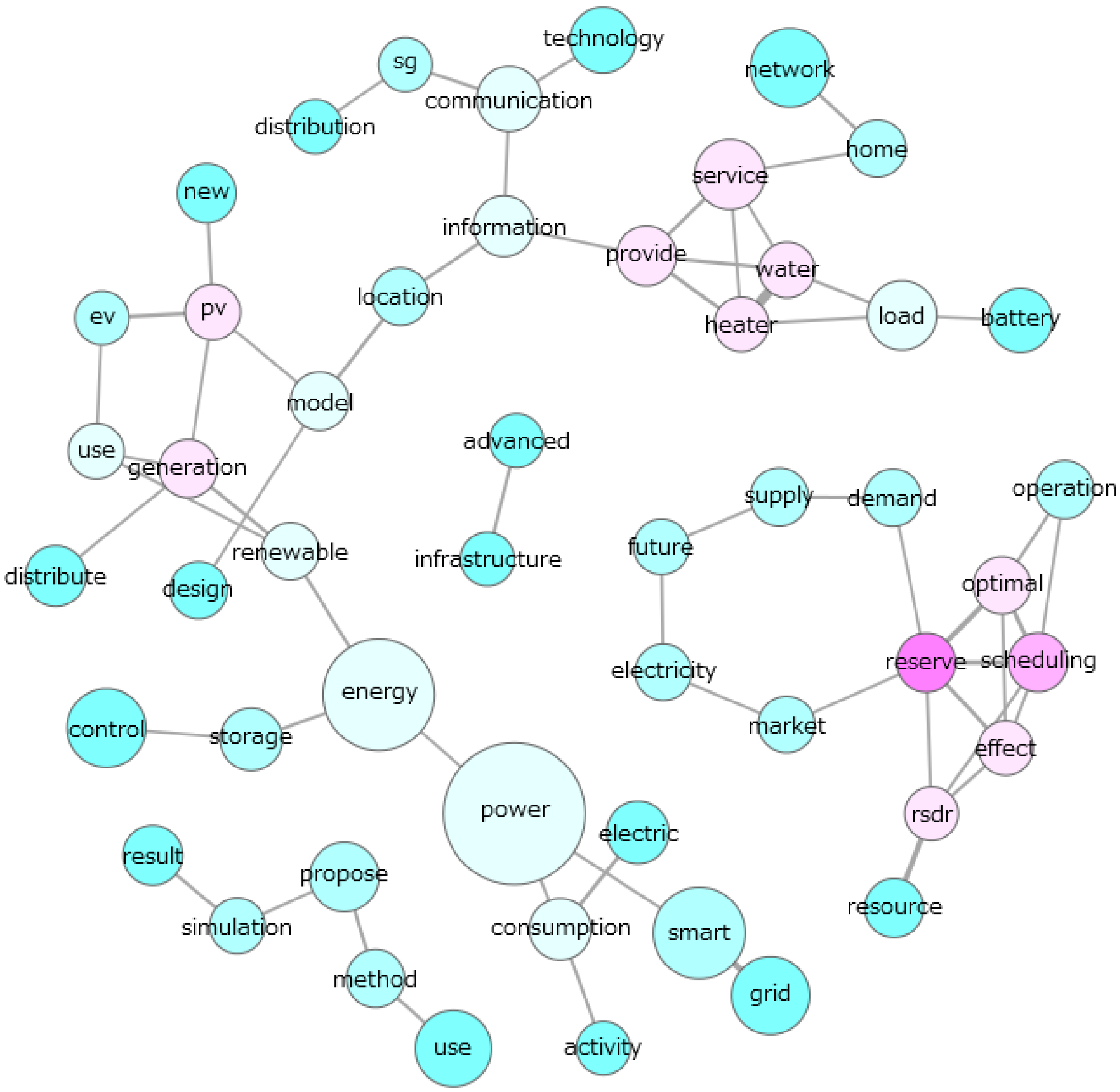

Figure 7 – Representation of the most common co-occurrences of words in academic journal abstracts with the key words smart grid and affiliations to institutions in Japan

A similar analysis using KH coder, which picks out the most relevant correlations instead of the most commonly occurring words, shows a similar result. There is a wide range of discourse, with distributed generation, energy storage, water heater, electricity market, communication technology, PV generation and EV use.

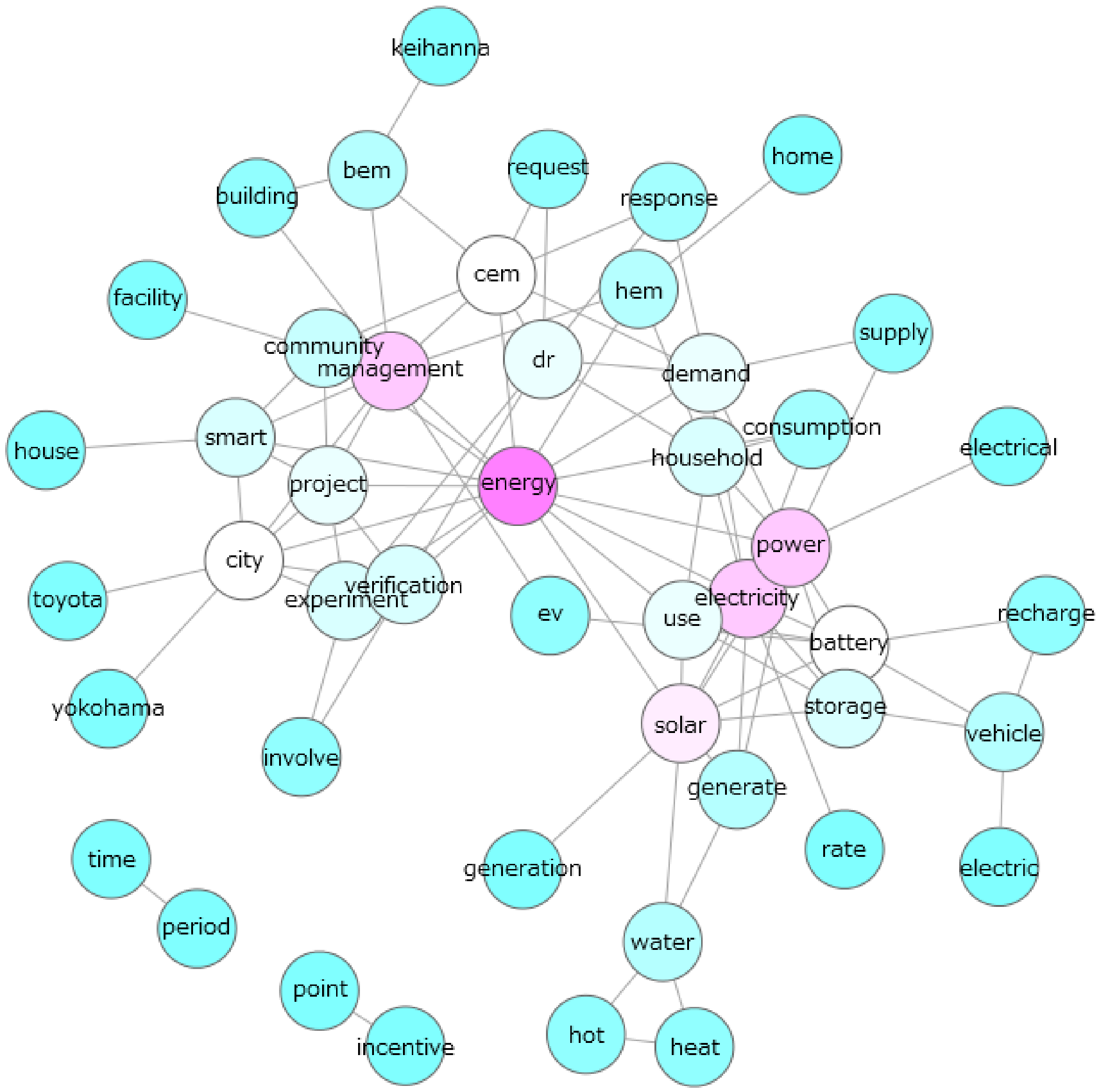

Figure 8 – Representation of the most common co-occurrences of words in the documentation of the Japan Smart City projects

An analysis of the documentation of the 4 Smart City projects shows much similarity with the analysis of academic abstracts. There is a diversity of the discourse, with energy management systems, energy storage, electric vehicles, hot water, and solar generation all present.

USA

vii. Policy environment

1) Market regulation

The USA was the birthplace of the commercial electric utility, and today over 3000 electric utilities of different shapes and sizes serve the world's largest economy[103]. The utilities can largely be separated into three categories. The most important group is the investment owned utilities that are few in number, often large, serve some of the most densely populated areas of the USA and are privately owned. The second most important group is the public utilities, which mostly serve urban areas, are usually small in geographic scope, and are owned by local authorities. The third, least important of the three groups are electric cooperatives, normally serving sparsely populated rural areas, and are owned by the electricity consumers. The two last categories mostly lacked generation capabilities before deregulation[104].

[103] *(O'Sullivan & Brévignon-Dodin, 2012)*
[104] *(Joskow, Deregulation and Regulatory Reform in the U.S. Electric Power Sector, 2000)*

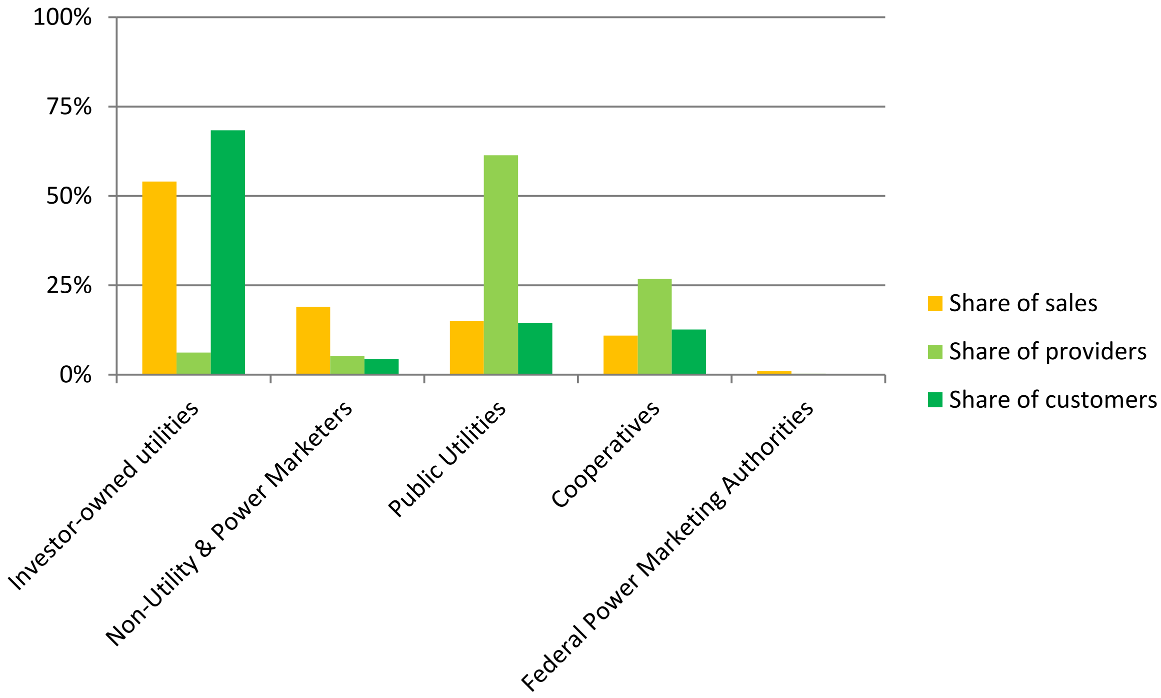

Figure 9 – Graph illustrating the distribution of utilities in the USA
Data from (Energy Information Agency).

Fossil fuels sources provide the large bulk of electricity supplied, with coal providing the largest share. Compared to the OECD average, US energy prices are low.

Energy policy is divided on the federal, state and local level in the USA, with the state level being the most important one. The electricity sector is regulated by the Department of Energy (DoE), the Environmental Protection Agency (EPA), and the Federal Trade Commission on the federal level. Inter-state electricity transmission is also governed by the Federal Energy Regulatory Commission (FERC). Electricity distribution is governed by the Public Utilities Commissions of the separate states.

Deregulation of the American power industry started in 1978, when limited market for generation capacity was created by the Public Utility Regulatory Policy Act of 1978. By 1991, this had developed into a market where utilities could choose from competitive bids of independent generation companies[105]. In 1996, a further market was created by order 888 of the FERC, which required transmission owners to allow open access to transmission services at cost-based prices. In 1999, FERC announced new rules that strongly promote the creation of regional transmission organizations, which makes it much easier to make long-distance transmission transactions and further divorces transmission from the other functions of utilities[106]. On the distribution and retail side, the states have proceeded with deregulation at their own pace, which has created a much fractured market in the USA. First was California, which in 1996 introduced new legislation which gives all end-users of electricity a theoretical option to choose electricity service provider, demands open access to all transmission and distribution networks to electricity service providers. Moreover, the cost of generation was unbundled from transmission and distribution. Deregulation was further pursued unevenly in different states, with Texas representing the most deregulated extreme, and some states in the south particularly did not deregulate from vertically integrated utilities significantly[107]. Market deregulation has brought a dynamic which incentivises utilities to achieve maximum efficiency for maximum profit[108].

2) *Origins of smart grid*

Smart grid R&D arguably started with EPRI's Intelligrid project in the early 2000s. Some events and processes of the 2000s spurred heightened interest in the electricity grid in the USA. Particularly, the Northeast blackout in 2003 was an important event that highlighted the vulnerability of the electricity system, and the ongoing debate about climate change mitigation policy created an overall concern about the current state of the electricity system.

[105] *(Joskow, 2000)*
[106] *(Joskow, 2000)*
[107] *(Joskow, 2000)*
[108] *(Zio & Aven, 2011)*

3) Government promotion

Smart grid is taken very seriously by the federal government[109]. The Energy Independence and Security Act of 2007 mandates roles for NIST, DOE and FERC within smart grid innovation[110]. In 2009, the United States Congress enacted the American Recovery and Reinvestment Act (ARRA), which was the greatest effort of the US government to counter the on-going Great Recession to date. Relying on Keynesian macroeconomic theory, the ARRA aimed to expand the aggregate demand of the US economy through increased public spending. The focus areas of ARRA (in descending order of importance) were tax relief, state and local fiscal relief, infrastructure and science, protecting the vulnerable, health care, education and training and energy. The total amount spent on energy related activities totalled at around $46 billion, with the largest posts being radioactive waste decontamination, loan guarantees for renewable energy, weatherizing low-income housing and grid modernization, including smart grid activities. The total of smart grid investment program under the ARRA was approximately $4.5 billion, and most of those funds had been spent by summer 2013[111].

4) Standardisation

The US standardisation landscape has been described as "decentralized, diverse and private sector-led"[112]. However, the government has played an important role in the smart grid sphere, and continues to do so. The American National Standards Institute (ANSI) and the National Institute for Standards and Technology (NIST) are the two most important actors within standardisation in the USA[113]. ANSI is a non-profit membership organization with members from the private sector, academia, government agencies and individuals. ANSI acts mostly as a forum for discussion, and a regulator of the framework

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[109] *(O'Sullivan & Brévignon-Dodin, 2012)*
[110] *(O'Sullivan & Brévignon-Dodin, 2012)*
[111] *(Pew Center on Global Climate Change, 2009)*
[112] *(O'Sullivan & Brévignon-Dodin, 2012)*
[113] *(O'Sullivan & Brévignon-Dodin, 2012)*

of standardisation[114]. NIST is a federal agency under the Department of Commerce. The standardization of smart grid technology is in many ways an extension of existing standards, but the work for standards under the concept of smart grid started in 2007, when NIST was given an unfunded mandate by the president to start investigating the needs and potentials for smart grid standards. NIST asked the Electric Power Research Institute (EPRI) to develop a draft for a standards roadmap. After consultations with a broad range of stakeholders, a roadmap was drawn up with was released in 2010 as the NIST Framework & Roadmap for Smart Grid Interoperability Standards[115]. An update was released in 2011. This document contains a clear vision for smart grid in the USA, and identifies areas where standardisation efforts are necessary[116]. (O'Sullivan & Brévignon-Dodin, 2012) find that the exercise of making the NIST Framework & Roadmap forced different kinds of actors together, which resulted in better communication between them. The involvement of the government through NIST has thus probably accelerated standardisation and innovation in the USA. Out of this process was created the Smart Grid Interoperability Panel, a private-sector led organisation furthering standardisation. The interoperability panel was initially funded by the federal government through ARRA, but support has decreased and as of 2013 most of the activities are financed through membership fees.

The stakeholders involved in standardization has somewhat shifted. At first, mostly vendors were committed, as they saw the commercial potential first. Utilities started to get involved as the national push for smart grid came in 2008 and 2009, which also brought in the regulatory organizations on the state and federal level, as well as IT and ICT companies eager to benefit from the opening markets. Recently, utilities have become

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[114] *(O'Sullivan & Brévignon-Dodin, 2012)*
[115] *(O'Sullivan & Brévignon-Dodin, 2012)*
[116] *(NIST, 2012)*

slightly less active in the standardization process, as it has become clear than a strong regulatory push is not coming, and that smart grid is for now voluntary for the utilities[117].

Compared to Japanese standards organizations, the work of American standards organizations is more focused on the interface between different components within the smart grid, rather than standardizing the function of the system as a whole[118].

In the US, the main focus areas now are connecting different communication networks that have been developed on the transmission, distribution and consumer unit levels. One example is a common protocol for DR signals across the transmission-distribution-consumption domains is a topic that is in focus in 2013. There is a trend towards harmonization, but there remain interoperability problems[119]. However, there seems to be little concern among experts about the pace of standardization or proliferation of equipment with diverging specifications.

viii. Structural analysis

A social network analysis was made using 199 projects in the SGI Clearinghouse database. A social network was modelled in which each joint project was treated as a connection, and organisation membership was treated as one connection to the organisation vertex. Table 7 below shows the most connected vertices according to the betweeness measure, or how important linking points the vertexes are for other vertices. The other indicators include degree (number of connections of vertex), average reciprocal distance (a measure of average distance between the vertex and any other vertex) and Eigenvector centrality (the influence of the vertex on the centrality measures of all other vertices).

[117] *(Wollman, 2013)*
[118] *(Wollman, 2013)*
[119] *(FERC, 2012)*

Table 7 – Top 20 Betweeness Vertices in USA Smart Grid TIS Social Network

	Type	Degree	ARD	Eigenvector	Between
EPRI	Research institute	28	194.8334	0.113018	7995.122
GE	Electronics giant	29	199.6667	0.122854	7513.267
Sensus	Meter vendor	17	178.0835	0.048041	6957.279
Landis+Gyr	Meter vendor	17	186.2501	0.086227	3986.014
Southern California Edison	Electric Utility	16	181.8334	0.069304	3706.082
IBM	Software vendor	26	189.8333	0.133678	3650.072
Pacific Gas & Electric Company	Electric utility	15	143.1001	0.022026	3307.329
Premium Power	Infrastructure vendor	8	135.2502	0.013672	3255.385
Aclara	Infrastructure vendor	10	170.0001	0.049314	2633.994
Eaton	Infrastructure vendor	12	175.3334	0.065682	2546.157
PJM Interconnection	RTO	8	174.25	0.055321	2383.878
Itron	Meter vendor	10	177.25	0.062162	1970.951
Navigant	Consultancy firm	4	169.5833	0.051425	1970
Science Applications International	Infrastructure vendor	8	105.0667	0.001076	1970
Oncor	Electric utility	19	183.4167	0.12121	1877.981
DTE Energy	Electric utility	2	165.5	0.041463	1749.594
Cooper Power Systems	Infrastructure vendor	8	178.2501	0.07408	1740.068
American Electric Power	Electric utility	18	188.5001	0.134307	1677.09
S&C Electric	Infrastructure vendor	12	148.4667	0.038026	1660.706
Austin Energy	Electric utility	8	138.0169	0.020919	1580

As can be seen from the table above and the illustration below, the most important actors are EPRI and GE, accompanied by metering vendors, utilities and infrastructure engineering companies. The core stakeholders are mostly members of both the GridWise Alliance and SGIP.

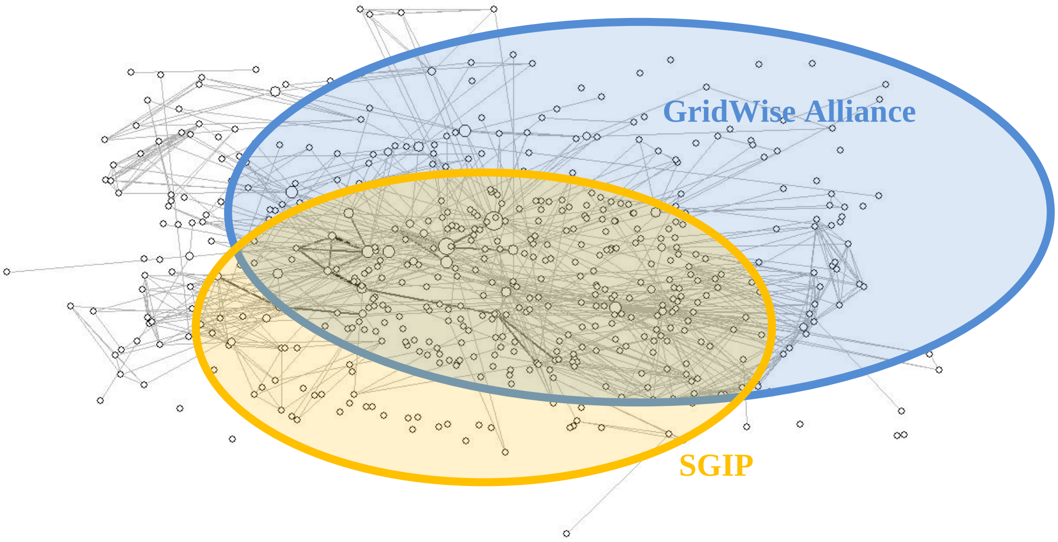

Figure 10 – Illustration of the smart grid social network in the USA

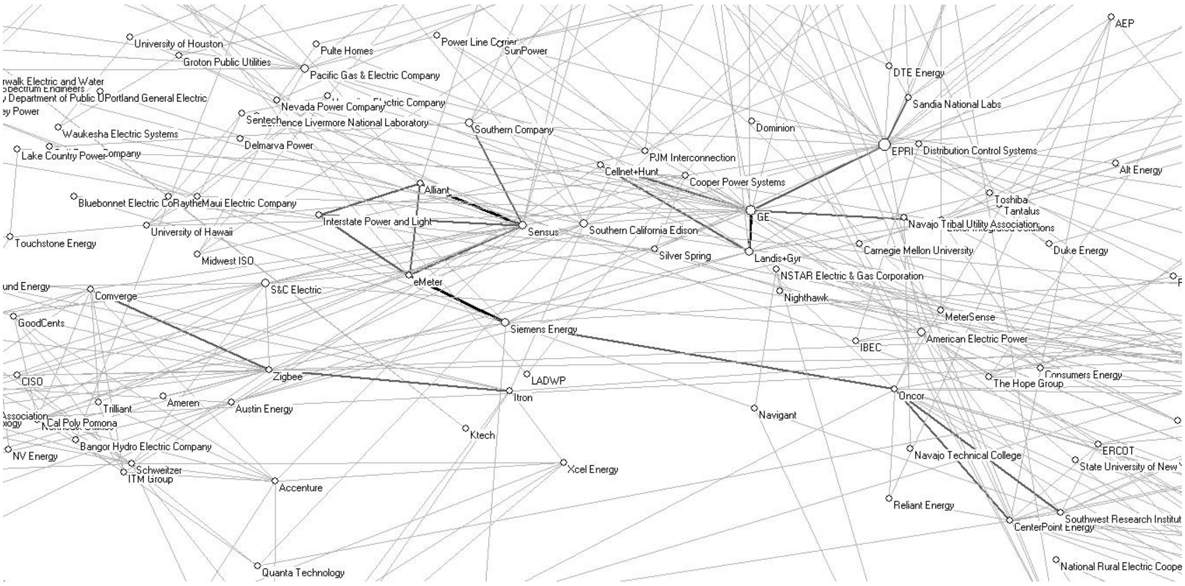

Figure 11 – Enlargement of central area of illustration of smart grid social network in the USA, with isolate vertices hidden

1) Actors

Government actors

The DoE is the primary strategic actor of the federal government within the smart grid TIS, while FERC holds an important regulatory position, with some strategic activities. The DoE's most active engagement with the smart grid TIS is through the work of NIST, which has been providing leadership in visioning and standardization, and helped to create collaborative networks. The administration of ARRA funds directed towards smart grid was also administrated by the DoE. In local authority areas where utilities are public, the local authorities play an important role in guiding the strategy and allocation of funding for smart grid activities.

Vendors

Heavy electric manufacturers such as GE, ABB and Siemens are important actors in the US smart grid TIS, as they aim to develop markets for more complex grid equipment. Other very active stakeholders are the makers of smart meters, such as Elster, Landis+Gyr and Sensus, as they are serving the most active market segment of the US smart grid TIS.

Academic actors

Many academic institutions with activities within computer engineering or power engineering have an active engagement with smart grid innovation.

Utilities

The majority of smart grid projects taking place in the USA are being led by utilities. The most activity can be found in the deregulated markets such as California, Texas and the Northeast. Especially large IOUs and public utilities in urban areas with a citizenry inclined towards progressive policies are active stakeholders.

2) Networks

GridWise Alliance is a private-sector led organisation established in 2003 to provide a forum for different stakeholders within the electricity system to influence decision-makers. Its membership numbers 42[120], many of whom are the most influential stakeholders in the smart grid TIS such as large IOUs, the DoE and smart meter vendors.

[120] *As of 11 November 2013*

As stated earlier, the Smart Grid Interoperability Panel (SGIP) was established through the NIST-led governmental inquiry into the standardisation needs within smart grid technology. The membership of SGIP is broad, and currently 204 members are listed[121].

ix. Functional Technology Areas

The interviewed experts were asked to rate their perception of the relative importance of different functional technology areas of smart grid, on a scale from 1 (not important) to 5 (very important). The classification of functional technology areas was taken from the IEA. The respondents were relatively unanimous about what the focus technology areas of smart grid are in the USA today.

The graph below shows the average ratings compared to the percentage of the projects in the SGI Clearinghouse database with a focus on the corresponding technology area. As can be seen, there is some correlation between the two indicators. Clearly, advanced metering and load control is the most important aspect of smart grid in the USA so far. Also, the results indicate that generation side technology, energy storage and EV charging infrastructure are relatively less important, and conductor technology and approaches is not as important within smart grid technology as it is seen in for example

[121] *As of 11 November 2013*

China.

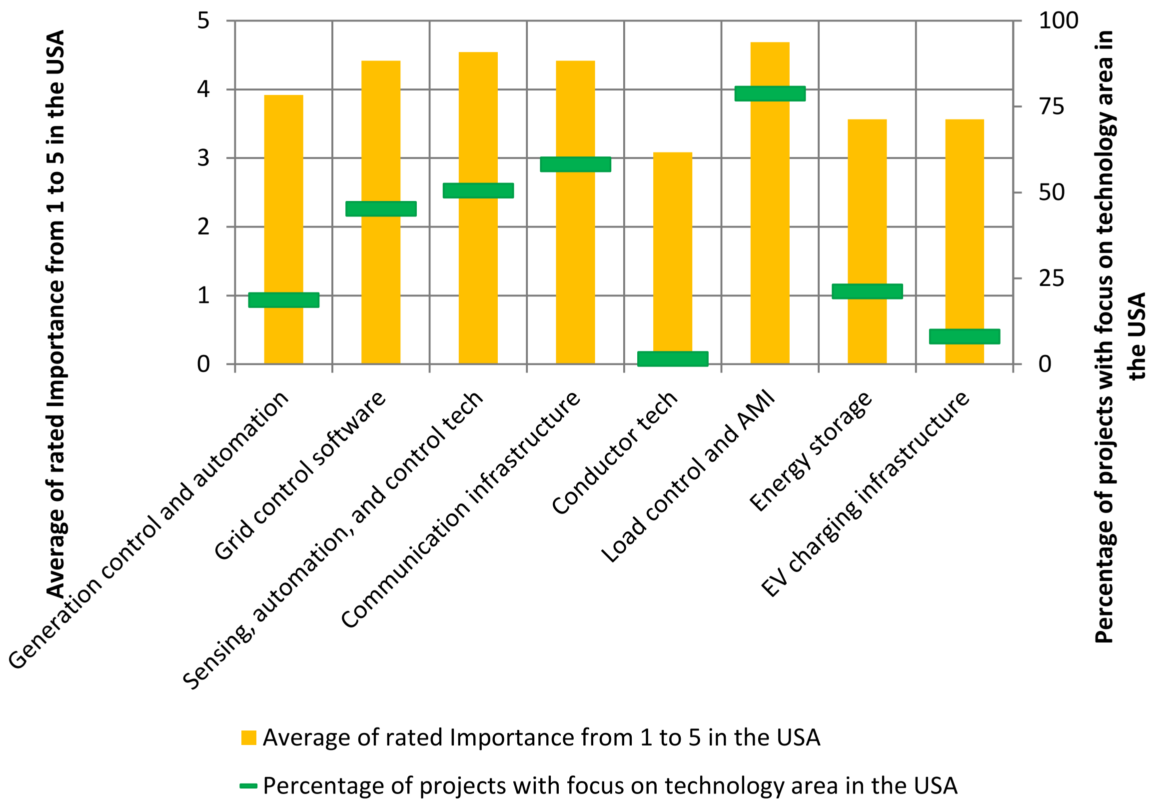

Figure 12 – Graph of respondent evaluation of importance of different functional technology areas and percentage of projects focusing on those areas in the USA.

Electrical load control and advanced metering was seen as important or very important by all respondents. Advanced computing and grid control software, embedded grid sensing and automation and communication systems were all seen as important or very important by 92% of respondents. These results show the high significance of smart meters and grid sensing in the US innovation system. Most activity so far has focused on the digitalization on the grid, especially metering, infrastructure monitoring and maintenance. This is nothing short of a revolution for utilities, which can cut down cost significantly by applying these technologies.

50% found energy storage moderately or not very important, and 58% thought the same about EV charging infrastructure. Most of the respondents giving such responses justified them by arguing that the rate of diffusion of EVs is still much too small for EV charging infrastructure to be taken seriously by utilities. A low importance of energy storage was often explained by lingering technical limitations to storage applications. However, a few respondents identified energy storage as “trending”, and rising to become one of the core aspects of smart grid.

The technological area rated lowest by respondents was conductor technology and approaches. Along with electricity generation control, automation and power electronics, conductor technology was often identified by respondents to be “already there” and therefore not an area with high importance today.

Advanced metering seems to be the most important aspects of smart grid in the USA. Smart meters have been the focus of smart grid projects up until now, and the progress has been fast. In 2012 the rate of penetration of advanced meters in the USA was estimated at 22.9%, with leading utilities reaching 80-99% penetration[122]. In spite of some protests, smart meters have been accepted by most consumers and utilities alike. In California, the roll-out of meters was done by the big IOUs without much consideration of the effect of consumers, and therefore communication was not prioritized. The resulting confusion among consumers helped create the situation that led to a legal requirement for an opt-out option[123].

The possibility to opt-out of smart meters concerns the retail sphere and is thus regulated on the state level. Allowing a few opt-outs could mean great costs for utilities, as staff cost per customer will go up very steeply if only a few customers require manual readings. Therefore, many public utility commissions (PUCs) have seen the issue as a balancing of consumer concerns and increased cost for utilities. In California, this resulted in a legal obligation to provide an opt-out program, but with the consumer paying for the

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[122] *(FERC, 2012)*
[123] *(Sullivan & Kahn, 2011)*

additional cost incurred by the utility. In Vermont, charging for opt-out has been outlawed[124]. These differences illuminate the wide range of political options in the question of how to distribute the cost and rights for grid maintenance and modernization. While this political question will be answered differently in different places, it is unlikely going to change the equation about smart meters. Opt-out programs have had very low enrolment rate, for example in the Portland General Electric program only 4 out of 720 000 chose to opt-out as of 2012[125]. This indicates that opt-out programs are not necessarily very costly for utilities while providing consumers a higher level of protection of rights. Overall, utilities have embraced smart meters because of the short-term cost-cutting they enable.

The second area in which smart grid activities seem to focus is on infrastructure sensing and automation. Both of these areas have short-term payoffs for the utilities, the actor with the highest economic stake, and therefore the step to deployment is much easier. Moreover, these two technology areas are not transformative technology. Rather, they improve the function of the grid as it currently works.

[124] *(FERC, 2012)*
[125] *(FERC, 2012)*

x. Visions

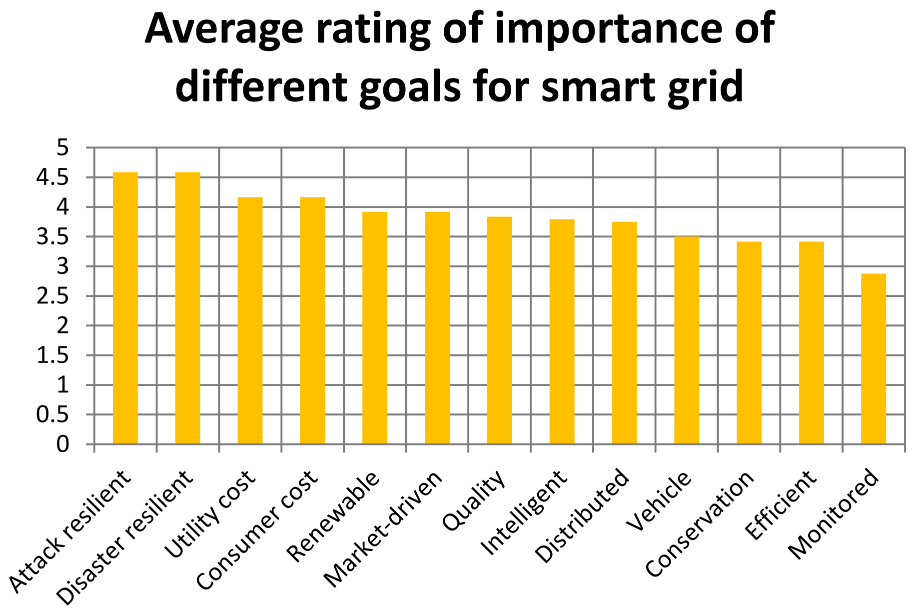

Figure 13 – Graph of respondent evaluation of importance of different visions for smart grid innovation in the USA.

The level of agreement about visions for smart grid within the USA smart grid community was about the same as for importance of technology areas. 100% found disaster resilience to be an important or very important goal, and 92% thought the same of resilience against physical or cyber-attacks. This illustrates that security is a strong driver for US smart grid efforts. The second most highly valuated set of goals was those related to cost. Utility cost efficiency and consumer cost-efficiency was evaluated as important or very important by 75%. Higher quality of power and the development of a distributed energy system were evaluated similarly, but on average respondents thought these less important goals.

Two other goals that were rated highly were the goals of renewable energy integration, and free market restructuring, seen as important or very important by 67%. 54% of responses evaluated peak shaving as an important or very important goal. 50% found that the goal of overall energy conservation was only moderately or not very important. This was often explained by that the market structure of the American energy system does not incentivize energy conservation, at least not for utilities. Less transmission losses and higher grid efficiency was evaluated in a similar way, with the justification that transmission and distribution efficiency is already high. Only 42% evaluated electrical vehicle integration an important or very important goal. Improved consumption monitoring was evaluated as moderately important, not very important or not important by 75%. Overall this was the only goal that respondents found overall to be on the lower end of the scale. This is understandable, as electricity theft is not a major problem for American utilities.

xi. Process situation

1) Knowledge creation and dissemination

Overall, many respondents reported that the situation of knowledge production and diffusion was good in the USA. Some attributed this to the availability of government funding. About the aspect of knowledge creation, almost all interviewees thought that there are no major obstacles. “The technology […] mostly all exists and it now comes down to proper incentives to get it put in”, as one interviewee put it. There is however many gaps in practical knowledge, and barriers to experimentation, due to regulation. “The regulative nature of the electricity system in the US hinders innovation more often than otherwise”.

Two respondents argued that the anti-trust laws and IPL and defensiveness attitude to data sharing is slowing down innovation. “Every meeting of the GridWise Alliance starts with a reading of the antitrust guidelines. […] They cannot share information. For engineers that’s a problem. For politicians antitrust considerations are sacred in American law and those considerations will trump all others.” This view was however dismissed by other interviewees. On the other hand, some interviewees commented that the level of communication on between different stakeholder is reaching an unprecedented level, and results of R&D projects is widely disseminated, much thanks to the hype of smart grid and the plethora of forums that exists to spread information about smart grid innovation.

2) *Social guidance*

Many challenges were identified in the creation of societal guidance of smart grid innovation.

The high-level goals and overall desirability was understood by most important stakeholders. “Smart grid is such a high-level term and the actual what that means, the implementation, the priorities, is still pretty much nebulous”. The work of the DoE to establish a common vision was mentioned as having been important. One thing that is lacking in the USA is an overarching strategy towards an economy with a lesser environmental impact in the energy sector. Many respondents argued that such a strategy could act as an important catalyst for smart grid innovation. “We are not aligning our policies in light of carbon intensity”.

Many respondents felt that utilities, manufacturers and government was in a solid common understanding about smart grid and its desirability, and that the big challenges lay in convincing consumers about its desirability. “The actors from the utility, consulting, manufacturing and entrepreneurial perspective have a fairly good understanding of what [smart grid] is. Society does not at all”. So far, the smart grid discourse has been accelerating but mostly within the electric power industry itself. When vendors try to sell their equipment, it is the demand of the utilities which are most important, and communicating value with end-users of electricity is neglected. “You’re an entrepreneur and you come up with idea you want to sell to the utility. You’re not consulting with the consumer.”

A fair amount of ambiguity about the smart grid concept was reported. Many respondents were frustrated that much already existing technology with little novel services and certainly no transformative characteristics, was now touted as smart grid technology as a way to attract funding. “People are packaging old things in new packages […] the old players are still there and they are packaging what they were doing before as smart grid”.

Several respondents argued that the openness of the term also brought positive aspects such as more room for experimentation and inclusiveness. “The vision is not uniform, but that’s a good thing, not a bad thing. […] People who can really influence choose the definition which can fit their interest”.

The importance of the consumer perspective was generally seen as low, and almost all respondents mentioned lack of awareness among the general public, and poor communication between utilities and consumers as the mayor problems here. In some areas, informed consumers do create social support for green technology. Practically all respondents argued that utilities must show leadership and be much more proactive in communicating the benefits of smart grid, also non-monetary benefits, to customers.

3) Entrepreneurship

The monopoly holder needs to see a good short-term return of interest otherwise innovation will only be “paper-based”. The heavily regulated electricity market is not one in which consumer-led entrepreneurship is very likely. The need for new business models was repeatedly stressed. Until the implementation of smart grid can bring big benefits to the established players, it is unlikely it will move ahead. This means the remaining monopolies will need to change.

One respondent argued that a key to smart grid growth lay in opening the entrepreneurial possibilities of a “network of things” that HEMS and electrical appliances can create. If such systems and markets would develop, the service potential would win over most consumers, it was argued. A comparison with the way the iPhone enabled a new market for mobile software and thus became indispensable for many customers was made.

A utility respondent commented that there are a lot of entrepreneurs trying to pitch technology to utilities which are smart grid related. “The number of people who have started to contribute to this area is growing exponentially”. Smart grid is pulling actors who had long abandoned the grid as an area for innovation to start paying attention again, and the attention has brought in much more interest from start-up companies.

Some of the entrepreneurial activities of the utilities seem to be declining after the initial enthusiasm. “The membership of the GridWise Alliance has dropped significantly. Why? It’s because the cost of being a member and [the members] are not getting the bang for their buck that they were hoping to get.”

4) Market creation

Most interviewees had a moderate view of the development of a market for smart grid technology. Especially the technology which is non-disruptive, and can give utilities a return on their investment in the short to medium term is having a favorable market development, with the most important examples being AMI, grid sensing and automation. For smart grid functionalities going beyond DR and cutting management and maintenance costs, the value propositions of smart grid for utilities was seen as still too vague and not explored fully enough. The example of Boulder, Colorado, was mentioned as a case of making some utilities more defensive about smart grid functionalities. Concerning utility markets, it seems that the more deregulated markets are seeing more engagement among utilities. However, a more deregulated market is not necessarily good for smart grid innovation, it was argued, as having more long-term capacity market are would provide the incentives needed for some of the more advanced smart grid functionalities. “Capacity incentives in certain areas, especially mid-term capacity incentives, are pretty useful for a lot of these somewhat expensive but quick turnaround investments. Something like a demand response program really values a capacity incentive because it only takes a few years to build up a program but you need some money up-front”

Industrial and commercial end-users are showing a demand for DR functionalities if financial incentives are available.

A limited demand for residential end-user interfacing technology was also mentioned “[The market] is more driven by utilities [rather than electricity consumers], there’s no doubt about that. But we do still get consumer demand for some of the products such as in-house displays, smart thermostats and things like that”. More advanced end-user interfacing functions, such as smart appliances have been appearing, but some respondents argued that those had come with a high cost premium that was not understood by the consumer. A more suitable situation would be, one respondent argued, if the smart grid interface features were standardized and not paid for with a high premium, as the rewards for such early installment would certainly come with time. Overall, the lack of consumer interest in advanced smart grid functionalities is contributing to the focus on cost savings as the primary value proposition of smart grid in the USA.

For vendors of smart grid technology, the situation was understood differently. Many vendors have high expectations about the development of the smart grid market in the USA, and they see the smart grid concept as a useful vehicle to be able to market sophisticated ITC equipment to the electric power industry. However, high uncertainty about investments because of market fragmentation, and fickleness of regulators are seen as obstacles, and many vendors would invest more in R&D, it was argued, if there existed more guarantees of future markets and more uniform market conditions across the USA. Despite this, the vendors based in the USA are primarily targeting the domestic market, as it is seen as a good "laboratory" for trying out different smart grid functionalities in different regulatory and technological contexts. The respondents were divided on the issue of whether the current situation is to be portrayed more like a technology-push or market-demand scenario, with vendor-related respondents arguing more that the R&D of vendors is a response to a demand, formulated by both utilities and regulators.

Most respondents argued that the more sustainability-oriented goals such as energy conservation would not be pursued as long as the current business models for utilities endure. "Until people take notice that we can do less, do less damage to the environment and minimize our cost, and we will still make the profits [electricity conservation will not be a strong goal]. But we got to change the business model."

5) Creation of legitimacy

The creation of legitimacy is seen as one of the more troublesome sub-processes.

At the level regulation, the legitimacy of smart grid is perceived to be high and strong, due to strong support from the Obama government. "There was a lot of initial enthusiasm and support monetarily [in 2009]. After that the slowdown of the economy has put large question marks about if it is going to be sustained…" "Right now all the push is coming from the government and […] the vendors. Not from the public" "The discussion is still very confused and flippant". A strong drive for renewable energy lends legitimacy to smart grid efforts. The need for smart grid technology is not interpreted as important in "parts of the country where they don't have renewable energy integration issues".

Among the utilities, there is some ambivalence about the legitimacy of smart grid technology. Most leaders agree that smart grid is inevitably going to be implemented and will be a positive thing, but there is a debate about the timeliness of current efforts to develop smart grid, and especially the cost of investments.

At the level of end-users, consumers are seen as most disinterested with the technology. However, two minorities, one strongly opposed, and one interested, are identified.

Overall, disinterested end-users are not favoring investments in smart grid functionalities that do not interface with the consumer. Some conflicts between grid maintenance and smart grid were identified, especially in the distribution networks which were identified by several respondents as a problem area. The reason stated is that the investments are invisible for consumers, and the benefits of lower transmission losses and higher quality and reliability of power, is not seen as visibly by consumers as is metering technology or electricity production technology. Thus, high investment costs are not favorable with consumers.

For the end user interfacing functionalities, there have been some negative developments around the legitimacy of smart meter technology due to communication failures. “Some things may or may not be well executed up until now, so there could be legitimacy problems with those projects that have not been well executed. Particularly some AMI networks that are just expensive time of use meters […] In some ways [the smart grid proponents] were a bit hasty and that might come back to bite them ” However most respondents argued that most consumers are positive to smart meters, and that the opposing minority is small and “silly”. “[Consumers] have the perception that smart grid investments are not cost-effective. […] They many times believe money is being wasted.”

One respondent argued that smart grid is getting a "buzz word" image, where many consumers think there is a lot of attention with little real substance.

The most critical issues for smart grid in terms of legitimacy are privacy concerns, data security, data ownership, and cost distribution.

Cost-efficiency was an important related theme. Many respondents argued that while smart grid technology and smart meters were accepted by most consumers as positive, the acceptable cost was not perceived in the same way by utilities and consumers. This necessitates much more experimentation with business models for selling smart grid services and appliances.

6) Resource mobilization

Overall most interviewees agreed that the financial resource mobilization of the federal government has been an important driver of smart grid innovation, but argued that this driver will not create a long-term momentum, and that investments by utilities themselves are too low. Compared to the size of the energy sector, which has US$ 370 billion revenues in 2011[126], the funding provided by utilities for R&D is seen as low. This is a persistent phenomenon within the electricity sector.

On the federal level, it was argued that government funding had been sufficient to significantly contribute to grid innovation. "They have realized the value of smart grid and they have put their money where their mouth is". "The government funding has been more than enough". Some respondents were however critical to the short time-span of the ARRA funding, and feared that the current motion would not be sustained as federal stimulus dries up. Also, there were some respondents who argued that the ARRA spending had been too focused on non-transformative technology, which is favored by utilities and

[126] *(Energy Information Administration, 2013)*

easier for vendors to produce, rather than the transformative, advanced smart grid applications. The general population was thought to be negative to further stimulus from the federal government. On the utility side, consumers are thought to be too averse to costs, which make it difficult for many utilities to raise funds for smart grid investments. It will cost more to maintain current services, but consumers are unaware of this.

On the human capital side, there were some concerns about the amount of power engineers trained in the USA. This is a long concern for the electric power industry in the USA. Many universities have closed their power electronics departments because the grid was seen in the 1990s as a finished product. Now, there is often reluctance to re-open those departments.

7) Development of positive externalities

Renewable energy deployment was identified as an important driver of smart grid innovation in particular states such as Hawaii and California because of integration issues.

Cyber security firms and defense contractors are moving into the scene as security is becoming a more important concept. These bring in much know-how and tested technology. After NIST's successes in facilitating the creation of a secure communication system for smart grids, the Obama administration requested NIST to device a cyber-security framework encompassing more kinds of infrastructure. This points to a potential future beneficial dynamic that can inform smart grid innovation.

Home energy management and big data were seen as technology areas contributing to and giving momentum to smart grid innovation, as well as the smartphones and augmented reality.

8) End user engagement

"The situation we have right now for electricity consumers in the USA is like going into a grocery store and buying things for nothing. There are no price tags. You buy anything you want, you go to the checkout, they scan but you don't pay. And at the end of the month, 15 days later you get a statement saying 'this is how much you have consumed'. We can't send price signals to consumers if they do not know the price when they are consuming it."

In 2011 35% of Americans were estimated to be aware about the term smart grid, and most would appreciate being better informed about their electricity consumption, and to be able to use technology to minimize costs[127]. All interviewed respondents agreed that consumers do not understand the meaning of smart grid, and that education is necessary. Most, including the utility respondent, argued that utilities must be at the forefront of communicating the benefits of smart grid.

The perspective of the end user is only really considered in smart meter deployment, much because of the lessons learned from consumer backlash in California in particular. However here communication is still poor and potential benefits to customers are not communicated. End users of electricity have has concerns about smart meter roll out due to worries about the effect of radiation on human health[128], concern about higher cost of electricity due to roll out[129]. End users only interact with utilities when paying monthly bills, and only think of electricity services in terms of cost. As current smart grid projects have been implemented during a time in which the electricity prices have been increasing, the benefit to consumers has seemed dubious to many.

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[127] *(Wimberly, 2011)*
[128] *(Barringer, 2011)*
[129] *(Sullivan & Kahn, 2011) and (Tweed, 2010)*

(Krishnamurti, et al., 2012) conducted mental interviews and a survey with electricity consumers in the USA, and found generally low knowledge of smart meter functionalities. They found that consumers generally tend to overestimate both benefits and risks of smart meter, but their respondents tended to more strongly overvalue the benefits. Thus they suggested that misinformation among consumers might be in favour of smart meter adoption rather than the other way around, as utilities have much more direct benefits.

A utility respondent argued that consumers could have a lot of influence if they took an active stance towards this new technology. “The vast majority of consumers don’t even know what smart grid is. They don’t have a clue and they don’t particularly care. But for those who do it’s a big thing, and they can influence decisions.” The respondents agreed that without the active participation of the end users, the transformative functionalities of the smart grid cannot be achieved. Many respondents stressed the importance of early adopters and people wanting to pay a premium for a greener grid. These end-users, stereotyped as young, progressive urbanites, have been important in creating a limited market for end user interfacing technology.

On the critical legitimacy issues of smart grid technology; privacy, data security and cost-distribution, the end users seem to still be disinterested. However, some respondents argued that this situation could change if knowledge increases. “If you tell someone that their power consumption can be tracked, that there’s these [satellite] images where you can see if doors are open or shut, they will be very skeptical.”

xii. Semantic analysis

As described in the Methods chapter, a search for academic journal abstracts with the key word smart grid was done on the Web of Knowledge database, with a filter selecting only papers with affiliation to an institution in the USA. The results were manually screened to only allow abstracts where the topic was related to electricity smart grid technology. The resulting corpus was analysed using FullText, TextSTAT, KH Coder and Pajek, to identify the most commonly occurring words in the corpus, and the most common co-occurrences of different words. Using Pajek and KH coder, the results were visualized as semantic networks, where more commonly occurring words are represented with larger nodes, and close position and a connecting edge means a high level of co-occurrence.

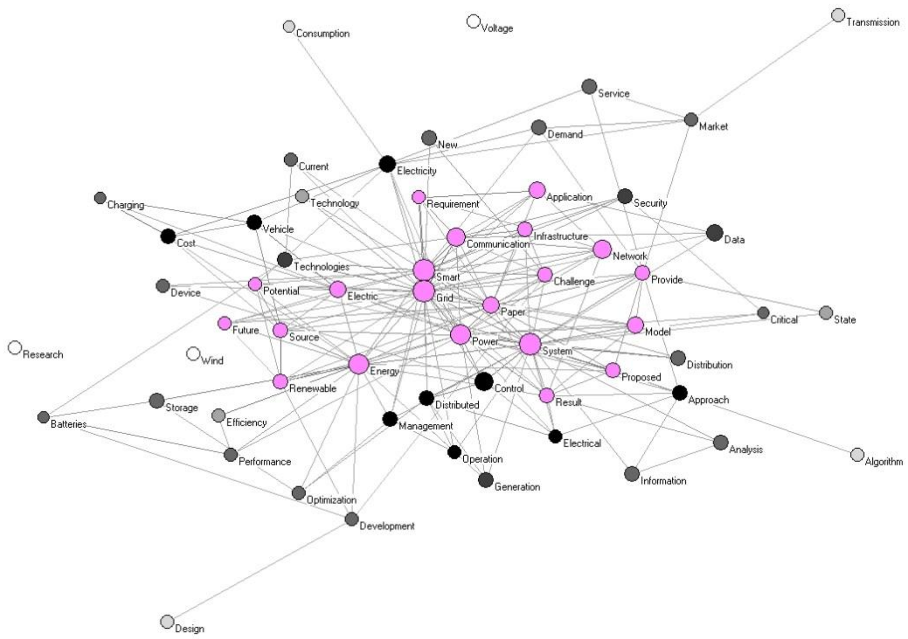

Figure 14 – Representation of the 60 most common words in academic journal abstracts with the key words smart grid and affiliations to institutions in the USA

The most important key words for smart grid-related academic research in the USA were found to be the “smart grid” concept itself, as well as “power system”. Other core terms include “infrastructure network”, “future renewable energy source” and “communication requirement”. Other important concepts are distributed generation, the creation of new service markets, EV charging infrastructure, energy storage and security.

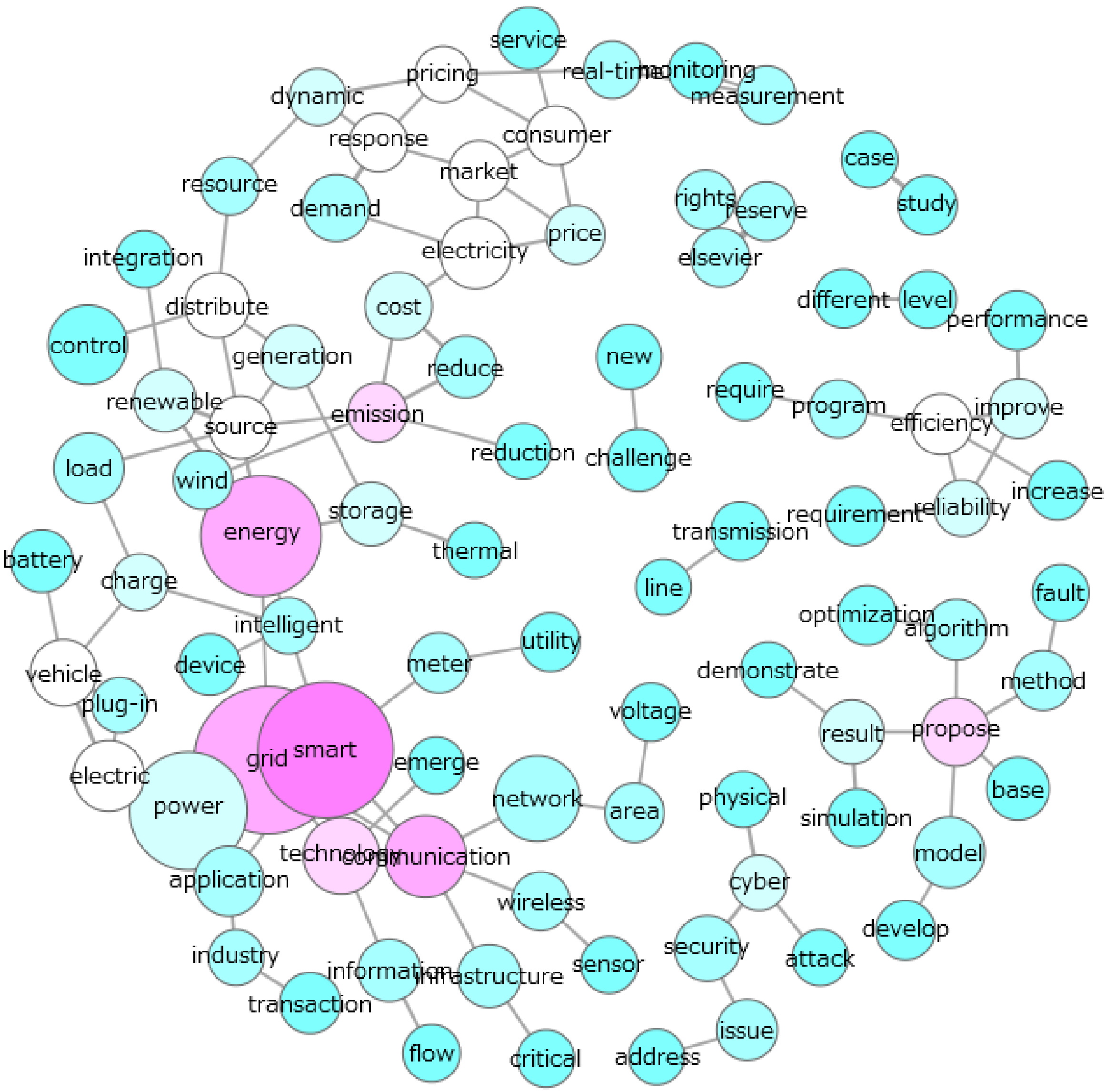

Figure 15 – Representation of the most common co-occurrences of words in academic journal abstracts with the key words smart grid and affiliations to institutions in the USA

A similar analysis using KH coder, which shows the most relevant correlations instead of the most commonly occurring nodes, shows an image of a wide scope of discourse. The topics include communication infrastructure, smart meters, electric vehicle, dynamic pricing, distributed generation, optimization algorithms, rea-time monitoring, physical and cyber-attacks and so on. Compared to the functional technology areas evaluation by the interviewees, and the focus technology areas of the analysed projects, the academic discussion in the USA seems to be broader.

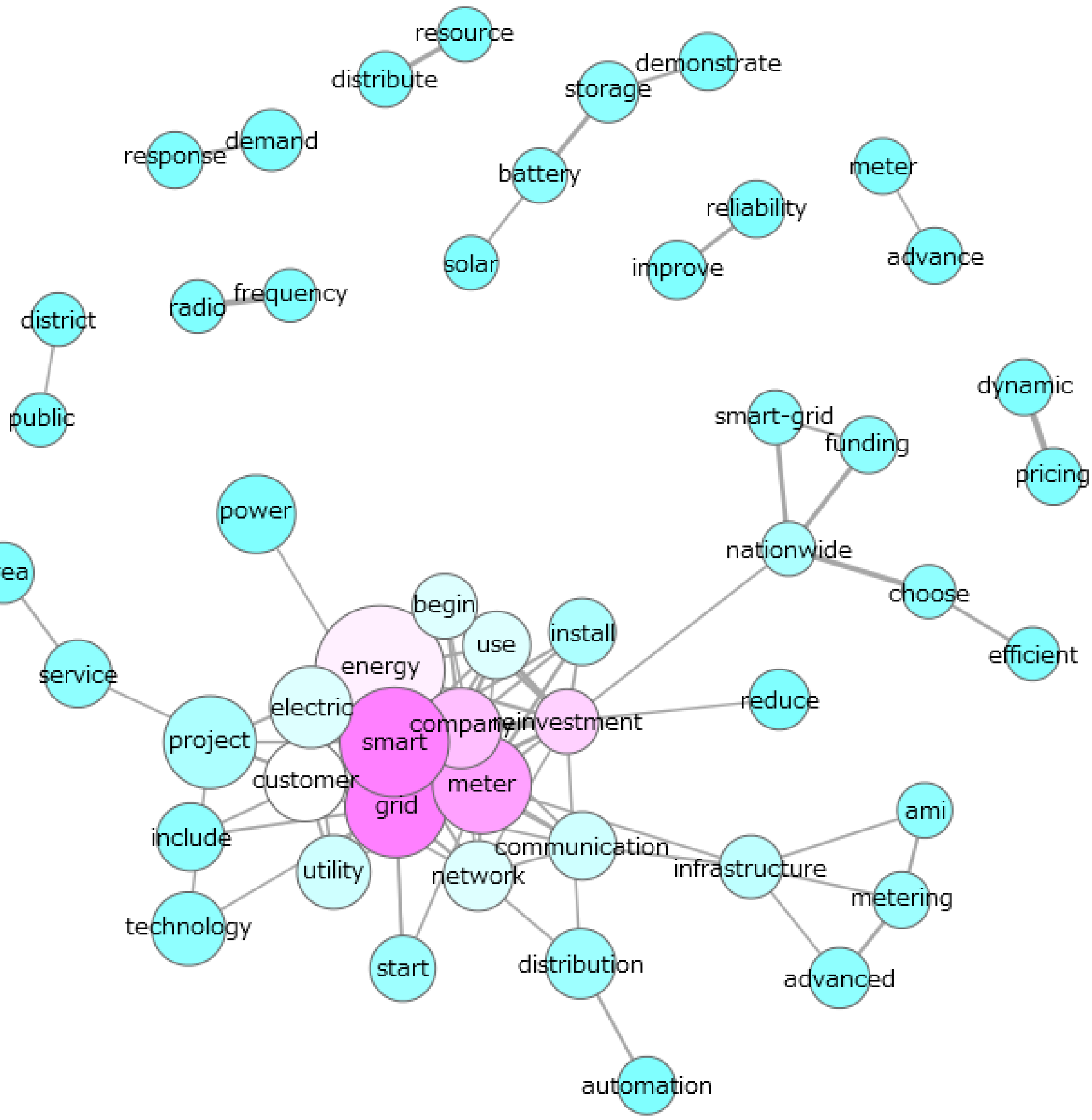

Figure 16 – Representation of the most common co-occurrences of words in the documentation of projects in the SGI Clearinghouse project database

An analysis of the documentation of the 199 projects in the database shows, in contrast the strong focus on smart meters and communication networks. Some other topics that are identifiable here are distribution automation, which is quite closely related to the core discourse, a solar energy and storage topic, demand response and dynamic pricing.

7. DISCUSSION

Normative Analysis

The TIS framework requires a normative analysis of what *should* be the case within the TIS being investigated. This study is informed by the perspective of sustainability science. As stated in the Methods section, sustainability science views sustainability as the normative goal of academic research as well as governance. Sustainability, as seen within sustainability science, is a holistic goal of promoting and preserving economic, social and environmental values. Sustainability is also a process, in which different perspectives, values and disciplines are allowed to influence the direction of governance.

In terms of sustainability as a holistic goal, the smart grid TIS in Japan and the USA should create the possibilities for an electricity system with less CO^2 emissions, with less cost and with higher satisfaction of social concerns such as fairness of supply security and pricing, and infrastructure resilience.

In terms of sustainability as a process, the smart grid TIS should create the possibilities for less empowered stakeholders to influence the governance of the electricity grid. Less empowered stakeholders are most importantly end users, especially residential end users and low income end users. As we have seen, these are generally uniformed about the governance of the electricity system, and they often have few methods of influencing the governance of the electricity grid. Influence could take different shapes. Market influence would entail end user selecting which services they want from the electricity grid and associated equipment, and then paying a price relating to those services. The concept of "energy citizens", as discussed above, constructs a broader vision of end users as more directly influencing the governance of the electricity system. By enabling more distributed generation, smart grid technology can make end users producers of electricity, the "prosumer" concept, which would allow the end users to be more independent of and taken together larger influence over the governance of the electricity grid.

As (Hoogma, Weber, & Elzen, 2005) describe, smart grid is a niche technology that develops within the established regime. Many of the end users who are interested in achieving a system with better sustainability performance decide to go 'off the grid', because they find that the existing system is too complex and inert to change. It is the role of policy makers to create the institutions that would allow these end users to act out their aspirations in the established grid, so as to build on the existing infrastructure capital and expertise pool, and this should be the goal of the innovation system.

As (Winner, 1986) would remind us, complex technological systems co-evolve with power structures that support them. The power structures thus need to evolve to support transformative smart grid innovation, and to support participation of marginalized stakeholders in the innovation process.

i. Prosumer

Initially launched by (Toffler, 1980), the prosumer concept is now most commonly used in discussions about media-related consumption, but is also used in discussions on the electricity system. The prosumer is widely seen as a positive force for equalizing the playing field within the political economy by making the consumer perspective more prominent, and a positive force for bringing more radical innovation by bringing in an actor that does not have profit maximization as a core goal, but rather utility of the innovation itself[130]. Moreover, the prosumer has a deep understanding of the needs of the consumer. Especially as manifest on the internet, on collaborative platforms such as Wikipedia, the prosumer is seen as an emancipatory ideal by progressive scholars[131]. Optimists argue that

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[130] *(Bruns, 2008) (Comor, 2011) (Ritzer, Dean, & Jurgenson, 2012)*
[131] *(Comor, 2011)*

prosumtion is a tool for reflexivity, as the prosumer will need to respond to and reflect over knowledge about itself[132]. According to (Comor, 2011), the new aspect about the prosumer is consciousness and consent about participation in the production process.

Critics would argue that as long as the presumption is governed by the capitalist system, the reflexivity of the prosumer is limited by the context of the market, and the information created is often appropriated by the system[133]. It is easy to see the resonance of both these arguments in smart grid innovation. The enlightened end user is widely seen as a key component to building a sustainable energy future. However, there are many concerns about the ownership of the data being produced by smart grid functionalities. And there are more significant risks of the prosumer concept. (Comor, 2011) critiques the prosumer concept by showing that the underlying mechanisms of capitalism is kept intact in a prosumer society, and that the increased creative autonomy of the consumer will always be bounded by the system within which the autonomy is created. In Comor's and Fuch's[134] analysis, prosumption becomes something akin to the Platonic noble lie, the semblance of potential for participation in governance which will guarantee social consent to appropriation of labour.

It is now generally agreed that simply increasing the availability of information for the end users of electricity will not result in a behaviour change. End users of electricity will not accept behavioural change designed to tack energy sustainability unless they are allowed to participate in the development of strategies[135]. In both Japan and the USA, consumer disinterest are important obstacles to achieving integrative smart grids, but there seems to be few attempts at involving consumers in innovation of the smart grid technology.

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[132] *(Ritzer, Dean, & Jurgenson, 2012)*
[133] *(Comor, 2011)*
[134] *(Fuchs, 2009)*
[135] *(Dowd & Hobman, 2013)*

It is also true for the electricity system that smart grid cannot be regarded as a panacea for the problems created by capitalistic governance of electricity production and consumption, as it alienates consumers from the environmental and other effects of their own consumption. However, in contrast to creative industries, in which consumers are generally extremely aware of the self and the way it relates to consumption, within the electricity system, the consumers are generally unaware, and few conceive of the possibility of being an agent. The dis-empowering potential of smart grid technology should be minimized and the empowering aspects should be enhanced. The involvement of end users within the innovation process could be a key to achieving this dynamic.

Japan

ii. Summary of findings

1) Drivers

Energy crisis

Security of electricity supply is the one value proposition that unites all stakeholders in Japan. The 5 highest ranked visions for smart grid technology in Japan in this study were concerned with infrastructure resilience in face of natural disaster and attacks, achieving more distributed electricity generation, increase the potential for renewable energy sources and to enable better peak-demand cuts. All of these visions are directly related to the experience of the post-Fukushima energy crisis. The dangers of Japan's centralized and isolated electricity system was felt. The promotion of renewable energy has not produced a significant share of renewable energy production, much thanks to the centralized and fractured infrastructure, and the market structure. Finally, demand response functionalities are now promising very high economic and also political and moral values, in the face of such large disruptions as the Fukushima disaster and the following nuclear shut-downs.

For TEPCO, the main drivers are renewable energy integration, and energy efficiency and demand response. In the post-Fukushima period, energy efficiency and demand response are the most important goal of smart grid engagement

Green energy and government promotion

The promotion of renewable energy sources is another important driver of smart grid technology, and motivates much of the public sector involvement with the innovation system. Japan has long tried to promote the increased use of renewable energy sources, all since the first oil shocks of the 1970s, due to macroeconomic and environmental negative aspects of fossil fuel and nuclear energy generation. In the last decade, the progress in japan has however been lacklustre compared to what has been achieved in other developed and even developing countries. The electricity market model of Japan and Japan's reliance on centralized energy production have been pointed out many times as the main obstacles to greater deployment of renewable energy sources in Japan. For the government stakeholder, this is a key goal.

The most important actor for promoting smart grid in Japan is the Japanese government. The Smart City projects are referenced by all respondents as being on the forefront of smart grid innovation efforts in Japan. METI and NEDO have been able to bring together diverse firms around smart grid and related functionalities on a city scale. The focus on the city level has meant that utilities only have a minor role, and the focus has been on the provision of social services. However, this constellation has come at a cost, as the local governments and equipment vendors that are the core partners of the Smart City projects are not natural bedfellows, and the potential markets created by such schemes are still highly uncertain as long as the electricity market structure does not change.

Future markets, smart appliances and homes

Despite experiencing a decade of decline, the Japanese electronics industry is very large and diverse. The core commercial actors in smart grid innovation in Japan are large Japanese corporations with portfolios stretching well beyond grid equipment and into consumer electronics. Japanese electronics firms compete on technological edge and value added, as compared to their East Asian competitors who have price advantages. Many of these firms identify green technology as a future market where value added appliances will be able to capture large market shares. Smart grid technology offers the technological platform to enable more advanced green services such as energy savings and residential renewable energy generation, and also the economic platform to sell the full range of products the Japanese firms have to offer.

TEPCO's roll out is expected to contribute to a much more rapid development both for smart grid and smart house technology[136]. Rising electricity costs and higher social awareness about energy problems among Japanese residential end users is also making end users more interested in smart house products. The Japanese smart grid/smart house market thus has potential to grow and to involve end users.

2) *Obstacles*

Market structure and regulation

The major obstacle of smart grid innovation in Japan is the current monopolistic market structure. Most of the interviewed experts support this interpretation. The Japanese electricity market structure incentivizes surplus capacity, because of the lack of price competition, and the reward for capital investments. The current market structure inhibits investments that enable distributed generation. The monopolistic utilities have over a long period of time made cost-calculations based on central generation and economies of scale within their service areas. The economic viability of some of the large scale power plants, especially nuclear power plants, will be seriously undermined by any move towards distributed generation. Culturally, the legacy of central generation and control has created a negative view of distributed generation within the utilities. TEPCO and other Japanese utilities pride themselves of their track record of keeping electrical outages at a minimum.

Regulation uncertainty

The uncertainty of the future of the Japanese electricity market looms large over the prospects of smart grid innovation. While a more favourable situation is expected by most, the uncertainties about the details of that situation make many investments look premature.

[136] *(Mochizuki, 2013)*

The plan of the current government of Japan for liberalization of the electricity market aims at full liberalization of the electricity retail market in about 2016, and decoupling of transmission and distribution sectors by 2018-2020[137].

iii. Future directions

In the short term, it is most likely that electricity prices will continue to increase in Japan, which will give additional weight to many of the drivers of smart grid innovation. This will probably mean that the consumption side technologies will be premiered. In the long term, the deregulation of the electricity market is likely to be carried out, and this could open the door for more focus on the transmission and distribution levels, especially if the case for more renewable energy integration grows.

USA

iv. Summary of findings

1) Drivers

Security of supply

(Vadari, 2013) argue that many of the key drivers relate to achieving security of electricity supply, and this research confirms this position. Achieving security of supply of electricity in face of both natural disasters and terrorism seems to be the strongest motivator for smart grid innovation in the USA. The goal of security is one that every stakeholder can subscribe to, and the common experience of large-scale events, especially the 2003 blackout in the North east and the hurricane Sandy in 2012 have made arguing for investments for security easier, and the post-9/11 concern for terrorism has been a conducive environment for arguments for security. The experts interviewed were unanimous in ranking the security goals as the most important, and security was often named as the main motivation for policy intervention.

[137] *(Ministry of Economy, Trade and Industry, 2013)*

Apart from natural disasters, terrorism is a growing threat. In 2012, the Industrial Control System Cyber Emergency Response Team (ICS-CERT) of the Department of Homeland Security (DHS) acted on 198 cyber-attacks on infrastructure deemed critical, and 41% of these cyber-attacks were directed towards energy infrastructure. In the first half of 2013, over 200 incidents were registered, with 53% being in the energy sector[138]. These figures seem to justify the view that there is a growing threat of cyber-attacks on energy infrastructure, and it is likely that policy will keep up with that threat. In 2013 the Pentagon claimed that Chinese army hackers had started to focus on hacking companies with access to the American power grid[139] The FBI warned in 2012 that private persons with only limited computer skills could easily hack a smart meter, and make it transmit false information to a utility[140].

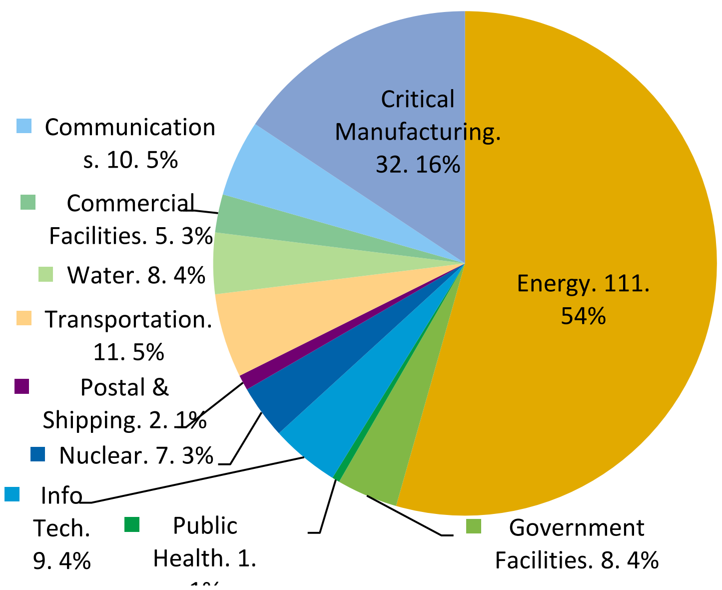

Figure 17 - ICS-CERT Incidents first half of 2013 by category, data from (ICS-CERT, 2013)

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[138] *(ICS-CERT, 2013)*
[139] *(Sanger & Perloth, 2013)*
[140] *(Krebs, 2012)*

Utility bottom-line

The utility bottom line has been a very important motivator and shaper of the smart grid innovation so far. As we have seen, the innovation has largely focused on smart meters and infrastructure automation. Both of these technological areas reinforce the current functioning of the grid, while decreasing the cost of utilities for maintenance, and sometimes allow a better cost-performance of existing infrastructure, in the case of dynamic transmission line monitoring.

The successes in demand response are another example of this. In California, where demand response has been growing rapidly, utilities were reported to develop this as they wish to avoid the cost of building additional generation capacity.

These technologies are not disruptive on a small-scale, but can become parts of a transformative dynamic. Smart meters are necessary for net metering and distributed generation, which could be threatening the existing utility model. Demand-response technology when more wide-spread could alter the demand curve and the utility-consumer relationship in a similarly disruptive way. However, it is important to note that this is not necessarily so, and that if utilities will be able to maintain their prominent position, smart grid technology will probably only improve, but not transform, the electricity system.

Renewable energy

Renewable energy is a third important driver for smart grid. The great majority states have implemented renewable portfolio standards or goals.

Wind and solar electricity generation is starting to become so important in some states that they are putting new demands on the electricity infrastructure. As the generation from dispersed renewables is not controllable to the same extent as traditional energy sources, utilities are forced to deploy technology that can better detect generation fluctuations, and can faster respond to this. The experts interviewed argued that smart grid technology is only seen as necessary in those states where renewables are growing, indicating the importance of this driver.

The importance of green consumers was also mentioned by many as the only important way in which consumers spur smart grid technology. Some consumers, who are willing to pay a premium for electricity from renewable sources, are also generally willing to pay a premium for smart grid functionalities if they are put in the context of making the electricity system more sustainable. Possibly, these consumers are lead users, demonstrating consumption preferences that over time will become more widespread. Many of the experts interviewed thought so, and argued that the younger consumers are more likely to be these green consumers.

2) Barriers

Market structure and regulation

The biggest barrier to smart grid innovation as seen by most experts interviewed is the market structure and regulation. Utilities, especially the investor-owned ones who account for 75% of the energy market, are widely seen as conservative and interested in short-term profits. Compared to the size of the energy sector, which has US$ 370 billion revenues in 2011[141], the funding provided by utilities for R&D is very low. R&D expenditure of US utilities fell by 72% between 1990 and 2004[142], and many US universities have closed their power engineering departments, as the demand for research was seen as declining.

For the vendors of smart grid technology, the market structure is also a barrier. As privately owned utilities account for 75% of the market, these are the primary targets for new technology. Vendors almost exclusively target utilities for purchasing technology, and the consumer seems far removed from this interface. This in spite of that many of the smart

[141] *(Energy Information Administration, 2013)*
[142] ***Invalid source specified.***

grid functions envisioned by the same vendors requires active and engaged electricity consumers. There are efforts to overcome this, such as the Smart Grid Consumer Collaborative, an organization with vendor, utility and NGO members which does research on consumer attitudes towards smart grid technology.

Other factors contribute to dampening the mood of vendors. The "patchwork" situation on the American electricity market is seen as a barrier to investors, as this increases the uncertainty for vendors. Also, the shale gas revolution is making the business case for expensive efficiency-enhancing technology less persuasive.

Communication failures and cost-distribution

Consumers in the USA are used to being able to take electricity for granted, and they are used to low prices. Any change in this status quo would naturally be met with skepticism.

Utilities are not used to communicating with consumers other than through electricity bills. However, the smart grid requires more participation from the consumers, more complicated billing systems which might incur extra cost on the consumers. Though some experts are hopeful that smart grid will become part of an "internet of things", which will spark much consumer-facing innovation, this dynamic seems still far away. Adding to this, the technology deployed so far has not been successful in engaging consumers. In-home displays and moderate time-of-use rate changes have failed to make consumers interested in interacting with the electricity system after the novelty wears off.

Smart meters deployments have met with some resistance during deployment. Some interviewed experts argued that hasty smart meter deployment without proper consultation with consumers has somewhat tarnished the image of smart grid technology. Some vocal opposing groups were concerned about the privacy and health issues that could arise from deploying smart meters. However most respondents argued that most consumers are positive to smart meters and that the opposing minority is small and "silly".

In view of the currently on-going debate about surveillance activities of the federal government, after the revelations of the whistle-blower Snowden, it's likely that the privacy issue will not decrease in salience. The California Public Utilities Commission adopted privacy safeguards for data gathered through smart meters in 2011. Under these rules, data can only be shared with a third party with consumer consent, or pursuant to a legal process. The rules also require utilities to report on their compliance with rules and breaches of data security. The first privacy report by utilities in 2013 revealed that one major utility, San Diego Gas & Electric, had released information about 4062 customers without their consent during FY 2012[143].

More serious is the perception by many consumers that smart meters and smart grid technology is positive, but not enough to warrant the extra cost investments would incur on consumers. Utilities have found it hard to communicate the long-term benefits of smart grid technology, while consumers have seen bills rise for reasons connected or disconnected to smart grid deployment. All interviewed experts expressed the need for more leadership and more communication efforts from utilities, but given the market incentives the utilities have, this might not lead to the situation smart grid proponents strive for.

There is a notion that the small, publicly owned utilities that cater for urban populations have been the most successful in smart grid projects. These utilities have generally a higher level of trust from the consumers, as the leadership is politically elected.

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[143] *(Cagle, 2013)*

Many of them cater to some of the most “green” demographics- young, educated and urban. However, they are small on average and only cover a small part of the electricity market.

Federal policy

The federal policy for smart grid innovation got mixed reviews from the experts. The federal government has, since the start of the Obama presidency, been a proponent of smart grid innovation. Especially the stimulus funding of the American Recovery and Reinvestment Act of 2009 was important, as it assigned $27.2 billion to energy-related R&D, of which $4.5 billion was directed to smart grid development. However, a nebulous use of the term “smart grid” had led to the federal government financing too much technology that was not innovative, and not transformative according to some experts. The use of smart grid funding for political objectives was also identified. The short-term nature of the stimulus money (over by the summer of 2013) was also criticized as insufficient, and it was noted that continued federal support would not be supported by the public.

The lack of an overall federal policy for achieving a green energy economy is another important drawback for smart grid innovation in the USA, it was also argued. A strong policy on the federal level would erase some of the uncertainties investors face, and would create economies of scale for smart grid technology. However, the current constitutional set-up of the USA would make this very difficult.

v. Future directions

The shale gas revolution and the end of stimulus funding have made utilities less engaged with the smart grid innovation process. One example is the standardization processes, where the utilities initially were active to prevent standards that would be negative to their interest, and many feared that smart grid standards would become binding standards. Now, stimulus funding has ended and there seems to be no federal smart grid requirements in the pipes. However, there seems to be a steady trickle of federal support for smart grid activities[144].

Security has been an important driver, and it is possible that this will continue to drive engagement on the federal level. After NIST's successes in creating a secure communication system, the Obama administration requested NIST to device a cyber-security framework encompassing more kinds of infrastructure. This points to a potential future beneficial dynamic that can inform smart grid innovation.

Another important process to look at is the situation in Boulder, Colorado. This city was the site of one of the most publicized smart grid demonstration projects by an investor-owned utility. However, the project was a failure on many accounts, due to technical difficulties, and a several lack of participation of consumers due to a lack of communication. The failure led to soaring costs for consumers and disruptions in service. As a result of this failure, and a strong opinion in the city for fast adoption of renewable energy, the City Council voted to municipalize the utility's holdings in the city in August 2013. While this issue is not settled, the effect of this affair on the attitudes of investor-owned utilities will probably be great.

Comparisons

vi. Progress of innovation

It is difficult to compare the two countries in terms of level of progress in smart grid innovation. It can be said without doubt that the USA has a longer history of engagement with the concept than Japan, and therefore a lot more projects aiming at smart grid innovation have been implemented and completed, and the discussion seems more mature. In terms of achievements, an evaluation in terms of a desired outcome (for example the

[144] *(Peeples, 2013)*

prosumer vision, reduction of peak demand or CO2 reductions enabled) of the implemented or demonstrated technology would be needed, and that is beyond the scope of this study.

However, this study is able to identify the phase of development of the TIS, and similarities and differences in the opportunities and difficulties the smart grid innovation efforts are facing in both countries.

The TIS in both countries are in the formative phase of development as defined by (Bergek, Carlsson, Jacobsson, Lindmark, & Rickne, 2008), with some elements of the TIS in the USA being in the growth phase. More specifically, if the smart meter TIS in the USA would be examined, it would have to be classified as being in the growth phase, as markets demanding smart meters exist, and there are already established strong players with links across the TIS. Indeed, this situation has coloured most of the analysis of the smart grid TIS in this thesis. The broader smart grid TIS in both countries are characterized by uncertainties about markets, applications of the technology, lack of demand, and lack of self-reinforcing dynamics, all the characteristics of the formative phase[145].

In both countries, large scale events that disrupted or showed the weakness of the existing infrastructure created a will to engage with smart grid technology. For the USA, this event was the 2003Northeastern blackout. For Japan, it was the Fukushima disaster and the subsequent energy crisis. These events seem to have provided the most important basis of legitimacy for smart grid technology, and this is reflected in the primacy of resilience visions for smart grid technology in both countries.

In both countries, the market regulation is a key obstacle to innovation. While the regulatory regimes in the countries are not identical, experts from both countries shared one

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[145] *(Bergek, Carlsson, Jacobsson, Lindmark, & Rickne, 2008)*

concern: The utility stakeholders are not given enough incentives under the current regulatory regimes to invest in transformative technology.

The lack of communication with end users of electricity was identified in both countries, while in both countries, there existed at least some expectation of a more proactive role by end users in the resulting electricity system following smart grid implementation. This lack of communication is both of a ‘soft’ and a ’hard’ kind[146]. The hard or formal system failure consists of the electricity market regulation regimes that do not incentivise interaction with consumers, and robs consumers of agency towards the electricity grid. This failure can most clearly be seen in Japan vis-à-vis residential end users of electricity, and in some states of the USA.

The dangers of a strong network failure, or an islanding effect among too highly connected actors with little contact to outside development[147], was referenced in Japan several times, but the global activities of many of the key players, the proactive stance to international standardisation taken by the vendors and the Japanese government seems to indicate that this is not a serious problem. Also, there is a larger diversity of actors in the Japanese TIS than in the one in the USA.

In fact, there could be argued to exist a strong network failure in the USA. (Granovetter, 1973) argued that a strongly interconnected social network benefits from weak ties with actors from other areas, who are able to introduce alternative perspectives that enhance innovation[148]. In the USA, as we have seen, there is a heavy focus on utilities and the vendors of AMI, which both operate within similar domains. Unlike in the Japanese TIS, these actors do not have many weak links to end user related technology areas or social networks. (Carlsson & Jacobsson, 1997) refer to this as a weak network failure.

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[146] *(Klein Woolthuis, Lankhuizen, & Gilsing, 2005)*
[147] *(Carlsson & Jacobsson, 1997)*
[148] *(Klein Woolthuis, Lankhuizen, & Gilsing, 2005)*

vii. Comparison of semantics

As the semantic analysis of smart grid literature suggests, there is not a wide gap of perspectives about smart grid within academia in Japan and the USA. One small difference is that smart grid is a more central concept in the USA than it is in Japan. However, there are discernible differences in the way the term is used outside academia. Here, the term smart grid is even more peripheral in Japan, while the terms smart community and smart house are used widely for describing smart grid functionalities. In the USA, smart grid is a strong buzzword. This gap relates to a difference of vision and focus technological areas within smart grid, as discussed below.

The semantic analysis of the project documentation is however more in line with the expert evaluation of functional technology areas, and the focus technology areas of the projects analyzed, and points to a difference in the focus between the two countries. This is not very strange, especially as the project analysis and the semantic analysis of projects use the same data source, albeit in different ways. It is also important to note that only English language abstracts from both countries were used, and therefore a large amount of literature written in Japanese was omitted. Academic articles written in English in Japan is written for an international audience, and researchers in Japan are very connected to the rest of the scientific community in the world. Thus, we should not be surprised to find more convergence in the academic discussion than in the innovation process.

viii. Comparison of drivers and visions

The visions for smart grid technology in Japan and the USA as rated by the interviewees differ in some ways and are similar in some ways.

Resilience is the core goal in both Japan and the USA, with resilience to physical and cyber-attacks being rate slightly higher than resilience towards natural disasters. Creating the potential for more integration of renewable energy is rated in both Japan and the USA as important goals.

Cost efficiency is the second core goal of smart grid innovation in the USA. In Japan, cost is indeed important and increasingly so after the Fukushima disaster. However, it seems that the monopolistic market, the uncertainty about future market structure, and the low involvement of utilities in smart grid innovation has made utility cost savings a goal of relatively low importance.

Distributed generation is a core goal of smart grid technology in Japan. Distributed generation is also rated highly in the USA, but was not chosen as a central vision. In Japan, distributed generation is seen as an important response to the current generation gap left by the nuclear power plants, and the failure of the monopolistic market structure. In the USA, generation is already more distributed, and a wish for a reliance on more renewable energy sources informs the visions of distributed generation.

In the USA better monitoring of consumption to avoid electricity theft and billing fraud was not considered a goal of smart grid technology, as there is no problem needing to be addressed in this area. In Japan, the same goes for better monitoring to avoid theft and fraud, lower transmission losses, and better quality power. Transmission losses are not high in Japan and contrary to the state in the USA; the electricity grid infrastructure is not as old. Similarly, power quality is already high, and the sectors of the Japanese industry which demand high quality power are well served.

The visions informing smart grid technology in both countries relate closely to the drivers identified as most important for smart grid innovation. In countries, large scale disruption to electricity service delivery or the threat of such events in the future are the main drivers of engagement. The renewable energy ambitions of regulators are another key driver in both countries. The vision of utility cost reduction in the USA is closely related to the driver of aging infrastructure and the push on utilities to improve their bottom-line. The visions of distributed energy generation and peak-shaving in Japan are closely related to the experience of the post-Fukushima energy crisis.

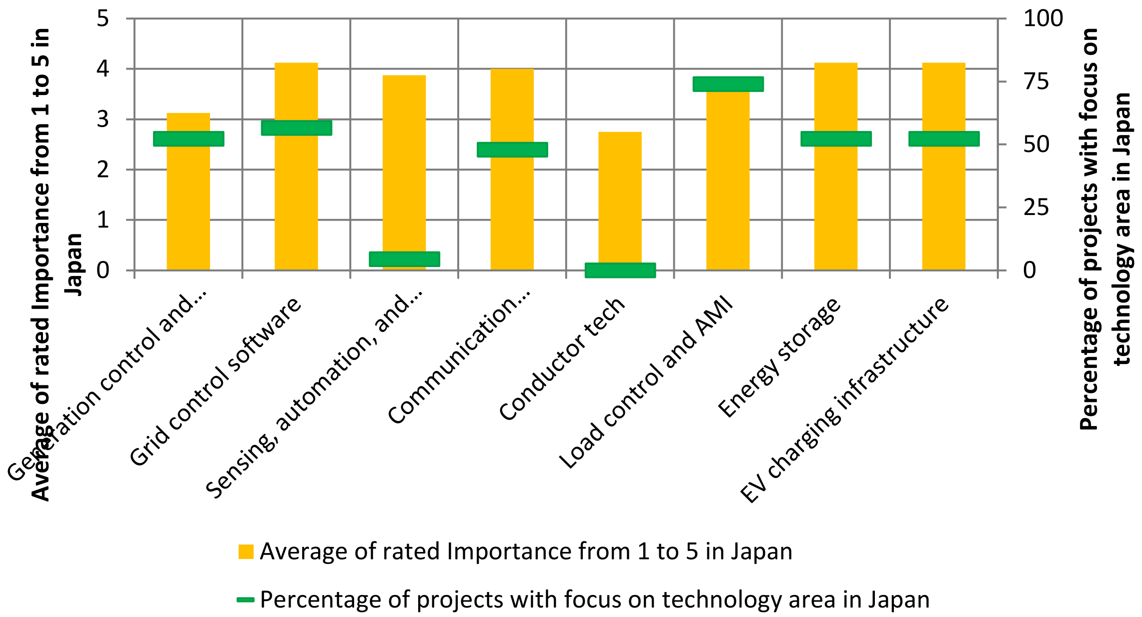

Figure 18 – Graph of respondent evaluation of importance of different functional technology areas and percentage of projects focusing on those areas in Japan.

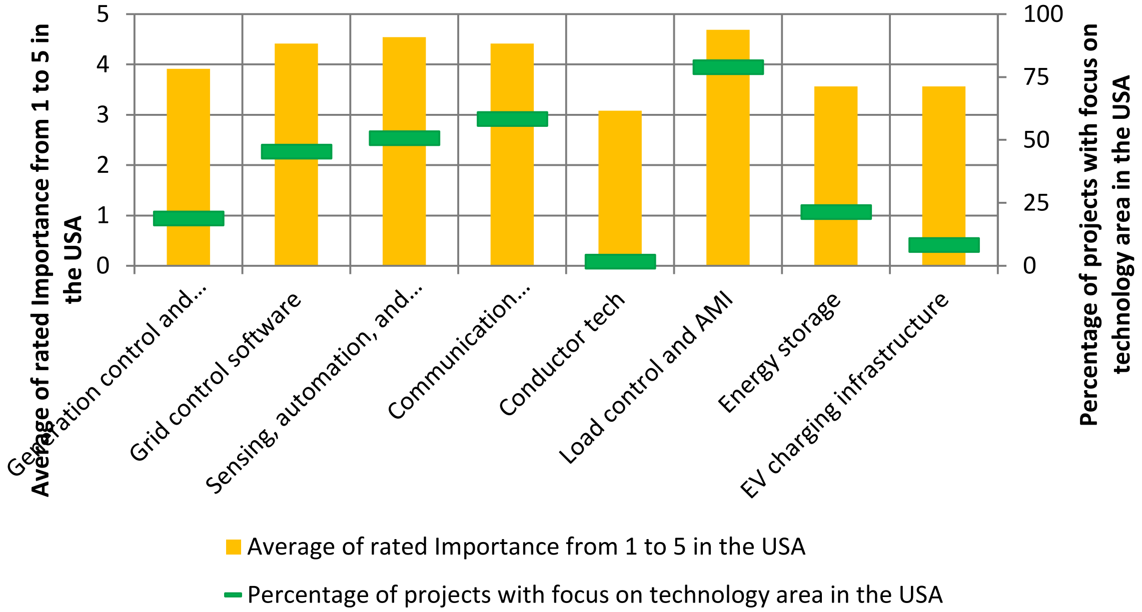

Figure 19 – Graph of respondent evaluation of importance of different functional technology areas and percentage of projects focusing on those areas in the USA.

When comparing the focus technology areas within smart grid in the two countries, the most important difference is that the USA TIS has a strong focus on AMI, and Japan has a broader focus, which is more oriented towards energy storage and EV charging infrastructure. One reason for this difference was identified in the difference of mode of government promotion of smart grid innovation.

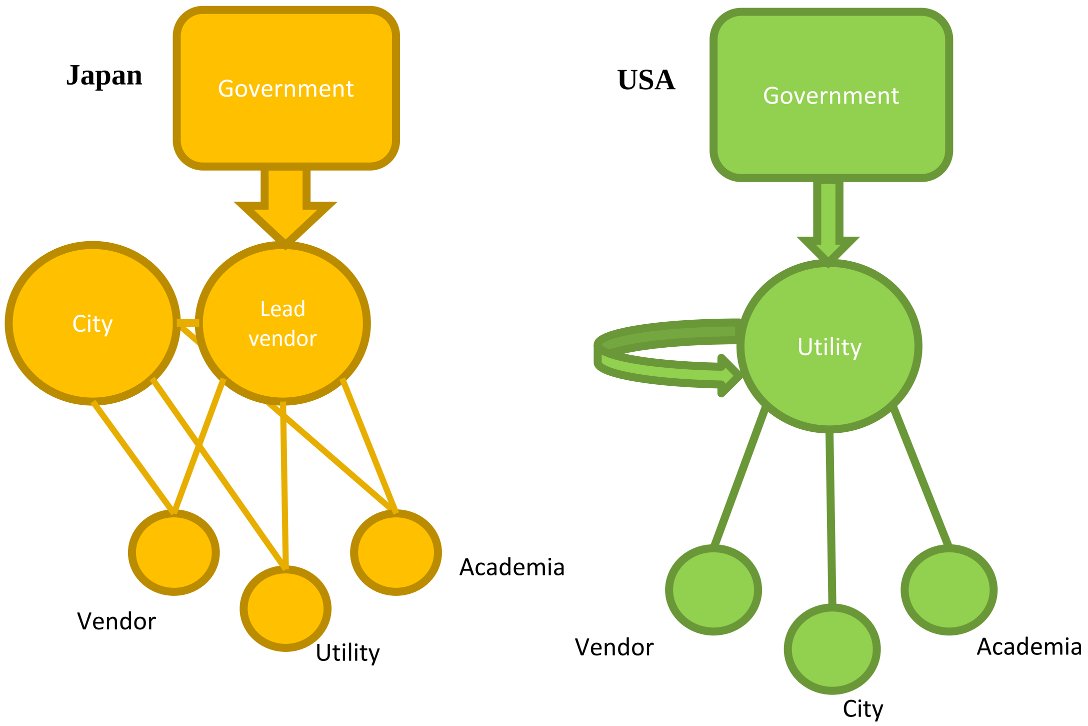

Figure 20 – Contrast between main modes of government promotion of smart grid innovation in Japan and the USA.

In Japan, the government gives funding to a lead vendor, who in cooperation with local government(s) coordinates different stakeholders and aspects of the smart grid project. In the USA, the federal government gives fund matching to mainly utilities, which then choose their cooperation partners and manages the project. The primary method of promotion in both countries is by providing finance for smart grid demonstration projects. In the USA, these projects have been mainly carried out by utilities. The two governments have different additional macroeconomic objectives that are strong motivators for the promotion efforts. In Japan, the future export markets for Japanese infrastructure equipment and appliances are important motivators of the government promotion. In the USA, the promotion of smart rid innovation investments was part of a wider economic stimulus program, aimed at accelerating the economy in special sectors identified by the government to have important macroeconomic and social benefits. The mode of government promotion should be seen in the wider context of politico-economic tradition of the two different governments. In Japan, the developmental state has been a key concept, and especially the predecessor of METI, the Ministry of International Trade and Industry, has had a strong role in coordinating the technological trajectory of innovation in the country, in close cooperation with the large export oriented firms that dominate the Japanese economy[149] Within the energy field, the sunshine program for solar energy innovation of MITI had before been able to create a positive dynamic of public funding of R&D leading to private confidence of future markets, leading to private funding for R&D. The demonstration projects of MITI carried out within the sunshine program created a demand for PV cells that proved crucial for Japanese companies to early on establish expertise within the PV industry[150]. In the USA, there is a long tradition of liberal economic governance, and 'picking the winners' in the competition between different technological trajectories is traditionally seen as best done by the market, not by the government. In this sense, it is not surprising that the federal government would give the utilities large responsibility to lead the innovation efforts using government funds.

As the financial support of the governments was pointed out by the interviewees in both countries to be a crucial, it is not surprising that the mode of government promotion is closely correlated to the most important stakeholders. In Japan,

[149] *(Johnson, 1986)*
[150] *(Kimura & Suzuki, 2006)*

vendors of smart grid equipment and local governments have been the key stakeholders. In the USA, the most important stakeholders seem to be the government, utilities and smart meter manufacturers. In Japan the most important stakeholders in smart grid innovation are the public sector and equipment vendors who also have significant interest in business areas that cater to the end user of electricity. This difference coincides with the difference of focus technology areas within the smart grid bundle. In the USA, the technology areas focusing on the transmission and distribution systems, and the functionalities that provide cost saving and enhanced control for the utilities, have been more prominent. In Japan, the technology areas relating to electricity generation and consumption, and the functionalities serving end users have been more prominent, because these functionalities could open new markets to the large electronic firms that dominate the smart grid TIS in Japan.

Table 8 – Comparison of Main Characteristics of Smart Grid Innovation Efforts in Japan and the USA

	Important stakeholders	**Mode of government promotion**	**Focus technology areas**
Japan	National government, local government, ICT and infrastructure vendors, appliance vendors	Funds to vendors who together with local governments coordinate projects	Load control, relatively more focus on generation, storage and EV charging infrastructure
USA	National government, utilities, smart meter vendors	Fund matching to utilities who manage projects	Load control, relatively more focus on grid control and automation

ix. The shapers of smart grid – Interpreting the results

While the alignment between the mode of government promotion, the focus technology areas and the important stakeholders cannot be taken as a causal relationship, the qualitative information gathered indicates that the mode of government promotion is an important shaper of smart grid technology (mostly in the resource mobilization sub-process and the development of positive externalities sub-process). The governments have other important points of influence over the shape of smart grid. In both countries, the role of governmental agencies in developing a consensus about what smart grid is (social guidance sub-process) and its desirability (creation of legitimacy sub-process) was also mentioned as an important positive factor. Finally, the market regulation was mentioned as an important obstacle in both countries, and regulatory uncertainty or fragmentation was identified as large hurdles. In Japan, the regulatory situation is leading to a less focus on transmission level investments, and in the USA, the regulatory situation seems to lead to less investment in transformative technology areas.

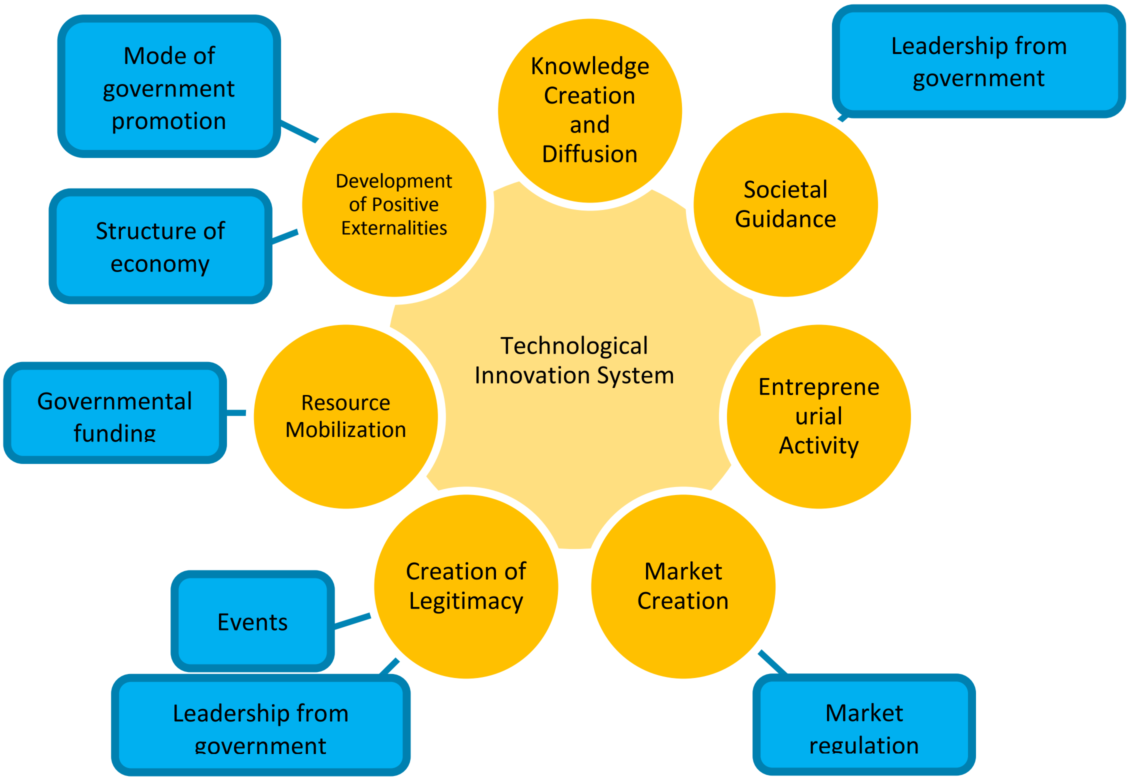

Figure 21 – Overview of shapers of smart grid technology identified in study

The other important shapers of smart grid technology identifiable from the two case studies are events and the background economic structure. In Japan and the USA, the experiences of the Fukushima disaster and the 2003 blackout informed the core vision for smart grid as providing resilient supply of electricity, and also provide legitimacy to the innovation efforts. In Japan, the structure of the economy with large horizontally integrated firms who are used to cooperating with competitors seems to have contributed to the broader focus of smart grid, and the strong link with smart appliances. In the USA, there are some indications that the strong anti-trust laws and the focus on the utility perspective have contributed to a more narrow focus on the transmission and distribution grid centered technology areas.

In both countries, the perspective of the consumer is not seen as influential, and with the exception of the small influence of the end user backlash in the USA against smart meters, the role of end users has been minimal. The experts interviewed in both countries reserve the wielding of agency to private companies, academic actors and the public sector in their explanations about the development of smart grid innovation, with references to end users as passive bystanders, which occasionally reacts in a misinformed manner to the doings of the main stakeholders. However, many of the interviewed experts saw smart grid technology as potentially altering the position of the end user. It is hard to see how the end users have influence the shaping of smart grid technology at all, with the exception of a rising concern with privacy issues in the USA.

Summary

The TIS in both Japan and the USA are mostly in the formative phase, where the need for experimentation with technology and business models is high The main drivers and obstacles differ between the two countries, but a societal desire for security of supply and governments promoting renewable energy integration are important drivers in both countries. The main obstacle in both countries is related to market structure issues. The more fine differences between the two countries are shaped by the way the electricity market is structured, the characteristics of the most involved private stakeholders, and the way smart grid is promoted by the governments.

In both countries, there are high hopes for end user participation in the use of smart grid technology, but end users have minimal involvement in the innovation of smart grid technology. End users are largely disinterested, and there seems to be few ways for the end users to interact with the innovation systems other than by demanding products that integrate with smart grid technology.

There is a difference of emphasis between the two countries. The USA TIS has more focus on the transmission and distribution related functionalities, as well as a very high importance given to AMI, while the Japan TIS has a broader focus, and ties in more with smart home innovation and other end user interfacing technology. It seems that this difference is largely explainable due to the market and regulatory structures in both countries, rather than attention to the perspective of end users.

8. IMPLICATIONS

Sustainability Science Implications

This study has illuminated the marginalized role of end users of electricity within the innovation system that aims to transform the electricity system. In light of the importance of the electricity system, and its influence on the efforts of society to combat sustainability problems such as pollution and climate change, this is a serious finding.

Sustainability science literature argues that integrating marginalized perspectives into decision-making processes is one key to working towards sustainability as a goal, and sustainability as a process. Because reflexivity is needed not only in relation to sustainability problems, but to the problem-solving itself, it is necessary that technology that aims to solve sustainability problems is not only implemented in dialogue with marginalized perspectives, but is innovated in dialogue with marginalized perspectives. This study sheds light on this problematic. While it is reasonable to believe that the electricity system is an extreme example of marginalization in the innovation process, due to the securitization and complexity of the system, it is probable that similar situations exist in other sectors such as health care, water supply or food production, and it is also probable that successful cases of modes of integration exist in other sectors. Sustainability science is well placed to research the processes of innovation in these sectors, to provide a better understanding and better models of transition governance.

This study has also indicated that the market structure of the electricity system, the mode of government promotion of smart grid and the characteristics of the main stakeholders in the smart grid TIS are important in shaping smart grid innovation, and that significant events such as the 2003 North Eastern Blackout or the 2011 Fukushima disaster significantly affect the way smart grid innovation plays out. Because smart grid technology has important potential utility in terms of sustainability, knowledge of the social construction of smart grid technology will be greatly useful for successful governance aiming for more sustainable electricity systems.

The Role of Governments

Both the case studies indicates that governmental policy is an important factor both driving and obstructing smart grid innovation, and that it is a significant shaper of the technology. Government promotion is seen as important for innovation in both countries, and national funding has been an important driver of the efforts undertaken to date. Market regulation, uncertainty about future regulation and fragmentation are obstacles to smart grid investments and innovation. As (Clastres, 2011) argues, governments need to take a strong lead in smart grid development because the uncertainties about the potential gains and the distribution of gains between players remains very uncertain. (Gangale, Mengolini, & Onyeji, 2013) found that consumer engagement projects are more likely to be carried out by or be funded by governments than by private actors. There are doubts as to whether the current regulation models will allow markets for smart grid technology to fully evolve. Modelling the investment incentives for a smart grid application under market conditions, (Agrell, Bogetoft, & Mikkers, 2013) found that existing regulatory approaches are not likely to be conducive to smart grid investments.

In view of this situation, it is important that governments recognise the influence policy has on the technology trajectory of the electricity system. Mainstream regulatory approaches, such as rate of return and price cap regulation, are government tools aimed at achieving an optimal economic outcome based on existing technology. This was a reasonable approach during the time period when the technology of the electricity system was taken as a given. However, the advent of smart grid has the promise of a radical change in the technological paradigm. Regulation of the electricity market will be one of the determinants of what kind of change that will be. As the electricity market is always created by the government through regulation, because it is a natural monopoly, the government cannot let the market decide by itself which technology is appropriate.

The current smart grid trajectories in Japan and the USA aim for the involvement and possibly the empowerment of end users of electricity in the electricity system. However, end users of electricity are not active in the smart grid innovation processes. If empowerment is truly to occur, the end users must also be empowered within the design of smart grid technology, and not only be seen as passive. Transition governance as envisioned by (Smith, Stirling, & Berkhout, 2005) of the first realm, in which the wielders of agency try to adjust the selection pressures for technology to achieve a qualitative change of innovation and to increase the pace of innovation can be seen in both countries, most clearly within the societal guidance sub/process. The work of NIST, SGIP, METI and JSCA within standardization and visioning for smart grid innovation are strong examples of this. However, transition governance of the second realm, in which the distribution of adaptive capabilities is addressed, is not prominent in either country, and this would be needed to achieve more sustainability oriented innovation.

9. POLICY RECOMMENDATIONS

This study lends credibility to the hypothesis that technology is socially shaped, and that this also applies to smart grid technology. This makes the stakeholders who are able to steer the social shaping of technology, especially governments, responsible for working towards an optimal outcome of the innovation process, not only in terms of pace of innovation, but in terms of the technology outcomes. Transition governance should be a goal of governments supporting smart grid innovation. In both countries, transition governance of the second realm as defined by (Smith, Stirling, & Berkhout, 2005) is not easily identified, but there are a few attempts to redistribute the adaptive capabilities and the potential to wield agency among different stakeholders. In Japan, the potential for such transition governance is easy to see. The smart community concept in itself can be seen as an instance of this kind of transition governance. This concept now guides much of the discussion and policy on smart grid in Japan, and it embraces more stakeholders and has made local governments more active in smart grid innovation activities. The coming restructuring of the electricity market in Japan also has the potential to redistribute much agency from the large utility companies to other actors. In the USA, the regulation on smart meters have often strengthened the position of consumers by demanding the possibility of opt-out from smart meter deployment, but this kind of regulation can only give consumers negative agency. The most simple way for the USA to distribute agency in the smart grid TIS is to change the mode of government promotion from the current scheme that goes through utilities, to one that is more conducive to broad stakeholder participation and collaboration.

The two countries studied here have different emphasis in smart grid innovation, and different modes of governance and constellation of stakeholders, so the way forward in the two countries should be different. In Japan, the broad focus can be maintained if the mode of government promotion of smart grid is preserved even after the technology becomes commercialized. To achieve this, business models that enable the current demonstration projects to be financially sustainable are needed. In the USA, the current innovation system is in many ways dominated by the utility stakeholders and the markets they act in. To counter the primacy of cost calculations within the electricity markets, the governmental stakeholders in the USA must formulate stronger goals for renewable energy deployment and consumer empowerment, as in Europe.

Transition governance should go further than just concentrating on the R&D efforts of public and private organizations. This study has identified electricity market structure as a key determinant of smart grid innovation shaping. As electricity markets are by nature constructions of governments, governments should take care when designing electricity markets to not only look for optimal performance in the short term, but also consider the evolutionary pressures that are created within electricity markets, and use these pressures to favour innovation for sustainability.

End users of electricity do in fact use electricity for a multitude of purposes every day. However, their creativity is not channeled into smart grid innovation as it stands now. This situation could hamper the innovation pace, and deprives the smart grid TIS of transdisciplinary knowledge production which would improve the potentials for sustainability. The creation of big data and novel communication capabilities could create ample possibilities for entrepreneurial end users to create the technology they need to be able to interact more with the electricity system. It is the responsibility of all stakeholders to create the necessary openness and flexibility. Communication with end users seems difficult for utilities and vendors of infrastructure related technology. For this reason, leadership is needed from the side of governments and utilities, to create awareness among end users of electricity and to engage in dialogue with end users of electricity.

10. SUGGESTED FUTURE RESEARCH

Further case studies about smart grid innovation processes would be helpful to understand the underlying forces and influences that shape the outcome of smart grid innovation. This study has focused on smart grid innovation on a macro level. On the macro level is very difficult to trace a causative relationship between the outcome of the innovation process and the processes and stakeholders that influence the process, and the findings presented here would be much stronger if combined with case studies on different levels of analysis. Case studies on the mezzo level, such as smart grid innovation in one service area, within one company or within a community would be able to give a clearer picture of cause and effect. Case studies on the micro level, such as specific projects, would also be useful for getting a more grounded picture. Smart grid is a very broad term, and research that focuses on specific aspects of smart grid would also be useful for getting a more in-depth understanding. Examples would be demand response innovation, smart metering innovation, or in house display innovation.

A study of the same countries in 5 years' time and 10 years' time would also be very beneficial for gaining a better understanding about the way different social processes shape technological change in the electricity sector. Smart grid is heralding a radical shift in the electricity system, and the process of change has only started. So far, the activities described in this study have not resulted in a radical change within the electricity system. As some smart grid technologies become widely adopted in the two countries, the real effects of social shaping will be more easily grasped.

A number of important shapers of smart grid technology were identified in the study. A good research area would be to isolate one or two of these shapers, and then incorporate a large number of cases in an analysis, in order to be able to establish causality and a universal relationship between the existence of a condition and the preference for a specific type of smart grid technology. Especially suitable for this goal is electricity market regulation. Regulation economics literature on the utility sectors is becoming increasingly preoccupied with promotion of investments and innovation, after a period of focus on allocative efficiency and economic efficiency. This literature would be enriched by a study that studies the difference in innovation incentives provided by different market regulation schemes, and how these differences shape smart grid technology innovated.

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12. APPENDICES

Appendix 1 – List of Projects in Database

	Generation control and automation	Grid control software	Sensing, automation, and control tech	Communication infrastructure	Conductor tech	Load control and AMI	Energy storage	EV charging infrastructure	Participants
Yokohama Smart City Project	1	1	0	1	0	1	1	1	City of Yokohama, Tokyo Institute of Technology, Urban Renaissance Agency, Marubeni, Accenture, NTT, ORIX, Sharp, JX Nippon Oil & Energy, Sumitomo Electric Industries, Sekisui House, Sony, DAIKYO ASTAGE, Taisei, Tokyo Gas, TEPCO, TOSHIBA, Nissan, JGC, NEC, Nomura, Panasonic, Hitachi, Misawa Homes, Mitsui Fudosan, Meidensha
Toyota City Smart City Project	1	1	0	1	0	1	1	1	Toyota City, Aichi Prefecture, Nagoya University, AISIN SEIKI, ENERES, KDDI, Sunkus, Sharp, Shinmei Industry, Sumitomo Electric Industries, SECOM, Systems Engineering Consultants, Chubu Electric Power Co, DENSO, TOSHIBA, TOHO gas, Toyota Motor, Toyota Industries, Dream Incubator, Central Nippon Expressway, Nagoya Railroad, Development Bank of Japan, Hewlett-Packard, Hitachi, FUJITSU, Mitsubishi, YAZAKI, Yamato Transport, Yamaha
Keihanna Smart City Project	0	1	0	1	0	1	1	1	Kyoto Prefecture, Kizugawa City, Kyotanabe City, Seika Town, Kansai Research Institute, Kansai Economic Federation, Kyoto Center for Climate Actions, Urban Renaissance Agency, Enegates, i-Energy, Osaka Gas, OMRON, Kansai Electric Power Co, Sharp, Nihon Unisys, Mitsubishi Motors, Mitsubishi, Mitsubishi Heavy

									Industries, Mitsubishi Electric, Fuji Electric, Furukawa Electric, Furukawa Battery, Renesas Electronics
Kitakyushu Smart City Project	1	1	0	1	0	1	1	1	Human Media Creation Center, Azbil, Iwatani, UCHIDA YOKO, ORIX, Saibugasu, JX Nippon Oil & Energy, Sharp, Nippon Steel, NS Solutions, Softbank, Daiwa House, DENSO, TOTO, TOPPAN Printing, Toyota Motor, Toyota Industries, Toyoda Gosei, NITTETSU ELEX, IBM, Japan Telecom Information Service, FamilyMart, Fuji Electric, Furukawa Electric, Furukawa Battery, Hohkohsya, Mitsubishi Heavy Industries, YASKAWA Electric, YASKAWA INFORMATION SYSTEMS
Fujisawa Sustainable Smart Town	1	1	0	1	0	1	1	1	Fujisawa Town, Panasonic
Teriha Smart Town	0	0	0	0	0	1	1	1	Sekisui House
Kashiwanoha Campus City Project	0	0	0	0	0	1	0	0	Chiba Prefecture, Kashiwa City, University of Tokyo, Chiba University, Mitsui Fudosan
Kesen Region Eco-future City	1	1	0	0	0	1	1	1	Tohoku Electric Power Co, Hitachi, NEC, Yokogawa Electric, Meidensha, ORIX, University of Tokyo, NTT
Ishinomaki City	1	0	0	0	0	0	1	0	TOSHIBA, Ishinomaki City
Japan US Island Grid Project	0	1	1	1	0	1	1	1	NEDO, DBEDT, HNEI, Hawaiian Electric Co, Maui Electric Co, medb, Mizuho, Hitachi, Sandia National Laboratories, NREL
AES Center Projects	0	0	0	0	0	1	1	1	Tokyo Institute of Technology, ENEOS, NTT, Tokyo Gas, Mitsubishi,
NEDO Lyon	0	1	0	0	0	1	0	1	NEDO, Grand Lyon Community, Toshiba, Bouyges, Veolia Transdev
NEDO Malaga	0	0	0	1	0	0	0	1	NEDO, Mitsubishi, Mitsubishi Heavy Industries, Hitachi, Endesa, Unipersonal, Sadiel Technologias de la Informacion
Java Feasibility Study	1	1	0	1	0	1	0	0	NEDO, Sumitomo Electric Industries, Mitsubishi Electric, NTT, Meidensha
都市型スマート交通シ	0	0	0	0	0	0	0	1	NEDO, Mitsubishi

ステムのグローバル展開（ＥＶ・ＥＶバス・充電システム）									
度産業集積型都市におけるスマートコミュニティ開発	0	0	0	0	0	1	0	0	Japan Research Institute, Toshiba, NTT, Itochu, NEDO
コジェネ・ＢＥＭＳ等エネルギー最適化事業の中国展開	1	0	0	0	0	1	0	0	Toshiba, Mizuho, Cubic S Consulting, NEDO
再生可能エネルギー・スマートグリッド運営	1	0	0	0	0	1	1	0	Japan Research Institute, Hitachi, Mitsubishi Heavy Industries, SMBC, NEDO
工業団地向け大規模太陽光発電システム実証	1	1	0	1	0	0	0	0	Hitachi, Itochu, NEDO
既存日系工業団地における複合マイクログリッド（電力・熱）	1	1	0	0	0	0	0	0	NEDO, Toshiba, Tokyo Gas
Delhi-Mumbai Industrial Corridor Initiative	1	1	0	0	0	1	1	0	JGC, Mitsubishi, Fuji Electric, Panasonic, City of Yokohama, Nikken, Ebara
工業団地スマート環境改善システム展開	0	1	0	1	0	1	0	0	Fuji Electric, NEDO

*(Gov=government, Ven=Vendor, Uti=Utility, Mix=Different actors contribute)

	Generation control and automation	Grid control software	Sensing, automation, and control tech	Communication infrastructure	Conductor tech	Load control and AMI	Energy storage	EV charging infrastructure	Participants
44 Tech Inc. Smart Grid Storage Demonstration Project	0	0	0	0	0	0	1	0	44 Tech Inc, Carnegie Mellon University
AEP Smart Grid Demonstration Project: Virtual Power Plant Simulator (VPPS)	0	1	1	1	0	1	1	0	AEP
AEP Texas grid SMART initiative	0	0	0	0	0	1	0	0	AEP, Landis+Gyr, MET Laboratories
ALLETE Inc., d/b/a Minnesota Power Smart Grid Project	0	1	1	1	0	1	0	0	ALLETE
Alliant Energy AMI Project	0	0	0	1	0	1	0	0	Alliant, Sensus
Amber Kinetics, Inc. Smart Grid Storage Demonstration Project	0	0	0	0	0	0	1	0	Amber Kinetics Inc, Lawrence Livermore National Laboratory
Ameren Illinois Utilities (AIU) Automated Metering Project	0	1	1	1	0	1	0	0	Ameren, Landis+Gyr
American Transmission Company LLC II Smart Grid Project	0	0	0	1	0	0	0	0	American Transmission Company
Appalachian Electric Co-op AMI Project	0	1	0	1	0	1	0	0	Appalachian Electric Co-operative

Aquion Energy (Sodium-Ion Battery for Grid-level Applications)	0	0	0	0	0	0	1	0	Aquion Energy
Arizona Public Service (APS) Community Power Project Flagstaff Pilot	1	0	1	1	0	1	1	0	Arizona Public Service, KORE Telematics, Elster Integrated Solutions, Aclara
Atlantic City Electric Company Smart Grid Project	0	0	1	1	0	1	0	0	Atlantic City Electric Company
Atmos Energy (Louisiana) AMI Project	0	0	0	1	0	1	0	0	Atmos Energy, Sensus
Austin Energy Smart Grid 1.0 and 2.0	0	1	1	1	0	1	0	0	Austin Energy, Landis+Gyr, Elster Integrated Solutions, GE, Cellnet+Hunt
Avista Utilities Smart Grid Project	1	1	1	1	0	0	0	0	Avista Utilities, Battelle
Baltimore Gas and Electric Company Smart Grid Project	0	1	0	1	0	1	0	0	Baltimore Gas and Electric
Bangor Hydro Smart Grid Initiative	0	1	0	0	0	1	0	0	Bangor Hydro Electric Company, Emera
Battelle Memorial Institute, Pacific Northwest Division Smart Grid Regional Demonstration Project	1	1	1	1	0	1	1	0	Battelle, Bonneville Power Administration, 3TIER, AREVA USA, IBM, Netezza, QualityLogic, Drummond Group, Idaho Falls Power, Flathead Electric Cooperative, Northwestern Energy, Portland General Electric, Inland Power & Light, City of Ellensburg, Peninsula Light, Benton PUD, Avista Utilities, Seattle City Light, Lower Valley Energy
Beacon Power Corporation Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	Beacon Power, PJM Interconnection, Midwest Generation

Black Hills Power, Inc. Smart Grid Project	0	1	0	1	0	1	0	0	Black Hills Utility
Black Hills/Colorado Electric Utility Co. Smart Grid Project	0	1	0	1	0	1	0	0	Black Hills Utility
Black River Electric Co-op AMI Project	0	0	1	1	0	1	0	0	Black River Electric Co-operative, Aclara, Hexagram, Nexus
Bluebonnet Electric Cooperative Smart Grid Project	0	0	0	0	0	1	0	0	Bluebonnet Electric Cooperative, Silver Spring, Siemens Energy
Burbank Water and Power Smart Grid Project	0	1	1	1	0	1	1	1	Burbank Water and Power, Itron
CCET—Technology Solutions for Wind Integration	1	1	1		0	1	1	1	ERCOT, CCET, CenterPoint Energy, American Electric Power, Electric Power Group, Land Tejas Developers, Oncor, Southwest Research Institute, Frontier Associates, Drummond Group, EcoEdge Consulting, Sharyland Utilities
CenterPoint Energy Smart Grid Project	0	1	1	0	0	1	0	0	CenterPoint Energy
Central Lincoln People's Utility District Smart Grid Project	0	1	1	1	0	1	0	0	Central Lincoln People's Utility District
Central Maine Power Company Smart Grid Project	0	1	0	1	0	1	0	0	Central Maine Power Company
Central Vermont Public Service (CVPS) Smart Grid Project: CVPS SmartPower	0	0	0	1	0	1	0	0	Central Vermont Public Service, Siemens Energy, eMeter
Cheyenne Light, Fuel and Power Company Smart Grid Project	0	0	0	1	0	1	0	0	Black Hills Utility

City of Anaheim Smart Grid Project	0	0	0	1	0	1	0	0	City of Anaheim
City of Auburn, IN Smart Grid Project	0	1	0	1	0	1	0	0	City of Auburn, Spectrum Engineers
City of Fort Collins Utilities Smart Grid Project	0	1	1	1	0	1	0	0	City of Fort Collins Utilities
City of Fulton, Missouri (Smart Grid Project)	0	0	0	1	0	1	0	0	City of Fulton Electric Utility
City of Glendale Water and Power Smart Grid Project	0	1	1	1	0	1	1	0	City of Glendale Water and Power
City of Leesburg, Florida Smart Grid Project	1	1	1	1	0	1	0	0	City of Leesburg
City of Naperville, Illinois Smart Grid Project	0	1	1	1	0	1	0	0	City of Naperville
City of Painesville Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	City of Painesville
City of Quincy, Florida Smart Grid Project	0	0	0	1	0	1	0	0	City of Quincy
City of Ruston, Louisiana Smart Grid Project	0	1	1	1	0	1	0	1	City of Ruston
City of Tallahassee Smart Grid Project	0	1	1	1	0	1	0	0	City of Tallahassee
City of Wadsworth, OH Smart Grid Project	0	1	1	1	0	1	0	0	Wadsworth Electric and Communications
City of Westerville, OH Smart Grid Project	0	0	0	0	0	1	0	0	City of Westerville
Cleco Power LLC Smart Grid	0	1	0	1	0	1	0	0	Cleco Power

Project									
Cobb Electric Membership Corporation Smart Grid Project	0	0	0	1	0	0	0	0	Cobb Electric Membership Corporation
Colorado Springs Utilities Smart Grid Initiative	0	1	1	1	0	1	0	0	Colorado Springs Utilities, Landis+Gyr, Cellnet+Hunt, GE
Columbia Gas of Ohio AMR Project	0	0	0	0	0	1	0	0	Columbia Gas of Ohio
Columbus Southern Power Company dba AEP Ohio Smart Grid Regional Demonstration Project	1	1	1	1	0	1	1	1	American Electric Power, Silver Spring, GE, S&C Electric, Cooper Power Systems, EPRI,
Connecticut Light & Power AMI Pilot Project: Plan-it Wise Energy Program	0	0	0	1	0	1	0	0	Northeast Utilities, Accenture, Comverge, GoodCents, ITM Group, Sensus, Trilliant
Connecticut Municipal Electric Energy Cooperative Smart Grid Project	0	1	0	1	0	1	0	0	Connecticut Municipal Electric Energy Cooperative, Groton Utilities, Jewett City Department of Public Utilities, South Norwalk Electric and Water,
Consolidated Edison Company of New York, Inc. Smart Grid Regional Demonstration Project	1	1	1	1	0	1	1	1	Consolidated Edison Company of New Yotk, EPRI
Consumer Energy Smart Meter Pilot Project	0	1	0	1	0	1	0	0	Consumers Energy, CMS Energy, IBM, GE, Elster Integrated Solutions
CPS Energy Smart Grid Project	0	1	0	0	0	1	0	0	CPS Energy, Landis+Gyr
Delmarva Power AMI Project	0	0	0	0	0	1	0	0	Delmarva Power, GE
Denton County	0	1	1	1	0	1	0	0	CoServ Electric

Electric Cooperative d/b/a CoServ Electric Smart Grid Project									
Detroit Edison Company Smart Grid Project	0	0	1	0	0	1	0	0	Detroit Edison Company, DTE Energy,
Dominion Virginia Power AMI Project	1	0	0	0	0	1	1	0	Dominion, Alt Energy,
Duke Energy Business Services, LLC Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	Duke Energy, EPRI,
East Penn Manufacturing Co. Smart Grid Storage Demonstration Project	0	0	0	0	0	0	1	0	East Penn Manufacturing, Noble Americas Energy Solutions,
Eastern Nebraska Public Power District Consortium Smart Grid Initiative	0	1	1	0	0	1	0	0	Cumin County Public Power District
El Paso Electric Smart Grid Project	0	1	1	1	0	0	0	0	El Paso Electric
Electric Power Board of Chattanooga Smart Grid Project	0	0	1	1	0	1	0	0	Electric Power Board of Chattanooga
Entergy New Orleans, Inc. Smart Grid Project	0	0	0	1	0	1	0	0	Entergy
Entergy Services, Inc. Smart Grid Project	0	1	1	0	0	0	0	0	Entergy
FirstEnergy Service Company Smart	0	1	1	0	0	1	0	0	FirstEnergy, EPRI,

Grid Project									
FirstEnergy Smart Grid Demonstration Project: Integrated Distributed Energy Resources (IDER) Management	1	1	1	0	0	1	1	0	FirstEnergy, PowerSense, Grid Sentry
Florida Power & Light Company Smart Grid Project	1	1	1	1	0	1	0	0	Florida Power & Light Company
French Broad Electric Membership Corporation AMI Project	0	0	0	1	0	1	0	0	French Broad EMC, Tantalus,
Georgia Power Smart Meter Program	0	0	0	1	0	1	0	0	Georgia Power, Southern Company, GridSense, EPRI
Georgia System Operations Corporation Inc. Smart Grid Project	0	0	0	1	0	0	0	0	GSOC
Golden Spread Electric Cooperative, Inc. Smart Grid Project	0	1	1	1	0	1	0	0	Golden Spread Electric Cooperative, Inc.
Groton Public Utilities AMI Project	0	1	0	0	0	1	0	0	Groton Public Utilities, Sensus, Northstar Utilities Solutions
Guam Power Authority Smart Grid Project	0	1	1	1	0	1	0	0	Guam Power Authority
Gulf Power Smart Meter Project	0	1	1	1	0	1	0	0	Gulf Power Company, Southern Company, Sensus
Hawaii Electric Co. Inc. Smart Grid Project	0	1	1	1	0	0	0	0	Hawaii Electric
HomePlug Green PHY Integrated Circuit	0	0	0	1	0	1	0	0	Qualcomm Atheros

Development									
Idaho Power Company Smart Grid Project	0	1	1	1	0	1	0	0	Idaho Power Company
Indianapolis Power and Light Company Smart Grid Project	0	1	1	1	0	1	0	1	Indianapolis Power and Light Company
Interstate Power and Light (Minnesota) AMI Project	0	1	0	0	0	1	0	0	Interstate Power and Light, Alliant, Sensus, eMeter
Iowa - Interstate Power and Light AMI Project	0	1	0	0	0	1	0	0	Interstate Power and Light, Alliant, Sensus, eMeter
Iowa Association of Municipal Utilities Smart Grid Project	0	1	0	1	0	1	0	0	Iowa Association of Municipal Utilities
ISO-New England (Synchrophasor Infrastructure and Data Utilization (SIDU) in the ISO New England Transmission Region)	0	0	1	1	0	0	0	0	ISO New England
JEA Smart Grid Project	0	1	0	1	0	1	0	0	JEA
Kansas City Power and Light (Green Impact Zone SmartGrid Demonstration)	1	0	1	0	0	1	1	0	Kansas City Power & Light Company
Knoxville Utilities Board Smart Grid Project	0	1	1	1	0	1	0	0	Knoxville Utilities Board
Ktech Corporation Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	Ktech, Raytheon Ktech, EnerVault
Lafayette	0	0	1	0	1	1	0	0	LUS, ZigBee,

Consolidated Government, LA Smart Grid Project									
Lake Country Power AMI Project	0	1	0	0	0	1	0	0	Lake Country Power, Touchstone Energy, Cooper Power Systems
Lakeland Electric Smart Grid Project	0	0	0	1	0	1	0	0	Lakeland Electric
Lee County Electric Cooperative Smart Grid Project	1	1	1	1	0	1	1	0	Lee County Electric Cooperative, ENERGYprism, Aclara
Long Island Power Authority Smart Grid Regional Demonstration Project	0	0	1	0	0	1	0	1	Long Island Power Authority, State University of New York,
Long Island Power Authority Smart Metering Program	0	0	0	0	0	1	0	0	Long Island Power Authority
Los Angeles Department of Water and Power Smart Grid Regional Demonstration Project	0	0	0	0	0	1	1	1	LADWP, UCLA, USC
Lyntegar Electric Coop AMI Project	0	0	0	1	0	1	0	0	Lyntegar Electric Coop, Aclara
M2M Communications Smart Grid Project	0	0	0	1	0	1	0	0	M2M Communications
Madison Gas and Electric Company Smart Grid Project	0	0	1	0	0	1	0	1	Madison Gas and Electric Company
Marblehead Municipal Light Department Smart Grid Project	0	0	1	1	0	1	0	0	Marblehead Municipal Light Department

Memphis Light, Gas and Water Division Smart Grid Project	0	1	1	1	0	0	0	0	Memphis Light, Gas and Water Division
Midwest Energy Inc. Smart Grid Project	0	1	1	1	0	0	0	0	Midwest Energy
Midwest Independent Transmission System Operator Smart Grid Project	0	1	1	0	0	0	0	0	MISO
Mississippi Power AMI Project	0	0	1	1	0	1	0	0	Mississippi Power, Southern Company, Sensus
Modesto Irrigation District Smart Grid Project	0	0	0	0	0	1	0	0	Modesto Irrigation District
Municipal Electric Authority of Georgia Smart Grid Project	0	0	1	1	0	1	0	0	Municipal Electric Authority of Georgia
National Rural Electric Cooperative Association Smart Grid Regional Demonstration Project	1	0	1	0	0	1	0	0	National Rural Electric Cooperative Association, SAIC, Power System Engineering, Cigital
Navajo Tribal Utility Association Smart Grid Project	0	1	1	0	0	1	0	0	Navajo Tribal Utility Association, Navajo Technical College,
New Hampshire Electric Cooperative Smart Grid Project	0	1	0	1	0	1	0	0	New Hampshire Electric Coop
nDanville, a broadband infrastructure to support Danville's Smart Grid Energy	0	0	1	1	0	1	0	0	City of Danville Utilities

Initiatives									
New York Independent System Operator, Inc. Smart Grid Project	0	0	1	1	0	0	0	0	New York Independent System Operator
New York State Electric & Gas Corporation Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	New York State Electric & Gas Corporation
Newport Utilities AMI Project	0	0	1	1	0	1	0	0	Newport Utilities, Tantalus,
Northeastern REMC AMI Project	0	0	1	1	0	1	0	0	Northeastern REMC, Tantalus,
Northern Virginia Electric Cooperative Smart Grid Project	0	0	1	1	0	0	0	0	Northern Virginia Electric Cooperative
NPPD's Smart Meter Installation	0	0	0	0	0	1	0	0	Nebraska Public Power District
NSTAR Electric & Gas Corporation Smart Grid Regional Demonstration Project	0	0	0	0	0	1	0	0	NSTAR Electric & Gas Corporation, Tendril Networks, Navigant
NSTAR Electric & Gas Corporation Smart Grid Regional Demonstration Project (2)	0	0	1	1	0	0	0	0	NSTAR Electric & Gas Corporation, Digital Grid, SoftStuf, Nighthawk
NSTAR Electric Company Smart Grid Project	0	0	1	1	0	1	0	0	NSTAR Electric & Gas Corporation
NV Energy, Inc. Smart Grid Project	0	0	0	1	0	1	0	0	NV Energy, Okanogan County PUD,
Okanogan County PUD	0	0	0	0	0	1	0	0	Okanogan County PUD

AMI project									
Oklahoma Gas and Electric Company Smart Grid Project	0	1	1	1	0	1	0	0	Oklahoma Gas and Electric Company, University of Oklahoma,
Oncor Electric Delivery Company, LLC Smart Grid Regional Demonstration Project	0	0	1	0	1	0	0	0	Oncor, The Valley Group, Southwest Research Institute, Siemens Energy, Chapman Construction Company
Oncor Smart Texas - Rethinking Energy	0	1	1	1	0	1	0	0	Oncor, Landis+Gyr, Siemens Energy
Pacific Gas & Electric AMI Project	0	1	0	1	0	1	0	0	Pacific Gas & Electric Company, Power Line Carrier, Landis+Gyr, GE
Pacific Gas & Electric Company Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	Pacific Gas & Electric Company
Pacific Northwest Generating Cooperative Smart Grid Project	0	1	0	1	0	1	0	0	Pacific Northwest Generating Cooperative
PEAR California	0	0	1	0	0	1	0	0	M2M Communications
Pecan Street Project, Inc. Smart Grid Regional Demonstration Project	1	0	0		0	1	1	1	Pecan Street Project, City of Austin, University of Texas, Austin Energy, Environmental Defense Fund
PECO Energy Company Smart Grid Project	0	1	1	1	0	1	0	0	PECO Energy Company
Pedernales Electric Cooperative AMI Project	0	0	1	0	0	1	0	0	Pedernales Electric Cooperative, Distribution Control Systems,
Piedmont Electric Membership	0	0	0	0	0	1	0	0	Piedmont Electric Membership Corporation, Touchstone Energy

Corporation Smart Grid Project									
PJM Interconnection, LLC Smart Grid Project	0	1	1	1	0	0	0	0	PJM Interconnection
PNM Smart Grid Demonstration Project: High-Penetration PV thru Grid Automation and Demand Response	1	1	0	1	0	0	1	0	PNM, Sandia National Labs, Northern New Mexico College, Premium Power, University of New Mexico, EPRI,
Portland General Electric Smart Meter Project	0	0	0	0	0	1	0	0	Portland General Electric, Sensus
Potomac Electric Power Company (PEPCO) Smart Grid Project	0	1	1	1	0	1	0	0	PEPCO
Potomac Electric Power Company (PEPCO) Smart Grid Project (Maryland)	0	1	1	1	0	1	0	0	PEPCO
Poudre Valley Rural Electric Cooperative AMI Project	0	0	1	0	0	1	0	0	PVREA, Landis+Gyr
Powder River Energy Corporation Smart Grid Project	0	0	1	1	0	0	0	0	Powder River Energy Corporation
Power Authority of the State of New York Smart Grid Regional Demonstration Project	0	0	1	0	1	0	0	0	New York Independent System Operator, New York Power Authority, EPRI, New York State Energy Research and Development Authority
PPL Electric Utilities Corp. Smart Grid Project	0	1	1	1	0	0	0	0	PPL Electric Utilities
Premium Power Corporation Smart Grid	1	0	0	0	0	1	1	0	Premium Power, National Grid, Worcester Polytechnic Institute, Science Applications

Storage Demonstration Project									International
Primus Power Corporation Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	Primus Power Corporation, Sandia National Labs, EPRI
Progress Energy Smart Grid Project	0	1	1	1	0	1	0	1	Progress Energy, Duke Energy
Public Service Company of New Mexico Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	Public Service Company of New Mexico, East Penn Manufacturing
Public Utility District No. 1 of Snohomish County Smart Grid Project	0	1	1	1	0	1	0	0	Snohomish County Public Utilities District
Puerto Rico Electric Power Authority (PREPA) - Smart Grid Broadband-over-Power Lines Communications Pilot Program	0	0	0	1	0	1	0	0	PREPA, IBEC, PowerNET, Distribution Control Systems
Puget Sound Energy AMI Project	0	0	0	1	0	0	1	0	Puget Sound Energy, Itron, Comverge, Zigbee
Rappahannock Electric Cooperative Smart Grid Project	0	1	1	1	0	1	0	0	Rappahannock Electric Cooperative
RDSI - Allegheny Power Demonstration Project - West Virginia Super Circuit	1	1	1	1	0	1	1	0	Ellegheny Power, Science Applications International, West Virginia University, North Carolina State University, Augusta Systems, Tollgrade Communications
RDSI - Alliant Techsystems	1	1	1	1	0	1	1	0	Alliant, P&G, Rocky Mountain Power

(ATK) Launch Systems Demonstration Project									
RDSI - Chevron Energy Solution's CERTS Microgrid Demonstration	1	0	0	0	0	1	1	0	Chevron Energy Solutions, VRB Power Systems, Satcon Power Systems, University of Wisconsin, NREL, LBNL, Alameda County, Pacific Gas & Electric Company, Energy and Environmental Economics
RDSI - Con Edison Smart Grid Demonstration Project: Interoperability of Demand Response Resources	1	1	0	0	0	1	0	0	Consolidated Edison Company of New Yotk, Innoventive Power, Verizon, Infotility
RDSI - Fort Collins Demonstration Project "3.5 MW Mixed Distributed Resources for Peak Load Reduction"	1	1	0	1	0	0	1	0	City of Fort Collins Utilities, Colorado State University, Spirae, Brendle Group, Advanced Energy, Woodward Governor, Caterpillar, Eaton, InteGrid
RDSI - IIT Perfect Power Demonstration	0	1	1	1	0	1	0	0	Illinois Institute of Technology, Galvin Energy Initiative, Exelon, S&C Electric, Schweitzer, Endurant Energy, Commonwealth Edison, Zigbee
RDSI - Maui Grid Modernization	1	0	1	0	0	1	0	0	Hawaiian Electric Company, University of Hawaii, Maui Electric Company, GE, Sentech
RDSI - SDG&E Beach Cities Microgrid	1	1	1	1	0	1	1	1	San Diego Gas and Electric Company, IBM, Horizon Energy Group, Motorola, Pacific Northwest National Labs, Oracle, Advanced Energy, University of Sand Diego, Lockheed Martin, GridPoint, Xanthus
RDSI - UNLV Demonstration Project - Integrated PV, Battery, Storage,	1	1	1	1	0	1	1	0	Nevada Power Company, Pulte Homes, University of Nevada, GE

and Customer Products with Advanced Metering									
Reliant Energy Retail Services, LLC Smart Grid Project	0	0	0	0	0	1	0	1	Reliant Energy, Oncor, CenterPoint Energy, AEP,
Sacramento Municipal Utility District Smart Grid Project	0	1	1	1	0	1	0	0	SMUD, EPRI, Lockheed Martin, Eaton,
Salt River Project Smart Grid Project	0	1	0	1	0	1	0	0	Salt River Project
San Diego Gas and Electric Company Smart Grid Project	0	1	1	1	0	1	0	0	San Diego Gas and Electric Company
SCE - AMI Project (Edison SmartConnect™)	0	0	0	0	0	1	0	0	Southern California Edison, Itron, Certicom, Zigbee
Seeo, Inc Smart Grid Storage Demonstration Project	0	0	0	0	0	0	1	0	Seeo, UC Berkeley
Silicon Valley Power AMI Project	0	0	0	0	0	1	0	0	Silicon Valley Power, Siemens Energy, eMeter
Sioux Valley Southwestern Electric Cooperative, Inc. Smart Grid Project	0	0	0	0	0	1	0	0	Sioux Valley Southwestern Electric Cooperative, Power System Engineering,
South Central Indiana REMC Smart Grid Investments and Information	0	0	1	0	0	1	0	0	South Central Indiana Rural Electric Cooperative, Northstar Utilities Solutions, MeterSense
South Kentucky Rural Electric Cooperative Corporation Smart Grid Project	0	1	1	1	0	1	0	0	South Kentucky Rural Electric Cooperative
South Mississippi	0	0	1	1	0	1	0	0	SMEPA

Electric Power Association (Advanced Metering Infrastructure and Associated Smart Grid Investments for Rural Mississippi)									
South Plains Electric Cooperative AMI Project	0	0	0	0	0	1	0	0	South Plains Electric Cooperative
Southern California Edison Company Smart Grid Regional Demonstration Project	1	1	1	1	0	1	1	1	Southern California Edison, GE, UC Irvine, University of Southern California, SunPower, EPRI,
Southern California Edison Company Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	Southern California Edison, LG, CISO, Quanta Technology, Cal Poly Pomona
Southern Company Services, Inc. Smart Grid Project	0	0	1	1	0	0	0	0	Southern Company
Southwest Transmission Cooperative, Inc. Smart Grid Project	0	0	1	1	0	1	0	0	Southwest Transmission Cooperative
Stanton County Public Power District (Advanced Metering Infrastructure Initiative)	0	1	0	1	0	1	0	0	Stanton County Public Power District
Stearns Electric Association AMI Project	0	0	0	0	0	1	0	0	Stearns Electric Association, Touchstone Energy

Sterling Electric Department AMI Project	0	0	0	1	0	1	0	0	Sterling Municipal Light Department, Mueller Systems
SustainX, Inc. Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	0	SustainX, MAN Diesel, Creare, The Hope Group, Mtechnology
Talquin Electric Cooperative, Inc. Smart Grid Project	0	1	1	1	0	1	0	0	Talquin Electric Cooperative
The Boeing Company (Boeing Smart Grid Solution)	0	1	0	0	0	0	0	0	Boeing, PJM Interconnection, Pacific Gas & Electric Company, Consolidated Edison Company of New York, Midwest ISO
The Detroit Edison Company Smart Grid Storage Demonstration Project	1	0	0	0	0	0	1	1	Detroit Edison Company, Chrysler, KEMA, Electrical Distribution Design, NextEnergy, National Grid,
Town of Danvers, MA Smart Grid Project	0	0	1	1	0	1	0	0	Town of Danvers
Transverter "One house at a time"	1	0	0	0	0	1	1	0	Heart Transverter
Tri State Electric Membership Corporation Smart Grid Project	0	0	1	0	0	1	0	0	Tri State Electric Membership Corporation
Tri-county Electric Coop AMI Project	0	0	0	0	0	1	0	0	Tri-county Electric Coop
TXU Energy AMI Projec	0	0	0	1	0	1	0	0	TXU Energy, Comverge, Digi international, Zigbee
United Cooperative Services AMI Project	0	0	0	0	0	1	0	0	United Cooperative Services, Hunt Technology
United Illuminating (UI) Smart Project	0	0	0	0	0	1	0	0	The United Illuminating Company, Ecologic Analytics
Unitil Smart Grid Pilot Program	0	0	1	0	0	1	0	0	Unitil

Vermont Electric Cooperative AMI Project	0	0	0	0	0	1	0	0	Vermont Electric Cooperative
Vermont Transco, LLC Smart Grid Project	0	0	1	0	0	1	0	0	Vermont Transco
Wabash Valley Power Smart Grid Project	0	1	0	0	0	1	0	0	Wabash Valley Power Association, eMeter, Siemens Energy
Waukesha Electric Systems Smart Grid Regional Demonstration Project	0	0	1	0	0	0	0	0	Waukesha Electric Systems, Southern California Edison, SPX Transformer Solutions, University of Houston
Wellsboro Electric Company Smart Grid Project	0	0	0	0	0	1	0	0	Wellsboro Electric Company
Westar Energy, Inc. Smart Grid Project	0	1	1	0	0	1	0	0	Westar Energy
Western Electricity Coordinating Council Smart Grid Project	0	1	1	0	0	0	0	0	Western Electricity Coordinating Council
Whirlpool Corporation Smart Grid Project	0	0	0	0	0	1	0	0	Whirlpool
Wisconsin Power and Light Company Smart Grid Project	0	0	0	0	0	1	0	0	Wisconsin Power and Light Company, Alliant
Woodruff Electric Smart Grid Project	0	0	1	0	0	1	0	0	Woodruff Electric Cooperative
Xcel Energy (Northern States Power Wisconsin) AMI Project	0	0	0	1	0	1	0	0	Xcel Energy, Cellnet, Itron
Xcel Energy's Smart Grid City	0	1	1	1	0	1	1	1	Xcel Energy, Accenture, Current Group, Schweitzer, Ventyx

*(Gov=government, Ven=Vendor, Uti=Utility, Mix=Different actors contribute)

Appendix 2 – Interview instrument sample

Interview Instrument
Smart Grid Innovation System in the USA: Shape and Performance

Martin Karlsson
Graduate Program in Sustainability Science
Global Leadership Initiative
Graduate School of Frontier Science
The University of Tokyo

Section 1
Functional Technology Areas

Smart grid visions typically include a wide range of different technological solutions providing different services to the users and managers of electricity grids. These different technological solutions can be categorized into functional technology areas depending on what functions they are expected to perform. In different contexts, different functional technology areas have different emphasis.

Please indicate your perception of how important the different functional technology areas are within smart grid innovation in the USA. Answer from an as objective viewpoint as possible.

Electricity generation control, automation and power electronics					
Not important	Not very important	Moderately important	Important	Very important	Don't know
1.2 Advanced computing and grid control software					
Not important	Not very important	Moderately important	Important	Very important	Don't know
1.3 Embedded grid sensing, automation, measurement and control technology					
Not important	Not very important	Moderately important	Important	Very important	Don't know
1.4 Communication infrastructure					
Not important	Not very important	Moderately important	Important	Very important	Don't know
1.5 Conductor technology and approaches					
Not important	Not very important	Moderately important	Important	Very important	Don't know
1.6 Electrical load control and advanced meters					
Not important	Not very important	Moderately important	Important	Very important	Don't know
Energy storage					
Not important	Not very important	Moderately important	Important	Very important	Don't know
1.8 EV charging infrastructure					
Not important	Not very important	Moderately important	Important	Very important	Don't know

1.9 What other functional technology areas are being prioritized in the USA?

Section 2
Visions of Smart Grid Technology

Smart grids have been envisioned to provide various different values to governments, consumers and utilities. Depending on perspective and context, the visions vary in content and emphasis.

Please indicate your perception of how important different visions are within smart grid innovation in the USA. Answer from an as objective viewpoint as possible.

2.1 Resilient– a grid that can withstand hostile physical and cyber attacks					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.2 Resilient– a grid that can withstand natural disasters and other unexpected events					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.3 Quality– a grid that provides reliable high-quality power					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.4 Conserving– a grid which utilizes less energy in total					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.5 Intelligent– a grid that achieves better allocative efficiency, including by achieving peak-shaving					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.6 Renewable– a grid that can integrate more fluctuating energy sources such as wind power or solar power					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.7 Distributed– a grid that can integrate more distributed energy sources, including renewables					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.8 Vehicle– a grid that can integrate more electric vehicles					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.9 Monitored– a grid in which electricity theft and reporting fraud is less					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.10 Efficient– a grid with less transmission and distribution losses					

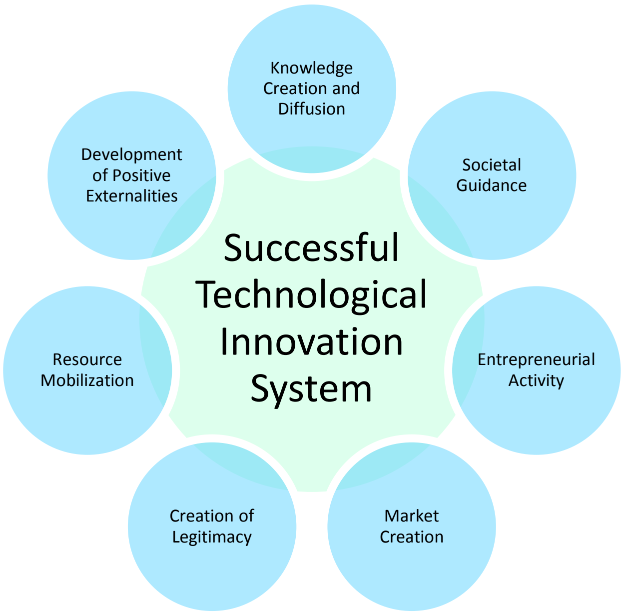
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.11 Cost-efficient– a grid with less cost for the utilities					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.12 Cost-efficient– a grid with less cost for consumers					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.13 Market-driven– a grid more fit for free market competition					
Not important	Not very important	Moderately important	Important	Very important	Don't know
2.14 What other goals are important for smart grid innovation in the USA?					

Section 3

Innovation System Performance

This research investigates the performance of and role of consumers in the smart grid technological innovation system (TIS) in the USA. A technological innovation system has been defined as: "A network or networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilise technology."[151]

For a TIS to be successful, meaning it is able to produce innovative technology that becomes diffused in society, it needs to fulfill many roles. This research investigates 7 functions[152] in terms of how well they are being fulfilled and how consumers are engaged in each of these functions



The following section will explain each of the 7 functions and ask for an evaluation of performance and degree of consumer engagement.

[151] *Carlsson, B. & R. Stankiewicz,, 1991 "On the Nature, Function, and Composition of Technological systems", Journal of Evolutionary Economics Vol 1 93-118.*
[152] *Based on Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. 2008. "Analyzing the functinoal dynamics of technological innovation systems: A scheme of analysis", Research Policy, Vol 37, pp.407-429. and van Alphen, K., 2011, Accelerating the development and deployment of carbon capture and storage technologies - An innovation system perspective, Uitgeverij BOXPress.*

Knowledge Creation and Diffusion
This is the core function of a TIS. It encompasses the creation of different kinds of knowledge, including scientific, technological, market or logistic knowledge. The state of knowledge creation and diffusion in a TIS can be investigated by asking the following questions:

The number and degree of variety in RD&D projects?
The type of knowledge (scientific, applied, patents) that is created and by whom?
The competitive edge of the knowledge base from an international perspective?
The (mis)match between the supply of technical knowledge by universities and demand by industry?
The amount and type of (inter) national collaborating between actors in the Innovation System?
The kind of knowledge that is shared within these existing partnerships?
The amount, type and 'weight' of official gatherings (e.g. conferences, platforms) organized?
Configuration of actor-networks (homo, or heterogeneous set of actors)?

3.1.1 Rate your perception of the performance of this system function

Very poor	Poor	Moderate	Good	Very good	Don't know

3.1.2 Rate your perception of end-user (electricity consumer) influence on this system function:

Very low	Low	Moderate	High	Very high	Don't know

3.1.3 Can you identify any important drivers and/or barriers within this function?

Societal Guidance
The function "Societal Guidance" refers to the way in which society creates incentives for a certain type of technology to emerge from a TIS. If this function is performing well, there is a clear common understanding of the expectation and probabilities of technology development and diffusion, shared by industry actors, the government and consumers. To investigate the performance of this function in a TIS, the following questions can be asked:

Amount and type of visions and expectations about the technology?
Belief in growth potential?
Clarity about the demands of utilities?
Clarity about the demands of electricity consumers?
Specific targets or regulations set by the government or industry?

3.2.1 Rate your perception of the performance of this system function					
Very poor	Poor	Moderate	Good	Very good	Don't know
3.2.2 Rate your perception of end-user (electricity consumer) influence on this system function:					
Very low	Low	Moderate	High	Very high	Don't know
3.2.3 Can you identify any important drivers and/or barriers within this function?					
Entrepreneurial Activity The function "Entrepreneurial Activity" refers to experiments carried out by actors expecting to be able to use the technology to achieve their aims. These activities are on the forefront of the innovation process. From a societal perspective, the experimentation of entrepreneurs makes uncertainty about the use of technology lower, as they create hard evidence for the likelihood of success or failure of certain types of technology. The state of entrepreneurship within the TIS can be investigated by asking the following questions: The number and the degree of variety in smart grid entrepreneurial experiments and demonstration projects? The number of different types of applications? The number of new entrants and diversifying established firms?					
3.3.1 Rate your perception of the performance of this system function					
Very poor	Poor	Moderate	Good	Very good	Don't know
3.3.2 Rate your perception of end-user (electricity consumer) influence on this system function:					
Very low	Low	Moderate	High	Very high	Don't know
3.3.3 Can you identify any important drivers and/or barriers within this function?					

Market Creation
For the benefits of innovation to become widespread, a market for the technology needs to be created. Emerging TIS often have very small and weak markets, but a strong market with ample possibilities for profit, innovation is normally accelerated. The function of market creation can be investigate by asking the following questions:

How is utility demand for smart grid technology articulated?
How is consumer demand for smart grid technology articulated?
Institutional stimuli for market formation?
Uncertainties faced by smart grid investors?

3.4.1 Rate your perception of the performance of this system function

Very poor	Poor	Moderate	Good	Very good	Don't know

3.4.2 Rate your perception of end-user (electricity consumer) influence on this system function:

Very low	Low	Moderate	High	Very high	Don't know

3.4.3 Can you identify any important drivers and/or barriers within this function?

Creation of Legitimacy
The function "Creation of Legitimacy" refers to the process in which the technology becomes socially accepted and becomes integrated into the legal system. When this function is not fulfilled, societal guidance and market creation is unlikely to occur as well, and regulatory barriers can create obstacles to innovation. The process of legitimacy creation can be investigated by asking the following questions:

What is the public opinion towards smart grid?
How is smart grid being portrayed in the media?
What are the main arguments of actors pro or against the deployment the technology?
Do utilities and consumers perceive smart grid differently?
Legitimacy to make investments in smart grids?
Strong lobby groups?

3.5.1 Rate your perception of the performance of this system function

Very poor	Poor	Moderate	Good	Very good	Don't know

3.5.2 Rate your perception of end-user (electricity consumer) influence on this system function:

Very low	Low	Moderate	High	Very high	Don't know

3.5.3 Can you identify any important drivers and/or barriers within this function?

Resource Mobilization

Normally, innovation requires different kinds of capital and assets in order to proceed. Financial capital and human capital are the most important among these, and the availability of those will enable innovation. To investigate this process, the following questions can be asked:

Availability of human capital (through education, entrepreneurship or management)?

Availability of financial capital (seed and venture capital, government funds for RD&D)?

3.6.1 Rate your perception of the performance of this system function

Very poor	Poor	Moderate	Good	Very good	Don't know

3.6.2 Rate your perception of end-user (electricity consumer) influence on this system function:

Very low	Low	Moderate	High	Very high	Don't know

3.6.3 Can you identify any important drivers and/or barriers within this function?

Development of Positive Externalities

Empirical studies have shown that the existence of complementary innovation systems is important for a TIS to be successful. For example, the success of nuclear power technology benefited greatly from advances within nuclear weapon technology, even though these are two distinct technology areas. The existence of positive externalities can be investigate through asking the following questions:

What other areas of innovation are benefiting from smart grid innovation?
What other areas of innovations is smart grid innovation benefiting from?

3.7.1 Rate your perception of the performance of this system function

Very poor	Poor	Moderate	Good	Very good	Don't know

3.7.2 What other technology areas are the most important for smart grid innovation?